2020 Virtual Meeting

Limb Lengthening and Reconstruction Society:

ASAMI–North America

July 30, 2020 – January 29, 2021

www.llrs.org

Program made available in part by

LLRS: ASAMI–North America

Future Meetings

AAOS Specialty Day

March 13, 2021

San Diego, CA

29th Annual Scientific Meeting

July 16 & 17, 2021

New York, NY

Upcoming AAOS Meeting

2021 Annual Meeting

March 9–13, 2021

San Diego, CA

For more information:

Karen R. Syzdek, Executive Director

info@llrs.org

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

LLRS: ASAMI–North America
Meetings & Presidents

Year	Location	President
1990	Baltimore, MD	Dror Paley, MD
1991	Kiawah, SC	Stuart A. Green, MD
1993	San Francisco, CA	Alfred D. Grant, MD
1994	New Orleans, LA	Deborah Bell, MD
1995	Orlando, FL	Jason Calhoun, MD
1996	Atlanta, GA	Mark T. Dahl, MD
1997	San Francisco, CA	John Herzenberg, MD
1998	New Orleans, LA	James Aronson, MD
1999	Dana Point, CA	J. Charles Taylor, MD
2000	Lake Buena Vista, FL	Charles T. Price, MD
2001	Berkeley, CA	Richard S. Davidson, MD
2002	Las Colinas, TX	John J. Gugenheim, MD
2003	Boston, MA	James C. Binski, MD
2004	Toronto, Ontario, CANADA	John G. Birch, MD
2005	New York, NY	William G. Mackenzie, MD
2006	San Diego, CA	James. J. Hutson, Jr., MD
2007	Chicago, IL	David W. Lowenberg, MD
2008	Albuquerque, NM	George Cierny, III, MD
2009	Louisville, KY	Paul T. Freudigman Jr., MD
2010	New York, NY	John K. Sontich, MD
2011	Chicago, IL	Doreen DiPasquale, MD
2012	Cincinnati, OH	James J. McCarthy, MD
2013	New York, NY	S. Robert Rozbruch, MD
2014	Montreal, Quebec CANADA	Sanjeev Sabharwal, MD
2015	Miami, FL (ILLRS Congress)	Reggie C. Hamdy, MD
2016	Charleston, SC	Joseph R. Hsu, MD
2017	Park City, UT	Karl Rathjen, MD
2018	San Francisco, CA	Kevin W. Louie, MD
2019	Boston, MA	J. Spence Reid, MD
2020	Virtual	Austin T. Fragomen, MD

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

First Vice President and Program Chair

Raymond W. Liu, MD
Professor, Division of Pediatric Orthopaedic Surgery
Victor M. Goldberg Endowed Chair in Orthopaedics
1st Vice President, Limb Lengthening and Reconstruction Society
Case Western Reserve University
Rainbow Babies and Children's Hospitals
11100 Euclid Avenue, RBC 6081
Cleveland, OH 44106
(216)844–7613 (o)
(216)844–1122 (f)
raymond.liu@uhhospitals.org

Program Committee

Raymond W. Liu, MD

Austin T. Fragomen, MD

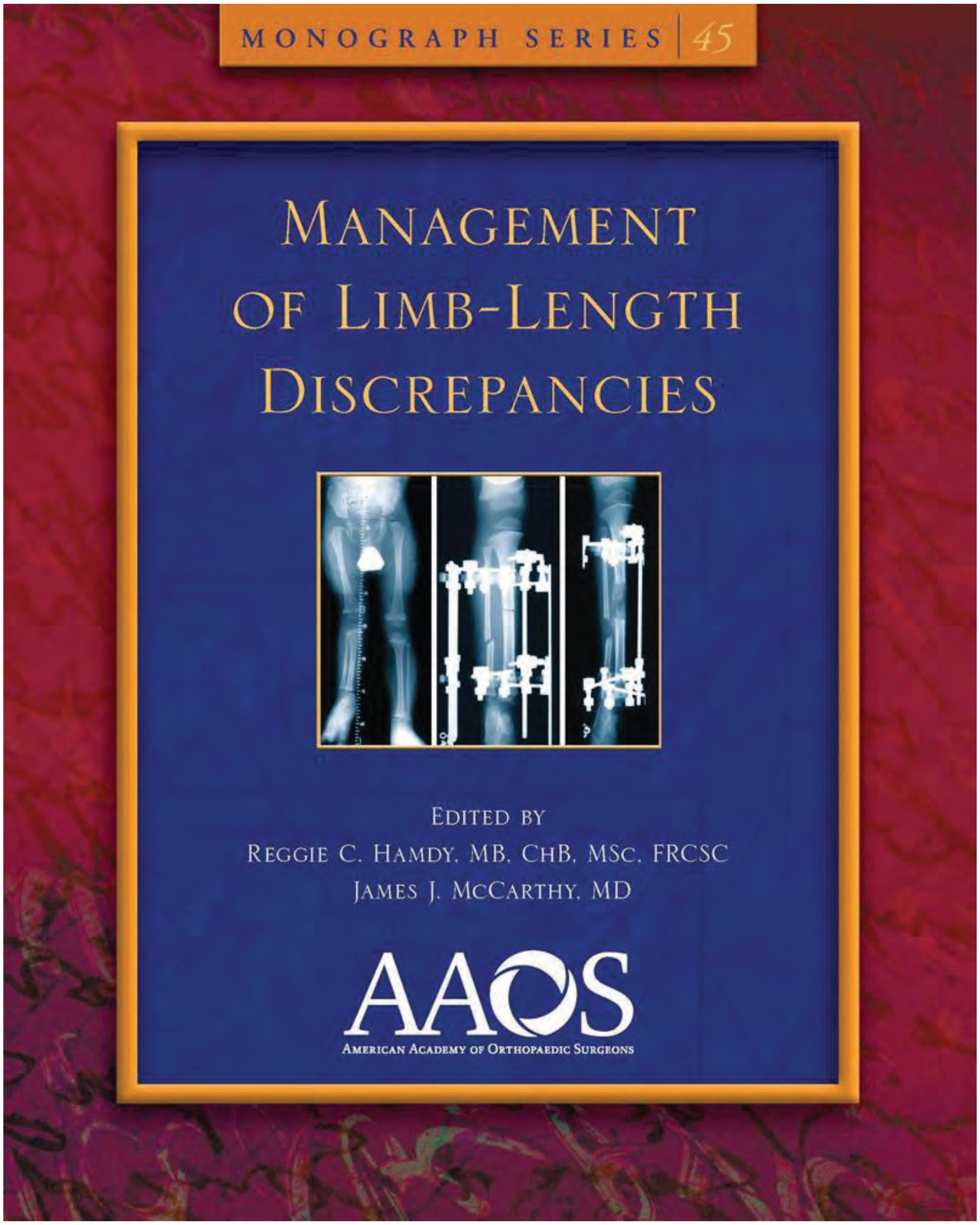
L. Reid Nichols, MD

David Podeszwa, MD

Karen R. Syzdek, Executive Director

Management of Limb–Length Discrepancies

Reggie Hamdy and Jim McCarthy (Eds.)



To review and order online visit

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Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Please join us!

LLRS
Limb Lengthening and
Reconstruction Society

29th Annual Scientific Meeting

Convene One Liberty Plaza

July 16 & 17, 2021

New York, NY

Visit www.llrs.org for more information.

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Helpful Web Sites

LLRS: ASAMI–North America

http://www.llrs.org

American Academy of Orthopaedic Surgeons (AAOS)

http://www.aaos.org

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

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Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

2020 Virtual Meeting

Objectives

Upon completion of LLRS's Virtual Meeting, physicians will be able to:

- apply the latest developments in the orthopedic subspecialties of limb lengthening and reconstruction;
- discuss the principles of tissue generation by distraction (distraction histogenesis); and
- understand surgical techniques of distraction histogenesis.

Selection of Content

Selection of material for presentation during the Virtual Meeting was based on scientific and educational merit. The selection process does not imply the treatment modality or research methodology is necessarily the best or most appropriate available.

LLRS disclaims formal endorsement of methods or research methodology used, and further disclaims any and all liability for claims which may arise out of the use of techniques discussed or demonstrated whether those claims shall be asserted by a physician or another person.

Food and Drug Administration

LLRS notes that approval of the FDA or national equivalent of its lists from other countries, is required for procedures and drugs that may be considered experimental. Instrumentation and procedures presented during the Virtual Meeting may not have received the approval of the appropriate federal authority, LLRS supports the use of techniques with the requisite government approval only.

Faculty Disclosure

Faculty members are required to disclose whether they have a financial arrangement or affiliation with a commercial entity related to their presentation(s). This disclosure in indicated on the Faculty List.

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

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<u>Exhibitors</u>

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Baltimore Limb Deformity Course

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Exhibitors

(listed in alphabetical order)

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Rubin Institute for Advanced Orthopedics
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The physicians at the Rubin Institute for Advanced Orthopedics (Baltimore) have earned a global reputation for their limb lengthening and deformity correction expertise. Sinai Hospital received accreditation for an orthopedic residency program. We offer clinical and research fellowships in adult and pediatric limb lengthening/reconstruction. We created two apps (Bone Ninja and Multiplier) and two The Art of Limb Alignment textbooks for use at the Baltimore Limb Deformity Course (deformitycourse.com). Our 2020 Course will be virtual; 25+ hours of pre-recorded talks/hardware application videos will be available from August 15th - September 30th. Three live sessions will occur August 29th and 30th.

Orthofix is a global medical device company focused on musculoskeletal healing products and value-added services. The Company's mission is to improve patients' lives by providing superior reconstruction and regenerative musculoskeletal solutions to physicians worldwide. Headquartered in Lewisville, Texas, the Company has two strategic business units: Extremities and Spine. Our Extremities portfolio offers innovative, minimally invasive solutions for surgeons to address both limb reconstruction and trauma specialties.orthofix.com

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Meeting Evaluation

The meeting evaluation is online. Please go to the following link and complete the evaluation by **Friday, February 12, 2021**. *Your responses are needed for CME credit to be valid.*

https://www.surveymonkey.com/r/LLRS2020

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Continuing Medical Education

This activity has been planned and implemented in accordance with the accreditation requirements and policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint providership of the American Academy of Orthopaedic Surgeons and the Limb Lengthening and Reconstruction Society. The American Academy of Orthopaedic Surgeons is accredited by the ACCME to provide continuing medical education for physicians.

The American Academy of Orthopaedic Surgeons designates this Other activity, 2020 LLRS Virtual Annual Meeting, for a maximum of 6.75 AMA PRA Category 1 Credits™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Please join us next year!

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Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Please complete the evaluation online at

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on or before **February 12, 2021**.

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Virtual Meeting

July 30, 2020 – January 29, 2021

Course Chairs
Austin T. Fragomen, MD
Raymond W. Liu, MD
L. Reid Nichols, MD
David Podeszwa, MD

8:00–8:04 p.m.	Welcome, Introduction

Live Presentations of Scientific Papers

Session 1: Radiograph Derived – L. Reid Nichols, MD, Moderator

8:05–8:12 p.m.	Comparison of Lower Extremity Segment Length Prediction Accuracy of the Sanders Multiplier, Paley Multiplier, and White–Menelaus Formulae *Marina R. Makarov, MD*
8:13–8:19 p.m.	Treatment for Ankle Valgus in Multiple Hereditary Exostoses *David S. Feldman, MD*
8:20–8:28 p.m.	Discussion

Session 2: Limb Salvage–Amputation – Austin T. Fragomen, MD, Moderator

8:29–8:36 p.m.	Quality of Life and Satisfaction Assessment After Successful Bone Transport in Patients with Segmental Tibial Deficit – *Gonzalo F. Bastias MD*
8:37–8:44 p.m.	Outcomes, Safety and Cost–effectiveness of Single–Stage Intramedullary Nails for Fracture Related Infections and Infected Nonunions *Olivia M. Rice, MD*
8:45–8:52 p.m.	Patient Reported Outcomes Assessment of 267 Children and Adolescents with Lower Limb Deficiency: A Multi–Center Study – *Sarah Nossov, MD*
8:53–9:04 p.m.	Discussion

Session 3: Pearls & Pitfalls – Raymond W. Liu, MD, Moderator

9:05–9:12 p.m.	Complications Requiring Readmission Following Limb Lengthening: A 10 Year U.S. Database Study – *Ashish Mittal, MD*
9:13–9:20 p.m.	Anesthesia Choice affects Length of Stay for Pediatric Acute Correction Patients *Philip K. McClure, MD*

9:21–9:28 p.m. Intramedullary Nailing with Supplemental Plate and Screw Fixation of Long Bones of Patients with Osteogenesis Imperfecta: Short–term Follow–up
Jeanne M. Franzone, MD

9:29–9:40 p.m. Discussion

Session 4: Intramedullary Implants – David Podeszwa, MD, Moderator

9:41–9:48 p.m. Weight–bearing Internal Lengthening Nail: Results on 57 Consecutive Stature Lengthening Patients – *Craig A. Robbins, MD*

9:49–9:56 p.m. Extramedullary Implantable Limb Lengthening (EMILL) for Congenital Limb Length Discrepancy – *Claire E. Shannon, MD*

9:57–10:05 p.m. Discussion

10:06–10:10 p.m. Closing Statements

Pre–Recorded Special Presentations

Traveling Fellowship 2019 Report (15 minutes)
James Blair, MD
Paul Matuszewski, MD
Claire E. Shannon, MD
Megan Young, MD

Clinician Scholar Career Development Program Presentation (10 minutes)
Joshua Speirs, MD

Pre–Recorded Scientific Papers

Session 1: Biomechanics & Metabolic (6 minutes each)

Rigidity of Hip–Spanning External Fixation as Affected by Pelvic Pin Location, Angulation, and Number of Pins – *Louis Bezuidenhout*

Effect of Dynamization Modules on Bone Segment Vertical and Lateral Displacements
Erin Honcharuk, MD

Does Vitamin D Insufficiency affect Healing during Distraction Osteogenesis?
Jessica C. Rivera, MD, PhD

Comparing Clinical and Radiological Outcomes in two Paediatric Cohorts undergoing Tibial Deformity Correction – *Juergen Messner*

Session 2: Trauma, Limb Salvage & Amputation Reconstruction (6 minutes each)

Union with Retained Cement Spacers – Deferment of Second Stage Grafting in the Masquelet Technique – *Stephen J. Wallace, MD*

Amputation Outcomes following Military Gustilo and Anderson 3C Lower Extremity Fractures *Jessica C. Rivera, MD, PhD*

Can We Predict When Exchange Nailing for Long Bone Nonunion Will Fail? *Brandon Collofello, MD*

Mid–term Results of Utilizing a Nail for Intercalary Allograft Reconstruction After Tumor Resection – *Lee M. Zuckerman, MD*

Complications of Regional and Local Anesthesia in the Operative Treatment of Tibia Fractures: Safety for the Patient and Staff – *Olivia M. Rice, MD*

Early Experience with Bone Anchored Osseointegration Prostheses – *Taylor J. Reif, MD*

Evaluation of Fracture and Osteotomy Union in the Setting of Osteogenesis Imperfecta: Multicenter Reliability of the Modified Radiographic Union Score for Tibial Fractures (RUST) *Jeanne M. Franzone, MD*

Vascularized Fibula Transfer with External Fixation for the Treatment of Bone Defects and Nonunions in Children – *Melissa Esparza, MD*

Session 3: Foot & Ankle (6 minutes each)

Hexapod–assisted Arthroscopic Ankle Arthrodesis for Severe Rigid Post Traumatic Equinus Deformity *Gonzalo F. Bastias, MD*

Functional Implications of the Flat–Topped Talus Following Treatment of Idiopathic Clubfoot Deformity *Anthony I. Riccio, MD*

Do We Really Need to Worry about Calcaneocuboid Subluxation during Lateral Column Lengthening for Planovalgus Foot Deformity? – *Anthony I. Riccio, MD*

The Effect of Lateral Column Lengthening on Subtalar Motion: Are We Trading Deformity for Stiffness? – *Jacob R. Zide, MD*

Subtalar Joint Deformity Correction and Arthrodesis – *Douglas N. Beaman, MD*

Session 4: Limb Deformity (6 minutes each)

Comparison and Validation of Pre–operative Planning Techniques for Distal Femoral Osteotomies and Proximal Tibial Osteotomies – *David T. Zhang, MD*

Pin Site Care – Updates on an International Multicentre Pin Site Infection Study – *Anthony Cooper*

The Effect of Silver–Plated Dressing on Pin Site Complication in Patients Undergoing Limb Lengthening and Deformity Correction using a Circular Frame – *Elaine Tran, MD*

Integrated Limb Lengthening is Superior to Classical Limb Lengthening: A Systematic Review and Meta–analysis of the Literature – *Gerard A. Sheridan MD, FRCS*

Correction of Tetratorsional Malalignment Improves Patient Reported Outcomes
Taylor J. Reif, MD

Epidural Anesthesia May Increase Opioid Consumption in Adult Gradual Correction Patients
John E. Herzenberg, MD

Accuracy and Safety of Distal Valgus Correction: Comparison of Three Techniques
Christopher A. Iobst, MD

Session 5: Internal Lengthening Nail (6 minutes each)

Humerus Lengthening: A Comparison of the Internal Lengthening Nail to External Fixation
Sherif Hassan

Nails for Femur Lengthening – *Sherif Hassan*

Magnetically Driven Intramedullary Limb Lengthening in Patients with Pre–Existing Implanted Programmable Devices: A Case Series – *Christopher A. Iobst, MD*

Cost Comparison of Tibial Distraction Osteogenesis with External Lengthening and Then Nailing (LATN) Versus Internal Magnetic Lengthening Nail (MLN) – *Aleksey Dvorzhinskiy*

Evaluating the Utility of the Pixel Value Ratio in the Determination of Time to Full Weight Bearing in Patients Undergoing Limb Lengthening Using an Intramedullary Device
Christopher A. Iobst, MD

Paediatric Femoral Lengthening Using Intramedullary Versus External Fixator Devices: A Single Surgeon Matched Cohort Series – *Laura Tillotson*

Session 6: Pediatric Limb Deformity (6 minutes each)

Does an Osteotomy Performed in Congenital Pseudarthrosis of the Tibia Heal? – *Nickolas J. Nahm*

Proximal Femoral Guided Growth for Dysplastic Hips in Children with Cerebral Palsy
Jacob R. Carl, MD

Modernization of Bone Age Assessment: Comparing the Accuracy and Reliability of an Artificial Intelligence Algorithm and Short–Hand Bone Age to Greulich and Pyle – *Mina Gerges*

What Matters Most to Children with Lower Limb Deformities – An International Qualitative Study Informing the Development of a New Patient Reported Outcome Instrument – LIMB–Q Kids
Harpreet Chhina

Estimating Skeletal Maturity using Knee Radiographs during Pre–adolescence –
The Epiphyseal: Metaphyseal Ratio – *Alex Benedick, MD*

Skeletal Maturity using Knee X–rays: Understanding the Resilience of Eight Radiographic Parameters to Rotational Position – *Julio C. Castillo Tafur*

Core Psychosocial Issues for Children and Adolescents in the Context of Limb Lengthening and Reconstruction Surgery Treatment – *Amber Hamilton*

Limb Lengthening in Russell–Silver Syndrome: An Update Confirming Safe and Speedy Healing
Christine M. Goodbody

Meta–analysis of Limb Lengthening and Related Complications in Osteogenesis Imperfecta
David S. Feldman, MD

Treatment Based Classification of Arthrogrypotic Hips and Knees – *David S. Feldman, MD*

Single Stage Surgery for Arthrogrypotic Hip and Knee Flexion Contractures
David S. Feldman, MD

Depression of the Medial Tibial Plateau in Infantile Blount Disease – Can Pathologic Bony Changes be Reversed with Guided Growth Treatment? – *Melinda S. Sharkey, MD*

Estimating Skeletal Maturity by Segmented Regression Analysis of Key Knee Radiograph Parameters – *Joshua T. Yuan*

<u>Poster Presentations</u>

Femoral Monofocal Sequential Compression–distraction Osteosynthesis Following Closing Wedge Osteotomy using a Magnetically–controlled Intramedullary Nail: A Case Report
John A. Scolaro, MD

Distraction Osteogenesis Using Dual Magnetically Expandable Intramedullary Nails for Large Diaphyseal Femur Defects in the Sarcoma Patient – *Steven Magister, MD*

Humeral Lengthening with Intramedullary Retrograde Nailing – A Surgical Technique and a Review of Three Cases – *Ulrik Kähler Olesen*

Redefining the Juvenile Bunion – *Anthony I. Riccio, MD*

Eliminating the Pain Generator may be More Important than the Deformity Correction in Calcaneus Fracture – *Ainsley K. Bloomer*

Tandem Use of a Single Magnetic Internal Lengthening Nail for Compound Femoral Lengthening
Harold J.P. van Bosse, MD

Regional Nerve Block Decreases Length of Stay in Pediatric Gradual Correction Patients
Philip K. McClure, MD

Nonvascularised Fibular Autograft for Reconstruction of Paediatric Bone Defects: An Analysis of 10 Cases – *Gerard A. Sheridan MD, FRCS*

Trends and Practices in Limb Lengthening Over 10 Years – A U.S. Database Study
Ashish Mittal, MD

Hexapod Education in Developing Nations – *Richard Gellman, MD*

Tiered Team Research: A Novel Concept for Increasing Research Productivity in the Academic Setting – *Joseph R. Hsu, MD*

Does Anesthesia Choice affect in Hospital Outcomes for Adult Acute Deformity Correction Patients? – *John E. Herzenberg, MD*

Prevalence of Vitamin D Deficiency in Adult Limb Lengthening and Deformity Correction Patients
John E. Herzenberg, MD

Accuracy of Virtual Surgical Planning and Custom 3D–printed Osteotomy and Reduction Guides for Acute Correction of Antebrachial Deformities in Dogs – *Christina Carolyn De Armond*

Clinical Observership Opportunities in North America for International Orthopaedic Surgeons
Sanjeev Sabharwal, MD

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July 16 & 17, 2021
Convene One Liberty Plaza
New York, NY

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Disclosures

Program Committee

Austin Thomas Fragomen, MD, FAAOS (New York, NY)
Submitted on: 04/06/2020
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant; Paid presenter or speaker
Smith & Nephew: Paid consultant; Paid presenter or speaker
Synthes: Paid consultant; Paid presenter or speaker

Raymond W Liu, MD, FAAOS (Cleveland, OH)
Submitted on: 06/10/2020
AAOS: Board or committee member
Journal of Pediatric Orthopedics: Editorial or governing board
Limb Lengthening and Reconstruction Society (LLRS): Board or committee member
Orthopediatrics Corporation: Royalties paid to my institution, part of which are placed into a research fund that i control: Other financial or material support
Pediatric Orthopaedic Society of North America: Board or committee member

Reid Boyce Nichols, MD, FAAOS (Wilmington, DE)
Submitted on: 04/22/2020
AAOS: Board or committee member
Journal of Pediatric Orthopedics: Editorial or governing board
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid presenter or speaker
Orthofix, Inc.: Paid consultant; Paid presenter or speaker
Orthopediatrics: Paid consultant; Paid presenter or speaker
Pediatric Orthopaedic Society of North America: Board or committee member
Ruth Jackson Orthopaedic Society: Board or committee member

David A Podeszwa, MD, FAAOS (Dallas, TX)
Submitted on: 06/15/2020
AAOS: Board or committee member
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Limb Lengthening and Reconstruction Society: Board or committee member
Orthopediatrics: Unpaid consultant
Pediatric Orthopaedic Society of North America: Board or committee member

Karen R Syzdek, Staff (Austin, TX)
(This individual reported nothing to disclose); Submitted on: 06/29/2020

Faculty
Jero Abad (Canada)
(This individual reported nothing to disclose); Submitted on: 03/31/2020

Jeffrey D Ackman, MD, FAAOS (Chicago, IL)
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Julie Agel, ATC (Seattle, WA)
Submitted on: 04/06/2020
Orthopaedic Trauma Association: Board or committee member

Jose Tomas Aldunate Sr, MD
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Sachin Allahabadi, MD
(This individual reported nothing to disclose); Submitted on: 06/28/2020

Vignesh K Alamanda, MD
(This individual reported nothing to disclose); Submitted on: 04/15/2020

Anirejuoritse Bafor, FACS, MD (Nigeria)
Submitted on: 06/22/2020
Bayer: Research support
Morison industries: Research support

Gonzalo Bastias Sr, MD (Chile)
(This individual reported nothing to disclose); Submitted on: 04/20/2020

Douglas N Beaman, MD, FAAOS
Submitted on: 06/13/2020
Acumed, LLC: Paid consultant
Extremity Medical: Paid consultant
Limb Lengthening and Reconstruction Society: Board or committee member
Smith & Nephew: Paid presenter or speaker

Michael Beck, BS (West Palm Beach, FL)
(This individual reported nothing to disclose); Submitted on: 04/02/2020

Alexander J Benedick, MD (Cleveland, OH)
(This individual reported nothing to disclose); Submitted on: 01/05/2020

Adam Biedrzycki, DVM, PhD (Gainesville, FL)
(This individual reported nothing to disclose); Submitted on: 04/05/2020

Louis Bezuidenhout, MD (Canada)
(This individual reported nothing to disclose); Submitted on: 03/31/2020

John G Birch, MD, FAAOS, FRCSC (Dallas, TX)
Submitted on: 07/01/2020
Journal of Children's Orthopedics: Editorial or governing board
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James Alan Blair, MD, FAAOS (Augusta, GA)
Submitted on: 06/29/2020
Orthopaedic Trauma Association: Board or committee member
Society of Military Orthopaedic Surgeons: Board or committee member

Ainsley Katherine Bloomer, BA, BS
(This individual reported nothing to disclose); Submitted on: 04/24/2020

Justine Borchard (Dallas, TX)
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Catharine Bradley (Canada)
(This individual reported nothing to disclose); Submitted on: 07/02/2020

Joshua Rory Buksbaum, BA, BS
(This individual reported nothing to disclose); Submitted on: 07/02/2020

Matthew Kevin Callahan, MSBA (San Francisco, CA)
(This individual reported nothing to disclose); Submitted on: 06/30/2020

Nancy Campbell, DO
(This individual reported nothing to disclose); Submitted on: 07/02/2020

Jacob R Carl, MD (Cincinnati, OH)
(This individual reported nothing to disclose); Submitted on: 04/11/2020

Laura Ann Carrillo, BA (Oakland, CA)
(This individual reported nothing to disclose); Submitted on: 06/23/2020

Jeffrey Allen Cassidy, MD, FAAOS
(This individual reported nothing to disclose); Submitted on: 06/28/2020

Iciar M Davila Castrodad, MD
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Felipe A Chaparro, MD
Submitted on: 04/20/2020
Orthofix, Inc.: Paid presenter or speaker

Fuhuan Chen
(This individual reported nothing to disclose); Submitted on: 03/31/2020

Alexander Cherkashin, MD (Dallas, TX)
Submitted on: 01/07/2020
Orthofix, Inc.: IP royalties; Paid consultant

Harpreet Chhina, MSc (Canada)
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Melih Civan, MD (Turkey)
(This individual reported nothing to disclose); Submitted on: 04/24/202

Brandon S Collofello, MD (Lexington, KY)
Submitted on: 04/28/2020
Chicago Street Medicine: Board or committee member

Anthony Cooper, FRCS (Ortho) (Canada)
Submitted on: 04/23/2020
Canadian Orthopaedic Association: Board or committee member
Pediatric Orthopaedic Society of North America: Board or committee member
Vilex, Inc.: Paid consultant

Jonathan Copp, MD
(This individual reported nothing to disclose); Submitted on: 01/23/2020

Natalio Rene Cuchacovich, MD (Chile)
(This individual reported nothing to disclose); Submitted on: 06/29/2020

Sophie Susan Davidson (Canada)
(This individual reported nothing to disclose); Submitted on: 04/15/2020

Christina Carolyn De Armond, DVM (Gainesville, FL)
(This individual reported nothing to disclose); Submitted on: 03/31/2020

Noelle DiGioia, DO
(This individual reported nothing to disclose); Submitted on: 06/30/2020

Aaron Paul Donnelly, MBChB
(This individual reported nothing to disclose); Submitted on: 03/29/2020

Scott Douglas, MD
(This individual reported nothing to disclose); Submitted on: 06/01/2020

Jarrod Edward Dumpe, MD, FAAOS
Submitted on: 07/10/2020
Orthopaedic Trauma Association: Board or committee member

Aleksey Dvorzhinskiy, MD
(This individual reported nothing to disclose); Submitted on: 06/18/2020

Molly Eskilson Duncan, BA, BS (Columbus, OH)
(This individual reported nothing to disclose); Submitted on: 06/22/2020

Paul W Esposito, MD, FAAOS (Omaha, NE)
Submitted on: 07/09/2020
Orthopediatrics: Paid consultant

Hayley Eng, BS
(This individual reported nothing to disclose); Submitted on: 07/01/2020

B. Sue Epstein, PhD (New York, NY)
(This individual reported nothing to disclose); Submitted on: 07/10/2020

Mario Escudero III, MD
(This individual reported nothing to disclose); Submitted on: 03/28/2020

Melissa Esparza, MD (Tucson, AZ)
(This individual reported nothing to disclose); Submitted on: 01/06/2020

Peter D Fabricant, MD, MPH (New York, NY)
Submitted on: 06/25/2020
Clinical Orthopaedics and Related Research: Editorial or governing board
Pediatric Orthopaedic Society of North America: Board or committee member
Pediatric Research in Sports Medicine Society: Board or committee member
Research in OsteoChondritis of the Knee (ROCK): Board or committee member

David S Feldman, MD, FAAOS (West Palm Beach, FL)
Submitted on: 07/01/2020
orthopediatrics: IP royalties; Paid consultant

Austin Thomas Fragomen, MD, FAAOS (New York, NY)
Submitted on: 04/06/2020
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant; Paid presenter or speaker
Smith & Nephew: Paid consultant; Paid presenter or speaker
Synthes: Paid consultant; Paid presenter or speaker

Kirsten Tulchin–Francis, PhD (Dallas, TX)
Submitted on: 07/01/2020
Gait and Clinical Movement Analysis Society: Board or committee member
Maxim Integrated, Inc: Stock or stock Options
Pediatric Research in Sports Medicine: Board or committee member

Jeanne M Franzone, MD
Submitted on: 04/22/2020
Limb Lengthening and Reconstruction Society: Board or committee member
Pediatric Orthopaedic Society of North America: Board or committee member

Patricio Fuentes, MD (Chile)
Submitted on: 07/01/2020
Orthofix, Inc.: Paid consultant

Richard Evan Gellman, MD, FAAOS (Portland, OR)
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Mina Gerges, BA
(This individual reported nothing to disclose); Submitted on: 04/01/2020

Patrick John Getty, MD, FAAOS (Cleveland, OH)
Submitted on: 06/23/2020
American Board of Orthopaedic Surgery, Inc.: Board or committee member
Musculoskeletal Transplant Foundation: Other financial or material support

Michael Githens, MD (Seattle, WA)
Submitted on: 04/02/2020
Synthes: Paid presenter or speaker
Techniques in Orthopaedics: Editorial or governing board
Western Orthopaedic Association: Board or committee member
Wolters Kluwer Health – Lippincott Williams & Wilkins: Publishing royalties, financial or material support

Christine Goodbody, MD (New York, NY)
(This individual reported nothing to disclose); Submitted on: 04/01/2020

Paulina Gutierrez, MD
(This individual reported nothing to disclose); Submitted on: 04/20/2020

Amber A Hamilton, BA
(This individual reported nothing to disclose); Submitted on: 06/01/2020
Regina Hanstein, PhD (Bronx, NY)
(This individual reported nothing to disclose); Submitted on: 06/22/2020

Madeleine D Harbison, MD (New York, NY)
(This individual reported nothing to disclose); Submitted on: 03/27/2020

Caitlin Hardin, ACNP–BC, ATC, BA, BOC, BOCO, BOCP, BS
Submitted on: 01/07/2020
IQVIA– contract for DePuy Synthes: Employee
Stryker: Employee

Mitchell Clark Harris, MD
(This individual reported nothing to disclose); Submitted on: 01/07/2020

Nathan Khabyeh–Hasbani
(This individual reported nothing to disclose); Submitted on: 04/21/2020

Sherif Galal Hassan, MBChB, PhD
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Brittany Hedrick, MD
(This individual reported nothing to disclose); Submitted on: 01/07/2020

John E Herzenberg, MD, FAAOS (Baltimore, MD)
Submitted on: 04/02/2020
Arthrex: Other financial or material support
Bonus BioGroup: Paid consultant
DePuy Synthes: Other financial or material support
Metro Prosthetics: Other financial or material support
MHE Coalition: Other financial or material support
Nuvasive: Other financial or material support; Paid consultant
Orthofix, Inc.: Other financial or material support; Paid consultant
OrthoPediatrics: Other financial or material support; Paid consultant
OrthoSpin: Paid consultant
Pega Medical: Other financial or material support
Smith & Nephew: Other financial or material support; Paid consultant
Stryker: Other financial or material support
Supreme Orthopedic Systems: Other financial or material support
Treace Medical Concepts, Inc.: Other financial or material support
Vilex: Other financial or material support
WishBone Medical: Paid consultant
Zimmer Biomet: Other financial or material support

Bailyn Hogue
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Erin Honcharuk, MD (Dallas, TX)
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Joseph R Hsu, MD, FAAOS
Submitted on: 04/15/2020
Smith & Nephew: Paid presenter or speaker

Christopher August Iobst, MD, FAAOS (Columbus, OH)
Submitted on: 04/02/2020
Nuvasive: Paid consultant
Orthofix, Inc.: Paid consultant
Smith & Nephew: Paid presenter or speaker

Cale Jacobs, PhD (Lexington, KY)
Submitted on: 06/16/2020
Flexion Therapeutics: Paid consultant; Research support
Journal of Sport Rehabilitation: Editorial or governing board
Smith & Nephew: Research support

Rishab Jayaram
Submitted on: 07/01/2020
Biomarin: Employee; Stock or stock Options

Chan–Hee Jo, PhD (Dallas, TX)
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Nicholas Johnson, MD (Charlotte, NC)
(This individual reported nothing to disclose); Submitted on: 06/28/2020

Srinivasa Prasad Venkata Kanuparthi, BS
(This individual reported nothing to disclose); Submitted on: 04/15/2020

Paul M Kelly, FRCSC, MD (Canada)
(This individual reported nothing to disclose); Submitted on: 06/29/2020

Simon Kelley, MBChB, FRCS (Ortho) (Canada)
Submitted on: 04/15/2020
International Hip Dysplasia Institute: Board or committee member
Journal of Pediatric Orthopedics: Editorial or governing board
Nuvasive: Paid presenter or speaker
Smith & Nephew: Paid consultant; Paid presenter or speaker

Laurence Kempton, MD, FAAOS (Charlotte, NC)
Submitted on: 06/30/2020
Orthopaedic Trauma Association: Board or committee member

Stanley Eunwoo Kim (Gainesville, FL)
Submitted on: 04/01/2020
Arthrex, Inc: Paid consultant; Research support
Intrauma: Research support
Journal of Orthopaedic Research: Editorial or governing board
Karl Storz: Other financial or material support
Veterinary Orthopedic Implants: Paid presenter or speaker

Anne Klassen, PhD (Canada)
(This individual reported nothing to disclose); Submitted on: 07/02/2020

Jacek Kopec, MD, MSc, PhD (Canada)
(This individual reported nothing to disclose); Submitted on: 07/02/2020

Chad A Krueger, MD, FAAOS
Submitted on: 06/29/2020
American Association of Hip and Knee Surgeons: Board or committee member
Journal of Arthroplasty: Editorial or governing board

Richard W Kruse, DO, FAAOS (Wilmington, DE)
Submitted on: 07/01/2020
AAOS: Board or committee member
Clinical education Medical Advisory Board: Board or committee member
orthopaediatrics: Paid consultant
osteogenesis imperfecta foundation: Board or committee member
Pediatric Orthopaedic Society of North America: Board or committee member

Cheryl Lawing, MD, FAAOS
(This individual reported nothing to disclose); Submitted on: 06/03/2020

Joel A Lerman, MD, FAAOS (Sacramento, CA)
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Daniel Dean Lewis (Gainesville, FL)
(This individual reported nothing to disclose); Submitted on: 03/31/2020

Katherine Li, MD (Charlotte, NC)
(This individual reported nothing to disclose); Submitted on: 06/01/2020

Raymond W Liu, MD, FAAOS (Cleveland, OH)
Submitted on: 06/10/2020
AAOS: Board or committee member
Journal of Pediatric Orthopedics: Editorial or governing board
Limb Lengthening and Reconstruction Society (LLRS): Board or committee member
Orthopediatrics Corporation: Royalties paid to my institution, part of which are placed into a research fund that i control: Other financial or material support
Pediatric Orthopaedic Society of North America: Board or committee member

James J McCarthy, MD, FAAOS (Cincinnati, OH)
Submitted on: 04/23/2020
DePuy, A Johnson & Johnson Company: Paid presenter or speaker
LADD–Living Arrangements for the Developmentaliy Disabled–Wife: Board or committee member
Nuvasive: IP royalties; Paid consultant; Research support
Orthopediatrics: Unpaid consultant
Orthopedics: Publishing royalties, financial or material support
Pediatric Orthopaedic Society of North America: Board or committee member
Wolters Kluwer Health – Lippincott Williams & Wilkins: Publishing royalties, financial or material support

Philip Kraus McClure, MD
Submitted on: 06/29/2020
Novadip: Paid consultant
Orthofix, Inc.: Paid consultant
Smith & Nephew: Paid consultant

Richard Randall McKnight Jr, MD (Charlotte, NC)
(This individual reported nothing to disclose); Submitted on: 04/15/2020

Maureen J Maciel, MD, FAAOS (Tampa, FL)
(This individual reported nothing to disclose); Submitted on: 06/09/2020

David Macknet, MD (Charlotte, NC)
(This individual reported nothing to disclose); Submitted on: 04/22/2020

Connor Maddock (Canada)
(This individual reported nothing to disclose); Submitted on: 04/15/2020

Christopher A Makarewich, MD (Park City, UT)
(This individual reported nothing to disclose); Submitted on: 04/15/2020

Marina Makarov (Dallas, TX)
Submitted on: 10/01/2019
Orthofix, Inc.: IP royalties; Paid consultant

Steven Magister, MD (Cleveland, OH)
(This individual reported nothing to disclose); Submitted on: 01/13/2020

Bryan J. Mark, BA, MD
(This individual reported nothing to disclose); Submitted on: 06/07/2020

Paul Edward Matuszewski, MD, FAAOS (Lexington, KY)
Submitted on: 07/01/2020
AAOS: Board or committee member
Orthopaedic Trauma Association: Board or committee member
Stryker: Paid consultant; Research support

Juergen Messner, MD
(This individual reported nothing to disclose); Submitted on: 04/15/2020

Ashish Mittal, MD (San Francisco, CA)
(This individual reported nothing to disclose); Submitted on: 06/24/2020

Hannah Delores Miravich, BA (Philadelphia, PA)
(This individual reported nothing to disclose); Submitted on: 04/15/2020

Nequesha Mohamed, MD
(This individual reported nothing to disclose); Submitted on: 06/29/2020

David Moore, MD (Ireland)
Submitted on: 04/23/2020
1. Irish Institute of Trauma & Orthopaedic Surgery
2. Royal College of Surgeons in Ireland: Board or committee member

Nickolas Jae Nahm, MD (Baltimore, MD)
(This individual reported nothing to disclose); Submitted on: 06/17/2020

Maria Noonan
(This individual reported nothing to disclose); Submitted on: 04/02/2020

Sarah Nossov, MD, FAAOS
(This individual reported nothing to disclose); Submitted on: 06/24/2020

Tobias Nygaard, MD (Denmark)
Submitted on: 03/31/2020
LLRS–NORDIC: Board or committee member

Susan Marie Odum, PhD (Charlotte, NC)
Submitted on: 06/18/2020
American Joint Replacement Registry: Paid consultant
Lumbar Spine Research Society: Board or committee member
North American Spine Society: Board or committee member

Ulrik Kähler Olesen, MD (Denmark)
(This individual reported nothing to disclose); Submitted on: 03/31/2020

John Oliffe, PhD (Canada)
(This individual reported nothing to disclose); Submitted on: 07/09/2020

Dror Paley, MD, FAAOS, FRCSC (West Palm Beach, FL)
Submitted on: 06/24/2020
Devise Ortho: Stock or stock Options
Nuvasive: IP royalties; Paid consultant
Orthex: Stock or stock Options
Orthopediatrics: IP royalties
Pega Medical: IP royalties
Smith & Nephew: IP royalties
Springer: Publishing royalties, financial or material support

Sahir Pervaiz, MD, MS
(This individual reported nothing to disclose); Submitted on: 06/01/2020

Kevin Daniel Phelps, MD (Charlotte, NC)
(This individual reported nothing to disclose); Submitted on: 04/22/2020

William Pierce (Dallas, TX)
(This individual reported nothing to disclose); Submitted on: 04/02/2020

David A Podeszwa, MD, FAAOS (Dallas, TX)
Submitted on: 06/15/2020
AAOS: Board or committee member
Elsevier: Publishing royalties, financial or material support
Journal of the American Academy of Orthopaedic Surgeons: Editorial or governing board
Limb Lengthening and Reconstruction Society: Board or committee member
Orthopediatrics: Unpaid consultant
Pediatric Orthopaedic Society of North America: Board or committee member

Kenneth Patrick Powell, MD, FAAOS (SHREVEPORT, LA)
Submitted on: 07/02/2020
Nuvasive: Stock or stock Options

Peter S. Principe, BS
(This individual reported nothing to disclose); Submitted on: 04/02/2020

Troy Rand, PhD (West Palm Beach, FL)
(This individual reported nothing to disclose); Submitted on: 04/15/2020

David Slade Ransdell, ACNP–BC, ATC, BA, BOC, BOCO, BOCP, BS (Lexington, KY)
(This individual reported nothing to disclose); Submitted on: 04/28/2020

Taylor Reif, MD (New York, NY)
(This individual reported nothing to disclose); Submitted on: 04/20/2020

Ethan Remily, DO
(This individual reported nothing to disclose); Submitted on: 06/25/2020

Anthony Ian Riccio, MD, FAAOS (Dallas, TX)
Submitted on: 06/25/2020
Arthrex, Inc: Research support
Childrens Orthopaedic Trauma and Infection Consortium for Evidence Based Studies (CORTICES): Board or committee member
Pediatric Orthopaedic Society of North America: Board or committee member
Saunders/Mosby–Elsevier: Publishing royalties, financial or material support
Smart Medical Devices: Research support

Olivia Rice, MD (Charlotte, NC)
(This individual reported nothing to disclose); Submitted on: 04/15/2020

Jessica C Rivera, MD, PhD, FAAOS
Submitted on: 06/29/2020
AAOS: Board or committee member
Limb Lengthening and Reconstruction Society: Board or committee member
Orthopaedic Research Society: Board or committee member

Craig A Robbins, MD, FAAOS (West Palm Beach, FL)
Submitted on: 03/30/2020
Nuvasive: Paid presenter or speaker
Orthopediatrics: Paid presenter or speaker
Smith & Nephew: Paid presenter or speaker

Kenneth J Rogers, PhD (Wilmington, DE)
(This individual reported nothing to disclose); Submitted on: 07/02/2020

Katherine Rosenwasser, MD
Submitted on: 04/15/2020
American Journal of Orthopedics: Editorial or governing board
Biomet: IP royalties
CoNexions: Stock or stock Options
DJ Orthopaedics: Paid presenter or speaker
Foundation for Orthopedic Trauma: Board or committee member
Radicle Orthopedics: Stock or stock Options
Stryker: Paid presenter or speaker
Zimmer: Paid presenter or speaker

S Robert Rozbruch, MD, FAAOS (New York, NY)
Submitted on: 06/16/2020
Informa: Publishing royalties, financial or material support
Limb Lengthening Reconstruction Society: Board or committee member
Nuvasive: Paid consultant; Paid presenter or speaker
Orthospin: Paid consultant; Stock or stock Options
Smith & Nephew: Paid consultant; Paid presenter or speaker
Springer: Publishing royalties, financial or material support
Stryker: IP royalties; Paid consultant; Paid presenter or speaker

Sanjeev Sabharwal, MD, MPH, FAAOS
Submitted on: 04/25/2020
Journal of Bone and Joint Surgery – American: Editorial or governing board; Publishing royalties, financial or material support
Journal of Limb Lengthening and Reconstruction: Editorial or governing board
Springer: Publishing royalties, financial or material support

Mikhail Samchukov, MD (Dallas, TX)
Submitted on: 12/04/2019
Orthofix, Inc.: IP royalties; Paid consultant

James O Sanders, MD, FAAOS (Chapel Hill, NC)
Submitted on: 06/15/2020
Abbott: Stock or stock Options
Abbvie: Stock or stock Options
GE Healthcare: Stock or stock Options
GreenSun: Other financial or material support
Orthopediatrics: Paid consultant
Pediatric Orthopaedic Society of North America: Board or committee member
Scoliosis Research Society: Board or committee member
Tether implant corporation: Stock or stock Options

Angelika Saribekyan, BS
(This individual reported nothing to disclose); Submitted on: 04/22/2020

John Alan Scolaro, MD, FAAOS (Orange, CA)
Submitted on: 04/02/2020
Foundation for Orthopaedic Trauma: Board or committee member
Globus Medical: IP royalties; Paid consultant
Nuvasive: Paid presenter or speaker
Smith & Nephew: Paid consultant
Stryker: Paid consultant
Zimmer: Paid consultant

Christopher Schneble, MD (Milford, CT)
(This individual reported nothing to disclose); Submitted on: 06/02/2020

Jacob Foster Schulz, MD, FAAOS
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Borja Segarra, MD
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Rachel Seymour, PhD (Charlotte, NC)
(This individual reported nothing to disclose); Submitted on: 04/20/2020

Claire Shannon, MD (West Palm Beach, FL)
Submitted on: 04/20/2020
Limb Lengthening and Reconstruction Society: Board or committee member
Novadip: Paid consultant
Nuvasive: Unpaid consultant
Orthopediatrics: Paid consultant
Pediatric Orthopaedic Society of North America: Board or committee member
Zimmer: Employee

Melinda Sharkey, MD, FAAOS
Submitted on: 07/01/2020
Pediatric Orthopaedic Society of North America: Board or committee member

Gerard Anthony Sheridan, FRCS
(This individual reported nothing to disclose); Submitted on: 04/02/2020

Jonggu Shin, MD
(This individual reported nothing to disclose); Submitted on: 04/21/2020

Matthew Siebert, MD
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Satbir Singh, BS (Columbus, OH)
(This individual reported nothing to disclose); Submitted on: 04/22/2020

Claire Shivers, BS (Dallas, TX)
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Felipe Silva Jr, MD
(This individual reported nothing to disclose); Submitted on: 04/20/2020

Stephen H Sims, MD, FAAOS (Charlotte, NC)
Submitted on: 06/30/2020
AO North America: Paid presenter or speaker
Synthes: Paid presenter or speaker

Danielle Thomas, MD
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Adrienne Socci, MD
(This individual reported nothing to disclose); Submitted on: 07/02/2020

John K Sontich, MD, FAAOS
Submitted on: 06/19/2020
Limb Lengthening and Reconstruction Society: Board or committee member
Smith & Nephew: Paid consultant
Stryker: IP royalties; Paid consultant; Paid presenter or speaker

Joshua Nelson Speirs, MD
(This individual reported nothing to disclose); Submitted on: 07/09/2020

Matthew Charles Starke, MD
(This individual reported nothing to disclose); Submitted on: 04/16/2020

Wilshaw Stevens Jr, BS (Dallas, TX)
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Daniel J Stinner, MD, PhD, FAAOS, FACS
Submitted on: 04/15/2020
AAOS: Board or committee member
Orthopaedic Trauma Association: Board or committee member
Society of Military Orthopaedic Surgeons: Board or committee member

Julio Cesar Castillo Tafur, BA, BS
Submitted on: 04/20/2020
3M: Stock or stock Options
Abbott: Stock or stock Options
Gilead: Stock or stock Options
Johnson & Johnson: Stock or stock Options
Moderna: Stock or stock Options
Pfizer: Stock or stock Options
Roche: Stock or stock Options
Sanofi–Aventis: Stock or stock Options
Stryker: Stock or stock Options

Peter Helmut Thaller, MD, MSc (Germany)
Submitted on: 03/31/2020
Gerhard Küntscher Society: Board or committee member

Danielle Thomas, MD
(This individual reported nothing to disclose); Submitted on: 07/01/2020

Laura Tillotson, FRCS (Ortho), MBBS, MRCS (Canada)
(This individual reported nothing to disclose); Submitted on: 04/15/2020

Cassandra Bree Tomczak, DPM
Submitted on: 07/01/2020
Stryker: Paid presenter or speaker
Synthes: Paid presenter or speaker

Elaine Tran, MD
(This individual reported nothing to disclose); Submitted on: 01/06/2020

Naveen K Uli (Cleveland, OH)
Submitted on: 04/13/2020
Gilead Sciences: Stock or stock Options

Harold J P Van Bosse, MD, FAAOS
Submitted on: 04/15/2020
Limb Lengthening and Reconstruction Society: Board or committee member
Pediatric Orthopaedic Society of North America: Board or committee member
Scoliosis Research Society: Board or committee member

Mohammed Waseemuddin, MD (Qatar)
(This individual reported nothing to disclose); Submitted on: 05/29/2020

Janet L. Walker, MD, FAAOS (Lexington, KY)
(This individual reported nothing to disclose); Submitted on: 06/12/2020

Maegen Wallace, MD, FAAOS (Omaha, NE)
Submitted on: 07/01/2020
AAOS: Board or committee member
Pediatric Orthopaedic Society of North America: Board or committee member

Stephen Wallace, MD
(This individual reported nothing to disclose); Submitted on: 04/20/2020

Joseph C Wenke, PhD (San Antonio, TX)
Submitted on: 04/21/2020
European Cell & Materials: Editorial or governing board
Journal of Surgical Orthopaedic Advances: Editorial or governing board

David Elbert Westberry, MD, FAAOS (Greenville, SC)
(This individual reported nothing to disclose); Submitted on: 07/03/2020

Wayne Alexander Wilkie, MHA
(This individual reported nothing to disclose); Submitted on: 04/16/2020

Nadine L Williams, MD (Loma Linda, CA)
(This individual reported nothing to disclose); Submitted on: 04/20/2020

Felipe Antonio Yanez Sr. MS
(This individual reported nothing to disclose); Submitted on: 07/03/2020

Megan Lynn Young, MD, FAAOS (Washington, DC)
(This individual reported nothing to disclose); Submitted on: 07/06/2020

Ziqing Yu, MS (Charlotte, NC)
(This individual reported nothing to disclose); Submitted on: 04/21/2020

Joshua Thomas Yuan, BA
(This individual reported nothing to disclose); Submitted on: 04/20/2020

David Zhang, BA
(This individual reported nothing to disclose); Submitted on: 04/01/2020

Jacob Rothschild Zide, MD, FAAOS
Submitted on: 04/20/2020
AAOS: Board or committee member
American Orthopaedic Foot and Ankle Society: Board or committee member
Orthofix, Inc.: Paid consultant

Lee Michael Zuckerman, MD, FAAOS (Duarte, CA)
Submitted on: 04/20/2020
NuVasive Specialized Orthopedics: Paid consultant; Paid presenter or speaker; Research support
Onkos Surgical: Research support

Live Presentations of Scientific Papers

Presented Live and Recorded on July 30, 2020
8:00 p.m. EDT

Session I: Radiographed Derived

Moderator: L. Reid Nichols, MD

Comparison of Lower Extremity Segment Length Prediction Accuracy of the Sanders Multiplier, Paley Multiplier, and White–Menelaus Formulae

Marina R. Makarov, MD; David A. Podeszwa, MD; James O. Sanders, MD; John G. Birch, MD, FRCS(C)
marina.makarov@tsrh.org

What was the question?
We sought to compare the accuracy of the Paley multiplier, Sanders multiplier, and White–Menelaus methods in predicting femoral and tibial lengths at maturity in an epiphysiodesis–age cohort.

How did you answer the question?
After identifying healthy unoperated femoral and tibial segments from both the longer and shorter leg from an epiphysiodesis database, we measured the actual growth that occurred in these unoperated segments from just prior to surgery to skeletal maturity. We determined the Sanders stage and skeletal age (using the Greulich and Pyle atlas), and compared predicted length to actual length using the Paley multiplier and White–Menelaus methods and Greulich/Pyle skeletal age, and Sanders multiplier for Sanders stages. We conducted an inter– and intra–rater reliability study of Sanders staging in a separate group of 76 hand and wrist films.

What are the results?
The cohort consisted of 148 femora and 195 tibiae in 197 patients (92 females and 105 males). The average initial age was 12.5 years (range, 9–16.5). All methods slightly overestimated tibial length at maturity. The Sanders multiplier/staging was more accurate than the Paley multiplier/Greulich and Pyle skeletal age in predicting femoral length at maturity, but the White–Menelaus formulae/Greulich and Pyle skeletal age method was the most accurate. The Sanders multiplier slightly underestimated femoral length and overestimated tibial length, rendering whole–leg prediction accuracy comparable to the White–Menelaus formulae. The Paley multiplier overestimated both femoral and tibial lengths. Inter–rater ICC was 0.85 (four observers) and intra–rater ICC was 0.90–0.93 (three observers) in the Sanders skeletal staging study of 76 films.

What are your conclusions?
The Sanders skeletal staging/multiplier was more accurate than the Paley multiplier/Greulich and Pyle skeletal age in this cohort. The White–Menelaus formulae using Greulich and Pyle skeletal age was slightly more accurate than the Sanders in predicting femoral length, and slightly less accurate in predicting tibial length. Sanders staging demonstrated high inter– and intra–rater reliability. Correlating Sanders stages with skeletal growth remaining, using the White–Menelaus formulae, would likely improve the accuracy of predicting epiphysiodesis effect.

Comparison of Lower Extremity Segment Length Prediction Accuracy of the Sanders Multiplier, Paley Multiplier, and White-Menelaus Formulae

Marina R. Makarov, MD
David A. Podeszwa, MD
James O. Sanders, MD
John G. Birch, MD, FRCS(C),
Chan-Hee Jo, Ph.D.

SCOTTISH RITE FOR CHILDREN
UTSouthwestern Medical Center

1

Disclosures

No disclosures
to report in relation to this study

2

Objectives

- To rate reliability of the Sanders' Skeletal Stages using ICC
- To compare limb length prediction @ maturity using

Sanders Multiplier & Sanders Skeletal Stages
Paley Multiplier & Greulich/Pyle Skeletal Age
White-Menelaus Formulae & Greulich/Pyle SA

3

Methods

- Sanders' Stage Intra- and Inter-Rater Reliability
- Four observers independently scored 76 hand and wrist films of skeletally-immature subjects selected from an epiphysiodesis database
- Three observers repeated scoring 3-4 weeks later

4

Methods

- Comparison of Prediction Accuracy of the different methods:
- We measured pre-operative and maturity scanograms of *__unoperated__* healthy leg segments identified from our epiphysiodesis DB.
- Preoperative hand and wrist films were scored according to Sanders' Stages, and the Greulich and Pyle Atlas.
- We then compared the *__actual multiplier to predicted__* (length at maturity/length at surgery)

Sanders Multiplier & Sanders Skeletal Stages
Paley Multiplier & Greulich/Pyle Skeletal Age
White-Menelaus Formulae & Greulich/Pyle SA

5

Study population

- 148 femora, 195 tibiae
- 197 patients (92 girls, 105 boys)
- Age at surgery, evarage 12.5 (range, 9-16.5)

6

Results

- Sanders' Stage intraclass correlation

Inter-rater ICC (four observers) was 0.85

Intra-rater ICC (three observers) was 0.90-0.93

7

Results: Limb Length Prediction Accuracy

Segment	Method	Length Mean (SD) (in cm)	Difference Mean (SD) (in cm)	P-value*
Femur (n=148)	Actual	45.6 (3.5)	-	-
	Sanders	45.3 (3.6)	- 0.3 (1.4)	<0.01
	Paley	46.7 (3.8)	1.1 (1.7)	<0.01
	White-Menelaus	45.7 (3.4)	0.1 (1.4)	0.69
Tibia (n=195)	Actual	36.6 (2.9)	-	-
	Sanders	36.9 (3.1)	0.3 (1.2)	<0.01
	Paley	37.6 (3.2)	1.0 (1.2)	<0.01
	White-Menelaus	37.3 (2.9)	0.7 (1.0)	<0.01

*paired t-test

8

Results: Limb Length Prediction Accuracy

Segment	Method	Length Mean (SD) (in cm)	Difference Mean (SD) (in cm)	P-value
Femur (n=148)	Actual	45.6 (3.5)	-	-
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	White-Menelaus	45.7 (3.4)	0.1 (1.4)	0.69
Tibia (n=195)	Actual	36.6 (2.9)	-	-
	Sanders	36.9 (3.1)	0.3 (1.2)	<0.01
	Paley	37.6 (3.2)	1.0 (1.2)	<0.01
	White-Menelaus	37.3 (2.9)	0.7 (1.0)	<0.01

All methods slightly overestimated tibial length (Paley the most)

9

Results: Limb Length Prediction Accuracy

Segment	Method	Length Mean (SD) (in cm)	Difference Mean (SD) (in cm)	P-value
Femur (n=148)	Actual	45.6 (3.5)	-	-
	Sanders	45.3 (3.6)	- 0.3 (1.4)	<0.01
	Paley	46.7 (3.8)	1.1 (1.7)	<0.01
	White-Menelaus	45.7 (3.4)	0.1 (1.4)	0.69
Tibia (n=195)	Actual	36.6 (2.9)	-	-
	Sanders	36.9 (3.1)	0.3 (1.2)	<0.01
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	White-Menelaus	37.3 (2.9)	0.7 (1.0)	<0.01

Sanders slightly underestimated femoral length at maturity

10

Results: Limb Length Prediction Accuracy

Segment	Method	Length Mean (SD) (in cm)	Difference Mean (SD) (in cm)	P-value
Femur (n=148)	Actual	45.6 (3.5)	-	-
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Paley multiplier overestimated femoral length at maturity

11

Results: Limb Length Prediction Accuracy

Segment	Method	Length Mean (SD) (in cm)	Difference Mean (SD) (in cm)	P-value
Femur (n=148)	Actual	45.6 (3.5)	-	-
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	Paley	37.6 (3.2)	1.0 (1.2)	<0.01
	White-Menelaus	37.3 (2.9)	0.7 (1.0)	<0.01

White-Menelaus formulae was near perfect

12

Results: Leg Length Prediction Accuracy

Segment	Method	Length Mean (SD) (in cm)	Difference Mean (SD) (in cm)	P-value
Femur (n=148)	Actual	45.6 (3.5)	-	-
	Sanders	45.3 (3.6)	- 0.3 (1.4)	<0.01
	Paley	46.7 (3.8)	1.1 (1.7)	<0.01
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	Paley	37.6 (3.2)	1.0 (1.2)	<0.01
	White-Menelaus	37.3 (2.9)	0.7 (1.0)	<0.01
Whole leg (n=29)	Actual	80.2 (6.4)	-	-
	Sanders	80.2 (5.9)	0.1 (2.4)	0.9
	Paley	82.2(8.3)	2.0 (3.2)	<0.01
	White-Menelaus	80.6 (6.7)	0.4 (2.0)	0.2

13

Results: Leg Length Prediction Accuracy

Segment	Method	Length Mean (SD) (in cm)	Difference Mean (SD) (in cm)	P-value
Femur (n=148)	Actual	45.6 (3.5)	-	-
	Sanders	45.3 (3.6)	- 0.3 (1.4)	<0.01
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14

Results: Actual vs. Predicted Multiplier

Segment	Method	Multipliers Mean (SD)	Difference Mean (SD)	P-value
Femur (n=148)	Actual	1.084 (0.052)	-	-
	Sanders	1.076 (0.025)	- 0.008 (0.03)	<0.01
	Paley	1.108 (0.058)	0.024 (0.04)	<0.01
	White-Menelaus	1.085 (0.039)	0.001 (0.03)	0.79
Tibia (n=195)	Actual	1.061 (0.048)	-	-
	Sanders	1.071 (0.021)	0.01 (0.04)	<0.01
	Paley	1.091 (0.054)	0.03 (0.04)	<0.01
	White-Menelaus	1.081 (0.037)	0.02 (0.03)	<0.01

Sanders multiplier was less than actual

15

Results: Actual vs. Predicted Multiplier

Segment	Method	Multipliers Mean (SD)	Difference Mean (SD)	P-value
Femur (n=148)	Actual	1.084 (0.052)	-	-
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	Paley	1.091 (0.054)	0.03 (0.04)	<0.01
	White-Menelaus	1.081 (0.037)	0.02 (0.03)	<0.01

Paley multiplier was more than actual

16

Results: Actual vs. Predicted Multiplier

Segment	Method	Multipliers Mean (SD)	Difference Mean (SD)	P-value
Femur (n=148)	Actual	1.084 (0.052)	-	-
	Sanders	1.076 (0.025)	- 0.008 (0.03)	<0.01
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	White-Menelaus	1.081 (0.037)	0.02 (0.03)	<0.01

White-Menelaus multiplier was consistently close to actual

17

Results: Actual vs. Predicted Multiplier

Segment	Method	Multipliers Mean (SD)	Difference Mean (SD)	P-value
Femur (n=148)	Actual	1.084 (0.052)	-	-
	Sanders	1.076 (0.025)	- 0.008 (0.03)	<0.01
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	White-Menelaus	1.081 (0.037)	0.02 (0.03)	<0.01

All methods tibial multipliers were higher than actual

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Discussions

Why Don't the Multipliers (using Skeletal Age) Beat the White-Menelaus Method with a Stick?

Because, on average, the femur and tibia grow approximately the same amount *in the epiphysiodesis age group*, irrespective of size of the subject.

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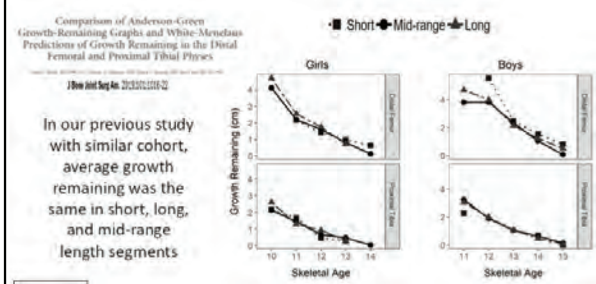

In our previous study with similar cohort, average growth remaining was the same in short, long, and mid-range length segments

20

Discussions

- White and Stubbins first reported this (JAMA, 1944)
- Menelaus (1966, 1981) and Little (1996) affirmed this
- Anderson et al (1964) noted:
  "..the average growths..were found to be almost identical for those with long, medium, or short bones"

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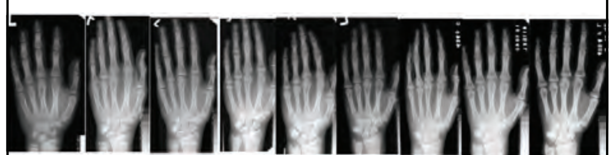
Conclusions

- Sanders' stage system revealed high intraclass reliability
- Sanders' Stages Do NOT = Skeletal Age (except girls, 3A (SA 11)and 3B (SA12)), and thus can't be used with White-Menelaus formulae



1 2 3A 3B 4 5 6 7 8

22

Conclusions

- The White-Menelaus formulae consistently predict growth remaining *in the epiphysiodesis age range.*
- Using a reliable, consistent skeletal age methodology in combination with the White-Menelaus formulae would likely improve epiphysiodesis timing/effect predictions.

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Thank You!

We particularly thank James Sanders, MD for his collaboration and guidance.

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24

Treatment for Ankle Valgus in Multiple Hereditary Exostoses

David S. Feldman, MD, Troy Rand, Melih Civan
dfeldman@paleyinstitute.org

What was the question?
Multiple Hereditary Exostoses (MHE) is a rare bone disease that results in formation of benign tumors and bone deformities. Especially problematic are deformities of the lower limb that result in most often valgus ankles with or without mortise disruption. Previous classifications only consider the amount of deformity but do not address the mechanisms responsible for the deformity. The purpose of this research is to classify ankles according to mechanism and describe the recommended treatments.

How did you answer the question?
A classification of ankle types was developed, and surgery was stratified according to classification. A retrospective analysis was performed to determine the effectiveness of classification–based treatments. The classification includes three types of ankles (Type I, II, and III). Type I is a valgus plafond, no talar shift, and the fibula is at station. This type is treated by medial distal hemi–epiphysiodesis of the tibia for skeletally immature patients or a supramalleolar osteotomy of the distal tibia and fibula in the skeletally mature. Type II is a valgus plafond, lateral talar shift, and the fibula is migrated proximally. Treatment for this type include releasing the distal tibio–fibular ligaments and shortening the tibia utilizing a varus supramalleolar shortening osteotomy (SHORdt). Type III is a v–shaped distal tibial epiphysis, lateral talar shift, and fibula migrated proximally. Treatment for this type is a pentagon osteotomy which includes shortening of the tibia and leveling the plafond. There are also three modifiers to consider, interosseous osteochondromas, subtalar motion, and ankle degenerative changes. If there are interosseous osteochondromas they should be removed, the amount of subtalar motion will determine how much correction can be achieved safely, and ankle fusion may be considered if significant ankle degeneration is present.

What are the results?
In an analysis of 102 ankles there was a 65% incidence of ankle valgus. We located 93% of the osteochondromas in the distal metaphyseal region between the tibia and fibula. The group with distal tibial valgus had a higher magnitude of ankle syndesmosis disruption (12.8 ± 7.9 mm vs. 6.4 ± 6.3 mm, $p < .001$), and osteochondromas that were larger and closer to the ankle joint ($p < .001$). Five ankles treated with hemiepiphyseodesis were converted to a shortening osteotomy due to failure to correct dynamic valgus and/or progressive ankle syndesmosis disruption. All ankles treated with the shortening osteotomy achieved a stable mortise and correction of valgus.

What are your conclusions?
Patients who have distal tibial valgus have larger osteochondromas, more syndesmosis disruption, and osteochondromas closer to the ankle joint. A new procedure, a SHORdt, in the treatment of ankle valgus with a short fibula was described, which resulted in stable mortise and correction of valgus in all ankles treated.

TREATMENT FOR ANKLE VALGUS IN MULTIPLE HEREDITARY EXOSTOSES

David S. Feldman, MD
Chief of Hip Preservation and Spinal Deformity
Co-Authors: Melih Civan, MD; Troy Rand, PhD
Paley Institute
West Palm Beach, Florida
LLRS Virtual Conference
July 2020

901 45th Street
Kimmel Building
West Palm Beach, FL 33401
561.844.5255
www.paleyinstitute.org

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Disclosure

- We have no conflict of interest regarding the research being presented

2

Background

- MHE results in benign tumor formation and various bone deformities
- Results in several problems
  - Functional limitations
  - Limb length discrepancies
  - Upper and lower extremity deformities
- Ankle deformities are of special concern
  - Long term morbidity, with instability and arthritis

3

Methods

- Retrospective analysis
  - 144 ankles
  - Radiographs were analyzed to determine
    - Osteochondroma location
    - Lateral distal tibial angle
    - Magnitude of ankle syndesmosis disruption
- Treatment that was stratified by classification was compared pre- and post-operatively

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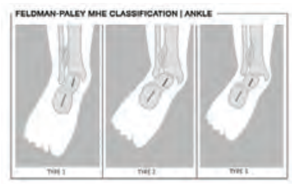
Classification



Three types were identified based on anatomical structure

- Three modifiers were included
  - Interosseous osteochondroma: absent vs. present
  - Subtalar motion: mobile vs. fixed varus
  - Ankle degenerative changes: absent vs. present

5

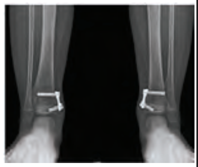
Classification – Type I

- Valgus Plafond
  - Sometimes the distal epiphysis may be wedged
- No talar shift
- Fibula at station

6

Treatment – Type I

- Medial distal tibial hemi-epiphysiodesis in skeletally immature individuals
- Supramalleolar osteotomy of the distal tibia and fibula in skeletally mature indivuduals



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Classification – Type II

- Valgus Plafond
- Lateral talar shift
- Fibula migrated proximal

8

Treatment – Type II

- Shortening Osteotomy Realignment Distal Tibia (SHORDT)
  - Releasing the anterior and posterior distal tibio-fibular ligaments
  - Varus supramalleolar osteotomy
  - Tibia shortened by the amount of fibular migration

9

Classification – Type III

- V-shaped distal tibial epiphysis
- Lateral talar shift
- Fibula migrated proximal

10

Treatment – Type III

- The distal tibiofibular ligaments are released
- Supramalleolar osteotomy is made in a V shape
- Second osteotomy is made more proximally to shorten the tibia, restoring fibular station
- Incomplete intra-articular osteotomy is added through the apex of the V to level the plafond

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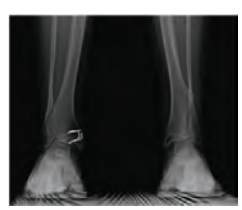
Preoperative radiographs showing valgus at both ankles



Left ankle treated with SHORDT

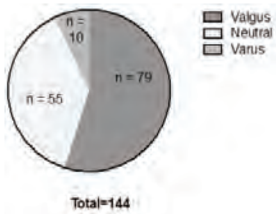
Right ankle treated with Pagoda osteotomy and a SHORDT

Post-operative radiographs showing the correction of the right ankle

12

Results

- ALDTA to determine ankle varus/valgus
  - 7% Varus
  - 38% Neutral
  - 55% Valgus



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Results

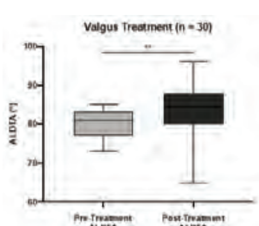
- 93% of the osteochondromas were in the distal metaphyseal region between the tibia and fibula
- The group with valgus had
  - Higher magnitude of ankle syndesmosis disruption
  - Osteochondromas that were larger and closer to the ankle joint

14

Results (treatment)

- All treatments resulted in improvement in ALDTA

Mean ALDTA increased from 80° to 84° (*p* = .0025)



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Results (treatment)

- Five ankles that were treated with hemiepiphyseodesis were converted to shortening osteotomy
  - Due to ankle valgus not correcting or progressive ankle syndesmosis disruption
- All ankles treated with a SHORDT achieved stable mortise and correction of ankle valgus

16

Conclusions

- The new classification was was effective at stratifying treatments and correction of distal tibial valgus was achieved
- The SHORDT procedure was effective in stabilizing the mortise and correcting valgus in all ankles treated

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Paley Institute
St. Mary's Hospital
901 45th St.
West Palm Beach, Florida 33407

www.PaleyInstitute.org
www.limblengtheningdoc.org

18

Session 2: Limb Salvage–Amputation

Moderator: Austin T. Fragomen, MD

Quality of Life and Satisfaction Assessment After Successful Bone Transport in Patients with Segmental Tibial Deficit

Gonzalo F. Bastias, MD
gfbastias@gmail.com

Felipe Silva, MD, Felipe Yañez MD, Natalio Cuchacovich

What was the question?
How is the quality of life and satisfaction rate of patients undergoing bone transport due to tibial segmental deficit?

How did you answer the question?
We performed an irb–approved retrospective review of patients treated with bone transport for segmental tibial deficit using monolateral or circular external fixation. Inclusion criteria: Patients with at least one year follow–up after frame removal and complete radiological monitoring. Telephonic interviews were conducted including evaluation with SF–12 and SFMA scores. It was requested to define the satisfaction degree with the procedure and indicate if they would rather preferred amputation over limb salvage.

What are the results?
Sixteen patients met inclusion criteria (13 male). Causes of tibial deficit were chronic osteomyelitis (11 patients) and Trauma (5 patients). Mean Follow–up after frame removal was 34 months (range 12–96 mo) The average treatment frame time was 14.4 months (range 7–22 mo) and the bone defect averaged 6.8 cms (range 1.5–15 cm). External Fixation Index was 2,73 months/cm. Internal fixation was performed in ten patients after frame removal. The results in SF – 12 score in its physical and mental dimension was 41 and 50 points respectively. The average SMFA Bother Index was 27,1 and SMFA function index 20,4. Five patients refer to using one crutch for ambulation. The satisfaction rate was: Excellent (11 patients), Good (4 patients Fair (1 patient). No patients were unsatisfied. None of the patients would have taken the option of amputation as a treatment.

What are your conclusions?
Bone transport has a high satisfaction rate for the treatment of tibial segmental deficits. Quality of life and functional results are comparable to the general population. Patients should be advised about the prolonged times of treatment. Nevertheless, none of the patients included in this series would have preferred amputation.

Virtual Meeting 2020

Quality of Life and Satisfaction Assessment after Successful Bone Transport in Patients with Segmental Tibial Deficit

Gonzalo F. Bastias MD, Felipe Silva MD, Felipe Yañez MD, Natalio Cuchacovich MD,
Patricio Fuentes MD, Mario Escudero MD, Jose T. Aldunate MD, Felipe Chaparro MD.
Hospital San José – Universidad de Chile
Clinica Las Condes – Hospital del Trabajador
Santiago CHILE

1

Disclosure

- **Orthofix (Verona, Italia)**

2

Introduction

- Segmental tibial deficit is still a challenging condition in limb preservation surgery
  - Defects > 4 cm
- Main Causes
  - Trauma
  - Infection
- Bone transport (BT) by means of distraction osteogenesis is a widely accepted alternative of management

Mauffrey C, Management of segmental Bone defects, JAAOS 2015

3

Bone Transport

- Pros
  - Reproductible
  - Corticalization
  - Ideal for segments under load
- Cons
  - Prolonged Treatment
  - Requires patient cooperation / compliance
  - Multiple complications / difficulties

Mauffrey C, Management of segmental Bone defects, JAAOS 2015

4

Limb Salvage vs Amputation

- Controversial
- Decision/Outcomes depends on the setting:
  - Access to Prosthesis Technology
  - Access to Limb Salvage Strategies
    - Hardware
    - Plastic / Vascular Surgeon
  - Access to adequate physical Therapy
  - Reinsertion Strategies
- This elements play an important role on subsequent Quality of Life/Function

5

What is Health Related Quality of Life?

"The *subjective* perception of patients about their level of *well-being and functionality*, concerning their physical, emotional (mental) and social situation, and the performance on *activities of daily living*."

-WHO

6

Objective

- To determine the health-related quality of life, functional status and satisfaction results on patients with segmental bone deficits treated with tibial bone transport.
- ***"Will I be able to have a normal life?"***

7

Patients and Methods

- Retrospective review 2012-2019
- Inclusion Criteria
  - Bone Transport for Segmental Tibial Deficit
  - At least 12 months follow-up after frame removal
- Medical records and X-rays review
- Telephone interview
  - SMFA (Short Muskuloskeletal Function Assesment)
  - SF-12 Mental – Physical
  - Satisfaction Rate

8

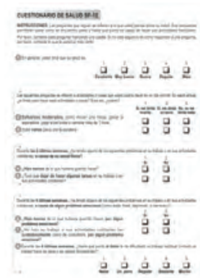
Patients and Methods

- **SMFA (Short Muskuloskeletal Function Assesment)**
  - Limb-specific.
  - Two-part, 46-item questionnaire
  - Designed to evaluate patients' perceived physical and emotional difficulty related to their injured or dysfunctional limb.

9

Patients and Methods

- **SF-12**
  - Self-reported outcome measure
  - Impact of health on an individual's everyday life.
  - 8 dominions divided on two Physical and Mental Components



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Patients and Methods

- **Satisfaction Rate (Kenneth – Johnson)**
  - Kenneth – Johnson Scale
    - 75-100% → Completely Satisfied
    - 50-75% → Partially Satisfied , Minor Objections
    - 25-50% → Partially Satisfied, Major Objections
    - 0-25% → Unsatisfied
  - All patients answered the following question

    *"After undergoing through the entire treatment, **would you have preferred to have your limb amputated in the first instance?"***

11

Results

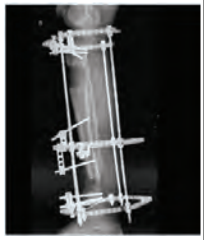
- 16 patients (14 male) → Mean FU: 47m (12-96m)
- Defect Size (mean) : **6,81 cm**.
  - Range: 1.5 -15 cm
- Frame Time (mean) : 14,4 months
  - 6,9-21,4 months
- External Fixation Index
  - **2,73 months/cm**

10 patients → Internal Fixation after frame removal

12

Results

- Etiology
  - Infection: 9 patients
  - Trauma: 7 patients.
- Type of Frame: Monolateral n:2 / Circular n:14
  - Bifocal 2 pts / Monofocal 14 pts



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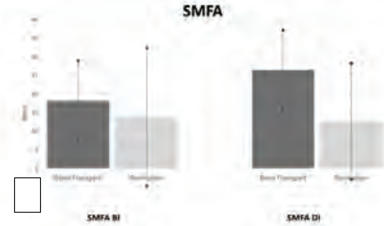
Results



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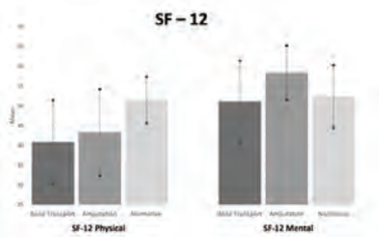
Results



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Results

- **Satisfaction**
  - **Completely Satisfied: 13 patients**
  - Satisfied with minor objections: 3 patients
  - 5/16 patients refer using walking aids
- *"After undergoing through the entire treatment,* ***would you have preferred to have your limb amputated in the first instance?"***
  - **NO : 16 patients (100%)**

16

Conclusions

- **BT patients on this series:**
  - Do not recover normative values of dysfunction (SMFA – DI).
  - But are bothered by their limitations similarly to the normative population (SMFA-BI)
  - Had similar SF12 mental scores as amputees and normative population.
  - SF-12 Physical scores comparable to amputation literature

17

Conclusions

- BT is an effective strategy for tibial segmental deficit.
  - 100% limb salvage in this series of 16 patients at 47 months mean FU
  - Long Treatment → 2,73 months / cm
- Independently of the size of the defect or total frame time:
  - Procedure with high satisfaction rates.
  - No patient on this serieswould have preferred amputation

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29 th Annual LLRS Scientific
Virtual Meeting 2020

Quality of Life and Satisfaction Assessment after Successful Bone Transport in Patients with Segmental Tibial Deficit

Gonzalo F. Bastias MD, Felipe Silva MD, Felipe Yañez MD, Natalio Cuchacovich MD,
Patricio Fuentes MD, Mario Escudero MD, Jose T. Aldunate MD, Felipe Chaparro MD.
Hospital San José – Universidad de Chile
Clinica Las Condes – Hospital del Trabajador
Santiago CHILE

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Outcomes, Safety and Cost–effectiveness of Single–Stage Intramedullary Nails for Fracture Related Infections and Infected Nonunions

Olivia M. Rice, MD, Joseph R. Hsu, MD
olivia.rice@atriumhealth.org

What was the question?
Intramedullary infections in the absence of bony union or in the presence of residual bone defects are challenging to treat. The goals of infection eradication and bony union are conflicting, as the former benefits from local antibiotic delivery that is often achieved at the expense of stability. Due to this, many surgeons currently approach these complex cases in a staged fashion by first eradicating the infection then addressing the nonunion or un–united fracture. This process typically involves initial irrigation and debridement with placement of a temporary antibiotic cement–coated guide rod within the intramedullary canal. After approximately four to six weeks, the patient is brought back to the operating room for exchange nailing to a standard intramedullary nail. Although this process has quoted success rates upwards of 100% for infection eradication in some case series, the patient and system are faced with a significant financial burden stemming from multiple trips to the operating room. Some authors have proposed a single–stage technique to treat these complex problems. This involves placing an antibiotic cement coated standard intramedullary nail during the index operation to both treat the infection and provide the stability necessary for bony union, without plans for future hardware removal.
The primary aim of this study is to assess complications, cost and clinical outcomes of single–stage antibiotic coated nailing for fracture–related infections. We aim to compare these results to the standard dual–stage antibiotic nailing strategy in a future study.

How did you answer the question?
We performed a prospective observational study, enrolling adult patients who presented with an infection of a long bone in the setting of a nonunion or un–united fracture that required insertion of an antibiotic cement coated intramedullary nail for treatment. An in–house antibiotic nail recipe was disseminated and used by board–certified orthopaedic trauma surgeons at our institution. The primary outcome measure of the study was cost–effectiveness, while secondary outcome measures included complications (intra–operative and post–operative), reoperation (related to extremity with antibiotic nail insertion), and eradication of infection. This is preliminarily reported here using a 'number of additional procedures' proxy.

What are the results?
32 patients were included in the study. The average age was 47 years old. The cohort included an equal number of closed (n=17) and open (n=15) injuries. The majority of patients had tibia fractures (n=23 total, n=10 closed); other fracture locations included femur (n=8 total, n=6 closed). Around 1/3 of patients (11/32, 34%) required reoperation following the intended single–stage antibiotic coated intramedullary nail placement (n =20 procedures; average 1.8 procedures/patient). 21/32 patients (76%) required no additional procedures. If patients were to have undergone a dual–stage antibiotic nail procedure, a minimum of ≥1 procedure per patient (n=32) would be required. Using 'number of additional procedures' as a proxy for cost, our preliminary results show that a single operation using an antibiotic coated intramedullary nail is both safe and cost–effective compared to the current standard of care.

What are your conclusions?
Single–stage antibiotic coated nailing for fracture–related infections is safe and has the potential to decrease the overall cost of care compared to the standard dual–stage antibiotic nailing strategy currently in widespread use.

How-To: Coat Intrameduallary Nails with Antibiotic-Impregnated Cement

Supplies: *{italic brackets correlate to supplies for small diameter version}*

NOTE: brand references are to provide a concrete example of listed supplies; none of the authors have any type of relations with these vendors

- Polymethyl Methacrylate (PMMA) Bone Cement (e.g. 'Palacos R+G' 1x40g)
- 2gm Vancomycin Powder (1gm x 2)
- 2.4gm Tobramycin Powder (1.2gm x 2)
- 320mg Gentamicin liquid (80mg/2ml x 4)
- 1/2in (12.5mm) diameter perfusion tubing (e.g. 'LivaNova Smart Perfusion Pack'); *{3/8in (9.525mm)}*
    - **NOTE**: the perfusion tubing diameter dictates the final diameter of the nail
- 10mm Intramedullary Nail of Appropriate Length *{8.5mm}*
- Cement gun: femoral for standard diameter (1/2in perfusion tubing) *{humeral for small diameter (3/8in perfusion tubing)}*
- Cement mixing pack

Steps:

1. Choose and open 10mm nail of appropriate length (any vendor); *{8.5mm}*
2. Cut perfusion tubing ~1cm longer than nail
3. Break nozzle extension off cement injection gun
4. Mix all powdered antibiotics and powder component of cement in cement mixing bowl
5. Add liquid monomer and all liquid antibiotics
6. Stir
7. Hand pack into cement gun tube
8. Inject cement into perfusion tubing; place cement gun back on table
    a. NOTE: it is normal for cement to only partially fill tubing
9. Insert nail into tubing from same end as injection (align curve of tubing with nail curve)
    a. NOTE: while inserting nail, use one hand to 'seal' opposite end of perfusion tubing (i.e. 'pressurize'); increased pressurization → more equal circumfrential distribution of cement around the nail; ineveitably, some cement will escape from the opposite end of the tube
10. Roll tubing on table to ensure smooth, even coat of cement
11. Leave on back table (time doesn't matter, since tubing doesn't melt)
12. After completely dry and cool, cut tubing off with #10 blade
13. Break excess cement off end of nail with Rongeur; bevel and smooth with bovie scratch pad

Insertion Tips:

1. Attach coated nail to targeting guide
2. Ream to 14.5mm (nail is 12.5mm); *{Ream to 12mm (nail is 9.5mm)}*
3. Remove reaming rod
4. Irrigate: put 1 suction though distal interlock or saucer, 2nd suction tip on irrigation ('cysto') tubing
5. Wiggle nail into place, gentle mallet blows if needed
6. Lock nail (standard fashion)

Atrium Health
Musculoskeletal Institute

Outcomes, Safety and Cost-effectiveness of Single-Stage Intramedullary Nails for Fracture Related Infections and Infected Nonunions

Olivia M. Rice, MD, Kevin D. Phelps, MD, Rachel Seymour, PhD, Joseph R. Hsu, MD

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Disclosures

- Dr. Joseph Hsu
  - Smith & Nephew: Speaker Bureau
  - Globus: Consultant

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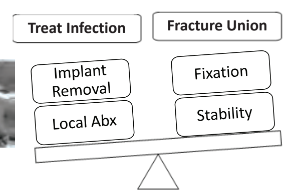
Introduction

Fracture related infections are challenging

3

Introduction

Goals of infection eradication and bony union can be conflicting….



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Introduction

Treatment often performed in a 'staged' fashion → **multiple surgeries**

5

Purpose

To assess general **safety** of single-stage antibiotic coated nailing for fracture-related infections

6

Methods

- Prospective observational study
- Adults with an infection of a long bone related to ununited fracture
- Treatment = antibiotic cement coated locked intramedullary nail
- Used In-house antibiotic nail recipe using low cost materials

7

Methods- Supplies

8

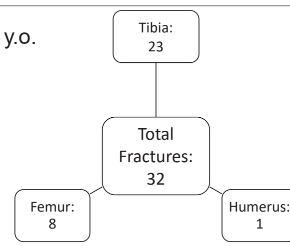
Methods

- Specific recipe and steps located in LLRS Abstract

9

Results

- **Average age** = 47 y.o.
- **Open vs. Closed**
  - 17 closed fractures
  - 15 open fractures



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Results

- **<u>76%</u>** of patients (21/32) **<u>avoided</u>** a 2nd operation
- 11 patients required reoperation
  - Total number of additional surgeries = 20

32 patients required 52 total surgeries →

<u>1.6 surgeries/ patient</u>

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Discussion

Is <u>single stage</u> fracture related infection eradication safe?

Are subsequent surgeries more difficult?

12

Discussion

Is <u>single stage</u> fracture related infection eradication effective?

13

Discussion

Is <u>single stage</u> fracture related infection eradication safe and effective?

Results are promising

Thonse R, Conway J. Antibiotic cement-coated interlocking nail for the treatment of infected nonunions and segmental bone defects. J Orthop Trauma. 2007; 21: 258-268.

Schmidmaier G, Lucke M, Wildemann B, Haas NP, Raschke M. Prophylaxis and treatment of implant-related infections by antibiotic-coated implants: a review. Injury. 2006; 37.

14

Discussion

Antibiotic locked IMNs

have **<u>potential to decrease total cost of care</u>**

<u>Single stage FRI treatment</u>	vs	<u>Multistage FRI treatment</u>
Goal = Single surgery Total # of surgeries = **1 * n** + (# of additional surgeries per patient)		Guaranteed ≥2 surgeries Total # of surgeries = **2 * n** + (# of additional surgeries per patient)

n= total # of patients treated for FRI

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Discussion

<u>Weaknesses</u>

- Small sample size
- Various stages of infection and fracture healing

<u>Strengths</u>

- Multiple surgeon series
- Prospective enrollment
- Low cost supplies + repeatable technique

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Conclusion

Single-stage antibiotic coated locked nailing is likely a **<u>safe and effective</u>** treatment strategy for fracture-related infections

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Patient Reported Outcomes Assessment of 267 Children and Adolescents with Lower Limb Deficiency: A Multi–Center Study

Sarah Nossov, MD, Joel Lerman, Janet Walker, Jeffrey Ackman
snossov@shrinenet.org

What was the question?
Patient Reported Outcomes Measurement Information System (PROMIS) measures are validated for outcome assessment of multiple conditions, but normative values for pediatric orthopaedic conditions are not well described. If PROMIS measures are sensitive to differences in function in children with conditions such as limb deficiency, they may be useful tools to measure treatment impact. For children with lower limb deficiency, we hypothesized that self–reported PROMIS scores for children with lower limb deficiency would be sensitive to differences in amputation level and uni– vs bilaterality.

How did you answer the question?
Three self–reported PROMIS measures (Mobility, Pain Interference, Peer Relationships) were administered to 267 individuals aged 8–17 years (mean 12.8) with lower limb deficiency. Two–tailed independent t–tests and one–way ANOVAs with Bonferroni post hoc analyses were used to determine whether scores were sensitive to differences in laterality, gender, diagnosis, and amputation level. Pearson product moment correlations were used to determine if the PROMIS measures correlated with patient age.

What are the results?
Subjects included 153 boys/114 girls, and 215 unilateral and 52 bilateral amputees. For the entire cohort, Mean Mobility scores were 45.5, Pain Interference 45.8, and Peer Relationships 51.9 (all in normal range). Age did not correlate with Mobility (r=–0.04, p=0.49), Pain Interference (r=–0.05, p=0.42), or Peer Relationship scores (r=0.002, p=0.98). Patients with bilateral amputations demonstrated significantly lower Mobility scores than those with unilateral involvement (38.8±9.3 vs. 46.9±9.3, p<0.001); however, Pain (Uni=45.7±9.9 vs. Bi=46.0±9.3, p=0.89) and Relationship scores (Uni=52.0±10.2 vs. Bi=51.4±11.1, p=0.71) did not differ based on laterality. When isolating unilateral patients, patients with transfemoral(TF) amputation demonstrated significantly lower Mobility scores than those with ankle level amputations (AD) (p=0.007, Table 1). When isolating bilateral patients, Pain Interference scores were significantly greater for those patients with ankle compared to trans–tibial(TT) amputations (p=0.008, Table 1). There were no other differences in Mobility, Pain, or Relationship scores based on gender, diagnosis, or amputation level when individually analyzing unilateral or bilateral patients. The mean mobility score for bilateral AD patients was in the mild impairment range, while the other bilateral groups averaged in the moderate impairment range, as did unilateral TF amputees. Bilateral amputees had a lower mean mobility score with more proximal deficiency. Mean PROMIS scores for fibular deficiency, proximal focal femoral deficiency, and tibial deficiency patients were each in the normal range.

What are your conclusions?
PROMIS Mobility scores differed between patients with unilateral compared to bilateral limb deficiency, with Mobility scores being greater amongst those with unilateral AD compared to TF amputations. In addition, Pain Interference scores were significantly lower for patients with bilateral TT compared to bilateral AD. Bilateral amputees had lower mean mobility scores with more proximal deficiency. Mean PROMIS scores for bilateral amputees demonstrated mild to moderate mobility impairment.

Patient Reported Outcomes Assessment of 267 Children & Adolescents with Lower Limb Deficiency: a Multi-Center Study

Joel Lerman MD, Janet Walker MD, Sarah Nossov MD (P),
David Westberry MD, Jeffrey Ackman MD, and Cale Jacobs PhD

Shriners Hospitals for Children Deformity Study Group
Including patients from Units:
Northern California, Lexington, Greenville,
Philadelphia, Erie, and Chicago

1

Author Disclosures

- Joel Lerman, MD: none
- Janet Walker, MD: none
- David Westberry, MD: none
- Sarah Nossov, MD: none
- Jeffrey Ackman, MD: none
- Nina Cung, BS: none
- Cale Jacobs, PhD: Consultant: Flexion Therapeutics, Research Funding: Flexion Therapeutics, Smith & Nephew

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Intro: *Patient* reported quality of life in *children with amputations*

- **PODCI in children with upper extremity amputations**
  - Progressively lower function in adolescents with more proximal amputation levels on several domains
    - Lerman et al, 2005
- **PODCI in children with lower extremity amputations**
  - Varying levels of decreased function on PODCI domains with more proximal amputation level; those with unilateral amputations performed better
    - McQuerry et al, 2019

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Patient Reported Outcomes Measurement Information System

- Standardized, reliable, patient reported outcome tool funded by the National Institutes of Health (NIH)
- Validated for use, and increasingly published use for *pediatric* conditions and *orthopedic* conditions
- Published use of PROMIS in *pediatric orthopedic* conditions just emerging
  - Normative values just being established
  - Utility in outcome assessment being clarified

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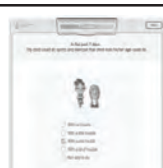
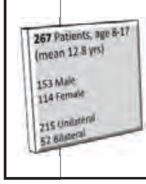
Methods: PROMIS Administration at Shriners



- 32 questions, 8 for each of 4 PROMIS domains
  - * Mobility
  - * Pain Interference
  - * Peer Relationship
  - (-) Upper Extremity



- 3-5 minutes required to complete
- English and Spanish available
- Patients **8-17 years** complete *self-reported* assessment
- Done for EVERYONE, we looked at regular lower limb deficiency clinics

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Data Analysis

- Compared age, gender, uni- vs. bi-laterality
- Assessed and compared by level of deficiency
  - partial foot
  - ankle disarticulation
  - transtibial
  - knee disarticulation
  - transfemoral

- Looked at congenital diagnosis separately
  - fibular deficiency, tibial deficiency, PFFD

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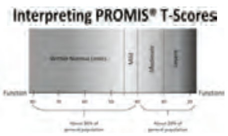
Overall PROMIS Scores
for Patients with Lower Extremity Amputations



Pain Interference

PROMIS Scores		
	Mean Score	Interpretation
Mobility	45.5	Normal
Pain Interference	45.8	Normal
Peer Relationships	51.9	Normal

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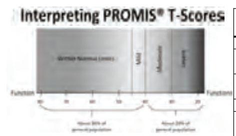
Overall PROMIS Scores
by Laterality



PROMIS Domains	Mean PROMIS Scores	P-value
Mobility		<0.001
Unilateral	46.9 Normal	
Bilateral	38.8 Moderate Impairment	
Peer Relationships		0.71
Unilateral	52.0 Normal	
Bilateral	51.4 Normal	
Pain Interference		0.89
Unilateral	45.7 Normal	
Bilateral	46.0 Normal	

Lower mean Mobility score in children with bilateral versus unilateral amputations (p<0.001)

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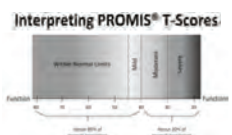
PROMIS *Mobility* Scores
by Amputation Level & Laterality



Amputation Level	Unilateral		Bilateral	
	Mean Score	Interpretation	Mean Score	Interpretation
Partial Foot	46.8 (N=11)	Normal	(N=0)	
Ankle Disarticulation *	**49.2** (N=94)	Normal	40.9 (N=14)	Mild Impairment
Transtibial	44.5 (N=34)	Mild Impairment	38.7 (N=10)	Moderate Impairment
Knee Disarticulation	46.2 (N=23)	Normal	36.6 (N=8)	Moderate Impairment
Transfemoral *	**39.0** (N=11)	Moderate Impairment	34.3 (N=6)	Moderate Impairment

Unilateral Mobility scores only significantly different b/w Unilateral Ankle Disarticulation and Transfemoral (p=.007)

Bilateral scored "worse" than unilateral for each level

Bilateral had incrementally lower scores with more proximal deficiency

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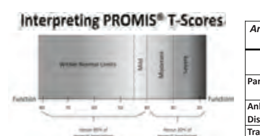
PROMIS *Peer Relationship* Scores by Amputation Level



Amputation Level	Unilateral		Bilateral	
	Mean Score	Interpretation	Mean Score	Interpretation
Partial Foot	45.9 (N=11)	Normal	(N=0)	
Ankle Disarticulation	52.7 (N=91)	Normal	48.8 (N=14)	Normal
Transtibial	50.9 (N=34)	Normal	52.3 (N=12)	Normal
Knee Disarticulation	51.0 (N=22)	Normal	53.3 (N=11)	Normal
Transfemoral	51.7 (N=10)	Normal	47.4 (N=7)	Normal

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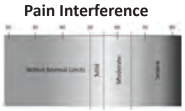
PROMIS *Pain Interference* Scores by Amputation Level

Pain Interference



Amputation Level	Unilateral		Bilateral	
	Mean Score	Interpretation	Mean Score	Interpretation
Partial Foot	46.3 (N=11)	Normal	(N=0)	
Ankle Disarticulation *	43.4 (N=93)	Normal	**51.7** (N=14)	Mild Impairment
Transtibial *	47.9 (N=34)	Normal	**45.9** (N=12)	Normal
Knee Disarticulation	45.8 (N=22)	Normal	44.5 (N=11)	Normal
Transfemoral	49.9 (N=10)	Normal	47.7 (N=7)	Normal

Pain Interference difference:
bilateral Ankle disarticulation and
bilateral Transtibial deficiencies (p=0.008)

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PROMIS Scores vs. Other Patient Criteria

Scores w/r/t to patient age or gender:
No differences in
- Mobility,
- Pain Interference, or
- Peer Relationship scores

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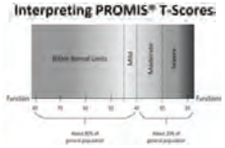
PROMIS *Mobility* Scores by Congenital Diagnosis

Interpreting PROMIS® T-Scores



Mobility		
Diagnosis	**Mean Score**	**Interpretation**
Tibial Deficiency	42.56 (N=34)	Mild Impairment
Fibular Deficiency	45.23 (N=56)	Normal
PFFD	43.65 (N=48)	Mild Impairment

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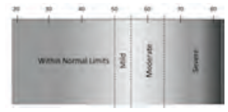
PROMIS *Pain Interference* Scores by Congenital Diagnosis

Pain Interference



Pain Interference		
Diagnosis	**Mean Score**	**Interpretation**
Tibial Deficiency	51.56 (N=5)	Mild Impairment
Fibular Deficiency	49.32 (N=15)	Normal
PFFD	46.74 (N=11)	Normal

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Conclusions

- Mean PROMIS Mobility, Pain Interference, and Peer Interaction scores for children with amputations in "Normal" range
- Children with bilateral amputations report more mobility impairment than those with unilateral
- Children with bilateral amputations have lower PROMIS Mobility scores with more proximal deficiencies, and in the "mild" to "moderate" impairment range
- Patients with PFFD and tibial deficiency had mean PROMIS mobility scores in "Mild Impairment" range, while fibular deficiency patients had a mean PROMIS Mobility score in the normal range

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Self Reported PROMIS in Assessment of Children and Adolescents with LE Amputations

- PROMIS Mobility scores appear to distinguish functional differences among children and adolescents with lower extremity amputations
  - PROMIS Mobility may be useful in outcomes and functional assessment for these patients
- PROMIS Pain Interference and Peer Relationship scores tended to be in the normal range
  - Consistent with overall lack of pain interference and socially well adjusted/non impaired patients
  - May be influenced by factors other than diagnosis, laterality, and amputation level

Thank you!

snossov@shrinenet.org

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Session 3: Pearls & Pitfalls

Moderator: Raymond W. Liu, MD

Complications Requiring Readmission Following Limb Lengthening: A 10 Year U.S. Database Study

Ashish Mittal, MD, Rishab Jayaram, Sachin Allahabadi, Sanjeev Sabharwal
Ashish.Mittal@dignityhealth.org

What was the question?
Distraction osteogenesis has historically been a long, arduous process with a high incidence of complications. The mainstay of treatment has been external fixation; however, attempts to decrease the time and use of external fixation have led to the incorporation of internal fixation in lengthening techniques. Fully implantable lengthening devices rely on rachet or magnetic mechanisms to progressively lengthen bone. Hybrid techniques involve the use of intramedullary or extramedullary implants to provide provisional stability of bone while lengthening through an external fixator. Our goal is to study the rate of various complications of lengthening of the femur and tibia using a publicly available inpatient database.

How did you answer the question?
Inpatient data was acquired using the Healthcare Cost and Utilization Project database from 2005 to 2014 including NY, CA, FL, NC, UT, NE. Patients with ICD–9 codes for limb lengthening of the femur, tibia, or both were included. Patients were subdivided based on procedure codes for internal lengthening only, lengthening via external fixation only, or hybrid techniques. Rates of hospital readmission (excluding ED visits and same day discharge) up to 1 year following the index procedure were collected. The rates of specific orthopedic complications at 1 year were compared across cohorts. Data was analyzed using descriptive statistics for comparison of subcategories.

What are the results?
4111 patients were identified with limb lengthening procedures between 2005–2014, of which 2073 (50.4%) had sufficient data to be included for analysis. There were 1176 males (56.7%), 856 females (41.3%), and 41 unknown (2.0%) with an average age of 27.2. 876 (42.3%) patients underwent femoral lengthening and 1197 (57.7%) underwent tibial lengthening. 459 patients (22.1%) had lengthening with an intramedullary implant alone, 1191 patients (57.5%) with external fixation alone, and 423 patients (20.4%) with a hybrid technique. 38.8% of patients required an inpatient readmission up to one year post–operatively (average: 46.3 days). Of these patients, 40.8% of patients had tibial lengthening and 36.1% of patients had femoral lengthening. The highest rates of readmission were found in patients with an underlying diagnosis of deep infection (71.9%) or tumor (60.0%). The most frequent complications requiring readmission were infection (7.6%) and mechanical failure (4.8%) in the femur and infection (12.3%) and nonunion in the tibia (10.2%). Of the patients readmitted with an underlying congenital diagnosis, 16.7% were readmitted for knee dislocation and 9.5 or hip dislocation.

What are your conclusions?
Limb lengthening procedures, regardless of technique, have a high rate of hospital readmission. This rate is highest in patients with an infectious or neoplastic diagnosis, and in patients undergoing tibial lengthening procedures. In cases of femoral lengthening, infection and mechanical failure were most the commonly observed orthopedic complication, whereas in cases of tibial lengthening, infection and nonunion were most common seen. Rates of certain complications are often influenced by underlying diagnosis. We are currently expanding the study population to include data from more recent years to further assess the complications requiring readmission in patients undergoing limb lengthening.

Complications Requiring Readmission Following Limb Lengthening: A 10 Year U.S. Database Study
LLRS Virtual Meeting 2020

Ashish Mittal MD, Rishab Jayaram, Sachin Allahabadi MD, Matt Callahan MBA, Sanjeev Sabharwal MD MPH

Dignity Health St. Mary Medical Center

UCSF University of California San Francisco

UCSF Benioff Children's Hospitals

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Disclosures

- None

2

Background

Codivilla 1905

ISKD 2006

Ilizarov 1951

PRECICE 2012

3

Background

Lengthening over a Nail

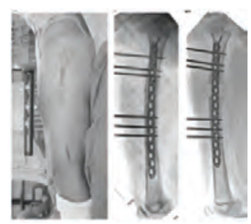

Plate Assisted Lengthening

4

Study Goals

- To determine the rate of various complications with respect to:
  - **Bone lengthened**
  - **Lengthening technique**
  - **Pre-operative diagnosis**

5

Methods

- Healthcare Cost and Utilization Project (HCUP) HCUP National Database queried (**2005-2014)**
- Data from **43 states** available (non-longitudinal)
- 4,111 limb lengthening procedures
- **1,954** patients with sufficient data
  - **780** femoral only (F)
  - **1,094** tibial only (T)
  - **80** femur + tibia (F+T)

6

Methods

- ICD-9 codes were used to determine:
  - Diagnoses
  - Procedure performed
  - Readmission Diagnoses
- Readmission data up to 1 year following lengthening collected for all patients (**excluding ED visits and same day discharges**)
- Statistical Analysis using Chi-square analysis with significance p< 0.05

7

Results – All Lengthenings

- **1954** patients included for analysis
- Most common states:
  - **Florida** (40.1%)
  - **New York** (19.0%)
  - **California** (18.6%)
- **57%** Male
- Average age **28 yrs** (range 1-90)
- Most common diagnosis
  - **post-traumatic** (55%)
  - **congenital** (23%)
- 756 pts readmitted at 1 year **(39%)**
- Average time to readmission **119 days** (range 0-365)

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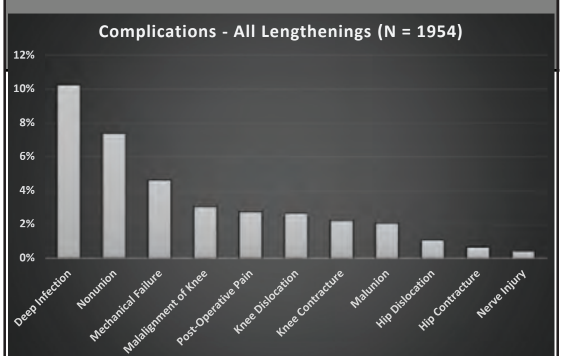

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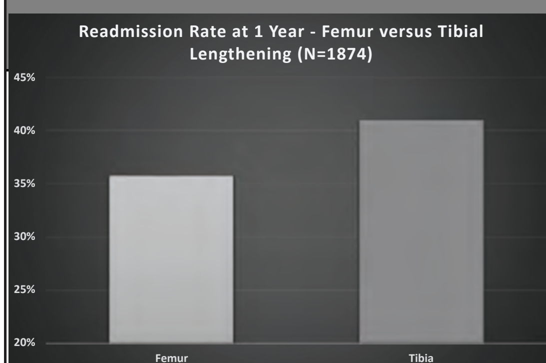

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Results – Femoral Lengthening

- **780** femur only lengthenings (F+T, T excluded)
- **55%** Male
- Average age **24** years (range 1-90)
- Most common diagnosis group
  - **Post-traumatic** (49%)
  - **Congenital** (31%)
- 279 pts readmitted at 1 year (**36%**)
- Average time to readmission was **119 days** (range 0-364)

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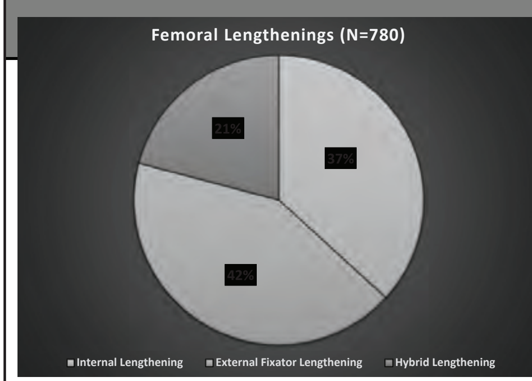

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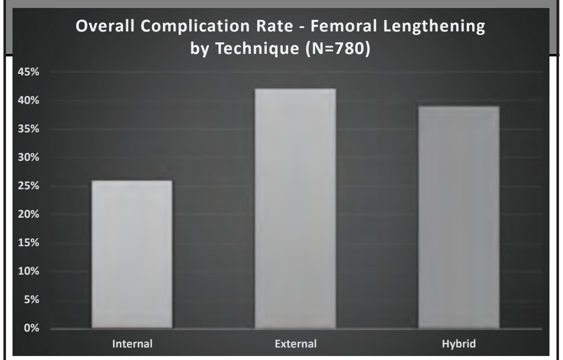

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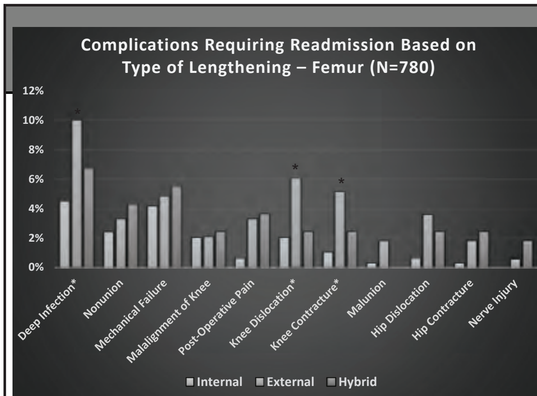

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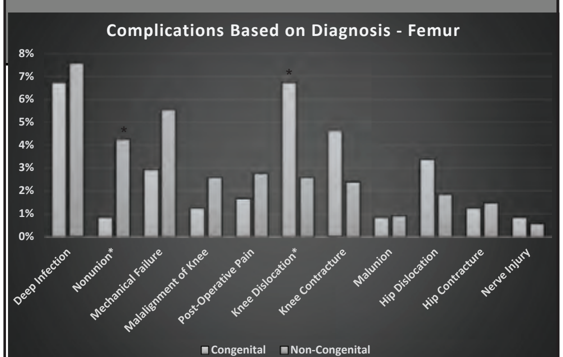

*p<.05

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Results – Tibial Lengthening

- **1094** tibial lengthenings included (T+F, F)
- **57%** Male
- Average age **32** (range 1-80)
- Most common diagnosis group
  - **Post-traumatic** (61%)
  - **Congenital** (17%)
- 448 pts readmitted at 1 year (**41%**)
- Average time to readmission was **118 days** (range 0-365)

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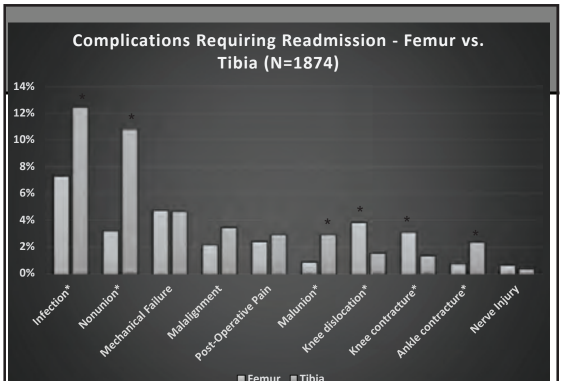

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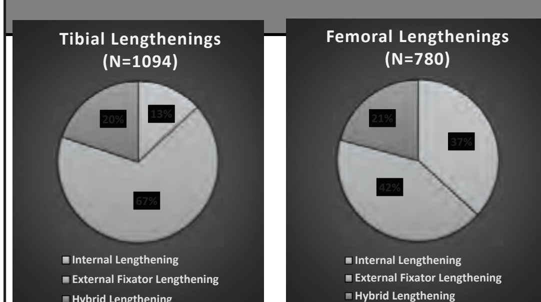

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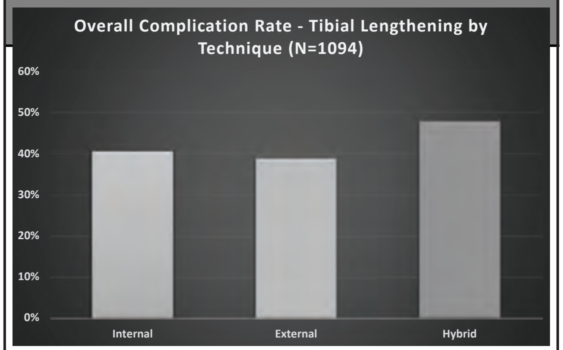

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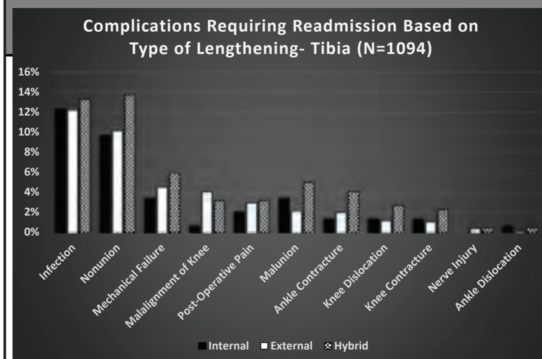

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Limitations

- Only complications requiring **hospital readmission**
- Complications likely **underreported** due to incomplete coding
- Certain diagnoses/procedures not represented in ICD-9
- Lack of Longitudinal Data

21

Conclusions

- Limb lengthening procedures have a high rate of 1 year readmission (**39%**)
- External lengthening more common with **tibial** (67%) compared to femoral lengthening (42%)
- Readmissions are higher in tibial (**41%**) compared to femoral (**36%**) lengthening
- **Infection** and **nonunion** are the most common reasons for readmission, and have a greater association with **tibial** lengthening

22

Conclusions

- **Knee dislocations** and **knee contractures** are more commonly seen with **femoral** lengthening, especially in patients with **congenital** deformity
- There is a lower rate of readmission with **internal lengthening** for the femur (26%)
- There is no difference in readmission rates between internal, external, and hybrid lengthening of the tibia

23

Thank You

Ashish.Mittal@dignityhealth.org
Sanjeev.Sabharwal@ucsf.edu

UCSF Benioff Children's Hospitals

Dignity Health St. Mary Medical Center

LLRS Limb Lengthening and Reconstruction Society

UCSF University of California San Francisco

24

Anesthesia Choice Affects Length of Stay for Pediatric Acute Correction Patients

Philip K. McClure, MD, Nequesha S. Mohamed, Ethan A. Remily, John E. Herzenberg, MD
pmcclure@lifebridgehealth.org

What was the question?
Acute correction is a mainstay for treatment of pediatric limb deformity. General anesthesia is typically utilized, with the addition of regional or epidural blockade as a supplemental option. This study assesses 1) demographics and 2) immediate outcomes in pediatric patients who received general anesthesia, regional block or epidural anesthesia for acute limb correction. We hypothesize that epidural anesthesia has limited additional effect in this population.

How did you answer the question?
A retrospective review was performed for all patients who underwent limb correction from 2014 to 2018. Patients under 18 were included (n=66). Patients were then stratified based upon type of anesthesia used: general (n=31), nerve block (n=13) or epidural (n=22). Analyzed variables included age, race, sex, American Society of Anesthesiologists (ASA) physical status class, body mass index (BMI), length of surgery, length of stay (LOS), eight–hour visual analog pain scale scores, pain intensity, total daily opioid consumption, and discharge destinations. Categorical variables were analyzed with chi–square, while continuous variables were analyzed with one–way analysis of variance.

What are the results?
Between modalities, there were no significant differences based on age, sex, BMI or ASA score. Epidural patients had longer lengths of surgery (248.77 vs. 271.69 vs. 329.27 minutes, p=0.003) and LOS (2.32 vs. 2.08 vs. 3.27 days, p=0.013) than general and block anesthesia. Except for pain score at 24 hours (3.45 vs. 1.50 vs. 2.00, p=0.041), there were no differences in pain scores, pain intesnsity, or opioid use. Discharge destination was similar (Home: 95.2 vs. 100.0 vs. 80.0%, p=0.217).

What are your conclusions?
Epidurals prolonged both length of surgery and LOS without significantly reducing pain or opioid consumption. The optimal anesthetic regime may be general anesthesia with a regional block, as evidenced by lower pain and shorter LOS. We recommend regional blockade over epidurals for acute extremity correction.

Anesthesia Choice Affects Length of Stay for Pediatric Acute Correction patients

Ethan Remily, John E. Herzenberg, Philip K. McClure

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Disclosures

- Novadip (consultant)
- Orthofix (teaching consultant)
- Smith & Nephew (teaching consultant)

- **I will not be discussing "off-label" or investigational uses for products or devices.**

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2

Shortest Distance Between Two Points?

Good Result, But…

6 days in hospital, 3.5 with epidural in place

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3

Patient Factors Associated with Increased Pain

- Being From the United States (unmodifiable)
- Psychosocial Factors
- Preoperative Pain
- Coping Strategies
- Soft Tissue Handling/Invasiveness of Surgery

https://rcni.com/nursing-standard/newsroom/clinical-update/pain-management-children-125116

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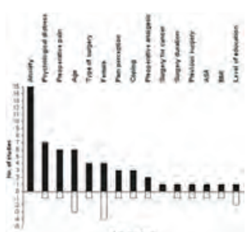
ANESTHESIOLOGY
Trusted Evidence: Discovery to Practice

From: Predictors of Postoperative Pain and Analgesic Consumption:A Qualitative Systematic Review
Anesthesiology. 2009;111(3):657-677. doi:10.1097/ALN.0b013e3181aae87a

Figure Legend:

Fig. 2. Predictive factors of postoperative pain intensity. ASA = American Society of Anesthesiologists status; BMI = body mass index (kg/m^2); black bars = number of studies with significant correlation;, white bars = number of studies with conflicting results.



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But What About Our Patients?

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Methods

- Case from 2014-2018
- 66 Pediatric Patients.
  - Anesthesia Choice: general alone (n=31), general with nerve block (n=13) or epidural (n=22).
- Data Points
  - Demographics: Age, Race, Sex
  - ASA class, body mass index (BMI)
  - Length of surgery, length of stay (LOS)
  - Eight-hour visual analog pain scale scores, pain intensity, total daily opioid consumption
  - Discharge destinations.

7

Table 1: Demographics

Parameter (N) (%)	General	Block	Epidural	p-value
Mean Age (years) (SD)	13.11 (4.77)	10.72 (3.19)	9.88 (5.63)	0.051
Sex				0.155
Male	17 (54.8%)	3 (23.1%)	10 (45.5%)	
Female	14 (45.2%)	10 (76.9%)	12 (54.5%)	
Race				0.676
White	19 (61.3%)	7 (53.8%)	17 (77.3%)	
Black	7 (22.6%)	3 (23.1%)	4 (18.2%)	
Asian	2 (6.5%)	1 (7.7%)	1 (4.5%)	
Other	3 (9.7%)	2 (15.4%)	0 (0.0%)	
ASA Score				0.840
1	17 (54.8%)	8 (61.5%)	11 (50.0%)	
2	13 (41.9%)	4 (30.8%)	10 (45.5%)	
3	1 (3.2%)	1 (7.7%)	1 (4.5%)	
Mean BMI (kg/m^2) (SD)	22.88 (7.60)	26.12 (24.47)	27.04 (24.69)	0.700

ASA: American Society of Anesthesiologists physical status, BMI: Body Mass Index, SD: Standard Deviation

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Table 2: Patient Outcomes

Parameter (N) (SD)	General	Block	Epidural	p-value
Mean Length of Surgery (minutes)	248.77 (69.68)	271.69 (69.32)	329.27 (98.90)	0.003
Mean Length of Stay (days)	2.32 (1.19)	2.08 (1.08)	3.27 (1.52)	0.013
Mean VAS Score				
Preoperative	0.52 (1.70)	0.33 (1.15)	0.44 (1.46)	0.940
8-Hour	1.97 (3.09)	1.35 (2.38)	1.95 (2.55)	0.777
16-Hour	2.74 (2.70)	1.65 (2.46)	2.43 (2.73)	0.470
24-Hour	3.45 (2.65)	1.50 (2.28)	2.00 (2.38)	0.041
32-Hour	3.23 (2.63)	2.73 (3.52)	1.70 (1.59)	0.133
40-Hour	2.08 (2.74)	1.90 (2.81)	2.42 (3.44)	0.890
48-Hour	2.54 (2.70)	1.60 (2.55)	2.90 (3.04)	0.492
Pain Intensity (AUC)				
24-Hour	62.97 (51.34)	35.08 (52.72)	48.00 (41.16)	0.199
48-Hour	50.84 (53.89)	40.00 (54.26)	50.18 (44.25)	0.799
Total Opioid Consumption (MME)				
Postoperative Day 0	361.62 (409.50)	96.73 (183.97)	356.48 (391.93)	0.081
Postoperative Day 1	115.25 (270.60)	24.40 (15.58)	246.91 (334.54)	0.053
Postoperative Day 2	141.62 (309.38)	21.75 (21.48)	131.51 (206.98)	0.315
Discharge Destination (%)				0.217
Home	20 (95.2%)	8 (100.0%)	8 (80.0%)	
Hospital Facility	1 (4.8%)	0 (0.0%)	2 (20.0%)	

AUC: Area Under the Curve, MME: Morphine Milliequivalents, SD: Standard Deviation, VAS: Visual Analog Pain Scale

9

What have we changed due to this information

- Decreased use of epidurals
  - Result – Apparent Decrease in length of stay overall
  - Needs to be evaluated carefully
- Increased use of Blocks
  - Nerve Injury?
  - Missed Compartment Syndrome?

10

Conclusion

- Epidurals associated with increased length of stay, without concurrent reduction in opioid consumption
- Future Directions
  - Larger scale randomized
  - Evaluate specifically “size” of surgical procedure to limit confounders

11

Intramedullary Nailing with Supplemental Plate and Screw Fixation of Long Bones of Patients with Osteogenesis Imperfecta: Short–term Follow–up

Jeanne M. Franzone, MD, Kenneth J. Rogers, PhD, ATC, Richard W. Kruse, DO, MBA
jeanne.franzone@gmail.com

What was the question?
Osteogenesis imperfecta (OI) is a heritable disorder characterized by bone fragility, fractures and long bone deformity. Although intramedullary fixation is the mainstay for OI bone, it often lacks rotational and length stability. A supplemental plate is one form of adjunctive fixation. The purpose of this study is to report on early results of supplemental plate and screw fixation in the setting of OI with minimum of one year follow–up.

How did you answer the question?
This is a retrospective review of patients with OI undergoing realignment and intramedullary fixation from January 2012–October 2018. Supplemental plate and screws were used to provide rotational or length stability or to treat a nonunion. The supplemental constructs included locking plates with the screws placed after rodding to avoid the intramedullary implant.

What are the results?
191 long bone segments in 64 patients with OI underwent realignment and intramedullary rodding. Supplemental plate and screw fixation was used in 22 patients and 41 segments – 21 femurs, 15 tibias, 4 humeri, 1 forearm. The mean age at surgery was 12.1 years (range 3–26.3). The mean follow–up was 37 months (13–61). Fifteen patients have OI Type III, 6 OI Type IV and one OI Type I. All 22 patients have received bisphosphonate treatment. The average time to union was 7.9 weeks (3.5–15). Two patients have sustained nondisplaced fractures adjacent to the plate and healed with nonoperative treatment. One patient sustained a displaced fracture at the distal aspect of the plate and required revision. One patient developed a transient snapping of the iliotibial band over a proximal femoral plate. One patient developed a nonunion at a tibial osteotomy site in the setting of a supplemental plate; the plate was removed and the nonunion site subsequently healed after a nonunion repair. A rod revision in the setting of a previously placed supplemental plate in the femur has been completed without revising plate and screw construct.

What are your conclusions?
The use of a small locking plate and screw construct as supplemental fixation in the setting of long bone realignment and intramedullary rodding is a useful form of adjunctive fixation in the challenging bone quality in OI patients. Future work to investigate the patient related outcomes with the use of a supplemental plate and screw is underway. The long–term fate of the supplemental fixation is not yet known and must be followed. Supplemental plate and screw fixation is one form of adjective fixation in patients with OI that may serve a role in select cases in order to provide rotational or length stability or treat a nonunion.

Intramedullary Nailing with Supplemental Plate and Screw Fixation of Long Bones of Patients with Osteogenesis Imperfecta: Short-Term Follow-up

Jeanne M. Franzone, MD; Kenneth J. Rogers, PhD, ATC; Richard W. Kruse, DO, MBA

Nemours A.I. duPont Hospital for Children Wilmington, DE

Nemours. Alfred I. duPont Hospital for Children

1

Disclosures

Limb Lengthening and Reconstruction Society: Board or committee member

Pediatric Orthopaedic Society of North America: Board or committee member

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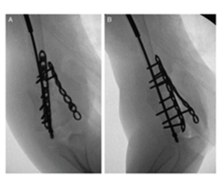
2

Introduction

- **Osteogenesis imperfecta (OI)**
  - Heritable disorder characterized by bone fragility, fractures and long bone deformity
- **Although intramedullary fixation is the mainstay for OI bone, it often lacks rotational and length stability**
- **Supplemental plate is one form of adjunctive fixation**
  - Hsiao et al. 2013, Cho et al. 2015



Hsiao et al.

Cho et al.

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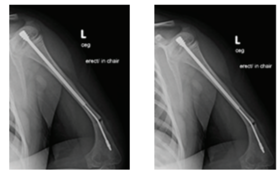
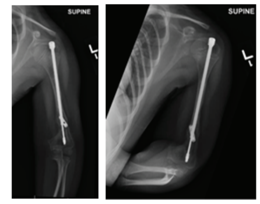
Objective

- **The purpose of this study is to report on early results of supplemental plate and screw fixation in the setting of OI with a minimum of one year follow-up**



10 year old boy



3 months postop

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Methods

- **Retrospective review of patients with OI undergoing realignment and intramedullary fixation January 2012 – November 2018; minimum 1 year follow-up**
- **Supplemental plate and screws used to provide rotational or length stability or to treat a nonunion**
- **Locking plates with screws placed after rodding to avoid the intramedullary implant**

10 year old boy

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Results

- **191 long bone segments (64 patients) underwent realignment and rodding**
- **Supplemental plate and screw fixation was used in 22 patients, 41 segments**
  - 21 femurs, 15 tibias, 4 humeri, 1 forearm
- **Mean age at surgery: 12.1 years (range 3-26.3)**
- **Mean follow-up: 37 months (13-61)**
- **OI Type: Type III – 15, Type IV – 6 ,Type I – 1**
- **All 22 patients have received bisphosphonates**
- **Average time to union: 7.9 weeks (3.5-15)**

1 year postop

10 year old girl

6

Complications

- Fractures:
  - Two nondisplaced - nonoperative treatment
  - One displaced at distal aspect of femoral supplemental plate (4 yrs postop) required revision
- Hip snapping: One patient, transient, over a proximal femoral plate
- Nonunion: One patient, at a tibial osteotomy site with a supplemental plate; the plate was removed and there was healing after nonunion repair

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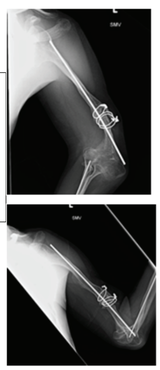
23 year old male with severe OI – longstanding multiply operated left humerus nonunion; also with radial nerve palsy.



Left radial nerve neurolysis, repair of left distal humerus nonunion; 2.5 months after surgery without pain, radial nerve function improved.

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Conclusions and Discussion

- **A locking plate and screw construct provides an adjunctive form of supplemental fixation in challenging bone quality in OI**
- **Plate fixation without intramedullary stabilization is not recommended**
- **Future work regarding patient related outcomes is underway**
- **The long-term fate of supplemental plate fixation is not yet known and must be followed**

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9

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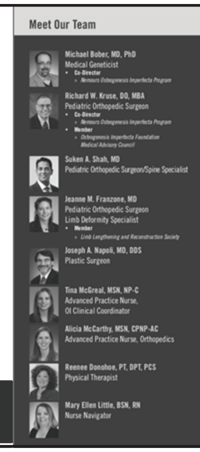

THANK YOU

Jeanne.Franzone@Nemours.org

11

12

Session 4: Intramedullary Implants

Moderator: David Podeszwa, MD

Weight–bearing Internal Lengthening Nail: Results on 57 Consecutive Stature Lengthening Patients

Craig A. Robbins, MD, Dror Paley, MD
crobbins@paleyinstitute.org

What was the question?
Can stature patients be immediate full weight–bearing with the internal lengthening nail?

How did you answer the question?
We performed a retrospective review of 57 consecutive stature patients utilizing the internal lengthening nail. 41 patients had bilateral femur, 4 had bilateral tibia, 12 had bilateral femur and tibia for a total of 138 implants.

What are the results?
One tibial nail failed out of 138 implants. It was exchanged and lengthening completed successfully. 3 other patients had unplanned surgeries: 1 for repeat femur osteotomies after premature consolidation, 1 to revise distal tibia–fibula temporary arthrodesis screws, 1 to stabilize a periprosthetic femur fracture at the distal end of the lengthening nail.

What are your conclusions?
Immediate full weight–bearing is safe during stature lengthening with the implant.

Weight-bearing internal lengthening nail:

results on 57 consecutive stature lengthening patients

Craig A. Robbins, MD
Dror Paley, MD, FRCSC

LLRS / ASAMI North America Virtual Meeting
July 30, 2020

1

Disclosures

- Speaker's Bureau:
  - Smith-Nephew
  - NuVasive
  - Orthopediatrics

2

Background

Intramedullary lengthening outside of US since 1990s:
- Fitbone
- Albizzia (Betz Bone, Guichet nail)
- Phenix (off market)

Intramedullary lengthening in US since 2001:
- ISKD (until 2011)
- Precice (2011 to present)

None allow immediate weight-bearing

3

Background

Stryde (2018 – present):
- Biodur 108 stainless steel (≤0.05% Nickel) *
- Femur (piriformis, trochanteric) & Tibia
- **Immediate post-op weight bearing within limits**

Diameter (mm)	Max weight (lbs)	Max weight (kgs)
10.0	150	69
11.5	200	91
13.0	250	114

* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5090547/

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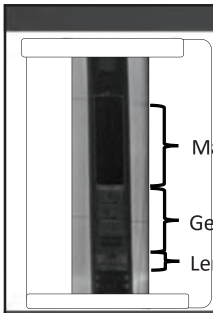

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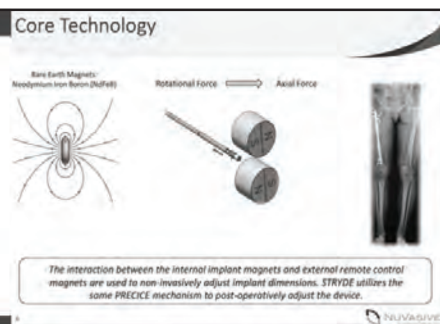

http://sadco-jo.com/mt-content/uploads/2019/03/introduction-to-stryde-presentation-surgeon-2.28.2019.pdf

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Hypotheses

1) No implant failure with full weight-bearing (within specified weight limits)
2) Biodur 108 is biologically compatible

7

Methods

IRB approval; retrospective review of consecutive stature cases between May 2018 and October 2019

57 bilateral skeletally mature (12F, 45M) patients had 138 implants

- 41 bilateral femur (82)
- 12 bilateral tibia and femur (48)
- 4 bilateral tibia (8)

All allowed immediate full weight-bearing

8

Methods

Radiographic measurements pre and post lengthening:
Lateral distal femoral angle (LDFA)
Medial proximal tibial angle (MPTA)
Femoral-tibial angle

9

Protocol

- All patients allowed immediate weight-bearing after surgery
- Crutches/walker used until patient felt comfortable without
- Single crutch or cane recommended for safety as needed

Diameter (mm)	Max weight (lbs)	Max weight (kgs)
10.0	150	69
11.5	200	91
13.0	250	114

10

Demographics

Sex	Age	Weight (kg)	Height (cm)
Female	29.1 [15-63]	50.8 [44-60]	155 [139-172]
Male	31.5 [16-56]	69.3 [36-98]	165.4 [147-179]

Mean [range]

11

Results

- 52/57 statures lengthened to within 10 mm of their goal
- 4/57 required unplanned secondary operations
- 1/138 nail failed and was exchanged
- All healed without secondary procedures
- No known biologic incompatibility

12

Results

- No statistically significant change in LDFA, MPTA, femoral-tibial angle
- No statistically significant relation between LDFA, nail diameter, or distraction gap

13

Patients not reaching goal (within 1 cm)

Reason for Stopping Lengthening	Segment	Achieved (cm)	Goal (cm)	% of goal
Decrease Knee ROM	femurs	5	8	63
Decrease Knee ROM	femurs	6	8	75
Fracture	femurs	6	8	75
Decrease Knee ROM	femurs	6.5	8	81
Decrease Ankle ROM	tibias	3	5	60
ROM = range of motion				

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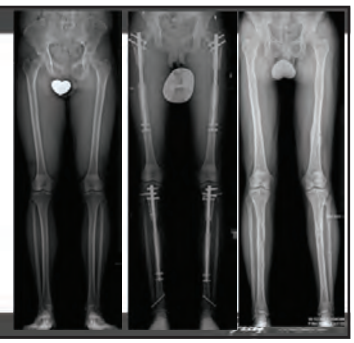
Unplanned Surgery

Complication	Segment / Diagnosis	Treatment	Achieved (cm)	Goal (cm)	% of goal
Fracture of femur	femurs	FAN Static nail exchange	6	8	75
Premature consolidation bilateral	femurs	repeat osteotomy femurs	6.5	6.5	100
tibia nail mechanism failure	femurs and tibias	repeat osteotomy and nail exchange	5.2	5	104
Bending of distal tibio-fibular fixation peg	tibias	revision distal T-F peg	5.5	5.5	100
FAN = Fixator-Assisted Nail					

15

F.C. 23 y/o

4 segment
6 cm femurs
5.2 cm tibias
(left tibial nail failure)



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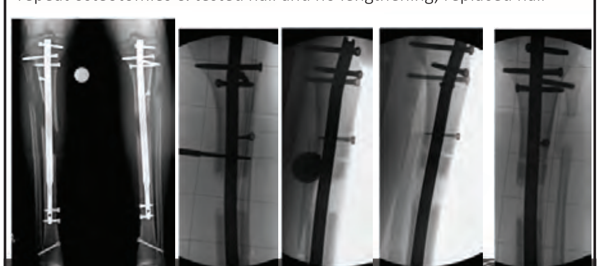
repeat osteotomies & tested nail and no lengthening; replaced nail



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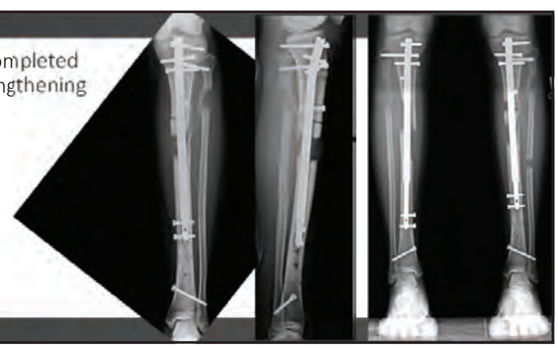
Completed lengthening



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Conclusion

- Stryde nails allow immediate weight-bearing within specified limits
- No known biologic incompatibility with Biodur 108 stainless steel

19

Extramedullary Implantable Limb Lengthening (EMILL) for Congenital Limb Length Discrepancy

Claire E Shannon MD, Dror Paley MD FRCSC, Craig Robbins MD
CShannon@PaleyInstitute.org

What was the question?
To evaluate whether EMILL can extend the indication for implantable limb lengthening to younger and smaller children, as well as patients otherwise unable to undergo intramedullary lengthening, an alternative to external fixation.

How did you answer the question?
A retrospective review of all cases of EMILL for the treatment of congenital leg length discrepancy during the past 5 years was performed. This study was approved by the Institutional Review Board. Seventeen patients (10 male, 7 female) underwent insertion of 18 nails for EMILL. Diagnoses consisted of Congenital Femoral Deficiency (CFD) (8), Tibial Hemimelia (TH) (2), Fibular Hemimelia (FH) (2), Combined CFD and FH (3), Hypophosphatemic Ricketts (1), and Myelomeningocele (1). Median age: 6.5 years (3.5–20 years). Femoral lengthening was performed with 12 nails in 12 patients and tibial lengthening with 6 nails in 5 patients. One femoral lengthening and 2 tibial lengthenings did not have a SLIM rod inserted. Four patients had hemiepiphysiodesis plates inserted concurrently for a preexisting coronal plane deformity.

What are the results?
Average follow–up was 11 months (1month–5 years). Average lengthening amount was 47.5mm (35–55mm). Pre–surgical lengthening goal was achieved in 16 of 17 patients. The regenerate bone healed in all cases. Radiographic healing was achieved in an average of 1.8 months (1–3.75 months). The healing index was 0.77months/cm. All patients returned to previous level of function with decreased or eliminated shoe lift. Complications consisted of 1 broken screw requiring revision fixation; 2 subluxations of hip treated by open reduction and periacetabular osteotomy, and 1 screw head that eroded through the skin not requiring revision. There were no infections and no significant undesired coronal or sagittal plane mechanical axis changes ($p>0.05$).

What are your conclusions?
EMILL is a safe alternative to external fixation lengthening and extends the indications for implantable lengthening to younger children (youngest in this series was 3 years), bones whose growth plates would be violated by intramedullary devices (tibia and younger femur apophysis), or bones that cannot accommodate intramedullary implants. One must follow the same principles as with external fixation lengthening: stabilization of joints with preparatory surgery (e.g. pelvic osteotomy) and bracing to prevent knee subluxation and contracture. Lengthening should be restricted to amounts no greater than 5cm.

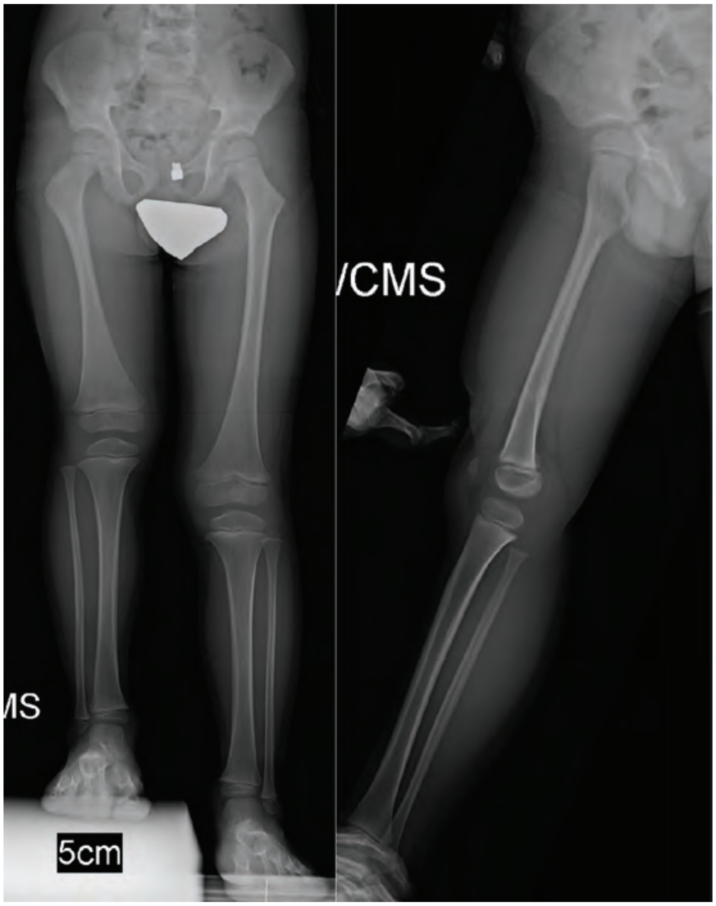

Fig 1: Preoperative standing AP and lateral xrays demonstrating right CFD Paley type $1A_1$ with a 5cm LLD.

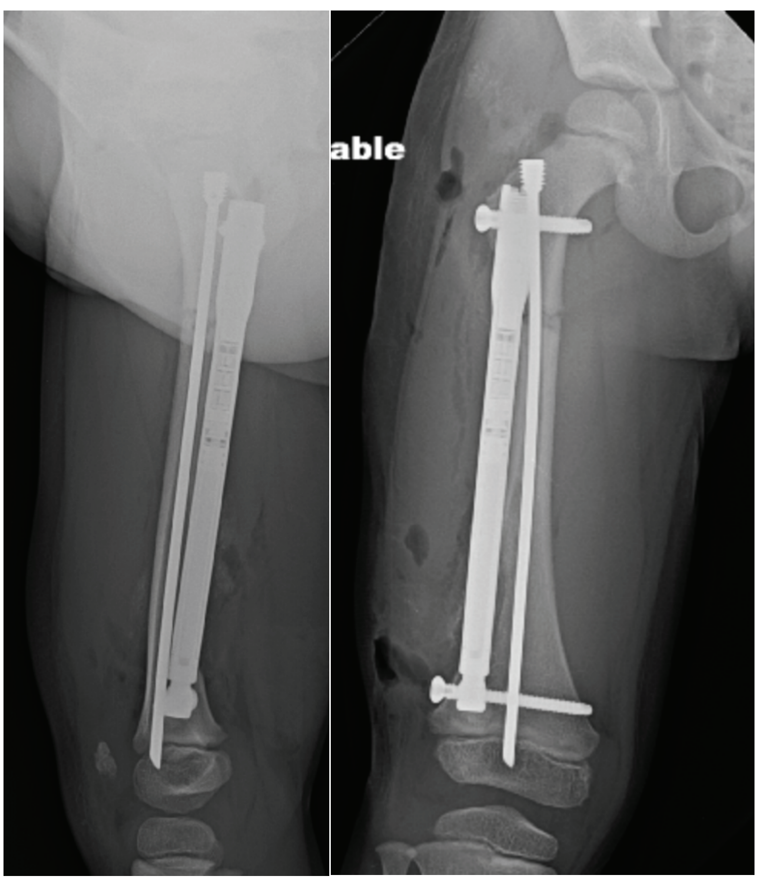

Fig 2: Immediate post-operative AP and lateral xrays after femoral EMILL insertion. Note that the distal end of the nail is "docked" into the femoral metaphysis

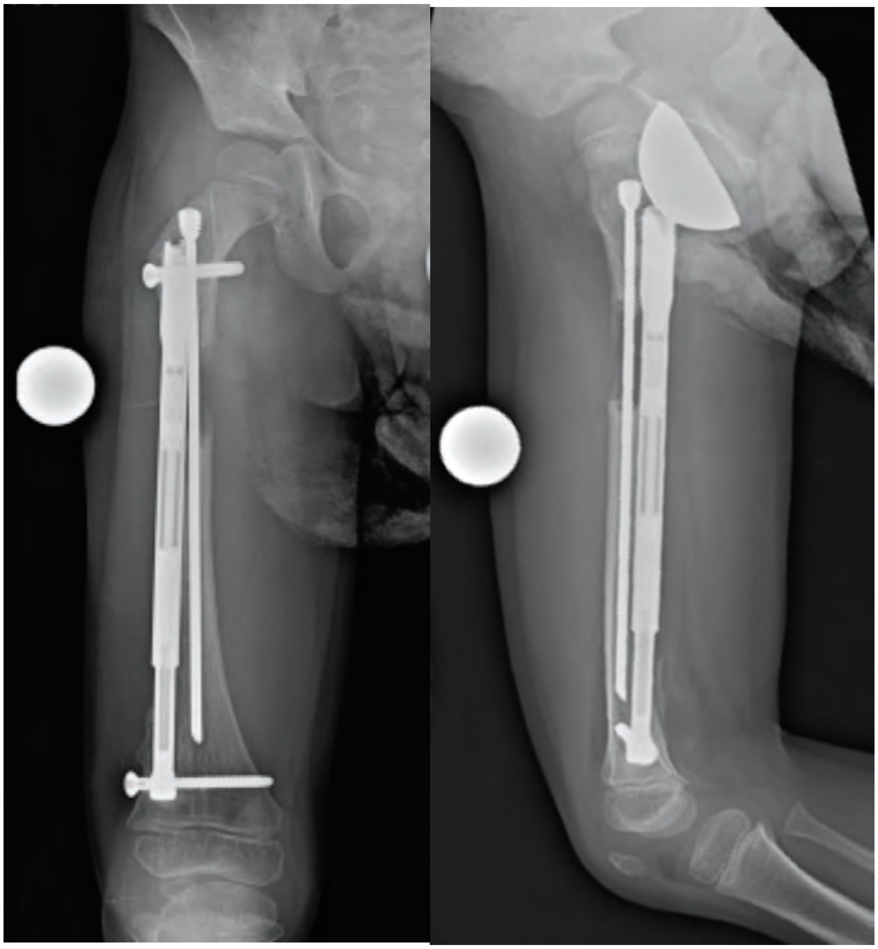

Fig 3: AP and lateral xrays after 6 weeks of lengthening.

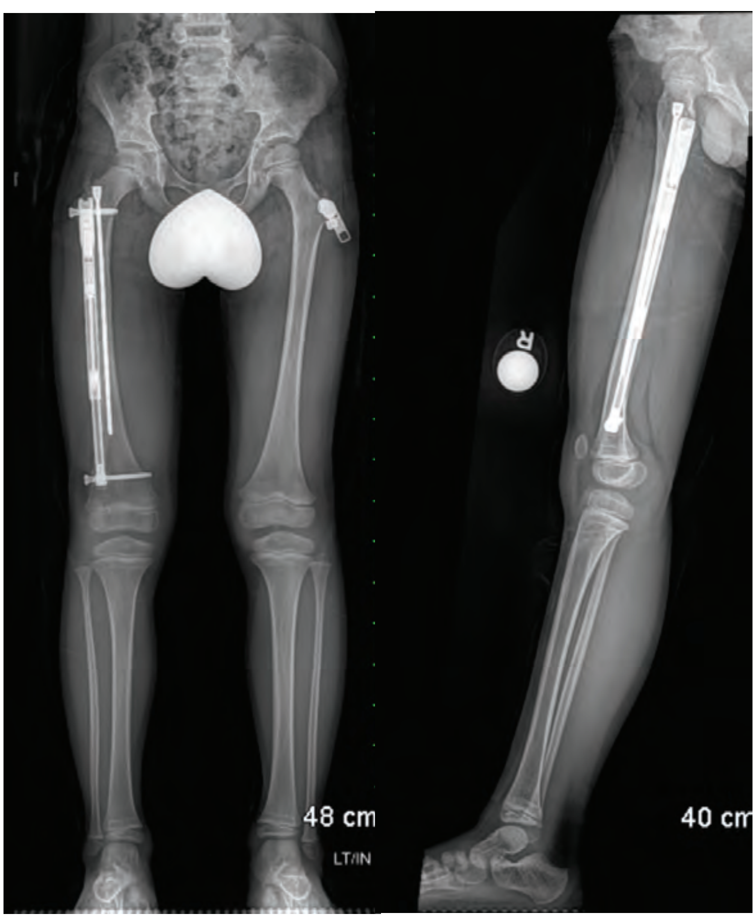

Fig 4: Weightbearing AP and lateral xrays after completion of 5cm lengthening and bone consolidation.

Paley ORTHOPEDIC & SPINE INSTITUTE at St. Mary's Medical Center

Extramedullary Implantable Limb Lengthening (EMILL) for congenital limb length discrepancy (LLD) is safe and effective

Claire E Shannon MD

Dror Paley MD FRCSC

Craig Robbins MD

www.PaleyInstitute.org

1

(I and/or my co-authors) have something to disclose.
Details are available on the AAOS disclosures site.

2

Purpose

- Limitations on intramedullary lengthening:
  - bones of small diameter or short length
  - open physes
  - anatomical limitations
- Evaluate whether EMILL can extend indications for implantable limb lengthening
  - younger and smaller children
  - patients otherwise unable to undergo intramedullary lengthening

3

Methods

- Retrospective review of all cases of EMILL for congenital LLD during past 5yrs.
- Approved by the Institutional Review Board .
- Inclusion criteria:
  - medullary canal too small for 8.5mm nail
  - minimum fixation length 150mm.
- A small diameter solid rod (SLIM, Pega) was inserted in the medullary canal to help maintain alignment and the lengthening nail was affixed outside the bone with screws.
- Protocol: Lengthening rate 0.75mm/day, daily physical therapy and night extension knee bracing for femurs, ankle dorsiflexion bracing for tibias. Concurrent hemiepiphysiodesis was performed for pre-existing coronal plane deformity when necessary.

4

Demographics

- 17 patients (10 male, 7 female) with 18 nails implanted have completed EMILL
  - **21 patients/24 nails have been implanted to date**
  - Femoral: 10 nails in 10 patients. Tibial: 8 nails in 7 patients.
  - 3 patients (1 femur, 2 tibial) did not have a SLIM rod inserted.
  - 4 patients had hemiepiphysiodesis.
- Diagnoses:
  - Congenital Femoral Deficiency (CFD) (8), Tibial Hemimelia (TH) (2), Fibular Hemimelia (FH) (2), Combined CFD and FH (3), Hypophosphatemic Ricketts (1), and Myelomeningocele (1).
- Median age 8 years (3.5-20 years)

5

Results

- 17 patients with completed lengthening and consolidation
- Average follow-up 14 months (1mo-5yr)
- Average lengthening 48mm (35-55mm)
  - Pre-surgical lengthening goal achieved in 16 of 17 patients.
- Radiographic healing achieved at 1.8 months (1-3.75 months).
- Average Healing Index 0.84 months/cm.
  - Femurs – 0.52 months/cm avg
  - Tibias – 1.0 months/cm avg
- No infections and no significant undesired mechanical axis changes (p>0.05)

6

AP and lateral xrays after 6 weeks of lengthening.

Weightbearing AP and lateral xrays after completion of 5cm lengthening and bone consolidation.

7

Complications

- 1 broken screw requiring revision fixation
- 2 hip subluxations
  - treated by open reduction and periacetabular osteotomy,
- 1 screw head erosion through skin
  - not requiring revision.

8

Discussion

- Implantable limb lengthening advantages:
  - decreased pain, increased mobility due to no pin tethering, less scarring and no risk of pin site infection.
- Unfortunately, intramedullary application is unavailable to patients with small bones, open growth plates, or other anatomical limitation
- Use of a small caliber intramedullary rod in this study prevented axial deviation.
  - Additionally the nail was "docked' in the metaphysis to counteract cantilever forces.
- Regenerate bone healing rates appear to be faster than other methods of lengthening, likely due to the minimal disruption of the endosteal and periosteal blood supply.

AP and lateral xray of the femur after removal of the extramedullary rod

9

Conclusion

- EMILL is a safe alternative to external fixation lengthening
- Extends indications for implantable lengthening
  - younger children,
  - bones whose growth plates would be violated by intramedullary devices (tibia and younger femur apophysis)
  - bones that cannot accommodate intramedullary implants.
- Must follow the same principles as with external fixation lengthening:
  - stabilization of joints with preparatory surgery (e.g. pelvic osteotomy)
  - bracing to prevent knee subluxation and contracture.
  - Lengthening should be restricted to amounts no greater than 5cm

10

References

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2. Paley, Dror MD, FRCSC; Harris, Matthew MD, MBA; Debiparshad, Kevin MD, FRCSC; Prince, Daniel MD, MPH: Limb Lengthening by Implantable Limb Lengthening Devices. *Techniques in Orthopaedics:* June 2014 - Volume 29 - Issue 2 - p 72-85 doi: 10.1097/BTO.0000000000000072
3. Paley, D. Treatment Congenital Femoral Deficiency, *Operative Techniques in Orthopaedic Surgery*, Lippincott Williams & Wilkins, Jul 10, 2015, 2 edition -- Part 4 Chapter 33).
4. Paley D, Chong DY: Congenital Femoral Deficiency Reconstruction and Lengthening Surgery, *Pediatric Lower Limb Deformities, Principles and Techniques of Management*, Springer, Cham, Heidelberg New York, Dordrecht London, 2016 Ch. 22, pg 361-427.
5. Dahl MT, Georgiadis AG, Laine JC, Novotny SA. Extramedullary Motorized Lengthening of the Femur in Pediatric Patients. Pediatric Orthopedic Society of North America, Charlotte, North Carolina, May 17, 2019

11

Traveling Fellowship 2019 Report

James Blair, MD
Paul Matuszewski, MD
Claire E. Shannon, MD
Megan Young, MD

Clinician Scholar Career Development Program Presentation

Joshua Speirs, MD

Narrated, Pre–Recorded Scientific Papers

Session 1: Biomechanics & Metabolic

Rigidity of Hip–Spanning External Fixation as Affected by Pelvic Pin Location, Angulation, and Number of Pins

Louis Wentzel Bezuidenhout, David Alexander Podeszwa, Mikhail Samchukov, Alexander Cherkashin, William Pierce, BS ENG
louisb@ualberta.ca

What was the question?
The duration of treatment in a hip spanning external fixator is often limited by pin infection, loosening, or both. A stable half pin configuration would help minimize these potential complications. The configuration of supra–acetabular pins that confers the most stable fixation is not described in the literature. We sought to determine whether a triangular supra–acetabular pin configuration would be stiffer in axial displacement and anterior–posterior bending compared to a linear configuration, and how the pin spacing and angulation might affect the construct stiffness.

How did you answer the question?
We developed a biomechanical model to test the axial and rotational stiffness of different supra–acetabular pin configurations. Six–millimeter diameter half pins were inserted to a depth of 4 cm into a 0.32 gcm–3 Sawbones® polyurethane foam block to simulate the periacetabular cancellous bone. They were all anchored at a distance of 12 cm along the pin from the bone entry to a custom built rigid frame so that all deflection was limited to the pins. We compared the effect of increasing spacing between two parallel pins placed in the same axial plane (spaced 2 cm, 3cm and 4 cm apart) and increasing convergence between two pins (parallel, 30º convergence, and 60º convergence, spaced 4cm apart at their entry into the bone). We then compared the effect of adding a third pin and the relative orientation of the three pins with three configurations: linear (equally spaced 2 cm), triangular and parallel (equally spaced 4 cm), and triangular and convergent (equally spaced 4 cm at the bone). These configurations are shown in Figure 1. The axial stiffness was determined by applying a cyclical sinusoidal load ranging from 1.0 – 50 kg and measuring the resulting displacement of the block. The rotational stiffness was measured by applying a cyclical sinusoidal load offset 4 cm in the AP plane from the center of the construct ranging from 1.0 – 50 kg and measuring the resulting rotation of the block. Rotational stiffness and angular displacement was measured for a clockwise (CW) and counter–clockwise (CCW) applied torque to the acetabular block.

What are the results?
Axial stiffness: There was little difference in stiffness when two pins were spaced 2 cm, 3 cm, or 4 cm apart (range 17.9 kNm–1 to 18.9 kNm–1), or whether they converged or were parallel (range 18.2 kNm–1 to 18.8 kNm–1). In contrast, there was significant difference in the stiffness between the different three pin configurations. The linear three pin configuration scaled as expected compared to the two pin linear configuration, with a 50% increase in stiffness from addition of the third pin (27.5 kNm–1). Moving the pin out of plane into the triangular configuration increased the stiffness by a further 250% (65.9 kNm–1). Convergent triangular pins had a greatly increased stiffness of 476 kNm–1, a 7–fold increase over the parallel triangular configuration and a 17–fold increase over the linear three pin configuration. In this stiffest construct, the acetabular block displaced 1.0 mm with 50 kg of applied force, compared to 18 mm displacement in the linear three pin configuration. Rotational stiffness: The stiffness was comparable between the two pin constructs with parallel pins spaced 2, 3, and 4 cm apart (range 125 to 159 Nmrad–1). The stiffness was comparatively higher with a CCW torque than a CW torque for each model, where a CCW rotation would act to screw the block onto the pin and a CW torque would act to unscrew the block from the pin (e.g 159 Nmrad–1 CCW and 125 Nmrad–1 CW for 4 cm spaced pins). However, the total angular displacement was lower when the pins were spaced further apart (11.5º CW and 8.8º CCW at 2 cm versus 5.9º CW and 1.9º CCW at 4 cm over 10 cycles). With increasing convergence of the pins, the stiffness increased slightly (159 Nmrad–1 when parallel and 225 Nmrad–1 when 60º convergent with CCW torque), again with a higher stiffness for CCW torque than CW torque with all models. The total angular

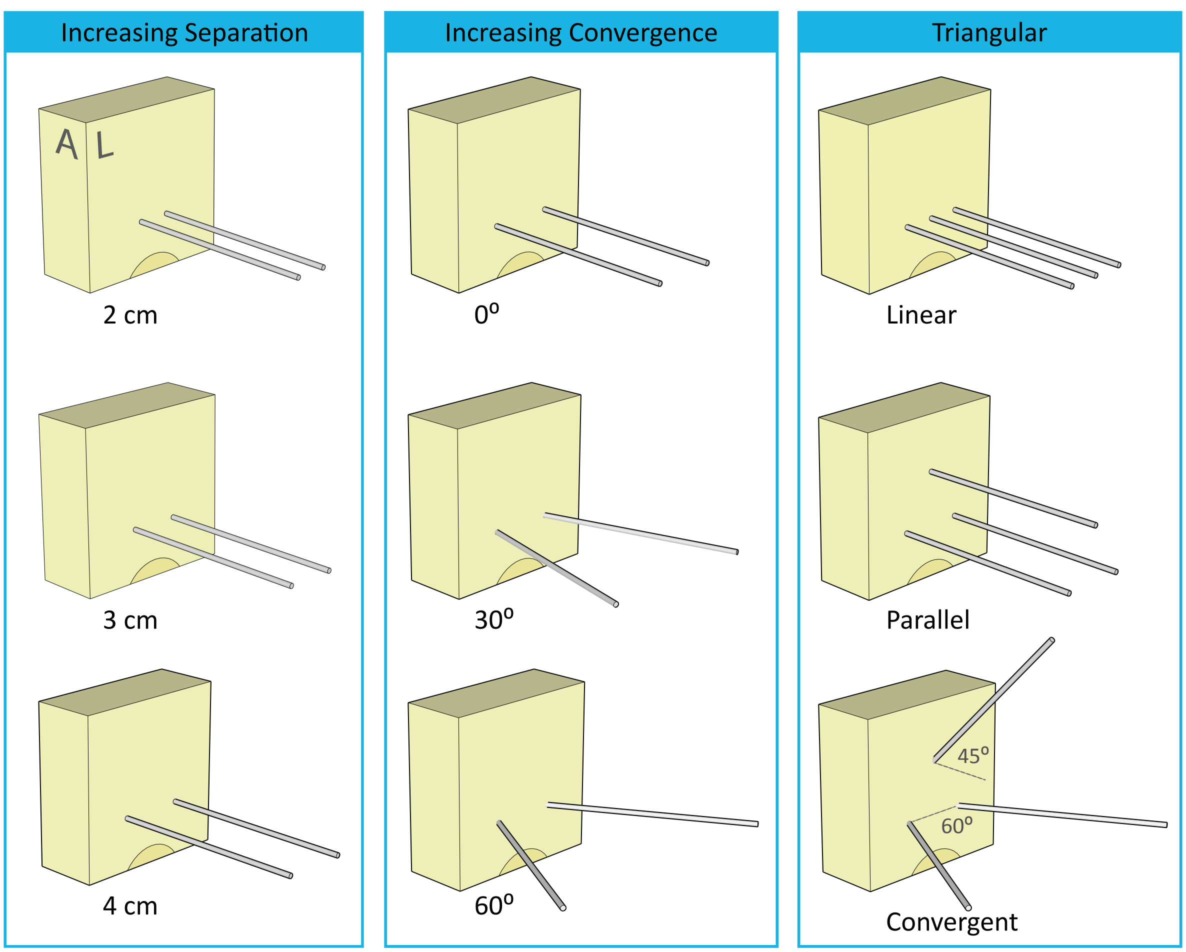
Rigidity of Hip–Spanning External Fixation as Affected by Pelvic Pin Location, Angulation, and Number of Pins *continued*

Louis Wentzel Bezuidenhout

displacement greatly decreased with increasing convergence (5.9º for parallel configuration, 1.6º when pins 30º convergent and 0.42º when pins 60º convergent with CW torque). In the three–pin configurations, the convergent model was much stiffer than the triangular parallel and linear parallel configurations (respectively, 391, 188 and 193 Nmrad–1 CW and 579, 205, and 220 Nmrad–1 CCW), with greater stiffness with CCW torque. Total angular displacement was negligible for the convergent model (0.45º CW and 0.30º CCW) compared to the two parallel models (6.4º CW and 5.4º CCW for the linear model and 7.8º CW and 2.4º CCW for the triangular model).

What are your conclusions?

The configuration of supra–acetabular half–pins in a hip spanning external fixator will have a pronounced impact on the stiffness of the construct. A convergent superior to inferior pin is a major contributor to axial stiffness, whereas convergent pins in the axial plane above the acetabulum are a major contributor to rotational stiffness. Pins convergent in the axial plane become less axially stiff with higher convergence angle, in trade–off with their increased rotational stiffness. The optimal construct for stiffness will have at least three convergent pins. The optimal angle of convergence will be determined with further study, will the expected incremental benefit of more pins. The results of this study should be directly clinically applicable in enhancing hip spanning external fixator stability and thereby decreasing infection and loosening rates. Clinical validation is necessary.



Rigidity of hip-spanning external fixation as affected by pelvic pin location, angulation, and number of pins.

Louis W. Bezuidenhout

D.A. Podeszwa, M.L. Samchukov, A.M. Cherkashin, W. Pierce.

Texas Scottish Rite Hospital for Children
UT Southwestern Medical Center

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The authors have no pertinent financial disclosures

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2 years postop

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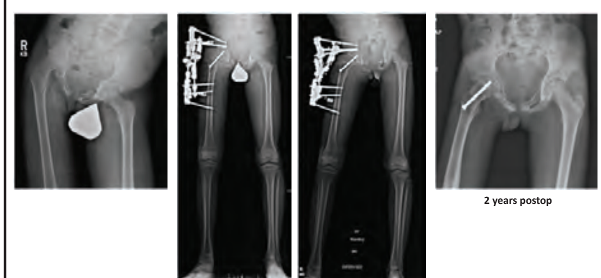

2 years postop

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Construct stability is important for:

- Pin movement
- Maintenance of joint distraction

Soft tissue irritation → Pin site infection

Pin loosening

5

Optimal pin placement and configuration is unknown

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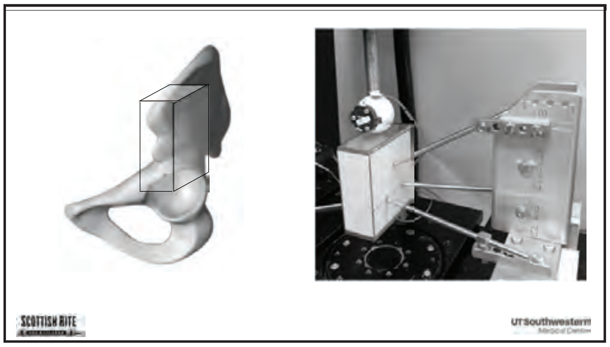
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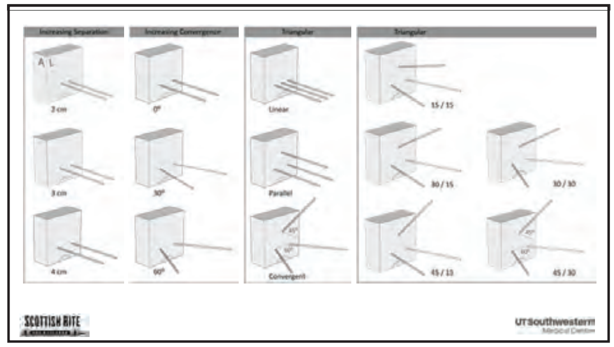
Increasing Separation
Increasing Convergence
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Triangular
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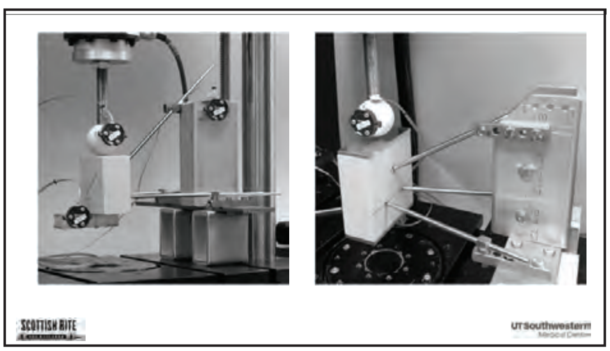
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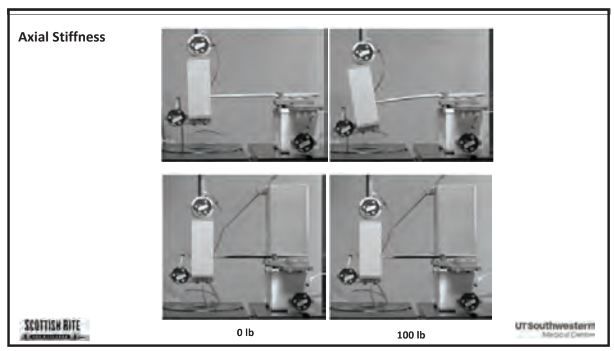
Axial Stiffness
0 lb
100 lb
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Axial Stiffness (lb/mm)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
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LP 2
LP 3
LP 4
LC 15
LC 30
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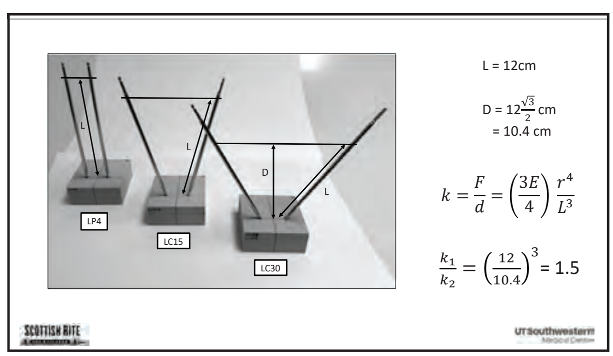
L
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L = 12cm
D = 12$\frac{\sqrt{3}}{2}$ cm
= 10.4 cm
$k = \frac{F}{d} = \left(\frac{3E}{4}\right)\frac{r^4}{L^3}$
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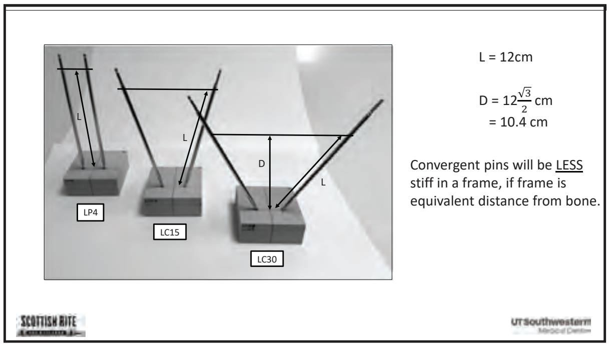

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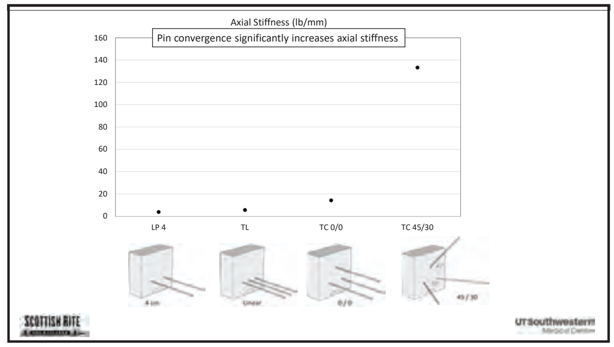

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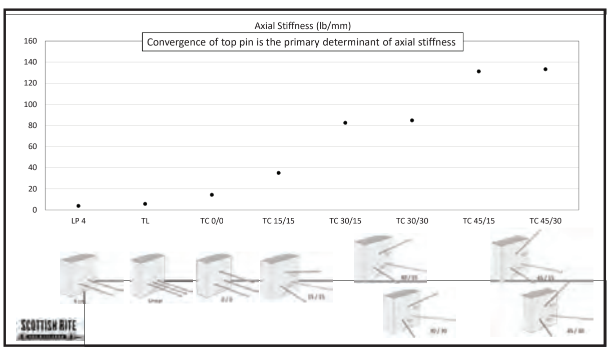

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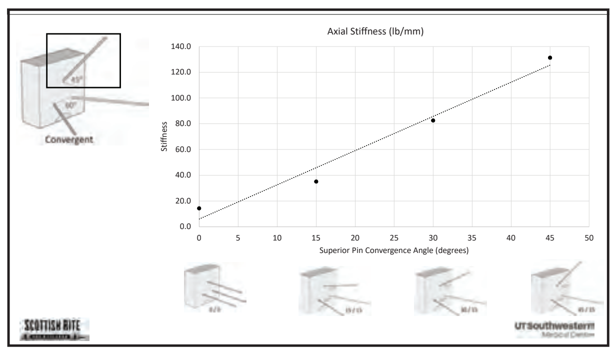

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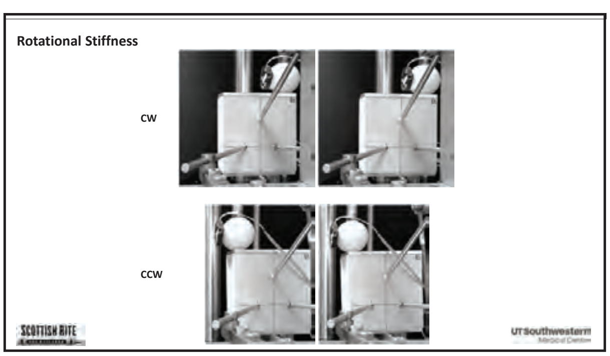

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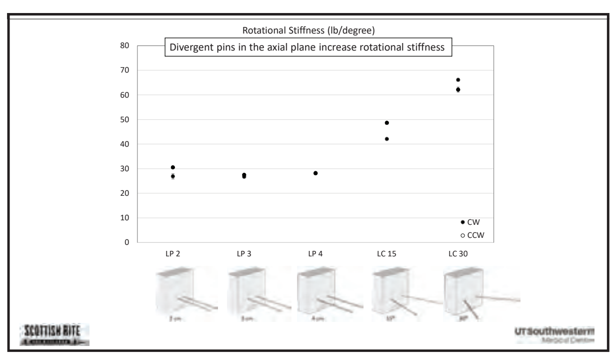

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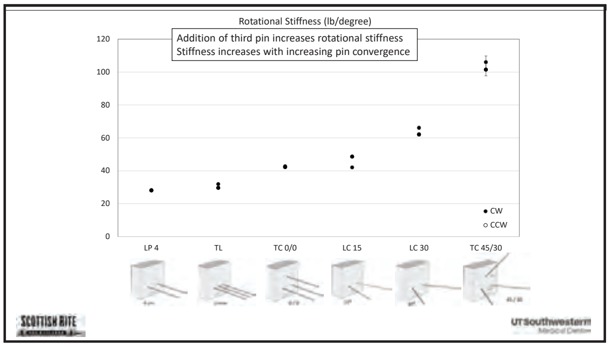

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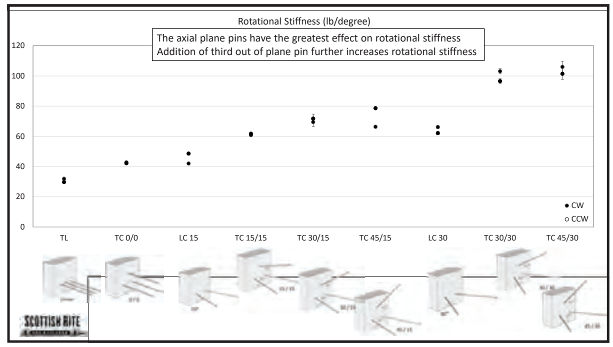

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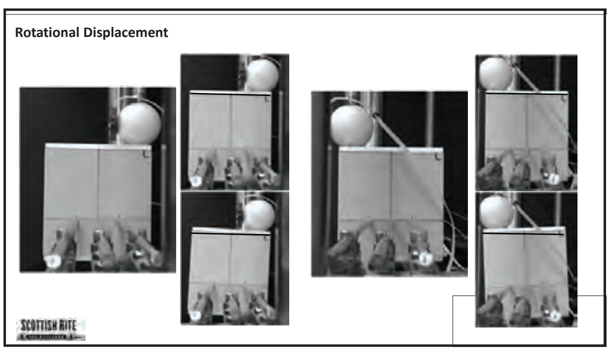

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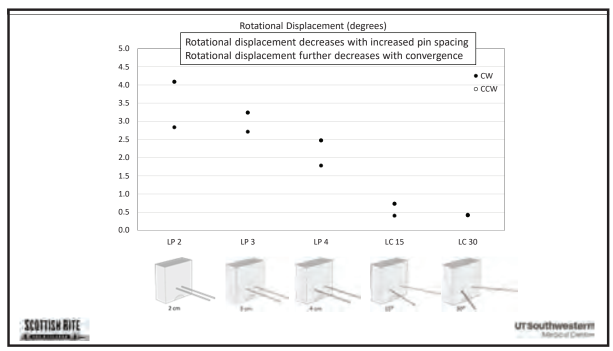

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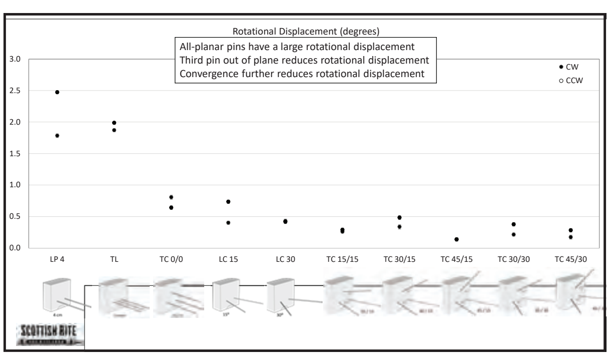

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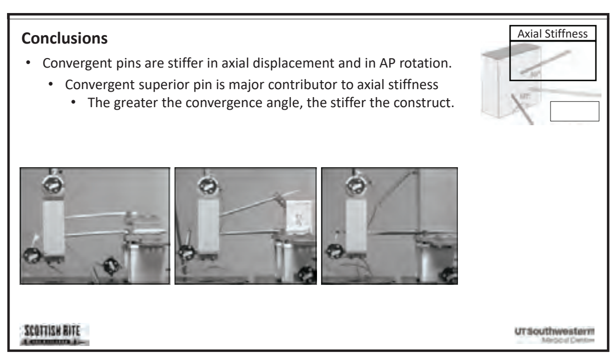

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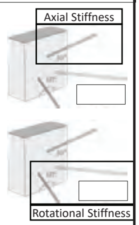
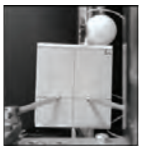
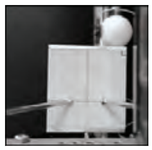
Conclusions

- Convergent pins are stiffer in axial displacement and in AP rotation.
  - Convergent superior pin is major contributor to axial stiffness
    - The greater the convergence angle, the stiffer the construct.
  - Convergent pins in axial plane are major contributor to rotational stiffness.







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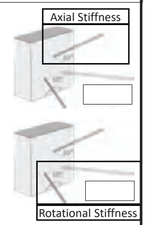
Conclusions

- Convergent pins are stiffer in axial displacement and in AP rotation.
  - Convergent superior pin is major contributor to axial stiffness
    - The greater the convergence angle, the stiffer the construct.
  - Convergent pins in axial plane are major contributor to rotational stiffness.
- Convergent pins protect against rotational displacement in AP rotation
  - This may affect pin loosening.



The ideal three pin construct will have pins convergent at as large an angle as practical, with two in the axial plane and one out of plane.

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Thank You!

SCOTTISH RITE FOR CHILDREN

UT Southwestern Medical Center

27

Effect of Dynamization Modules on Bone Segment Vertical and Lateral Displacements

Erin Honcharuk, MD, William Pierce, BS ENG, Alexander Cherkashin, MD, Mikhail Samchukov, MD
erin.honcharuk@tsrh.org

What was the question?
It is well recognized that axial interfragmentary micro movement remains an essential component for successful fracture healing and new bone formation during external fixation. In cases of modern (post Ilizarov) circular frames, bone fixation is predominantly achieved by multiple thick half–pins, either alone or in combination with tensioned wires, significantly reducing axial micromotion of bone segments under loading. One of the proposed methods of improving axial micromotion is the incorporation of special dynamization modules in the external frame allowing controlled increase in interfragmentary vertical movement. The purpose of this study was to investigate whether the use of dynamization modules in circular external fixation with different wire or half–pin configurations can change the amount of displacement that occurs in the sagittal, coronal, and axial planes.

How did you answer the question?
Seven different circular external fixation frame models were constructed using Acetyl (Delrin) cylinders to simulate the long bone segment. One model used three 1.8 mm tensioned wires to represent the classic all–wire (AW) Ilizarov model. The second model used one half–pin and two wires (1P2W) and the third model used two half–pins and one wire (2P1W) to represent the most common configurations of half pins and wires used for distal femoral, proximal tibial, and distal tibial fixation. Four threaded rods were used to connect the proximal dynamic aluminum external fixation ring to a distal static ring of the identical size. Each of the threaded rods in the last two models were placed with either a cylindrical spring–loaded aluminum dynamization module (MD), a novel 3D–printed plastic dynamizer (PD), or with no dynamization unit (ND). These frame constructs were placed on the loading platform and Delrin cylinders were displaced axially in load control from 0.5Kg (1.1Lbs) to 50Kg (110Lbs) for 11 cycles. The displacements of the bone model in three planes were measured at the end of the Delrin cylinder using custom–made 3D displacement sensor.

What are the results?
The range of maximum axial displacement for the models was between 1.9 and 6.79 mm (Fig. 1, Table 1). When going from the AW model to the models that used half–pin constructs and no dynamization, there is a decrease in axial motion. The addition of dynamization increases axial motion compared to both the AW and ND models. Furthermore, while the curves for the ND and AW models appear as a straight line, the dynamized models show a transition point with two distinct curves. This means that at the same applied force, there is more axial displacement with dynamization. However, after the inflection point, the dynamized models have a line that is almost parallel to their ND counterpart. When comparing the two different dynamization options, the printed dynamizers initially allow even more axial displacement than the metal dynamizers at the same level of force. The range of maximum sagittal displacement for all models was between 2.25 and 6.44 mm. The use of half–pins, when compared to the all wire construct, actually increases sagittal motion. The addition of either form dynamization decreased the amount of displacement. In the coronal plane, the motion for almost all models displaced less than 1 mm of motion throughout the 50 kgs of force applied. The sole exception was the 1P2W–PD model, which showed a maximum displacement of 2 mm at 50 kgs of force. When specifically looking at axial displacement compared to sagittal displacement, we found that the addition of half–pins to the construct causes a decrease in axial displacement at the same level of sagittal displacement. Stated differently, to reach the same level of axial displacement, more sagittal displacement occurred. However, the addition of dynamization modules increased the amount of axial displacement for the same amount of sagittal displacement.

What are your conclusions?
Increasing rigidity of bone segment stabilization in circular external fixation frames (e.g., by the addition of half–pins) can lead to decreased beneficial axial motion and increased detrimental sagittal motion. Incorporation of axial dynamization modules to frame construct allows to achieve desirable amount of axial micromotion at the significantly less anterior displacements.

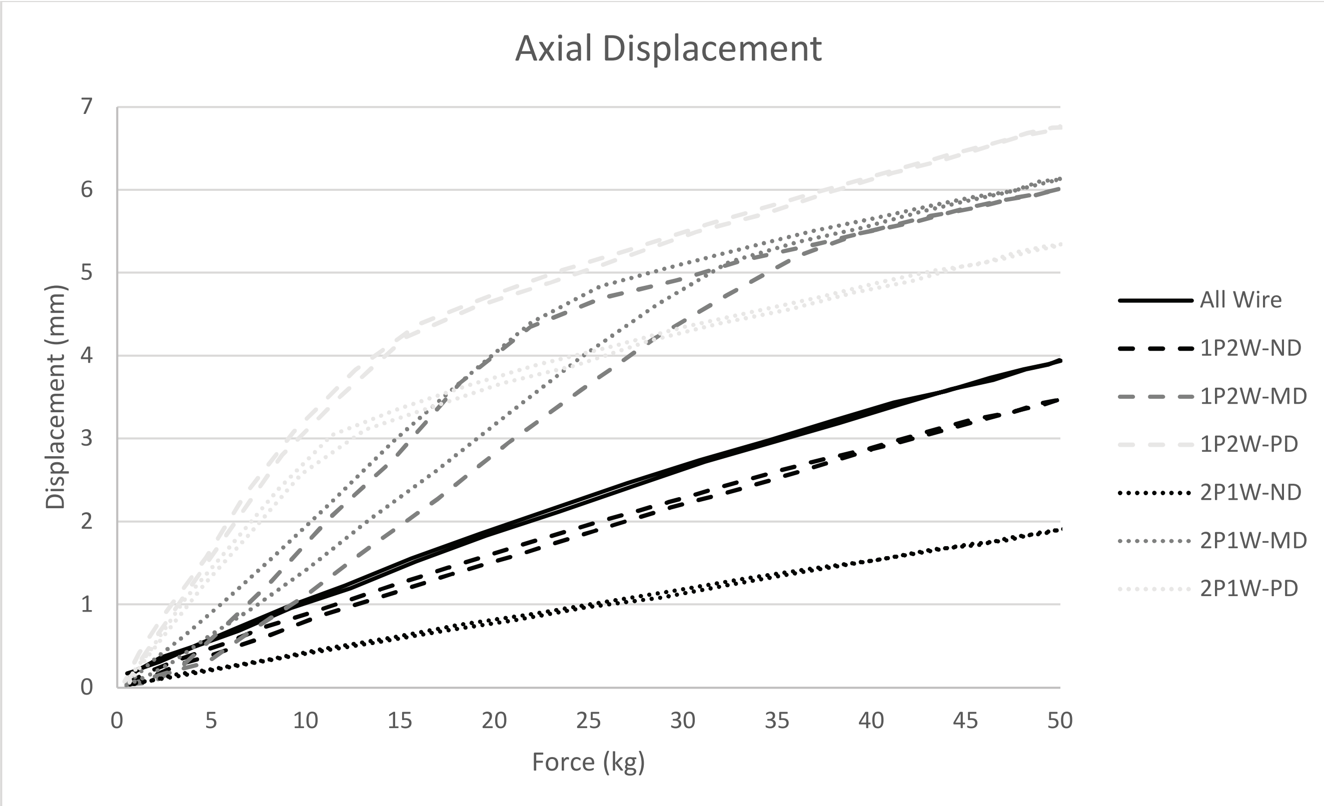


Figure 1. Force versus axial displacement in all fixation models.

Table 1. Delrin cylinder displacement (mm) in axial, sagittal and coronal planes at 50 kg of axial loading

Model	Axial Displacement	Sagittal Displacement	Coronal Displacement
All Wire	3.90	2.25	0.19
1P2W-ND	3.46	4.71	0.60
1P2W-MD	6.02	4.72	0.19
1P2W-PD	6.79	4.43	1.96
2P1W-ND	1.90	5.64	0.29
2P1W-MD	6.15	5.16	0.20
2P1W-PD	5.35	6.44	0.11

Effect of Dynamization Modules on Bone Segment Vertical and Lateral Displacements

Erin Honcharuk, MD; Michael Samchukov, MD;
Alexander Cherkashin, MD; Bill Pierce

1

Author(s) have something to disclose:

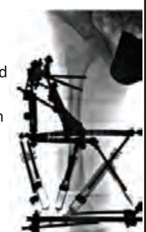
Consultant Orthofix, Inc

Royalties through Texas Scottish Rite Hospital for TrueLok Circular Fixation system

2

Introduction

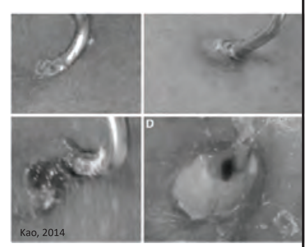
- External fixator frames used for deformity correction and limb lengthening
- Balance between stability of the frame and micromotion
- Micromotion
  - Axial micromotion ↑ healing
    - Affected by stability in any plane
  - Bending/shear micromotion ↓ healing
    - Affected by stability only in that plane of motion



3

Introduction

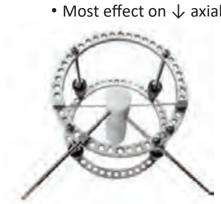
- Original Ilizarov frame
  - All wire
    - Limited trajectories
      - Muscle fibrosis
    - Micromotion→
      - Pain
      - Pin site infection



4

Introduction

- Original Ilizarov frame
  - All wire
    - Limited trajectories
      - Muscle fibrosis
    - Micromotion→
      - Pain
      - Pin site infection
- Use of half pins
  - ↑ Stiffness and stability
  - Most effect on ↓ axial motion



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All Wire Construct

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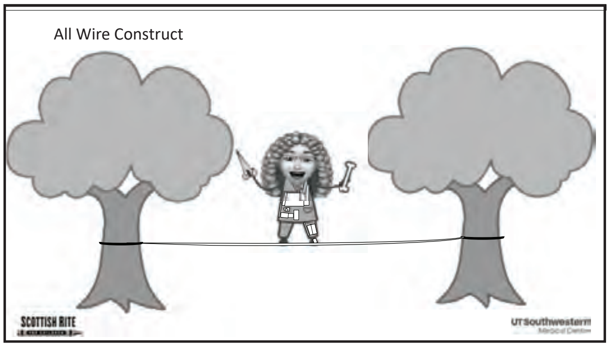
All Wire Construct

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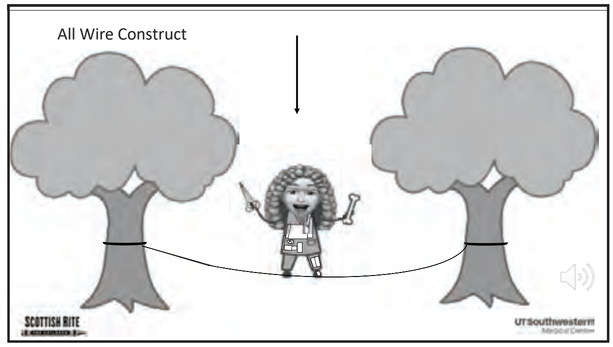
All Wire Construct

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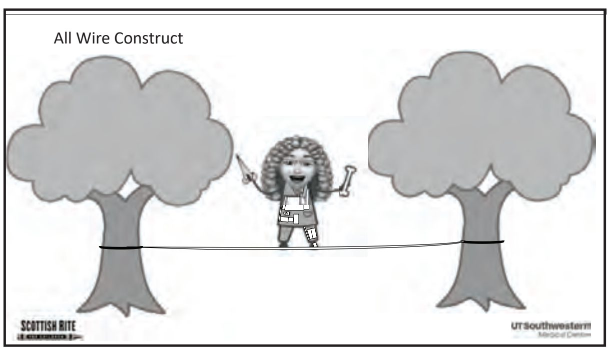
All Wire Construct

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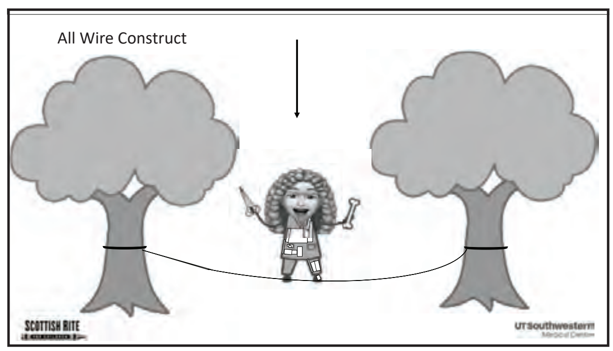
All Wire Construct

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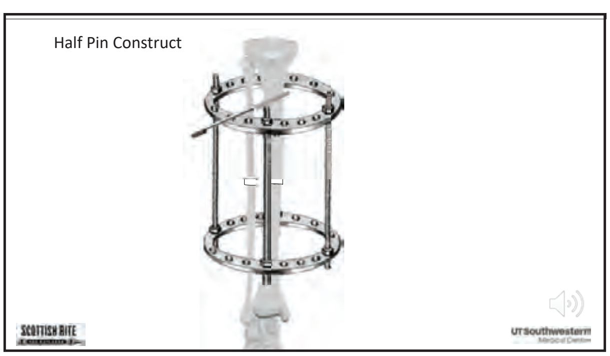
Half Pin Construct

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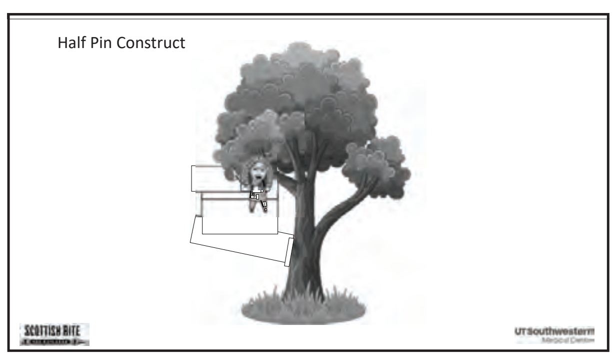
Half Pin Construct

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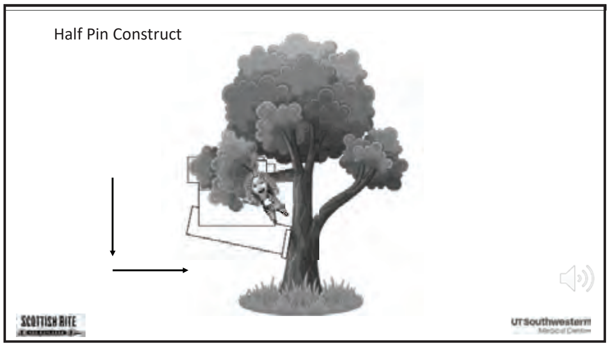

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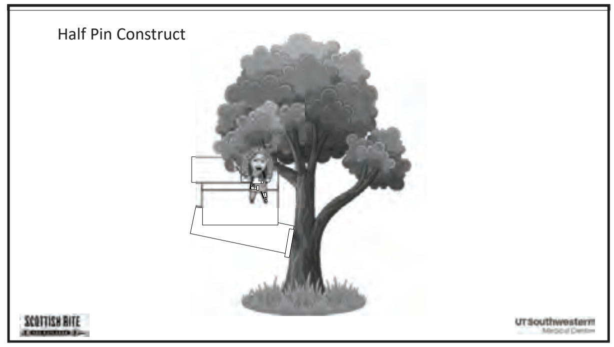

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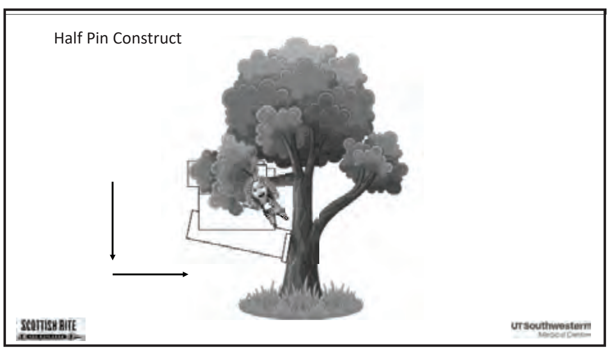

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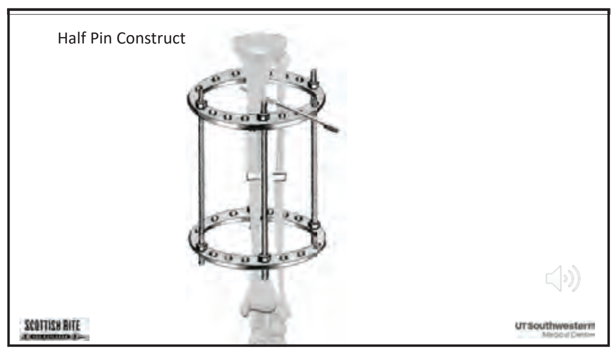

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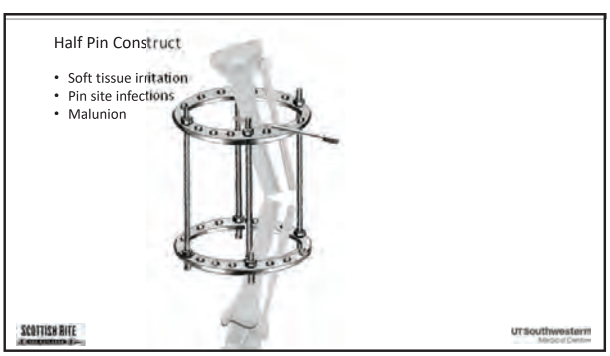

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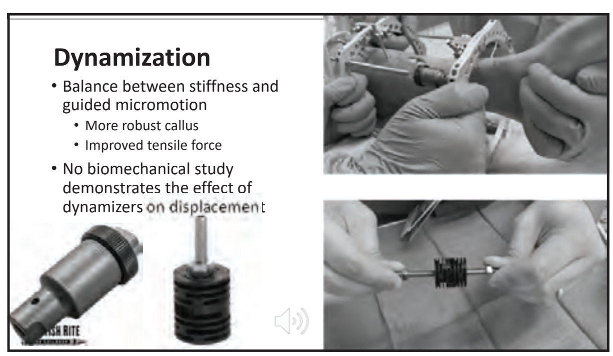

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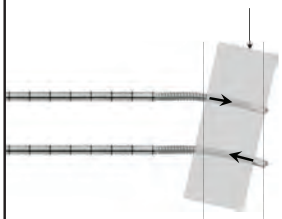
Pins under load



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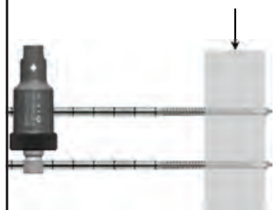
Frame dynamized



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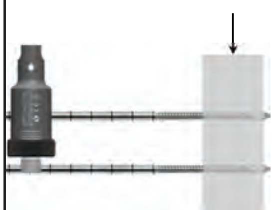
Frame dynamized



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Hypothesis

- Use of dynamization will promote beneficial axial micromotion while limiting detrimental bending motion

22

Methods

- 7 circular external fixator frames with three pin/wire constructs
- Frame constructs loaded cyclically up to 50 kg
- Displacement in the axial, sagittal, coronal planes were measured

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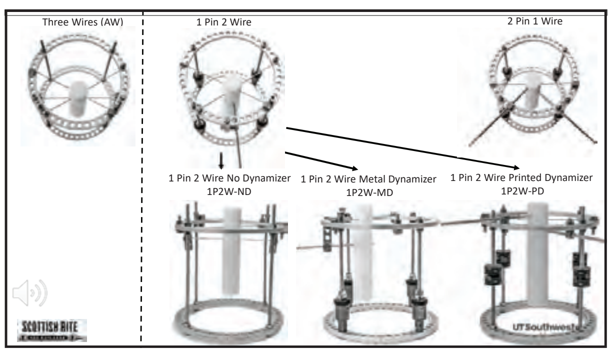

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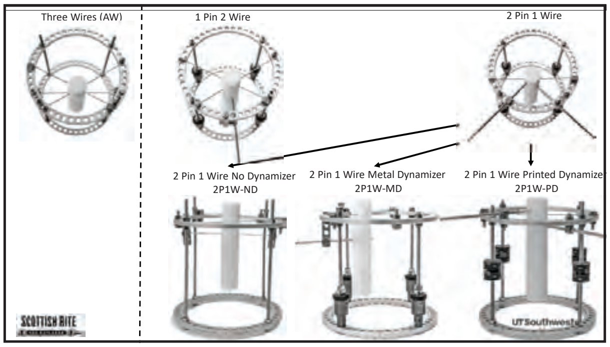

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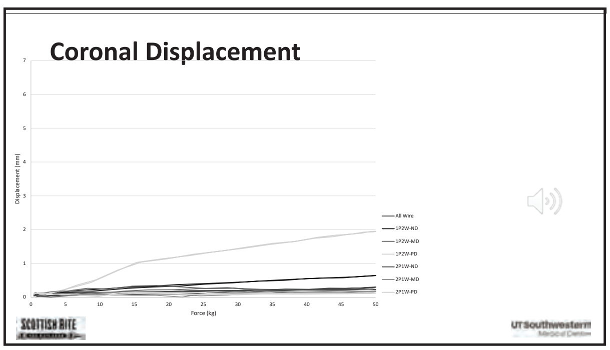

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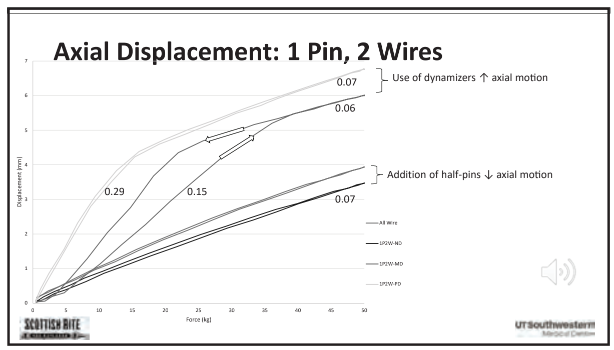

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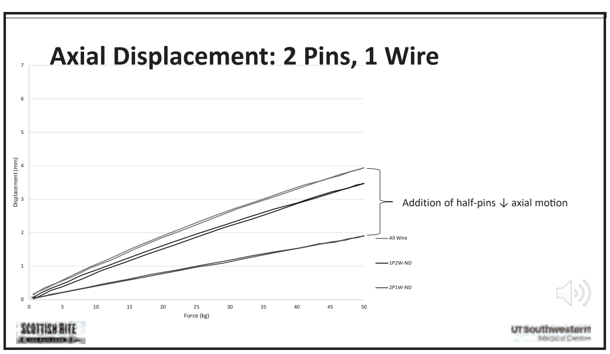

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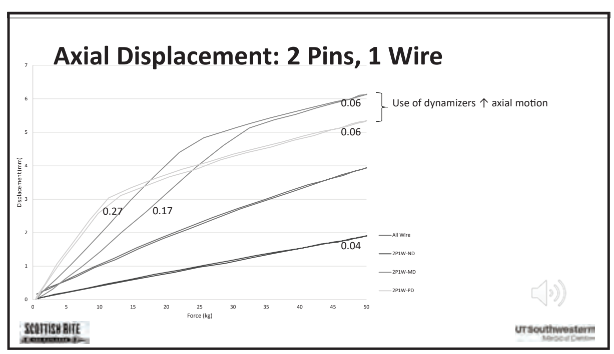

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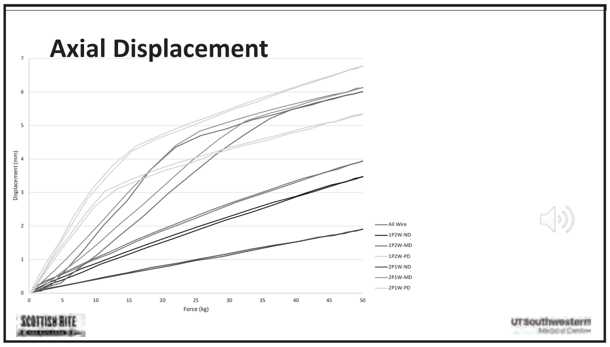

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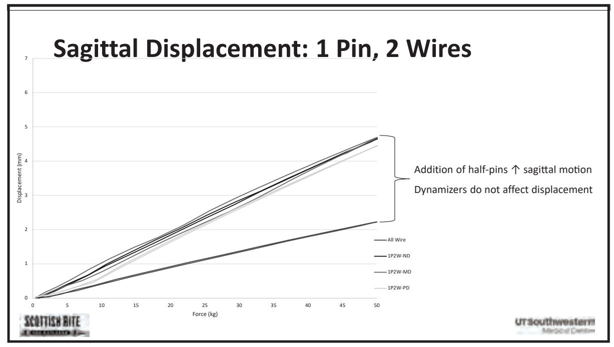

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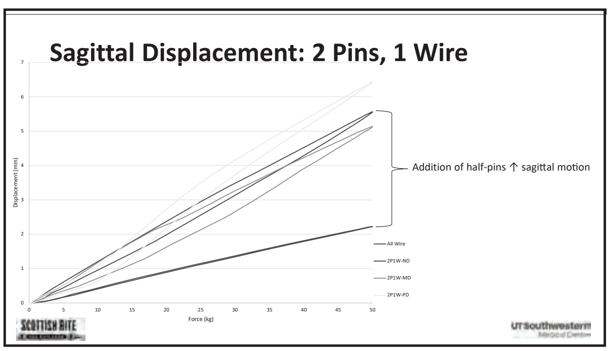

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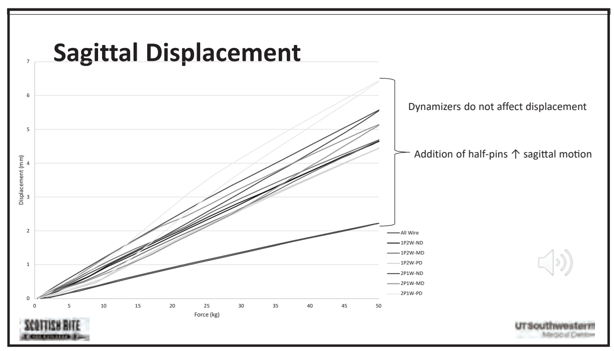

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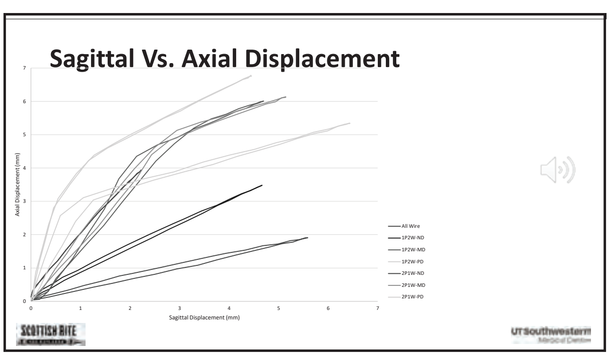

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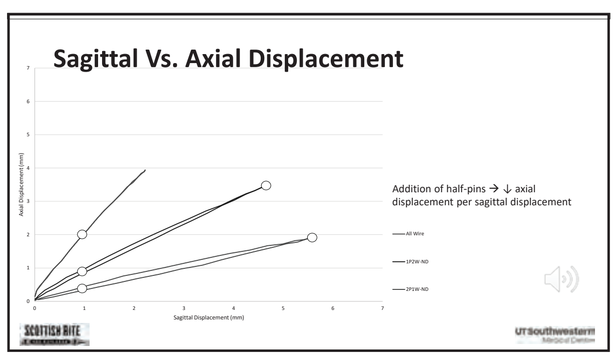

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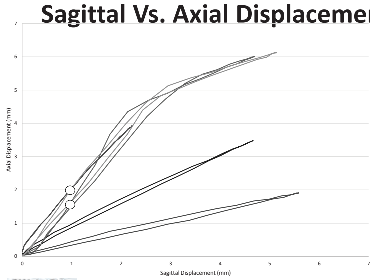
Sagittal Vs. Axial Displacement



Addition of metal dynamizer → return to similar displacement patter

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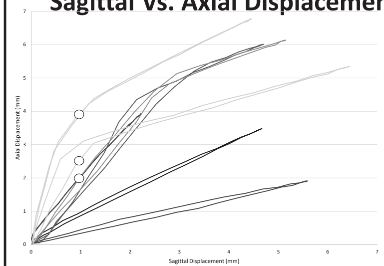
Sagittal Vs. Axial Displacement



Addition of printed dynamizer → ↑ in axial motion per sagittal displacement

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Weakness

- Bone model ≠ actual bone
  - Soft tissues
  - Muscle forces
  - Contact with distal segment
- Alterations in rate/how force applied

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Conclusions

- The use of half-pins is common practice for external fixators
  - ↓ axial motion
  - ↑ sagittal motion
- Dynamizers → ↑ axial motion
  - Together, this increases the ratio of axial:sagittal motion
    - Limit soft tissue irritation
    - ↓ occurrence of malunion
  - Increase force at fracture site →
    - Earlier healing
    - More robust callus
    - Improved torsional stiffness
  - Especially true with early pressure
    - Smaller patients
    - Earlier in the consolidation phase

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Thank You!

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42

Does Vitamin D Insufficiency affect Healing during Distraction Osteogenesis?

Jessica C. Rivera, MD PhD, K. Patrick Powell, MD, Nequesha S. Mohamed, MD,
Iciar M. Davila Castrodad, MD, John E. Herzenberg, MD
riverajessicac@gmail.com

What was the question?

Insufficient vitamin D is a common nutritional deficit which has been associated with fracture risk and poor bone health. Serum 25–hydroxyvitamin D [25(OH)D] levels less than 30 mg/mL are considered insufficient. This research aimed to determine if vitamin D deficiency in adult and pediatric patients undergoing limb lengthening affected healing of the regenerate bone.

How did you answer the question?

This retrospective study of patients undergoing limb lengthening with a magnetic internal lengthening nail at a single, referral center between 2014 and 2018. Perioperative vitamin D levels were collected from the medical record along with age and sex. Distraction index was calculated by dividing the lengthening achieved (cm) by the number of days of active lengthening. Consolidation index was calculated by dividing the total number of days from surgery to weightbearing by the length achieved. Maturation index was calculated by dividing the number of days between completion of distraction and weightbearing by length achieved. Univariate analysis was performed to determine if vitamin D level affected distraction, consolidation, or maturation indices.

What are the results?

One–hundred thirty–eight patients had a perioperative vitamin D level available for analysis. Patient age average was 18 ± 11 years (range 8–72 years). Male patients comprised 52% (n=72) of the subjects. Thirty–seven patients (27%) had perioperative vitamin D levels < 20ng/mL, or deficient range; 45 (33%) had levels 20ng/mL, or the insufficient range. Age and sex were not associated with vitamin D insufficiency or deficiency. On univariate analysis, an increase in vitamin D level tended to result in lower consolidation index (p=0.197) though no trend was present for maturation index. Lower vitamin D levels were associated with an increased distraction index (p=0.037).

What are your conclusions?

In this cohort of limb lengthening patients, 60% had perioperative vitamin D levels in the insufficient or deficient range. Higher distraction indices indicate a slower distraction prescription. The higher distraction indices in low vitamin D patients may indicate the surgeons' need to slow the distraction rate based on radiographic regenerate. While this did not translate into longer healing indices, consolidation indices trended towards being higher in patients with lower vitamin D levels. A larger cohort is required to adequately model control variables in a regression model.

Does Vitamin D Insufficiency affect Healing during Distraction Osteogenesis?

JESSICA C. RIVERA, MD, PHD,
PATRICK POWELL, MD, NEQUESHA S. MOHAMED, MD, ICIAR M. DÁVILA CASTRODAD, MD
& JOHN E. HERZENBERG, MD, FRCSC
INTERNATIONAL CENTER FOR LIMB LENGTHENING, SINAI HOSPITAL BALTIMORE, MARYLAND

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AAOS Disclosures

Jessica C Rivera, MD, PhD, FAAOS
Submitted on: 06/29/2020
AAOS: Board or committee member
Limb Lengthening and Reconstruction Society: Board or committee member
Orthopaedic Research Society: Board or committee member

Kenneth Patrick Powell, MD, FAAOS (SHREVEPORT, LA)
Submitted on: 07/02/2020
Nuvasive: Stock or stock Options

Nequesha Mohamed, MD
(This individual reported nothing to disclose); Submitted on: 06/29/2020

Iciar M Davila Castrodad, MD
(This individual reported nothing to disclose); Submitted on: 07/01/2020

John E Herzenberg, MD, FAAOS (Baltimore, MD)
Submitted on: 04/02/2020
Arthrex: Other financial or material support
Bonus BioGroup: Paid consultant
DePuy Synthes: Other financial or material support
Metro Prosthetics: Other financial or material support
MHE Coalition: Other financial or material support
Nuvasive: Other financial or material support; Paid consultant
Orthofix, Inc.: Other financial or material support; Paid consultant
OrthoPediatrics: Other financial or material support; Paid consultant
OrthoSpin: Paid consultant
Pega Medical: Other financial or material support
Smith & Nephew: Other financial or material support; Paid consultant
Stryker: Other financial or material support
Supreme Orthopedic Systems: Other financial or material support
Treace Medical Concepts, Inc.: Other financial or material support
Vilex: Other financial or material support
WishBone Medical: Paid consultant
Zimmer Biomet: Other financial or material support

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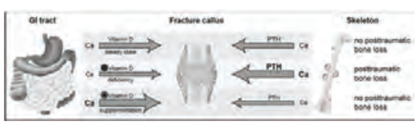
Introduction

- 25(OH)D > 30 ng/mL are adequate for bone health
- Higher rate of nonunion in vitamin D deficient fracture patients



Fischer V et al. Calcium and vitamin D in bone fracture healing and post-traumatic bone turn over. Eur Cells Material, 2018; 35: 365-85.
Gorter EA et al. Vitamin D status and adult fracture healing. J Clin Orthop Trauma, 2017; 8: 34-37.
WHO Scientific Group on the Prevention and Management of Osteoporosis. 2003 Prevention and management of osteoporosis: report of a WHO scientific group. Geneva: World Health Organization.

3

Methods

- Retrospective
- Internal lengthening nails placed between 2014-2018
- Recorded peri-operative 25(OH)D level*
- Data collected:
  - demographics
  - diagnosis
  - long bone treated
  - peri-operative 25(OH)D level

4

Methods

- Vitamin D status categorized
  - 25(OH)D > 30 ng/mL are adequate for bone health
  - 25(OH)D < 30 ng/mL insufficient
  - 25(OH)D **< 20 ng/mL DEFICIENT**
- **DI = lengthening(cm)/ days of lengthening**
- **CI = days between surgery and WB/ length (cm)**
- **MI = days between end of distraction and WB/ length(cm)**

WHO Scientific Group on the Prevention and Management of Osteoporosis. 2003 Prevention and management of osteoporosis: report of a WHO scientific group. Geneva: World Health Organization.

5

Results

PEDIATRIC PATIENTS

84 subjects
- 45 (54%) female
- 70 (83%) Caucasian
- Mean Age 13.6 ± 2.2 years

Diagnoses
- 57 (68%) congenital limb deficiency
- 9 (11%) dwarfism
- 6 (7%) post-traumatic growth arrest
- 5 (6%) post-infectious growth arrest
- 7 (8%) miscellaneous

ADULT PATIENTS

43 subjects
- 23 (54%) female
- 35 (81%) Caucasian
- Mean Age 28.3 ± 15.4 years

Diagnoses
- 10 (23%) congenital limb deficiency
- 25 (58%) post-traumatic or post-infectious bone loss
- 8 (21%) miscellaneous

6

Results

PEDIATRIC PATIENTS

Mean 25(OH)D level 33.0 ± 19.6 ng/mL [range 13.1-103.5 ng/mL]
- 31 patients (37%) > 30 ng/mL adequate for bone health
- 30 (36%) < 30 ng/mL insufficient
- 23 (27%) < 20 ng/mL **DEFICIENT**

Calcium low – normal, mean 8.3 ± 0.4 [range 7.6-9.5 ng/mL]

ADULT PATIENTS

Mean 25(OH)D level 31.7 ± 15.5 ng/mL [range 13.1-95.9 ng/mL].
- 18 patients (42%) > 30 ng/mL adequate for bone health
- 16 (37%) < 30 ng/mL insufficient
- 9 (21%) < 20 ng/mL **DEFICIENT**

Calcium normal, mean 8.3 ± 0.4 [range 7.5-9.0 ng/mL]

7

Results

- Age and sex NOT associate with Vitamin D status
- Higher Vitamin D level tended to be associated with lower CI (p=0.197)
- No association with MI
- **Higher Vitamin D levels were associated with increased distraction index (p=0.037)**

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Similar to prior literature

Ortho Trauma
- Smith et al.
  - 75 patients (16-80 years) with ankle fractures
  - 47% of patients had insufficient vitamin D levels
  - 13% had deficient vitamin D levels

Fractures
- Gorter et al.
  - 187 pediatric fracture pts
  - 34% were vitamin D deficient
  - 527 adult fracture pts
  - 40% were vitamin D deficient / 11% were severely deficient

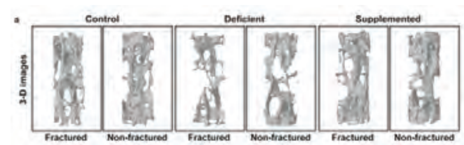
Pediatric deformities & painful conditions
- Davies et al.
  - 187 children admitted to the orthopedic service
  - 32% had vitamin D insufficiency
  - 8% were vitamin D deficient

Smith JT, et al. Prevalence of Vitamin D Deficiency in Patients With Foot and Ankle Injuries. Foot Ankle Int 2014;35:8–13.
Gorter EA, et al. Vitamin D Deficiency in Pediatric Fracture Patients: Prevalence, Risk Factors, and Vitamin D Supplementation. J Clin Res Pediatr Endocrinol. 2016;8(4):445-451.
Davies JH, et al. Epidemiology of Vitamin D Deficiency in Children Presenting to a Pediatric Orthopaedic Service in the UK. J Pediatr Orthop. 2011;31(7):798-802.

9

Pre-habilitation?

- Post traumatic bone loss in vitamin D deficient animal model
  - Higher
  - Recoverable



Fischer V et al. Calcium and vitamin-D deficiency marginally impairs fracture healing but aggravates post-traumatic bone loss in osteoporotic mice. Sci Rep, 2017; 7(1: 7223.

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Conclusion

- Low vitamin D levels consistent with prior literature
- Unknown surgeon decision making for distraction prescription changes
- Vitamin D status may be associated with regenerate quality

11

Comparing Clinical and Radiological Outcomes in two Paediatric Cohorts undergoing Tibial Deformity Correction

Juergen Messner, Jero Abad, Sophia Davidson, Anthony Cooper
juergen.messner@nhs.net

What was the question?
Our aim was to compare our A frame experience with the B frame, specifically how the design and software concept of the B frame affects the healing index, pin infection rate, regenerate quality and density, software residual rate and strut changes.

How did you answer the question?
A comparative study was conducted reviewing prospectively collected clinical and radiological data from our institutional database. Paediatric patients with congenital and acquired tibial deformities treated with either A (2014–2016) or B (2017–2018) frames were included in our study.

What are the results?
Seventeen patients (18 frames) were included in the group A (15 male, median age 12 years) and 21 patients (26 frames) in group B group (11 male, median age 13 years). The most common indications for tibial deformity correction were fibular hemimelia (14), septic or traumatic growth arrest (8), Blount's disease (4) and hemihypertrophy (4). The median frame time was 239 days in the A group vs. 208 days in the B group ($p=0.12$). The mean lengthening in the A group was 54mm and 48mm in the B group ($p=0.23$). The healing index was 48 days/cm (A) vs. 44 days/cm (B) ($p=0.54$). Tibial pin site infection episodes occurred in 44 half–pins out of 94 in the A group (46.8%) and in 20 half–pins out of 135 (14.8%) in the B group ($p<0.0001$). The regenerate in the B group was less polarized (0% vs. 11.1%, p0.89, 72% vs. 38.9%, $p=0.0314$). Software residuals were necessary 1.6 times/frame with the A system compared to 0.2 times/frame with the B system ($p<0.0001$). Strut changes were less frequent with the B system (0.6/frame vs. 2.0/frame, ($p<0.0001$).

What are your conclusions?
The B system achieved similar healing indices compared with the traditional A system. To our knowledge, this is the first study to compare these two systems. It showed superiority in regenerate quality and a significant reduction in pin site infection rates. In addition, fewer residuals and strut changes were necessary. Further analysis is planned to measure the improvement in the patients' experience and potential cost savings for the provider.

Comparing Clinical and Radiological Outcomes in two Pediatric Cohorts undergoing Tibial Deformity Correction

J. Messner, J. Abad, H. S. Davidson, A. Cooper
British Columbia Children's Hospital, Vancouver, Canada

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Disclosures

- Juergen Messner – None
- Jero Abad – None
- Sophia Davidson – None
- Anthony Cooper -
  - Cooper lab is supported by BC Children's Hospital Foundation
  - AC has received research support from Vilex
  - AC has done consultation for Vilex and OrthoPediatrics

2

FLE1

Aim

- Our aim was to compare our Taylor Spatial frame (TSF, Smith&Nephew) experience with the Orthex frame (OrthoPediatrics)

3

Method

A comparative study was conducted reviewing prospectively collected clinical and radiological data from our institutional database.

Endpoints:

- Healing index
- Pin infection rate
- Regenerate quality
- Software residual and strut change rate

4

Statistics

- Descriptive
- Parametric and non-parametric testing
- Poisson regression analysis

5

Results

	TSF Group (2014-16)	Orthex Group (2017-19)	
Patients	17 (18 frames)	21 (26 frames)	
Age range	5-17 years	3-17 years	
Time in frame	239 days	208 days	P=0.15
Healing Index	48 days/cm	44 days/cm	P=0.36
Infection rate	**46.8%**	**14.8%**	**P<0.0001**
Density at 3 months (PVR>0.9)	**38.9%**	**72%**	**P=0.031**
Software residuals	**1.6 times/frame**	**0.2 times/frame**	**P<0.0001**
Strut changes	**2 times/frame**	**0.6 times/frame**	**P<0.0001**

6

Infection rate – Regression analysis

Parameter	Estimate	95%CI	p-value
Age (years)	0.005	-0.066 to 0.069	.892
Time in frame (days)	0.002	-0.002 to 0.006	.327
Length (mm)	-0.004	-0.017 to 0.008	.519
Rings (n.)	0.245	-0.161 to 0.636	.225
Half Pins (n.)	0.058	-0.112 to 0.220	.495
Wires (n.)	**0.217**	**0.047 to 0.392**	**.013***
Extended HA coating (y/n)	**-1.250**	**-1.805 to -0.700**	**<.0001***
Foot rings (n.)	-0.062	-0.909 to 0.730	.881

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Pin infection rate

TSF n_{inf}/n_{total}

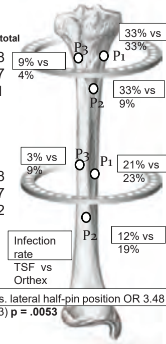
Proximal
21/46 (45.6%)

P1 9/18
P2 9/17
P3 3/11

Distal
12/47 (25.5%)

P1 7/18
P2 4/17
P3 1/12

Total
33/93
(35.4%)



Medial vs. lateral half-pin position OR 3.48 (CI95% 1.39-8.83) **p = .0053**

Orthex n_{inf}/n_{total}

P1
7/25
P2
2/25
P3
1/19

Proximal
10/69 (14.5%)

Distal
11/61
(18.0%)

p = .34

P1
5/25
P2
4/23
2/13

p = .0009

Total
21/130
(16.2%)

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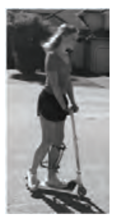
Conclusions

Similar healing indices

Orthex superior in:

- Regenerate quality
- Pin infection rate
- Strut changes and software residuals

Patient in an Orthex frame



Patient in a TSF

BC Children's Hospital

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Session 2: Trauma, Limb Salvage & Amputation Reconstruction

Union with Retained Cement Spacers – Deferment of Second Stage Grafting in the Masquelet Technique

Stephen J. Wallace, Julie Agel, Michael F. Githens
sjwall@uw.edu

What was the question?

What are union rates in both segmental and partial bony defects after deferment of second stage Masquelet technique in acute, traumatic long bone fractures?

How did you answer the question?

After retrospective chart review, 61 extremities (30 femurs and 31 tibias) in 60 patients were identified that were treated with Stage 1 Masquelet technique at a Level 1 trauma center between January 1st, 2010 and February 28th, 2019. Patients 16 years or older treated with internal fixation and placement of a cement spacer for an acute, traumatic bony defect of the femur or tibia were included. Defect size was calculated as the average linear distance of each cortical void measured on the anteroposterior (AP) and lateral radiographs obtained immediately after Stage 1 surgery. Partial defects were those defects with a minimum of one cortex that had contact between main bony fragments at the time of fixation. Union was defined as three or more healed cortices on follow–up radiographs. Implant–dependent union was defined as two or fewer healed cortices without implant failure at least 1 year postoperatively. Student's t–test and Fisher's exact tests were used for comparison between groups with a statistical significance set to $p < 0.05$.

What are the results?

Out of the 61 extremities treated with Stage 1 of the Masquelet technique, 17 (27.9%) had deferment of Stage 2 grafting – nine with segmental defects and eight with partial defects. Average defect size was 53.6mm in those that had retention of their cement spacer and 54.7mm in those that underwent Stage 2 Masquelet ($p = 0.915$). Of the nine patients with segmental, retained cement spacers, six (66.7%) went to union or implant–dependent union without a grafting procedure. One patient with bilateral segmental distal femur nonunions and retained cement spacers was lost to follow up but had no signs of hardware failure at 11 months postoperatively. All (100%) of the partial defects with retained cement spacers went to union or implant–dependent union. There was no significant difference in union or implant–dependent union rates between those with a retained cement spacer versus those that underwent Stage 2 grafting ($p = 0.363$ for segmental defects and $p = 1$ for partial defects).

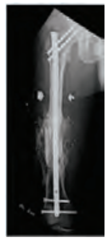
What are your conclusions?

The Masquelet technique is a strategy to manage both segmental and partial bony defects after acute, traumatic bone loss. Successful union has been demonstrated with retention of the cement spacer – even in segmental defects. Deferment of Stage 2 grafting could avoid additional operations.

Union with Retained Cement Spacers

Deferment of Second Stage Grafting in the Masquelet Technique

Stephen Wallace, MD; Julie Agel, MA; Michael Githens, MD
Department of Orthopaedic Surgery
Harborview Medical Center, Seattle, WA



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Disclosures

- Stephen Wallace, MD
  - No disclosures or conflicts of interest
- Julie Agel, MA
  - Orthopaedic Trauma Association: Board or committee member
- Michael Githens, MD
  - Synthes: Paid presenter or speaker
  - Techniques in Orthopaedics: Editorial or governing board
  - Western Orthopaedic Association: Board or committee member

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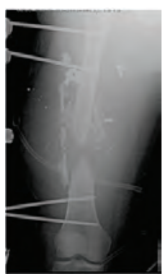
Acute Bone Defects

- Management
  - Distraction Osteogenesis
  - Autograft or Allograft Struts
  - Acute shortening
  - Amputation
- Masquelet Technique



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Masquelet Technique

- Stage 1
  - debridement
  - cement spacer (+ antibiotics)
  - bridging fixation
- Stage 2
  - preservation of induced membrane
  - bone grafting

4

Methods

- Retrospective Chart Review
  - Level 1 Trauma Center
  - 2010-2019
- Acute, traumatic bone defects underwent Stage 1 Masquelet
  - 24 Femurs and 29 Tibias
  - 33 Segmental and 20 Partial
- Primary Outcome
  - Union or implant dependent union

53
Stage 1 Masquelet with at least 1 year follow up

36
Completed Stage 2 Masquelet

17
No Stage 2: Retention of Spacer

5

Patient Demographics

	Stage 1 Only (n = 17)	Stage 2 (n = 36)	
Age (average, range)	44 (21-75)	40 (20 - 68)	⇐ p = 0.36
Sex (M / F)	14 / 3	29 / 7	
Tobacco Use (No / Yes)	6 (35%)	16 (44%)	
Diabetes (No / Yes)	2 (12%)	3 (8%)	
Femur / Tibia	11 / 6	23 / 13	
Proximal / Diaphyseal / Distal	0 / 10 / 7	0 / 13 / 23	
Partial / Segmental	9 / 8	11 / 25	
Gustilo-Anderson Type I / II / IIIA / IIIB / IIIC	0 / 0 / 11 / 4 / 2	0 / 2 / 25 / 7 / 2	⇐ all open fractures
Defect Size (mm; average, range)	49 (10 - 122)	52 (6 - 203)	⇐ p = 0.78
Construct: Plate / Nail / Plate-Nail	7 / 9 / 1	19 / 13 / 3	

*Student's t-test and Fisher's exact test were used for continuous and categorical values, respectively, with a significance set to $p < 0.05$)

6

Outcomes

	Stage 1 Only (n = 17)	Stage 2 (n = 36)	
Follow-up, mo	18	20	
Success	14 (83%)	35 (97%)	⇐ $p = 0.09$
Union	12 (71%)	30 (83%)	
Implant Dependent Union	2 (12%)	5 (14%)	
Amputation or Shortening	3 (18%)	1 (3%)	
Time to Success (average, range)	6.4 (3-16)	11.8 (3-51)	⇐ $p = 0.049$*

*Student's t-test and Fisher's exact test were used for continuous and categorical values, respectively, with a significance set to $p < 0.05$)

Overall Success Rate: 92% (49 out of 53 defects)

- 2 amputations before Stage 2 due to failure of a vascular repair or flap
- 1 acute shortening before Stage 2 grafting
- 1 amputation after Stage 2 because of a recurrent ipsilateral prosthetic joint infection

7

Discussion

- Success with retention of cement spacers
- Shorter time to union
  - 6.4 months vs 11.8 months
- When to retain vs proceed with grafting?
- Need for larger cohort
  - Partial vs segmental; defect location; type of fixation
  - Patient reported or functional outcomes?

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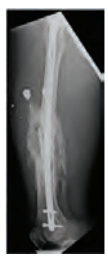
Conclusions

- Masquelet Technique valid option for acute, traumatic bone defects
- Success with cement retention
  - Partial and Segmental
- Shorter recovery?
- Avoidance of additional surgery?



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Amputation Outcomes following Military Gustilo and Anderson 3C Lower Extremity Fractures

Jessica C. Rivera, MD, PhD, David S. Kauvar, MD, MPH, Amanda M. Staudt, PhD, MPH, Thomas J. Walters, PhD
riverajessicac@gmail.com

What was the question?
Lower extremity long bone fractures that occur concomitantly with vascular injuries present a multidisciplinary reconstructive challenge. The Gustilo and Anderson (G&A) classification attempts to account for open fracture injuries plus vascular injury requiring repair in the 3C category. Literature on the outcomes of G&A 3C fractures includes small case series where amputation outcome generally occur in 30–40% of limbs. Recently, a large retrospective cohort of military lower extremity vascular injuries has been studied. The purpose of this research was to report amputation outcomes and predictors in a military cohort of lower extremity vascular plus fracture trauma.

How did you answer the question?
This retrospective study comprised subjects from the Fasciotomy and Vascular Injury Outcomes database, a joint effort of the Department of Defense Trauma Registry and the Wartime Vascular Injury Initiative. These subjects sustained a lower extremity arterial, venous, or combined vascular injury and underwent at least one vascular limb salvage procedure. Data collected for this database also included femur and tibia fracture status, vascular repair procedures, recovery complications, and limb retention outcomes. Descriptive statistics were used to report limb retention outcomes and amputation timing. Logistic regression was used to report odds of amputation relative to potential predictor variables.

What are the results?
Within the database, 546 limbs were included for analysis. Subjects were nearly all male with an average age of 26 +/–7 years of age. The predominate mechanism of injury, as typical from recent military operations, was blast mechanism. Femur fractures were sustained in 115 (21%) of subjects; tibia fractures were sustained in 171 (31%) of subjects. Among all limbs included, a concomitant femur or tibia fracture sustained with vascular injury resulted in an odds ratio of 3.9 (95I 2.3, 6.5) for an amputation outcomes. An higher Mangled Extremity Severity Score (MESS) score (OR 2.1; 95I 1.7, 2.7) and more distal vascular injury location (OR 1.6; 95I 1.2, 2.2) were also associated with higher odds of amputation. Overall Injury Severity Score (ISS), combined arterial and venous injury, and post reconstruction vascular complications did not affect amputation odds. When subjects without fracture were eliminated, amputation rate was 3%: 38/115 (33%) of femur fractures and 61/171 (36%) of tibia fractures. Forty–one percent of amputations were performed within seven days of injury while 27% per performed beyond ninety days (late amputations). Analysis of remaining only MESS score was associated with a higher odds of amputation (OR 2.9, 95I 1.8, 4.7). Amputations performed within 1 week of injury had a significantly higher MESS than later amputations (7.4 +/– 0.9 v. 6.4 +/– 1.1).

What are your conclusions?
In this large cohort of military G&A 3C lower extremity fractures, amputation rates are similar to published smaller cohorts. Fracture versus non–fracture vascular injury subjects had a higher odds of amputation, likely indicating a cumulative reconstruction challenge that may have driven the clinical decision for amputation. A higher MESS score was associated with odds of amputation, though it is difficult by retrospective means to interpret if this is an indication of the MESS' predictive value or a reflection of the Score influencing early amputation decision making. While this study was not focused on the orthopaedic specific treatments, this study highlights the importance of considering all structures required to successfully reconstruct a traumatically injured limb and should encourage additional collaborative orthopaedic and vascular research efforts.

Amputation Outcomes following Military Gustilo and Anderson 3C Lower Extremity Fractures

JESSICA C. RIVERA, MD, PHD,

LOUISIANA STATE UNIVERSITY HEALTH SCIENCE CENTER

DEPARTMENT OF ORTHOPAEDIC SURGERY

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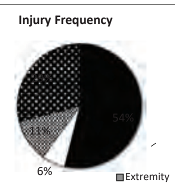
AAOS Disclosures

Jessica C Rivera, MD, PhD, FAAOS
Submitted on: 06/29/2020
AAOS: Board or committee member
Limb Lengthening and Reconstruction Society: Board or committee member
Orthopaedic Research Society: Board or committee member

2

Introduction

Military Extremity Injuries



Owens BD, Kragh JF, Macaitis J, Svoboda SJ, Wenke JC. Characterization of Extremity Wounds in Operation Iraqi Freedom and Operation Enduring Freedom. J Orthop Trauma. 2008; 21:254-7.
Doucet JJ, Galarneau MR, Potenza BM, et al. Combat versus civilian open tibia fractures: the effect of blast mechanisms on limb salvage. J Trauma. 2011; 70(5): 1241-7.

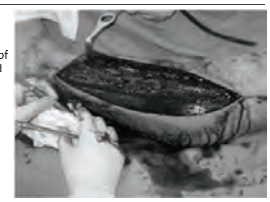
3

Introduction

Early Limb Complications

COMPARTMENT SYNDROME AND FASCIOTOMIES

- Following an educational effort, the rates of fasciotomies performed on injured, deployed U.S. service members increased 500% after 2009.
- Complications include:
  - sensory deficits,
  - pain,
  - decreased motion and strength, and
  - limb swelling



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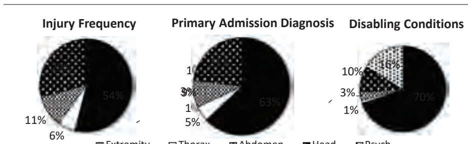
4

Introduction

Long Term Consequences?



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Cross JD, Ficke JR, Hsu JR, Masini BD, Wenke JC. Battlefield orthopaedic injuries cause the majority of long term disabilities. J Am Acad Orthop Surg. 2011; 19: S1-S7.

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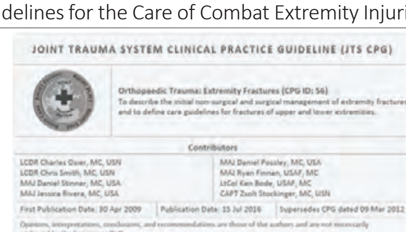
Introduction

Guidelines for the Care of Combat Extremity Injuries


JOINT TRAUMA SYSTEM CLINICAL PRACTICE GUIDELINE (JTS CPG)

Orthopaedic Trauma: Extremity Fractures (CPG ID: 56)
To describe the initial non-surgical and surgical management of extremity fractures and to define care guidelines for fractures of upper and lower extremities.

Contributors

LCDR Charles Osier, MC, USN	MAJ Daniel Possley, MC, USA
LCDR Chris Smith, MC, USN	MAJ Ryan Finnan, USAF, MC
MAJ Daniel Stinner, MC, USA	LtCol Ken Bode, USAF, MC
MAJ Jessica Rivera, MC, USA	CAPT Zsolt Stockinger, MC, USN

First Publication Date: 30 Apr 2009 | Publication Date: 15 Jul 2016 | Supersedes CPG dated 09 Mar 2012

Opinions, interpretations, conclusions, and recommendations are those of the authors and are not necessarily endorsed by the Services or DoD.

JTS Clinical Practice Guidelines. Accessed at: http://www.usaisr.amedd.army.mil/cpgs.html

6

Introduction

Table 2 Gustilo Classification of Open Fractures*

Type	Description
I	Clean wound <1 cm in length
II	Clean wound >1 cm in length without extensive soft-tissue damage, flaps, or avulsions
IIIA	Adequate soft-tissue coverage despite extensive soft-tissue damage, flaps, or high-energy trauma irrespective of the wound size
IIIB	Inadequate soft-tissue coverage with periosteal stripping, often associated with massive contamination
IIIC	Arterial injury requiring repair

- Gustilo and Anderson open fracture classification first published in 1976 and later modified in 1984

7

Question

What are the limb retention outcomes of Gustilo and Anderson type 3C fractures after combat injury?

8

Study Design
Population

- Retrospective cohort study of U.S. servicemembers injured during deployment-related oversees operations from theFasciotomy and Vascular Injury Outcomes database
  - Identified by DoDTR search of ICD-9 codes
  - Injuries confirmed with DoD EMR and/or MOTR
  - Data abstracted from DoD EMR, MOTR, and VA EMR
- Descriptive statistics were used to report limb retention outcomes and amputation timing
- Logistic regression was used to report odds of amputation relative to potential predictor variables
- Approved by the U.S. Army Medical Research and Materiel Command and University of Texas Health Science Center San Antonio Institutional Review Boards and South Texas Veterans Health Care System Research and Development Office.

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Study Design
Data Sources

Table 4.2. Description of study data sources

Data Source	Description
Department of Defense Trauma Registry (DoDTR)	Data repository for all DoD trauma data; entrants must be seen at a Role 3 (some 2b) or higher level of care; trauma data through either return to duty or through first hospital discharge at a Role 5 facility recorded
Military Orthopaedic Trauma Registry (MOTR)	Orthopaedic module of DoDTR; entrants must first be in DoDTR; orthopaedic specific injury, treatment, and complication data from Role 3 care through all available documented follow ups, including VA
DoD Electronic Health Record	Essentris: in-patient hospital record specific to each medical center AHLTA: out-patient record linked between medical centers including clinic notes, labs, radiology reports, et cetera
VA Electronic Health Record	CPRS: in- and out-patient record of VA medical care; includes VA service connected disability ratings

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Krueger CA, Ching W, Wenke JC. Completing records-based research within the military: A user's guide. J Surg Orthop Adv, 2013; 22(1): 82-94.

10

Results

- 546 limbs were included for analysis.
- Subjects were nearly all male with an average age of 26 +/-7 years of age.
- The predominate mechanism of injury, as typical from recent military operations, was blast mechanism.
- Femur fractures were sustained in 115 (21%) of subjects; tibia fractures were sustained in 171 (31%) of subjects

11

Results

- Fracture with vascular injury versus no fracture resulted in an odds ratio of 3.9 (95% CI 2.3, 6.5) for an amputation outcomes.
- An higher Mangled Extremity Severity Score (MESS) score (OR 2.1; 95% CI 1.7, 2.7) and more distal vascular injury location (OR 1.6; 95% CI 1.2, 2.2) were also associated with higher odds of amputation.
- Overall Injury Severity Score (ISS), combined arterial and venous injury, and post reconstruction vascular complications did not affect amputation odds

12

Results

- When subjects without fracture were eliminated, amputation rate was 3%%:
  - 38/115 (33%) of femur fractures and
  - 61/171 (36%) of tibia fractures.
- Forty-one percent of amputations were performed within seven days of injury while 27% per performed beyond ninety days (late amputations).
- Amputations performed within 1 week of injury had a significantly higher MESS than later amputations (7.4 +/- 0.9 v. 6.4 +/- 1.1).

13

Discussion

- Amputation rates are similar to published smaller cohorts.
- Fracture versus non-fracture vascular injury subjects had a higher odds of amputation
- A higher MESS score was associated with odds of amputation,

**It is difficult by retrospective means to interpret if this is an indication of the MESS' predictive value or a reflection of the Score influencing early amputation decision making. **

While this study was not focused on the orthopaedic specific treatments, this study highlights the importance of considering all structures required to successfully reconstruct a traumatically injured limb and should encourage additional collaborative orthopaedic and vascular research efforts.

14

Can We Predict When Exchange Nailing for Long Bone Nonunion Will Fail?

Brandon Collofello, Slade Ransdell, Paul Matuszewski
Collofello@uky.edu

What was the question?
Exchange nailing for the treatment of long bone nonunion has reported success rates ranging from 54–100%. Given this wide variability in failure rates, identifying patient and injury factors which are associated with failure is critical in order to help guide surgeons in choosing optimum methods for the treatment of nonunion. The purpose of this study was to identify factors associated with failure of exchange nailing. We hypothesized that cortical contact less than 100% (but greater than 50%), and a foot type appearance (elephant or horse hoof) would be associated with higher rates of failure.

How did you answer the question?
We performed an IRB approved, retrospective review of all femur and tibia nonunions at our institution treated with exchange nailing. Septic nonunions and patients whose primary mode of treatment was not exchange nailing were excluded from the analysis. Failure of exchange nailing was defined as either 1. Absence of bridging bone on 3 or more cortices on xrays obtained at least 1 year following exchange nailing, or 2. Patient required an additional surgery during the follow–up period to promote union. Treatment method and return to the operating room for secondary procedure was at the treating surgeon's discretion. Demographics, presence of comminution, location of fracture, use of graft, and cortical contact were recorded. Fisher's exact test and forward logistic regression was utilized to assess confounders.

What are the results?
A total of 115 patients met inclusion criteria with 64 eing femurs and 36% tibias. Average age at exchange nailing was 39 (9537.00 – 42.50) with 68 eing male. Followup was available on 71% (82/115). Overall union rate was 66%, with 24% (20/82) requiring at least one secondary surgery to promote union. Age, gender, BMI, smoking status, history of diabetes, open/closed fracture, foot type, presence of comminution, and non–diaphyseal location were not associated with failure. Overall, use of graft (auto– or allograft) (aOR 2.96 95I [.891 – .855]), p= 0.076) and less–than 100ortical contact (aOR 2.2695I [.781 – 6.517] p=0.132) trended towards increased risk of failure. In the femur, use of graft was associated with a significant increase in failure (aOR 5.10 95[1.240 – 21.020], p = 0.024) while cortical contact was not. In the tibia, use of graft or decreased cortical contact was not associated with increased rates of failure.

What are your conclusions?
In our series, we demonstrated a 34 ailure rate of exchange nailing, which is higher than previously reported in some studies, although consistent with other reports in the literature. Use of bone graft and the lack of 100ortical contact is associated with increased risk of failure, especially in the femur. Other patient and fracture characteristics (comminution, location, foot type, open/closed, etc) do not appear to be associated with increased risk of failure. Surgeons should utilize caution when considering bone grafting if the primary treatment is exchange nailing. Alternative treatment options may be more successful.

Can We Predict When Exchange Nailing for Long Bones Will Fail?

Brandon Collofello, MD
Slade Ransdell, BS
Paul E. Matuszewski, MD

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Disclosures

I (and/or my co-authors) have something to disclose

Detailed disclosure information is available via:

AAOS Orthopaedic Disclosure Program on the AAOS website at http://www.aaos.org/disclosure

2

Background

- Nonunion occurs in 5-10% of all fractures
- Reported exchange nail nonunion in long bones (femur/tibia) success rates vary widely from 54—100%
- Why the discrepancy?
- Can we predict when exchange nailing will fail?

3

Purpose and Hypothesis

- Study Design: Retrospective Chart Review
- Purpose:
  - Identify factors associated with failure of exchange nailing for femur and tibia fracture nonunions
- Hypothesis:
  - Failure of exchange nailing will be associated with fractures with less than 100% cortical contact and large "hoof" nonunions.

4

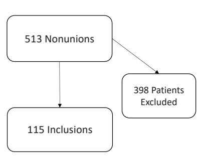
Methods

Inclusions:

All tibial and femoral nonunions treated with exchange nailing from 2006-2019 at Lvl 1 Trauma Center

Exclusions:

1. Septic nonunions
2. Patients whose primary treatment was not exchange nailing



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Methods

- Failure of exchange nailing/nonunion criteria defined:
  1. Absence of bridging bone on 3 or more cortices on xrays at least 1 year following exchange nailing
  2. Patient required additional surgery during follow up period to promote bony union
- Investigated demographics, presence of comminution, fracture location (metaphyseal vs diaphyseal), nonunion type, foot type appearance, use of graft (auto- and allograft), open/closed fx, and cortical contact
- Fischer's exact test and forward logic regression utilized to assess confounders

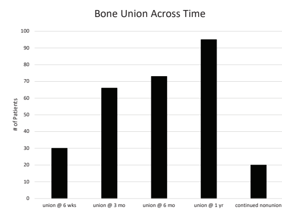
6

Results

- 115 nonunion patients
  - 64% femur (74/115)
  - 36% tibia (41/115)
- Avg age at exchange nailing = 39 (95%CI 37.00-42.50
  - 68% male (78/115)
- Follow up available on 71% (82/115)
- Overall union rate 66%
  - 24% (20/82) requiring at least one secondary surgery to promote union
- Age, gender, BMI, smoking status, history of diabetes, open/closed fracture, foot type, presence of comminution, and non-diaphyseal location were not associated with failure.

7

Results



- 66% of patients continued to union
- Approximately 26% of patients healed by 6 weeks
  - 57% by 3 months
  - 63% by 6 month

8

Progression to Union Post Exchange (Femur)

6 weeks → 3 months → 6 months → 1 Year

9

Discussion and Conclusions

- 34% failure rate of nail exchange
  - 66% rate of union
- Bone graft use and lack of 100% cortical contact is associated with increased risk of exchange nailing failure in femoral nonunions
  - Potentially a confounding variable
- Other patient and fracture characteristics (comminution, location, foot type, open/closed, etc) not associated with increased risk of failure in our series
- Surgeons should utilize caution when considering bone grafting if the primary treatment is exchange nailing
  - Alternative treatment options may be more successful

10

Limits and Future Studies

Limitations

- Retrospective design relying on record keeping/charting
- Loss to follow up
- Limited sample size

Future Studies

- Compiling nonunion data from multiple institutions

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Thank you!

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Mid–term Results of Utilizing the Nail for Intercalary Allograft Reconstruction After Tumor Resection

Lee Zuckerman, Nadine Williams
lzuckerman@coh.org

What was the question?
Would the previously reported rate of union and complications of intercalary allograft reconstruction be similar with an increase in the number of patients and longer–term follow–up?

How did you answer the question?
A retrospective review of 12 patients with 27 osteotomy sites on 7 femurs and 7 humeri was performed. The average age was 45 (9–73) with an average follow–up of 22 months (4–60). Diagnoses included two pleomorphic sarcomas, three osteosarcomas, one metastatic endometrial stromal sarcoma, and six metastatic renal cell carcinomas. Twenty–four osteotomy sites were primary resections, one site was a chronic non–union previously treated with a carbon fiber nail, and two sites were for a revision of a previously fractured intercalary allograft. Five patients received neoadjuvant and adjuvant chemotherapy, and seven patients received only adjuvant chemotherapy. One patient received neoadjuvant radiation. An intercalary allograft with a magnetic growing intramedullary nail was placed. No autograft was used. The average allograft length was 14 cm (5.5–29). The nails were compressed intraoperatively. Radiographs were evaluated to determine union rates, time to union and to evaluate for any graft reabsorption or hardware complications.

What are the results?
Twenty–four out of 27 sites demonstrated evidence of healing after an average of 8 months (4–26). Complications included 1 fracture through the allograft after a fall, 1 wound dehiscence, an intraoperative fracture of the native bone during surgery in 2 patients and an intraoperative fracture of the allograft in 1 patient. Hardware complications occurred in 6 patients and included the backing out of 4 screws/pegs with one that required removal, fracture of 1 screw, fracture of 1 nail, and cut–out of the nail from the humeral head in 1 patient. Six patients underwent subsequent in–office compression in order to obtain a union. Two patients successfully underwent a total of 3 surgeries for an acquired limb–length discrepancy. There was no evidence of reabsorption of any of the allograft, recurrent tumor, or infections at final follow–up.

What are your conclusions?
In this series, there was a union rate of 89% which is similar to the previously reported rate of 87% in 15 osteotomy sites. Intraoperative fractures of the host and allograft bone did not prevent healing of the osteotomy sites. Hardware complications were common, and this should be considered. Longer–term complications with allograft including fracture, reabsorption, infection and recurrent tumor did not occur at mid–term follow–up.

MID-TERM RESULTS OF UTILIZING A MAGNETIC LENGTHENING NAIL FOR INTERCALARY ALLOGRAFT RECONSTRUCTION AFTER TUMOR RESECTION

Lee Zuckerman, Division of Orthopaedic Surgery, City of Hope National Medical Center

Nadine Williams, Department of Orthopaedic Surgery, Loma Lind University Medical Center

The LLRS 2020 Virtual Meeting, July 30, 2020-January 29, 2021

1

DISCLOSURE

- *Dr. Zuckerman is a consultant for NuVasive Specialized Orthopedics*

2

BACKGROUND

- *Intercalary allograft reconstruction can be used for joint preservation after resection of long bone tumors*
- *Major complications have been recorded in up to 70% of patients and include:*
  - *Fracture of the allograft (27-30%)*
  - *Infection (14-18%)*
  - *Non-union at the allograft-host sites (15-55%)*
  - *Complete failure requiring allograft removal (15-31%)*

3

BACKGROUND

- *Historically, difficulty with compression across the allograft-host site is a factor for non-union*
  - *This occurs when using intramedullary nails or plate osteosynthesis*
    - *Traditionally higher rates of non-unions with:*
      - *Intramedullary nail fixation*
      - *Post operative chemotherapy*
      - *Allograft length ≥10cm*
      - *Age >18 years old*
      - *Diaphyseal location*

4

PURPOSE

- *We previously reported on 8 patients with 15 osteotomy sites with an 80% union rate after a single surgery and an 87% overall union rate at final follow-up*
- *Here, we present a larger series of patients with longer-term follow-up*
- *All patients were treated with the PRECICE nail (NuVasive Specialized Orthopedics, Inc., Aliso Viejo, CA)*

5

METHODS

- *Retrospective review of 13 patients with 28 osteotomy sites*
- *Average age of 45 years old (9-73)*
- *Average follow up of 25 months (4-60)*
- *Pathologic diagnoses of our patients included:*
  - *Two pleomorphic undifferentiated high grade sarcomas*
  - *Three conventional high grade osteosarcomas*
  - *Six metastatic renal cell carcinomas*
  - *One metastatic endometrial stromal sarcoma*
  - *One metastatic hepatocellular carcinoma*

6

METHODS

- *Adjuvant therapies:*
  - *5 patients underwent both neoadjuvant and adjuvant chemotherapy*
  - *7 underwent only adjuvant chemotherapy*
  - *1 patient neoadjuvant radiation*
- *Seven tumors were located in the femur and eight in the humerus*
- *Average allograft length was 14 cm (5.5-29)*
- *One osteotomy site was for a chronic nonunion previously treated with an intramedullary nail*
- *Two sites were for a prior allograft fracture*

7

TECHNIQUE

FEATURE ARTICLE

BLUE

Use of Magnetic Growing Intramedullary Nails in Compression During Intercalary Allograft Reconstruction

Robert C. Vercio, MD; Troy G. Shields, MD; Lee M. Zuckerman, MD

Orthopedics. 2018;41(6):330-335 https://doi.org/10.3928/01477447-20181102-02

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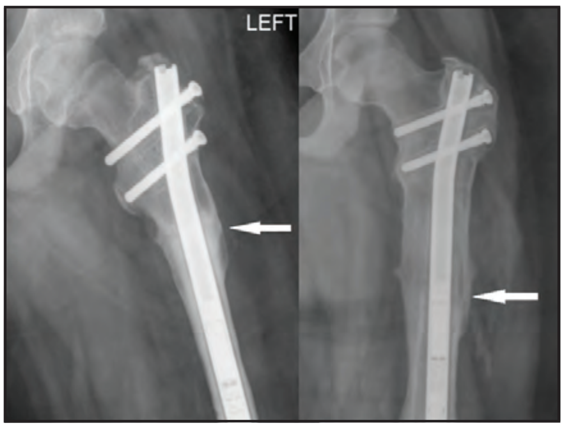

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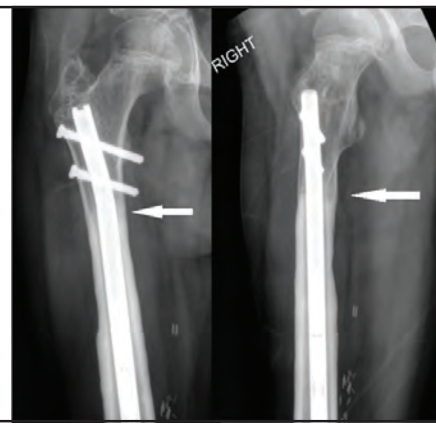

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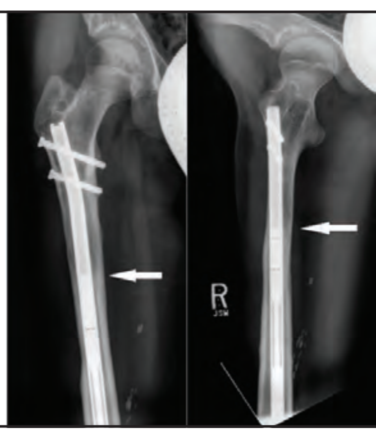

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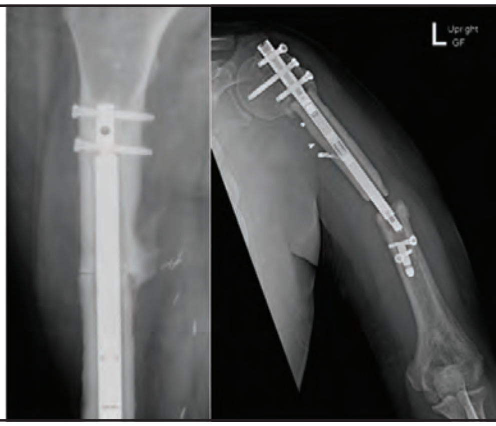

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RESULTS

- 22 out of 28 (79%) allograft-host sites healed at an average of 8 mo (4-26)
- 2 patients underwent successful lengthening of 5 and 6 cm for an acquired limb-length discrepancy after the index surgery.
- Hardware complications occurred in 6 patients
  - 4 screws/pegs backed out, 1 required removal
  - One screw fractured
  - 2 nails fractured
  - 1 nail cut out of the humeral head

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RESULTS

- Intraoperative fractures occurred in 3 patients, 2 in the native bone and 1 in the allograft
- One post-operative allograft fracture
- One wound dehiscence

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RESULTS

- 6 patients underwent in-office compression to obtain union
- All patients had an R0 resection and no evidence of local recurrence at latest follow up
- No definite evidence of reabsorption of the allograft at final follow-up

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CONCLUSIONS

- Overall, the union rate still remains on the higher end (79% vs 45-85%) but decreased compared to our previous results (87%)
- Two fractures of the allograft (13% vs 27-30%)
- No infections (vs 14-18%)
- One allograft failure treated with removal (7% vs 15-31%)
- Stainless steel nail may decrease the hardware complications
- Scheduled compression in the office may be beneficial
- Longer-term follow-up and a larger sample size is needed

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18

18

Complications of Regional and Local Anesthesia in the Operative Treatment of Tibia Fractures: Safety for the Patient and Staff

Joseph R. Hsu, MD, Olivia Rice, Matthew Starke, Richard Randall McKnight, Rachel B Seymour
Kevin D. Phelps
Joseph.Hsu@atriumhealth.org

What was the question?
Despite known benefits of regional and local analgesia in the treatment of perioperative pain, there remains a stigma among orthopaedic surgeons concerning the use of regional anesthesia in the treatment of tibia fractures. Regional and local analgesia have the potential benefit to control perioperative pain, decrease opiate requirements, and lower airborne droplet exposure associated with intubation if used as the method of operative anesthesia. The purpose of this study is to determine the complications associated with regional and local analgesia in the treatment of operatively treated tibia fractures in adults.

How did you answer the question?
Using chart review data from a single level–one trauma center, we examined complications in patients with operatively treated tibia fractures (AO/OTA 41, 42, and 43). All patients with operatively treated tibia fractures were subcategorized based on the use of perioperative use of regional or local block. Statistical analysis was performed to determine the complication rates and the significance of any differences between the two groups.

What are the results?
Of the 191 patients with operatively treated tibia fractures in our study, 51 (26.70%) received regional or local block perioperatively. Nerve injury rate was 4% in the patients who did not receive a block and 2% in those that did (p value = 0.99). Additionally, the rate of neurogenic pain was 12% in the block group versus 16% in the group without blocks (p value = 0.645). The wound dehiscence rate was 6% in each of the study groups. There was a low rate of diagnosed compartment syndrome (2%) between the two study groups. Further examination of rates of potential compartment syndrome (or missed compartment syndrome) sequelae (foot drop, intraoperative myonecrosis, joint contraction, AKI, and sensory disturbances) showed no significance between groups.

What are your conclusions?
We report no statistically significant differences in complications between patients who received regional or local block and those who did not receive a block in the operative treatment of their tibia fractures. We report a 2% rate of compartment syndrome and no statistically significant difference compartment syndrome sequelae between groups. The use of regional or local block in the operative treatment of tibia fractures can benefit patients in perioperative pain management and decreasing opiate requirements without significantly increasing risk of postoperative complications. The use of regional or local blocks as the method of operative anesthesia in tibia fracture fixation could reduce operating room staff exposure to airborne droplets without significantly increasing risk to the patient.

1

Atrium Health
Musculoskeletal Institute

Complications of nerve block in the operative treatment of tibia fractures

Matthew Starke MD, Olivia Rice MD, Susan Odum PhD, Randy McKnight MD, Katherine Li MD, Jarrod Dumpe MD, Rachel Seymour PhD, Laurence Kempton MD, Stephen Sims MD, Madhav Karunakar MD, Joseph Hsu MD

OrthoCarolina NeuroSurgery & Spine Atrium Health Musculoskeletal Institute

2

Disclosures

- Smith & Nephew – speakers bureau
- Globus Medical -- consulting

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3

Relevant Disclosures:
CDC Funding Co-PIs: Rachel Seymour, PhD; Joseph Hsu, MD, FAOA

- PRIMUM
  - Funding from CDC (CE14-004 Award Number CE002520)
- Guidelines Decision Support
  - Funding from CDC (102114-1)
- CDC RO1: Implementing a Multimodal Path to RecOVEry (IMPROVE): Primary and Secondary Prevention of Opioid Overdose in Acute Care (Mental Health, Substance abuse, OUD)
  - 1 R01 CE003001-01

- Collaborators:
  Michael Beuhler, MD
  Michael Bosse, MD
  Stephen Colucciello, MD
  Tina Fuller, RN
  Michael Gibbs, MD
  Christopher Griggs, MD
  Steven Jarrett, PharmD
  Daniel Leas, MD
  Michael Runyon, MD
  Animita Saha, MD
  Sharon Schiro, PhD
  Phillip Smith
  Timm Tanner
  Meghan Wally, MSPH
  Brad Watling, MD
  Stephen Wyatt, DO
  Many more…

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4

Balance

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5

Clinical Practice Guidelines for Pain Management in Acute Musculoskeletal Injury

Joseph R. Hsu, MD, Hassan Mir, MD,† Meghan K. Wally, MSPH,* and Rachel B. Seymour, PhD,* the Orthopaedic Trauma Association Musculoskeletal Pain Task Force*

J Orthop Trauma • Volume 33, Number 5, May 2019

APPENDIX 1. Members of the Orthopaedic Trauma Association Musculoskeletal Pain Task Force

Kristin R. Archer, PhD, DPT: Department of Physical Medicine and Rehabilitation, Vanderbilt University Medical Center, Nashville, TN. Basem Attum, MD: Department of Orthopaedic Surgery, University of Louisville School of Medicine, Louisville, KY. Chad Coles, MD: Department of Orthopaedic Surgery, Dalhousie University School of Medicine, Halifax, Nova Scotia, Canada. Jarrod Dumpe, MD: Department of Orthopaedic Surgery, Navicent Health, Macon, GA. Edward Harvey, MD: Division of Orthopaedic Surgery, McGill University Health Centre, Montreal, QC, Canada. Thomas Higgins, MD: Department of Orthopaedic Surgery, University of Utah, Salt Lake City, UT. Joseph Hoegler, MD: Department of Orthopaedic Surgery, Henry Ford Hospital, Detroit, MI. Jane Z. Liu, MD: Department of Orthopaedic Surgery, Case Western Reserve University, Cleveland, OH. Jason Lowe, MD: Department of Orthopaedics, Banner Health University of Arizona, Tucson, AZ. Christiaan Mamczak, DO: Orthopaedics and Sports Specialists, Beacon Health System, South Bend, IN. J. Lawrence Marsh, MD: Department of Orthopaedics and Rehabilitation, University of Iowa Health Care, Iowa City, IA. Anna N. Miller, MD: Division of Orthopaedic Trauma, Washington University Orthopaedics, St. Louis, MO. William Obremskey, MD: Orthopaedic Surgery and Rehabilitation, Vanderbilt University Medical Center, Nashville, TN. Michael Ransone, MD: Department of Orthopaedic Surgery, Carolinas Medical Center, Charlotte, NC. William Ricci, MD: Orthopaedic Trauma Service, Hospital For Special Surgery, New York City, NY. David Ring, MD: Institute of Reconstructive Plastic Surgery of Central Texas, Austin, TX. Babar Shafiq, MD: Department of Orthopaedic Surgery, Johns Hopkins School of Medicine, Baltimore, MD.

6

Field block

- Liposomal bupivacaine
  - Effective vs. placebo
  - Limited evidence superiority bupivacaine
  - Equivalent to less expensive cocktails
- CERT (Cloni, Epi, Ropi, Toradol)

CERT Injection (50ml):
Ropivacaine 125mg (25ml of 0.5%)
Ketorolac 15mg
Clonidine 40mcg
Epinephrine 0.25mg
Normal Saline QS to 50ml total volume

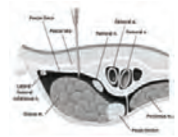
Dalury et al. JBJS 2011

Hamilton TW, Athanassoglou V, Mellon S, Strickland LH, Trivella M, Murray D, Pandit HG. Liposomal bupivacaine infiltration at the surgical site for the management of postoperative pain. Cochrane Database of Systematic Reviews 2017, Issue 2. Art. No.: CD011419

7

Fascia Iliaca Compartment Block

- High volume "compartment" block
- Anatomy:
  - Femoral n. & LFCN underneath fascia of iliacus muscle
- Indication:
  - Major surgery of the hip, femur, & knee
- Pros:
  - Simple to execute
  - Multiple nerves anesthetized with single injection
  - ↓ pain scores, ↓ opioid intake, ↓ decreased delirium
  - Lower risk of femoral n. injury
- Cons:
  - Quad weakness



UpToDate

Yang L, Li M, Chen C, Shen J, Bu X. **Fascia iliaca compartment block versus no block for pain control after lower limb surgery: a meta-analysis**. J Pain Res. 2017 Dec 14; 10:2833-2841

8

Adductor Canal Block

- Anatomy:
  - Sensory distribution: Medial knee, lower leg, and ankle
  - Motor: +/- nerve to VMO
- Indication:
  - Surgery of the knee & medial leg
  - Supplemental anesthesia for surgery of the ankle
- Pros:
  - Motor sparing
  - ↓ pain scores, ↓ opioid intake
  - ↓ risk of post-op falls
- Cons:
  - ø posterior knee anesthesia
  - ↑ risk of intravascular injection

Gray's Anatomy for Students. 2nd Ed.

9

Displaced Tibia fractures

- High complication rates, up to 20% compartment syndrome in 41C
- Concern that nerve block = missed compartment syndrome
- Medicolegal

Connelly CL, Bucknall V, Jenkins PJ, Court-Brown CM, McQueen MM, Biant LC. Outcome at 12 to 22 years of 1502 tibial shaft fractures. *Bone Joint J.* 2014;96-B(10):1370-1377.

10

Compartment Syndromes Associated with Postoperative Epidural Analgesia

- Case report 1996
- Thigh and leg ACS following elective osteotomy
- No signs of ACS detected for 8 hours
- Significant muscle necrosis

Compartment Syndrome Masked by Epidural Anesthesia for Postoperative Pain

- Case report 1986
- Leg ACS following free fibula transfer
- No signs of ACS for 4 days
- Permanent neurologic sequelae

11

Conflation (n.): the merging of two or more sets of information, texts, ideas into one.

Google powered by Oxford Languages

12

Compartment syndrome and regional anaesthesia: Critical review

- 22 articles reviewed
- 8 case reports of regional block, no missed ACS
- 4/10 patients with spinal/epidural delayed diagnosis

Regional anesthesia or patient-controlled analgesia and compartment syndrome in orthopedic surgical procedures: a systematic review

- 34 articles reviewed
- Block vs PCA alone
- 28 case reports, 3 surveys
- All patients with one or more clinical signs of ACS

13

Purpose

To determine if nerve blockade increases complication rates in patients undergoing operative management of tibia fractures.

14

All AO/OTA 41/42/43 fractures, single center, 2016 (n=257)

Excluded:
Non-operative (n=49)
Proximal Avulsion (n=7)
Amputation (n=6)
Prophylactic fasciotomies (n=4)

Operatively treated tibia fractures (n=191)

No block (n=140) | Block (n=51)

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Methods: Fracture Complications

- Surgical site infection
- Hardware failure
- Unplanned reoperation
- Non-union
- Wound dehiscence

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Methods: Block and Opioid Complications

Opioid Complications

- Post operative fall
- Delirium

Nerve Block Complications

- Nerve Injury
- Neurogenic pain
- Call to clinic (rebound pain)

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Results

	No block (n=140)	Block (n=51)	p-value
Closed Fractures	105 (75%)	37 (72.5%)	0.7315
Open Fractures	35 (25%)	14 (27.5%)	
Female	46 (33%)	18 (35%)	0.8626
Male	94 (67%)	33 (65%)	
Age years (Median, Range)	44 (18-81)	48 (18-87)	0.0788

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Results

OTA Fracture Code	No block (n=140)	Block (n=51)
41A	7 (5%)	0 (0%)
41B	18 (13%)	4 (8%)
41C	29 (21%)	16 (31%)
42A	20 (14%)	9 (17.5%)
42B	20 (14%)	9 (17.5%)
42C	20 (14%)	3 (6%)
43A	6 (4.5%)	2 (4%)
43B	6 (4.5%)	3 (6%)
43C	14 (10%)	5 (10%)

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Results: Fracture and Opioid Complications

	No block (n=140)	Block (n=51)	p-value
Hardware Failure	5 (4%)	1 (2%)	0.9999
Nonunion	9 (6%)	1 (2%)	0.2941
Wound Dehiscence	8 (6%)	3 (6%)	0.9999
Reoperation	20 (14%)	5 (10%)	0.4779

	No block (n=140)	Block (n=51)	p-value
Delirium	1 (1%)	1 (2%)	0.4638
Postoperative Fall	2 (1%)	1 (2%)	0.9999

20

Results: Block Complications

	No block (n=140)	Block (n=51)	p-value
Call to Clinic c/o Pain	15 (11%)	8 (16%)	0.4504
Nerve Injury	5 (4%)	2 (4%)	0.9999
Neurogenic Pain	22 (16%)	6 (12%)	0.645

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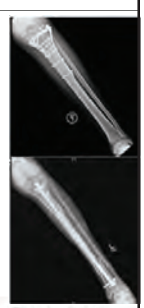
Results: Compartment Syndrome

	No block (n=140)	Block (n=51)	Pvalue
Compartment Syndrome	4 (3%)	0 (0%)	0.5751
Sequelae of Compartment Syndrome	22 (16%)	6 (12%)	0.645
Foot Drop	2 (1.4%)	0 (0%)	0.999
Joint Contraction	6 (4%)	1 (3%)	0.6771
Sensory Disturbance	15 (11%)	5 (10%)	0.998

22

Discussion

- Unable to detect difference in complications with nerve blockade
- 2% overall rate of compartment syndrome
- Similar compartment syndrome sequelae
- Largest known series of regional anesthesia in tibia fractures



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Efficacy of Popliteal Block in Postoperative Pain Control After Ankle Fracture Fixation: A Prospective Randomized Study

- Single shot block vs general anesthesia
- Significant decrease in pain up to 8 hours
- Found significant increase in rebound pain (12-24h)

Does Regional Anesthesia Improve the Quality of Postoperative Pain Management and the Quality of Recovery in Patients Undergoing Operative Repair of Tibia and Ankle Fractures?

- Single shot block vs general anesthesia
- Ankle and tibia fractures
- "at risk" patients selected out
- Higher patient satisfaction
- Did not find significant rebound pain
- No significant other complications

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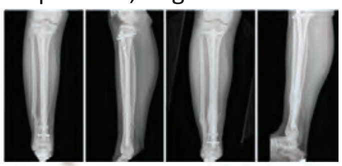
Limitations

- Retrospective
- Susceptibility bias
  - 41C: 21% in “no block”, 31% in “block”
- Low number of patients, largest known in literature



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Conclusion

Regional anesthesia may be safe in the operative management of tibia fractures.

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Early Experience with Bone Anchored Osseointegration Prostheses

Taylor Reif, Nathan Khabyeh–Hasbani, Austin T. Fragomen, S. Robert Rozbruch, Tom Jonggu Shin
reift@hss.edu

What was the question?
Reconstruction of amputated limbs with a bone anchored osseointegrated (OI) prostheses has been performed throughout the last 20 years in Europe and more recently Australia with overall success. However due to regulatory delays the procedure and implants were not available to American surgeons until recently. This investigation evaluates whether the early results of osseointegrated implants used in the United States match those of the rest of the world.

How did you answer the question?
Patients with a below knee or above knee amputation who underwent reconstruction with an osseointegration implant were evaluated. The osseointegrated prosthetic limb prosthesis was used in nearly all cases. The primary outcome measures were the Questionnaire for Persons with a Transfemoral Amputation (QTFA), which was also applied to patients with below knee amputations, the 2–minute and 6–minute Walk Tests, and the Timed Up and Go (TUG) test. Radiographic changes in cortical bone were evaluated using the Region of Interest (ROI) imaging function and assessed for signs of loosening. Complications were recorded and categorized as mechanical, infectious, or surgical. Student t–tests were used for comparison of outcome measures.

What are the results?
Thirteen patients have undergone osseointegration implantation of the femur and 12 of the tibia with average follow up of 10.6 months. Two patients underwent traditional 2 stage implantation (8 weeks between intramedullary implant and application of loading apparatus), 18 were implanted in a single stage with immediate loading protocol, while 5 had the remaining limb revised and an antibiotic spacer placed for 6 weeks followed by single stage implantation with immediate loading protocol. The prosthetic leg was attached an average of 9 weeks (3.4 SD) post–implantation for the femurs and 8 weeks (2.9 SD) for the tibias. For the patients with at least 6 months follow up (n=11), all domains of the QTFA Score were significantly improved (Table 1) including Prosthetic use (70.3 to 96.5, $p=0.048$), Mobility (58.1 to 82.9, $p=0.047$), Problem score (41.6 to 7.8, $p < 0.001$) and Global score (33.3 to 84.1 $p < 0.001$). For the 2–minute, 6 minute, and Time Up and Go tests there was limited data (n=4) but the average distance increased from 146 to 325 feet in 2 minutes, 374 to 958 feet in 6 minutes, and the average TUG decreased from 14.9 to 8.6 seconds. There were 5 mechanical problems that were handled in the clinic (3 dual cones lengthened, 1 bushing replaced, 1 dual cone screw tightened). There were 4 superficial infections treated with oral antibiotics, and 1 septic loosening requiring removal of the entire prosthesis. There were 3 surgical complications: 1 dual cone replacement, 1 ORIF for peri–implant fracture, and the 1 septic loosening noted above. One tibial implant also dislodged from the patient prior to obtaining osseous integration. Other than the patient with septic loosening, radiographs consistently demonstrated apparent osseointegration with no implant subsidence. The medial and lateral cortical bone adjacent to the implant did not have significant changes in pixel density using the ROI function between 1 and 6 months postoperatively ($p=0.38$ medial, $p=0.37$ lateral)

What are your conclusions?
Our early experience with amputee reconstruction using osseointegration implants mirrors that of other established centers with significant improvements in all aspects of QTFA patient reported outcomes. The overall experience from both the patient and surgeon perspective has been overwhelmingly positive, with many patients reporting increased ease of use, osseoperception, and a renewed connection to their prosthetic limb. The complications thus far are in line with other institutional experience in the literature.

QTFA Score	Average Preoperative Score (SD)	Average Postoperative Score (SD)	p value
Global	33.3 (19.0)	84.1 (19.2)	**< 0.001**
Prosthetic Use	70.3 (40.0)	96.5 (8.9)	**0.048**
Prosthetic Mobility	58.1 (31.1)	82.9 (20.5)	**0.046**
Prosthetic Problem	41.6 (14.8)	7.8 (6.1)	**< 0.001**

Table 1: Preoperative and 6 month Postoperative Questionnaire for Persons with a Transfemoral Amputation (QTFA) score.

Early Experience with Lower Extremity Bone Anchored Osseointegration Prosthesis

Taylor J. Reif M.D., Nathan Hasbani B.S, Austin T. Fragomen M.D., S. Robert Rozbruch M.D.

Limb Lengthening and Complex Reconstruction Service

1

Disclosures

- I have no disclosures

 2

2

Background

- Traditional socket prostheses are often unsatisfactory due to:
  - Pain
  - Skin blisters
  - Dermatitis
  - Sweating
  - Poor fit
  - Short residual limb
- Suboptimal energy transfer from the bone to prosthesis

3

Osseointegration Prosthesis

- Osseointegrated prosthesis directly anchors the implant to the bone
- The mechanical axis of the lower limb is restored

4

Osseointegration Prosthesis

- Short bone segments
  - Too short for traditional socket
  - Reconstruction possible with osseointegration

5

5

Materials and Methods

- Osseointegration implants approved in United States by FDA for compassionate use
- Implantation began in late 2017
- Osseointegrated Prosthetic Limb Implant utilized
- Patient reported outcome measured 6mo -1yr
  - Questionnaire for Persons with Transfemoral Amputation (Q-TFA)
  - Also applied to tibial reconstructions
- Complication data collected

 6

6

Results

HSS

- 15 femurs and 12 tibias implanted, average follow up 13.5 months
  - 3 traditional (8 weeks closed soft tissue envelope)
  - 19 single stage
  - 5 antibiotics spacer placed for 6 weeks prior to implantation

	Femur	Tibia
Residual Bone (range)	**23.7 cm** (8.5 - 41)	**12.0 cm** (6.5 – 16.5)
Implant Length	**16 cm (13x)** 10 cm (1x) 8 cm (1x)	**11 cm (Ave)** (6 – 16 cm)
Implant Diameter (range)	**17 mm (Ave)** (14 – 25 mm)	**20.6 mm (Ave)** (14 – 31 mm)
Leg Attachment (Std dev)	**8.4 weeks** (3.6)	**9.1 weeks** (2.4)

7

7

Patient Reported Outcomes (Q-TFA)

HSS

QTFA Score	Average Preoperative Score (SD)	Average Postoperative Score (SD)	p value
Global	25.9 (21.0)	83.3 (17.6)	**< 0.001**
Prosthetic Use	57.8 (43.6)	95.2 (8.3)	**0.004**
Prosthetic Mobility	60.5 (29.9)	83.6 (18.7)	**0.026**
Prosthetic Problem	39.6 (16.1)	6.3 (8.0)	**< 0.001**

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8

Complications

HSS

- Surgical
  - 1 Bushing Replacement, 1 Dual Cone Replacement
  - 1 ORIF for periprosthetic fracture
  - 1 Explant for septic loosening
- Nonsurgical
  - 3 Dual Cone lengthened
  - 2 Bushing Replaced/Repaired
  - 1 Dual Cone Tightened
- Infectious
  - 1 deep requiring removal (same patient as explant above)
  - 9 cellulitis requiring PO antibiotics (6 patients)
- One failure of osseointegration (implant dislodged from bone)

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Discussion

- Overwhelmingly positive patient experience
  - Osseoperception
  - Connection with limb
  - Ease of prosthetic use
- Complications comparative with other published series
  - Overall 1 infection per 3.1 patient-years
  - 15% implant failure at 1 year (2 tibia, 0 femur)
  - Most mechanical complications solved in office

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Osseointegration

HSS

- Long term studies indicate viable future for osseointegration
  - Hagberg et al**. A 15-year follow-up of transfemoral amputees with bone-anchored transcutaneous prostheses.** *Bone Joint J* 2020;102-B(1):55–63.
    - Improvement in all domains of QTFA throughout life of implant
    - 72% implant survival at 15 years
    - 55% with mechanical complications → related to higher activity level
    - 9% cumulative risk of explant due to infection at 10 years
- Need longer term follow up on tibial implants to determine success versus traditional socket

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HSS

Thank You

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Evaluation of Fracture and Osteotomy Union in the Setting of Osteogenesis Imperfecta: Multicenter Reliability of the Modified Radiographic Union Score for Tibial Fractures (RUST)

Jeanne M. Franzone, MD, Maegen J. Wallace, MD, Kenneth J. Rogers, PhD, ATC,
Richard W. Kruse, DO, MBA, Paul W Esposito MD, Cheryl Lawing MD, Maureen J Maciel MD, Mark S Finkelstein DO, Mary Kay Drake MD, M Steven Farber, MD
jeanne.franzone@gmail.com

What was the question?
Evaluation of the union of osteotomies and fractures in patients with osteogenesis imperfecta (OI) is a critical component of patient care. Studies of the OI patient population have thus far used varied criteria to evaluate bony union. The radiographic union score for tibial fractures (RUST), which was subsequently revised to the modified RUST, is an objective standardized method of evaluating fracture healing. The purpose of this study to build upon the single center reliability of the modified RUST in the setting of OI with a multicenter evaluation of the reliability of the modified RUST in the setting of the tibias of patients with OI.

How did you answer the question?
Tibial radiographs of 30 patients with OI with fractures or osteotomies were scored by three observers (2 pediatric orthopaedic surgeons, 1 radiologist) at three institutions on two separate occasions. Each of the four cortices was given a score (1 = no callus, 2 = callus present, 3 = bridging callus and 4 = remodeled, fracture not visible) and the modified RUST is the sum of these scores (range 4–16). Interobserver reliabilities were evaluated using intraclass coefficients (ICC) with 95% confidence intervals. ICC values greater than 0.8 indicate near perfect agreement.

What are the results?
The ICC representing the interobserver reliability between the raters at all locations was 0.968 (0.947–0.983). The ICCs representing the interobserver reliability between physician groups was the following: senior surgeon – 0.887 (0.751– 0.948); radiologist – 0.914 (0.855 – 0.954); junior surgeon – 0.946 (0.903 – 0.972).

What are your conclusions?
The modified RUST has excellent inter– and intraobserver reliability in the setting of OI despite challenges related to the poor quality of the bone and its dysplastic nature. The application and routine use of the modified RUST in the OI population will have meaningful clinical implications to help correlate radiographic healing with patient related outcome measures and postoperative quality of life measures. The standardization of the assessment of fracture and osteotomy healing in the setting of OI will help facilitate multicenter efforts to better study surgical outcomes in this heterogeneous patient population and help correlate radiographic healing with patient related outcome measures.

Evaluation of Fracture and Osteotomy Union in the Setting of Osteogenesis Imperfecta: Multicenter Reliability of the Modified Radiographic Union Score for Tibial Fractures (RUST)

Jeanne M. Franzone, MD
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Paul W. Esposito, MD

Cheryl R. Lawing, MD
Maureen J. Maciel, MD

Nemours. Alfred I. duPont Hospital for Children
Children's Hospital & Medical Center
Shriners Hospitals for Children — Tampa

The authors would like to thank our Radiology colleagues: Mark S. Finkelstein, DO, Mary K. Drake, MD and M. Steven Farber, MD

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Disclosures

Limb Lengthening and Reconstruction Society: Board or committee member

Pediatric Orthopaedic Society of North America: Board or committee member

2

Background

- Evaluation of union of both fractures and osteotomies is important for all aspects of care of patients with osteogenesis imperfecta (OI)
- Studies of the OI patient population have used varied criteria to evaluate union of fractures

3

Development of the Radiographic Union Score for Tibial Fractures for the Assessment of Tibial Fracture Healing After Intramedullary Fixation

Daniel B. Whelan, MD, FRCSC, Mohit Bhandari, MD, MSc, FRCSC, David Stephen, MD, FRCSC, Hans Kreder, MD, FRCSC, Michael D. McKee, MD, FRCSC, Rad Zdero, PhD, and Emil H. Schemitsch, MD, FRCSC

- ***Journal of Trauma*** **2010**
  - Standardized means of assessing fracture healing of tibial fractures treated with intramedullary fixation

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RUST – Radiographic Union Score for Tibial Fractures

TABLE 1. Assessment Tool for the Radiographic Union Score for Tibial Fractures (RUST)

Cortex	Fracture Line, No Callus (Score = 1)	Fracture Line, Visible Callus (Score = 2)	No Fracture Line, Bridging Callus (Score = 3)	Total score: Minimum = 4, Maximum = 12
Anterior				
Posterior				
Lateral				
Medial				

Figure 1. Anteroposterior and lateral radiographs of a tibial shaft fracture after intramedullary nailing. Application of the scoring system yielded medial cortex (RUST = 2), lateral cortex (RUST = 3), anterior cortex (RUST = 2), and posterior cortex (RUST = 1). Total RUST score possible is 12.

JOT 2010

5

Modified RUST – J. Orthop Trauma 2015

- **Improved upon reliability**
- **Each of 4 cortices of a fracture or osteotomy receives an independent score**
  - 1 – no callus
  - 2 – callus present
  - 3 – bridging callus
  - 4 – remodeled fracture not visible

  Modified RUST = Sum of 4 scores (range 4-16)
- **Score of 13 - labeled as benchmark for union**

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RUST – Background

A radiographic scoring system to assess healing in congenital pseudarthrosis of the tibia

B. Stephens Richards, David Wilkes, Molly Dempsey and Pamela Nurenberg

- **JPO B 2015 – High intra- and interobserver reliability of RUST in the setting of congenital pseudarthrosis of the tibia**

Evaluation of Fracture and Osteotomy Union in the Setting of Osteogenesis Imperfecta: Reliability of the Modified Radiographic Union Score for Tibial Fractures (RUST)

Jeanne M. Franzone, MD, Mark S. Finkelstein, DO,† Kenneth J. Rogers, PhD, ATC,* and Richard W. Kruse, DO, MBA**

- **JPO 2020 – Excellent intra- and interobserver reliability of [redacted] f OI, single-center study**

7

Purpose

- **Evaluate the reliability of the modified RUST in the setting of the dysplastic and poor quality bone of patients with OI in a multicenter setting**

[redacted]

8

Methods

- <u>Setting:</u> 3 United States pediatric hospitals treating OI patients.
- <u>Reviewers</u>: 3 at each site
  - 1 senior orthopedic surgeon
  - 1 junior orthopedic surgeon
  - 1 radiologist

[redacted]

9

Methods

- <u>Images:</u>
  - 30 deidentified DICOM images of tibia radiographs of OI patients with fractures or osteotomies at different stages of healing were deidentified and placed on 2 CDs: Time 1 and Time 2.
  - Images were randomly ordered on each CD and read on each institution's PACS system.
- <u>Evaluation:</u> Three reviewers scored the radiographs on two separate occasions at least two weeks apart.

[redacted]

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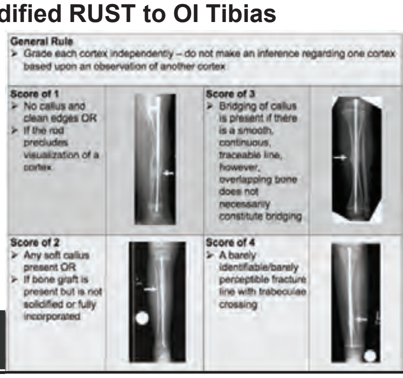
"Ground Rules" for Application of the Modified RUST to OI Tibias



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11

Methods

Statistics:

- **Intraclass coefficient (ICC) with 95% confidence interval (CI) used to quantify agreement**

< 0.5	**poor reliability**
0.5 – 0.7	**moderate reliability**
0.75 – 0.9	**good reliability**
>0.90	**excellent reliability**

[redacted]

12

Total Score Interobserver Reliability

Location	ICC	95% CI
1	.921	.809 - .965
2	.893	.820 - .943
3	.943	.900 - .970

13

Intraobserver Reliability by Location

Location 1

Rater	ICC	95% CI
1	.851	.656 - .929
2	.993	.986 - .997
3	.971	.935 - .987

Location 2

Rater	ICC	95% CI
1	.824	.713 - .934
2	.862	.663 - .916
3	.869	.713 - .934

Location 3

Rater	ICC	95% CI
1	.907	.805 - .956
2	.893	.772 - .949
3	.962	.920 - .982

14

Interobserver Reliability - All locations and observers

ICC	95% CI
.968	.947 - .983

15

Interobserver Reliability by Cortex (all observers at each site)

Cortex	ICC	95% CI
Lateral	.964	.943 - .981
Medial	.958	.932 - 977
Anterior	.958	.932 - .977
Posterior	.931	.889 - .962

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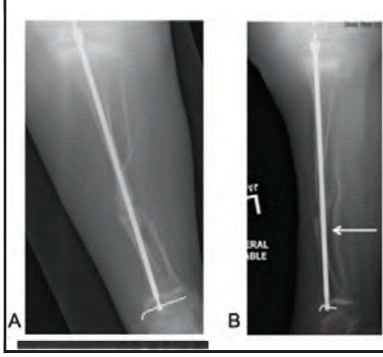
Clinical Example



13 year old girl with severe OI 6 weeks following a two-level osteotomy

Intramedullary rod obscures the posterior cortex of the distal osteotomy on the lateral radiograph

17

Clinical Example

5 year old girl with severe OI 4 months following osteotomy

Inter- and intraobserver agreement regarding a modified RUST of 16

18

Conclusions

- Excellent multicenter inter- and intraobserver reliability of modified RUST in setting of OI tibias
- Modified RUST serves as an objective scoring system to evaluate bony union with an intramedullary device in place
- Limitation: Inter-and intraobserver reliability demonstrate precision of a score not accuracy

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Future Directions

- Apply the modified RUST to other long bones
- Establish modified RUST score to indicate union in setting of OI
- Correlate modified RUST with healing and clinical outcomes
- Utilize to standardize nonunion assessment in literature and facilitate multicenter studies

20

THANK YOU

Jeanne.Franzone@Nemours.org



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Vascularized Fibula Transfer with External Fixation for the Treatment of Bone Defects and Nonunions in Children

Melissa Esparza, Alexander Cherkashin, David Podeszwa, Mikhail Samchukov
melissa.esparza@tsrh.org

What was the question?
Reconstruction of bone defects with free vascularized fibula transfer has been described as a treatment option following resection of tumors, post–traumatic or post–infectious bone loss, pseudoarthrosis, and avascular necrosis. However, complications are common including prolonged immobilization, non–union, fracture, and donor site morbidity. Is vascularized fibula grafting with Ilizarov frame fixation an effective method for treating bone defects and nonunions in children and does it have an acceptable complication rate?

How did you answer the question?
We performed a retrospective analysis of pediatric patients at a single institution from 2006 to 2019 who underwent vascularized fibula transfer with external fixation for the management of large bone defects or nonunion. Data collected includes: patient factors (e.g. age, diagnosis, location), surgical parameters (defect size, graft length, harvest technique), and clinical and radiographic outcomes (time to union, hypertrophy of graft, fracture, donor and graft site complications, need for subsequent surgery).

What are the results?
A total of 9 pediatric patients underwent vascularized fibular transfer with the placement of Ilizarov frame fixation to promote healing in the setting of large bone defects or nonunion. Mean age at index surgery was 7 years (range 1.5 to 15.4 years). There was one patient who did not initially achieve union and underwent a second vascularized fibula transfer six years later with subsequent union achieved. Mean follow–up time was 35 months (range 9–94). Mean graft length was 9.8 cm (range 5–21). Diagnoses included: osteomyelitis sequelae (5), femoral neck nonunion (2), neurofibromatosis with congenital radius pseudarthrosis (1), and fibrous dysplasia (1). Defects were located in the femur (3), tibia (2), forearm (3), and humerus (1). The mean time to union was 13.6 weeks (range 8–21) and mean time in the external fixator was 15.1 weeks (range 8–25). Three patients in the series had complications, one of which was a donor site complication. The donor site complication was a transient peroneal nerve palsy after graft harvest and development of an equinus contracture, both of which resolved with non–operative treatment. Two patients developed fractures of the fibular graft. One was a fracture of a humeral graft treated with two attempts at plating and subsequently requiring a second free fibular transfer which healed without complication. Another patient fractured a 21–cm fibular graft in the tibia after premature weightbearing. It was treated with an intramedullary rod and second external fixator. The fracture healed and this patient is now undergoing lengthening of the remodeled fibula graft.

What are your conclusions?
Vascularized fibula grafting provides an effective method for promoting bone union in pediatric patients with large bone defects and nonunions. Stabilization with external fixation has the benefits of limiting exposure to the docking site, creating an ideal mechanical environment for healing and offering versatile options for revision fixation without exposure of the graft. Use of circular external fixation aids in the reduction of graft complications. A recently introduced harvesting technique with partial preservation of the donor site periosteum promotes regrowth of that fibula at the donor site and will likely reduce donor site complications.

Vascularized Fibula Transfer for the Treatment of Bone Defects and Nonunions in Children

Melissa Esparza, MD; Alex Cherkashin, MD;
Mikhail Samchukov, MD; David Podeszwa, MD

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UTSouthwestern Medical Center

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Disclosures:

Dr. Cherkashin, Dr. Samchukov:
Consultant OrthoFix
Royalties through TSRH from TrueLok Ring Fixation System

2

Background

- 1905 Huntington described a vascularized fibula transfer to reconstruct a large tibial defect secondary to osteomyelitis
- 1975 Taylor reported on successful use of free vascularized fibula graft using microvascular techniques

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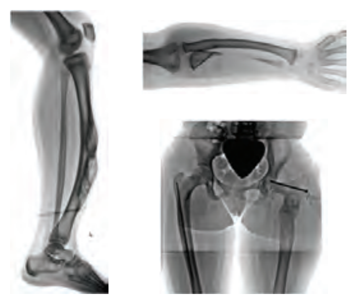
Indications

- Avascular necrosis
- Non-unions
- Bone defects
  - Oncologic
  - Post-traumatic
  - Post-infectious



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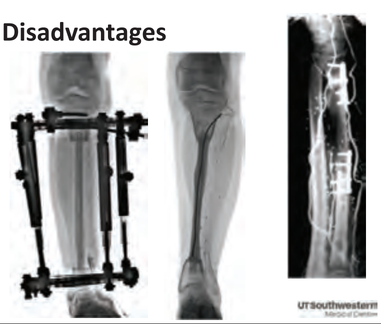
Advantages & Disadvantages

- Advantages:
  - Primary bone healing
  - Dual blood supply
  - Resistance to infection
  - Graft hypertrophy
- Disadvantages:
  - Donor site morbidity
  - High complication rate



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Complications

- Prolonged time to union
- Graft fracture – up to 52.6%
  - Secondary treatments
- Donor site – up to 11.5%
  - Ankle valgus, peroneal nerve injury, infection

6

Purpose

- To report on the indications, surgical technique, and outcomes of using vascularized fibular graft with circular frame fixation for the treatment of bone defects, nonunions, and AVN in a variety of clinical settings

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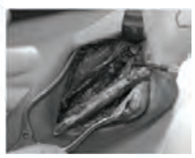
Methods

- Retrospective Review
- 2001-2019
- Outcomes
  - Patient factors
  - Surgical parameters
  - Clinical and radiographic outcomes

8

Surgical Technique

- Preserve lateral periosteum
  - In children <8yo
  - Try to leave 1/3 – 1/2 periosteum intact
  - Difficult if take skin with bone



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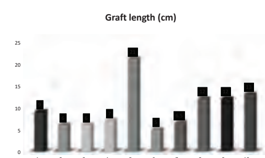
Results

- 9 pediatric patients treated with vascularized fibula graft and external fixator
- 1 patient treated w/ vascularized fibula twice (2011, 2017)
- Mean age – 7 y.o. (range 1.5 -15.4)
- Mean follow-up 35 months (range 9-94)
- Mean graft size 9.8 cm (range 5-21)



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Results – Diagnoses & Anatomic sites

- Diagnosis
  - Chronic osteomyelitis – 5
  - NF/congenital radial pseudarthrosis– 1
  - Femoral neck fracture – 2
  - Fibrous dysplasia – 1
- Segments
  - Forearm – 3
  - Humerus – 1
  - Femoral neck – 2
  - Femoral shaft – 1
  - Tibia – 2

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Results

- Mean time to union – 13.6 weeks (range 8-21)
- Mean time in frame –15.1 weeks (range 8-25)
- Graft hypertrophy – 7/8 cases (10 cases total, hypertrophy N/A in 2 femoral neck pts)

12

Results - Complications

- 1 Donor site complication: transient peroneal nerve palsy resolved without intervention
- Free fibula + frame for humeral bone defect from chronic OM → plating for proximal non-union → peri-implant fracture → repeat free fibular graft + frame with good healing
- Fracture of 21cm fibular graft in the tibia after premature weightbearing → treated with IM rod and second frame

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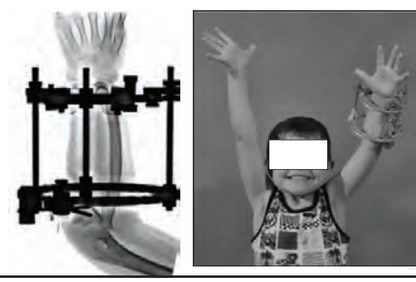
Case #1: 4 years 10 months old boy

- Chronic osteomyelitis at age of 1 year

14

Frame for 6 week for ulna transport



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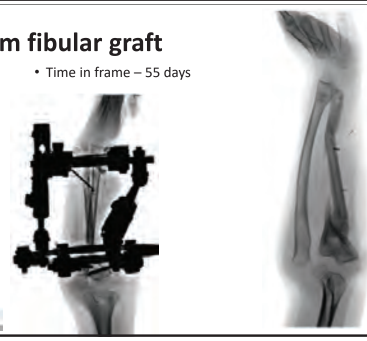
7 cm fibular graft

- Time in frame – 55 days



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Outcome

before after

17

Outcome

before after

18

Case #2

- 8-year-old boy
- S/p femoral open fracture
- Segmental bone defect
- Multiple attempts of bone grafting using iliac crest, fibula, ribs
- 14 cm LLD
- Limited joint ROM

3/13/2006

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Treatment strategy

- Free vascularized fibular graft
- External circular fixation

- Increasing weight bearing
- Restoration of joint ROM
- Ambulation with brace

3/13/2006

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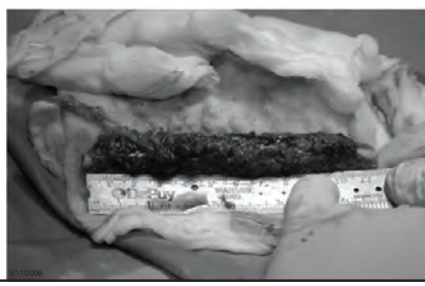
Harvested fibular graft



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Proximal and distal segment fixation

22

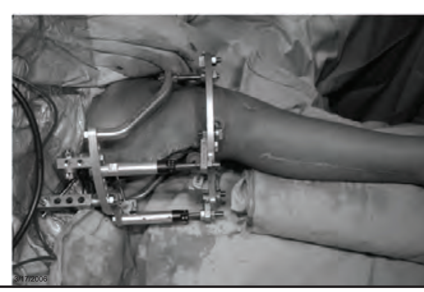
Femoral defect area

Fibular graft placement

3/17/2006

23

Frame at the end of surgery



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Stabilization period

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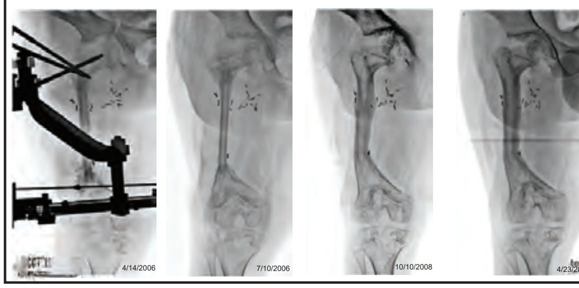
Bone remodeling



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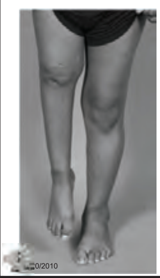
Four-year follow up



- No complaints
- Fibula-to-femur remodeling
- Walking with & without prosthesis
- Increased joint ROM
- 10 cm LLD

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Four-year follow up

28

Four-year follow up

29

Conclusions

- Vascularized fibula grafting provides an effective method for promoting bone union in pediatric patients with large bone defects and nonunions
- Stabilization with external fixation limits exposure to the docking site, creates an ideal mechanical environment for healing and offers versatile options for revision fixation without exposure of the graft
- Partial preservation of donor site periosteum during harvesting promotes regrowth of the fibula and will likely reduce donor site complications

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Thank You!

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Session 3: Foot & Ankle

Hexapod–assisted Arthroscopic Ankle Arthrodesis for Severe Rigid Post Traumatic Equinus Deformity

Gonzalo F. Bastias MD, Paulina Gutierrez MD, Natalio Cuchacovich MD, Patricio Fuentes MD
gfbastias@gmail.com

What was the question?
What are the functional and radiological results of a group of patients with rigid post–traumatic equinus deformity treated with hexapod–assisted arthroscopic ankle arthrodesis?

How did you answer the question?
We retrospectively reviewed patients undergoing minimally invasive correction of posttraumatic rigid equinus consisting of percutaneous tendoachilles lengthening, gradual equinus correction using a hexapod external fixator and arthroscopic ankle arthrodesis once correction was completed. We included patients with at least one–year follow–up following frame removal. Demographic and etiologic data was obtained from medical records. Preoperative and final postoperative VAS and Foot Function Index scores were assessed. Radiological analysis of preoperative and postoperative x–rays was included and complications were noted throughout the follow–up period.

What are the results?
Five patients with severe post–traumatic rigid equinus deformities were treated in our institutions between 2014 and 2019. All patients had undergone previous surgeries and presented with poor soft tissue envelopes. The mean age at the time of surgery was 35,4 years (range 23–61). The mean duration of the deformity was 4,5 years (range:1,9 – 7,2 years). The mean follow up was 24.5 months (range, 19 – 32 months). All deformities were gradually corrected into a plantigrade foot using the fixator over an average duration of 6 weeks (range: 3,4 – 8,1 weeks). After the correction of the deformity was completed, arthroscopic arthrodesis was performed leaving the fixator in compression with one or two percutaneous screws augmenting stability of the construct. The frame was removed between 4 and 6 months postoperatively depending on radiologic signs of union. The average frame time was 30,9 weeks (range: 23,1– 35,1 weeks). The mean preoperative radiographic ankle equinus was 42,3° (range, 35,3 to 46,1°) and was corrected postoperative to 1,5° (range 0,5° to 3,4°). Foot Function Index score improved from a mean of 86,6 (range 78– 93) to 24,2 (range 16 – 31). The average preoperative VAS score was 8,1 and improved postoperatively to 2,2. At final follow up tibiotalar joint osseous consolidation was proved in all cases using CT scan. All deformities maintained correction and there were no cases of recurrence. One patient had a superficial pin site infection treated with oral antibiotics and one patient had a calcaneal pin loosening secondary to a marginal fracture which needed no further treatment.

What are your conclusions?
Severe posttraumatic rigid equinus deformity treated using hexapod external fixator correction, Achilles tendon lengthening and arthroscopic ankle arthrodesis has excellent functional and radiological results with a low rate of complications.

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LLRS Limb Lengthening and Reconstruction Society

Hexapod-assisted Arthroscopic Ankle Arthrodesis for Severe Rigid Posttraumatic Equinus Deformity

Patricio Fuentes MD, Paulina Gutierrez MD,
Natalio Cuchacovich MD, Gonzalo F. Bastias MD
Hospital del Trabajador
Santiago, CHILE

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Disclosures

- Dr. Fuentes, Dr Cuchacovich and Dr Bastias
  - Orthofix
- Dr. Gutierrez
  - Nothing to disclose

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Introduction

- **Posttraumatic ankle equinus is a challenging condition:**
  - Rigid deformity
  - Poor skin condition
  - Multiple prior surgeries.
- **Acute correction alternatives:**
  - Osteotomies
  - Talectomy
  - Arthrodesis
  - Amputation

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Introduction

- **Concerns Acute Correction**
  - Soft tissue complications
  - Neurovascular alterations
  - Secondary limb discrepancy
  - Loss of bone stock.

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Objectives

We must obtain a foot that is :
- Plantigrade
- Stable
- Non Ulcered/No prominences
- Painless
- Shoe Friendly

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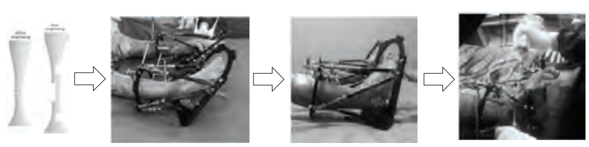
Patients and Methods

We propose a minimal invasive strategy including:
- Percutaneous Achilles Lengthening
- Gradual correction of the deformity
- Arthroscopic ankle arthrodesis (AAA)



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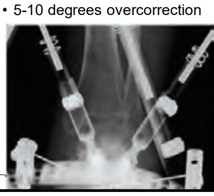
Patients and Methods

- **Gradual correction of the deformity (TSF)**
  - 5 to 7 mm initial axial distraction phase (avoid ant impingement)
  - 1 mm/day equinus correction + posterior translation (avoid dislocation!)
  - 5-10 degrees overcorrection

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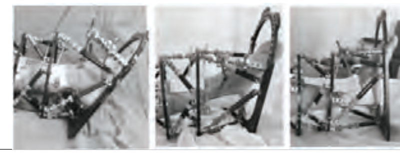
Patients and Methods

- **Gradual correction of the deformity w/ TSF (Smith&Nephew,Memphis,TN)**
  - 5 to 7 mm initial axial distraction phase
  - 1 mm/day equinus correction + posterior translation (avoid dislocation!)
  - 5-10 degrees overcorrection



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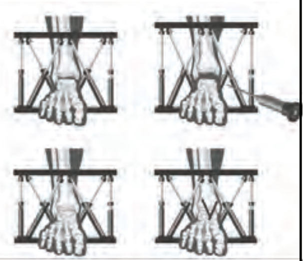
Patients and Methods

- **Arthroscopic ankle arthrodesis (AAA)**
  - Once correction is achieved → Additional 5-7 mm distraction
  - Arthroscopic AM- AL portals
  - Joint preparation, Acute compression
  - Augmentation with 1 or 2 cannulated 6.5 screws.
  - WB as tolerated inmediately after AAA
  - Frame Removal after fusion is visible on CT-scan



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Patients and Methods

- Radiological Outcomes
  - Xrays
  - Tibio-talar Angle
    - Tibial anatomical axis and the axis of the talus
    - True ankle equinus → >115º
  - Union
    - Clinical
    - CT-Scan

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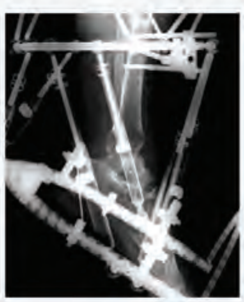
Patients and Methods

- Retrospective Review 2014-2019
  - Demographics
  - Etiology
  - Total Fixator Time
  - Complications
- Functional Outcomes: one month before the procedure and 12 months following frame removal
  - Foot Function Index
  - Visual Analog Scale
- Satisfaction Rate



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Results

- 5 patients
- Age: 35,4 yo
- Follow Up (mean)
  - 30.9 months
- Duration of deformity (mean)
  - 4.5 years
- Concomitant Procedures
  - Tibial malunion correction
  - 1 patient

Patient	Age (y) / Gender	Etiology	Skin integrity	Follow-Up (m)
1	23, M	Degloving injury of the lower leg and ankle	ALT flaps, partial-thickness skin grafts	50
2	26, F	Open Knee Dislocation. Peroneal Nerve Palsy	ALT flap, Partial Thicknesss skin grafts	32,9
3	61, M	Open tibia fracture, osteomielitis, equinus secundary to bone transport	ALT flap	28,2
4	38, M	Open Ankle Fracture	Partial thickness skin grafts	25,5
5	29, F	Degloving injury of the ankle.	ALT flap	18,1

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Results

- Gradual Correction Phase (mean)
  - **6 weeks**
- AAA Fusion Phase (mean)
  - **Union was achieved in all patients**
  - **Time to fusion: 24,9 weeks**
- Total Frame Time (mean)
  - **30,9 weeks**
- TTA (mean)
  - Preop: 132.2°
  - Final FU: 91,5°
  - **Correction: 40,8°**

Patient	TTA		Degrees of Correction	Progresive Correction Phase (w)	AAA Fusion Phase (w)	Total Fixator Time (w)
	Pre	Post				
1	132,5°	90,5°	**42°**	3,4	**19,7**	**23,1**
2	136,1°	91,3°	**44,8°**	6,4	**25,6**	**32**
3	139°	93,4°	**45,6°**	6	**28,2**	**34,2**
4	125,3 °	90,8°	**34,5°**	8,1	**22,1**	**30,2**
5	128,7°	91,7°	**37°**	6,4	**28,7**	**35,1**

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Results

- FFI 0-100 max
  - Preop: 86,6
  - Postop: 24
- VAS 0-100 mm
  - Preop: 81 mm
  - Postop: 22 mm
- Satisfaction
  - Excellent 4
  - Good 1

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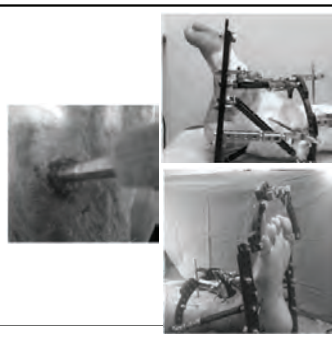
Results

- Complications
  - Pin Site Superficial infections: 4/5 patients
  - Lesser toe Clawing: 1
  - Calcaneal Half pin Loosening / Marginal Fracture : 1
- 4/5 regained ambulation without walking aids



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Conclusions

- **Hexapod-assisted AAA is a minimally invasive, safe and reproducible procedure.**
- **Patients in this series had excellent functional and radiological results.**
- **Low complication rate, comparable time to fusion w/ conventional AAA and open arthrodesis reports**
- **This technique allows inmediate weightbearing after AAA**
- **No secondary limb length discrepancy (bone stock preservation)**

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Thanks for your attention!

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Patricio Fuentes MD, Paulina Gutierrez MD,
Natalio Cuchacovich MD, Gonzalo F. Bastias MD
Hospital del Trabajador
Santiago, CHILE

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Functional Implications of the Flat–Topped Talus Following Treatment of Idiopathic Clubfoot Deformity

Anthony Riccio, Matthew Siebert, Kirsten Tulchin–Francis, Jacob Zide
Anthony.Riccio@tsrh.org

What was the question?
The flat–top talar dome is a well–known potential consequence of both operative and non–operative clubfoot management. While it is assumed that patients with a flat–top talus will have greater problems with daily activity, the functional impact of this deformity has not been characterized in the literature. The purpose of this study is to analyze the relationship between talar dome morphology and ankle function at skeletal maturity in patients treated for idiopathic clubfoot deformity during infancy.

How did you answer the question?
33 skeletally mature patients (average age 17.9 years, SD 1.6 years) with 52 idiopathic clubfeet were identified from our institution's clubfoot registry. Plain weight bearing lateral foot films, gait analysis and patient reported outcomes (PRO) using the Pediatric Orthopaedic Data Collection Instrument (PODCI) were obtained in all patients. Radius of curvature (ROC) of the talar dome and tibial plafond were measured along with numerous other parameters of talar and calcaneal morphology. All measurements were correlated to PODCI scores and gait analysis data.

What are the results?
Patients demonstrated marked variability in ROC of the talar dome (mean 33.1mm, SD 19.6 mm), talar dome radius to talar length (R/L) ratio (mean 0.60, SD 0.39), opening angle of the talar dome (alpha angle) (mean 88.7°, SD 29.5°) and incongruity in the ROC between the talar dome and tibial plafond (TD/TP ratio) (mean 1.17, SD 0.44). Increased TD/TP ratio correlated negatively with maximal plantarflexion (PF) ($r=0.404$, $p=0.005$), ankle range of motion (ROM) ($r=0.383$, $p=0.008$) and maximum power generation during step off ($r=0.381$, $p=0.008$). A less acute alpha–angle correlated positively with PF ($r=0.404$, $p=0.005$), ankle ROM ($r=0.383$, $p=0.008$) and maximum ankle power generation ($r=0.381$, $p=0.008$). Lower ROC of the of the talar dome correlated with increased maximum power generation ($r=0.326$, $p=0.025$). Increased R/L and TD/TP ratios correlated negatively with PODCI happiness domain scores ($r=–0.353$, $p=0.044$; $r=–0.377$, $p=0.025$, respectively) while talar length correlated with higher happiness domain scores ($r=0.393$, $p=0.024$), higher global function scores ($r=0.360$, $p=0.040$) and lower pain scores ($r=0.354$, $p=0.043$).

What are your conclusions?
While flatness of talar dome correlates significantly with altered gait mechanics, the effects on patient reported function are more modest during the second decade of life. Further study is required to assess the longer–term effects of the flat top talus on function and joint health.

Functional Implications of the Flat-Topped Talus
Following Treatment of Idiopathic Clubfoot Deformity

Matthew J. Siebert, BS   Jacob R. Zide, MD   Claire Shivers, BS   Kirsten Tulchin-Francis, PhD
Stephens Wilshaw, BA   Justine Bourchard, BA   Anthony I. Riccio, MD

SCOTTISH RITE HOSPITAL FOR CHILDREN   UT Southwestern Medical Center

I (and/or my co-authors) Have Something to Disclose. Details are Available on the LLRS Annual Meeting App

Correspondence: anthony.riccio@tsrh.org

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Flat-Top Talus

Well Known Sequela of Clubfoot Treatment

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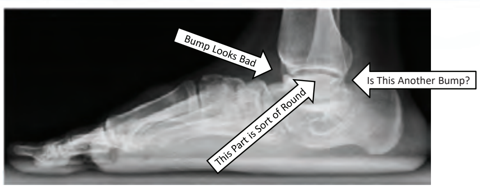
Flat-Top Talus



Classification of Severity Remains Subjective

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Flat-Top Talus

The Effect on Ankle Function is Unstudied

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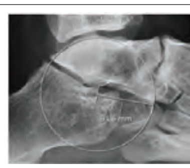
Purpose

To Comprehensively Assess The Flat Top Talus Radiographically and Correlate Deformity Parameters to Patient Reported Outcomes and Gait Mechanics.



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Methods

- **IRB Approved Retrospective Study**
- **Idiopathic Clubfeet at Skeletal Maturity**
- **Operative and Non-op Patients Included**
- **Standardized Weightbearing Films**
- **Pediatric Outcomes Data Collection Instrument**
- **3-Dimensional Motion Analysis**
  - **Peak Dorsiflexion at Midstance**
  - **Peak Plantarflexion at Push Off**
  - **Peak Ankle Power Generation**
  - **Total Ankle Range of Motion**

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Radius of the Talar Dome

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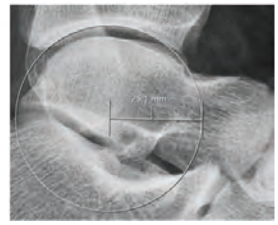
Radius of the Tibial Plafond



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Opening Angle of the Talar Dome

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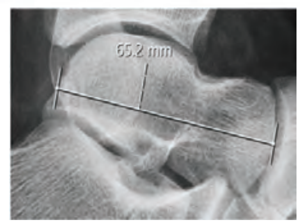
Talar Height and Length



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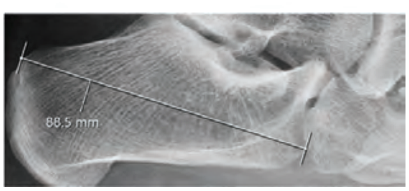
Calcaneal Length



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What is Normal?

26 Aged Matched Feet Without Deformity

Establish a Basis to Compare Severity of Talar Morphologic Changes

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Results

- 33 Patients (52 Feet)
- Average Age 17.9 Years
- 73% Male

- 60% Managed Surgically
- 40% Managed Non-Operatively

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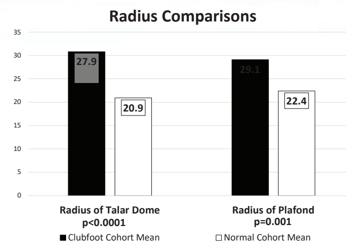
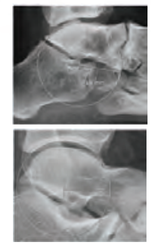
Results: Radiographic Parameters





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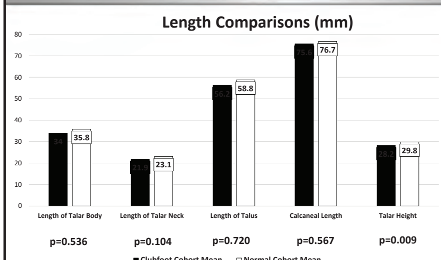
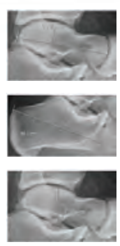
Results: Radiographic Parameters





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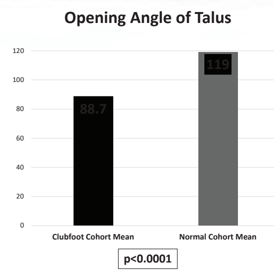
Results: Radiographic Parameters



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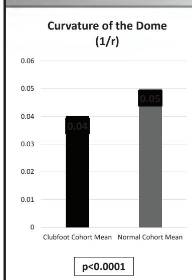
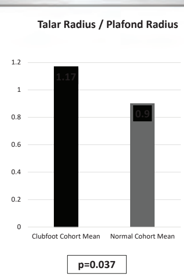
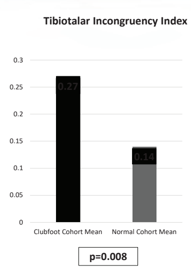
Results: Radiographic Parameters







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Patient Reported Outcomes

- Higher <u>Talar/Tibial Plafond Ratio</u> Correlated With <u>Worse</u> Happiness Scores (r=-0.377, p=0.025)
- Increased <u>Talar Length</u> Correlated With <u>Better</u> PRO Scores:
  - Happiness (r=0.393, p=0.024)
  - Global Function (r=0.360, *p*=0.040)
  - Less Pain (r=0.354, *p*=0.043)
- Increased <u>Talar Height</u> Correlated With <u>Better</u> PRO Scores:
  - Happiness (r=0.392, p=0.024)
  - Global Function (r=0.395, p=0.023)
  - Less Pain (r=0.416, p=0.016)

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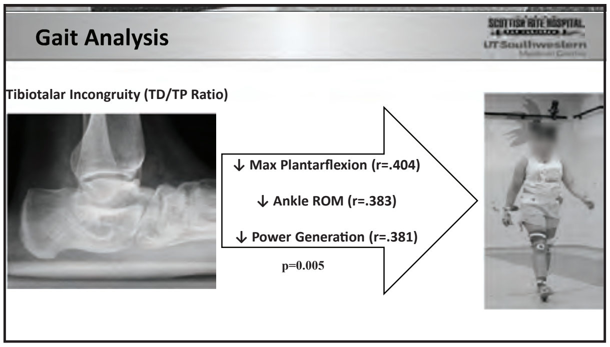

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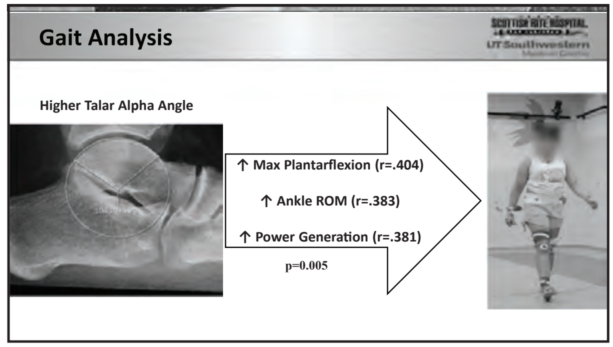

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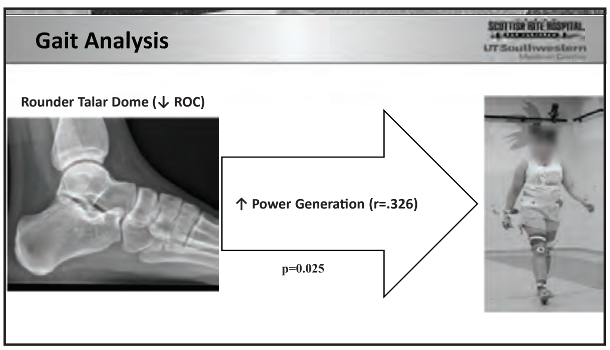

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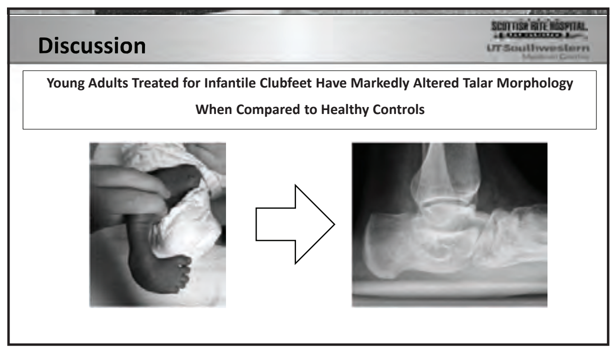

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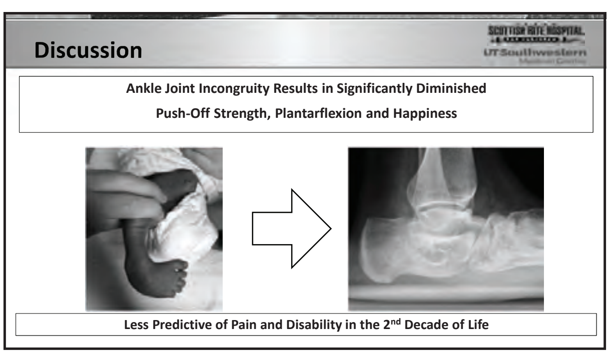

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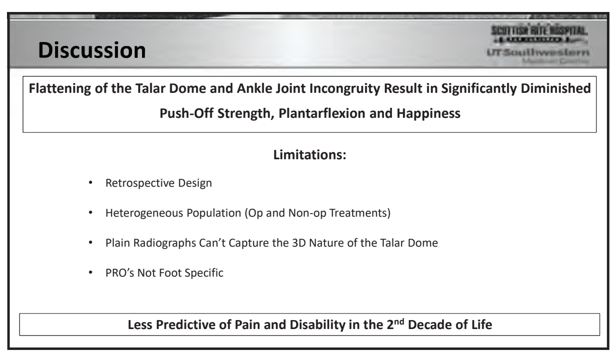

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Conclusion

- Talar Flatness May be Less Impactful on PRO's Than Previously Thought
- Other Talar Morphologic Changes May be More Important
- Talar Dome Flatness Does Significantly Alter Gait Mechanics
- The Effects of Altered Gait and Joint Incongruity Later In Adulthood Remain Unstudied
- Better Methods are Needed to Accurately Measure the Complexity of Talar Dysmorphology in these Patients

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Thank You!

UT Southwestern Medical Center

Texas Scottish Rite Hospital for Children

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Do We Really Need to Worry About Calcaneocuboid Subluxation During Lateral Column Lengthening for Planovalgus Foot Deformity?

Anthony Riccio, Jacob Zide, Brittany Hedrick, Claire Shivers
Anthony.Riccio@tsrh.org

What was the question?
While lengthening of the lateral column through a calcaneal neck osteotomy is an integral component of flatfoot reconstruction in younger patients with flexible planovalgus deformities, the procedure has been implicated in iatrogenic calcaneocuboid (CC) subluxation and subsequent degenerative changes at the CC articulation. The purpose of this study is to characterize alterations at the CC joint following lateral column lengthening (LCL) as well as to determine if Steinman pin stabilization of the CC joint prior to distraction maintains a normal CC relationship.

How did you answer the question?
Seven matched pairs of fresh frozen cadaveric feet underwent pre–procedure plain radiography and cross–sectional computed tomography (CT) imaging. LCL via a calcaneal neck osteotomy was then performed. One foot of each matched pair had a single smooth Steinman pin placed centrally across the CC joint prior to osteotomy distraction. Distraction across each osteotomy was then performed and maintained with a 12mm porous titanium wedge. Repeat imaging was obtained and compared to pre–procedure studies to quantify sagittal and rotational differences at the CC articulation.

What are the results?
Following LCL, plain radiography demonstrated statistically significant increases in the percentage of the calcaneal articular surface dorsal to the superior aspect of the cuboid in both the pinned (8.2% vs 17.6%, p=0.02) and unpinned (12.5% vs 16.3%, p=0.04) specimens. No difference in the percentage of subluxation was found between the two groups following LCL. CT imaging demonstrated statistically significant increases in rotation between the calcaneus and cuboid following LCL in both the pinned (7.6° +/– 5.6°, p=0.01) and unpinned (17° +/– 12.3°, p=0.01) specimens. Though a greater degree of rotation was present in the unpinned specimens following LCL, this difference was not statistically significant (p=0.28).

What are your conclusions?
Both sagittal and rotatory subluxation seem to occur at the CC joint following LCL regardless of pin stabilization. As a single pin would be expected to limit pure translation while having little effect on rotation, it is possible that the rotational changes identified on three–dimensional imaging are interpreted as dorsal translation when viewed two dimensionally using plain radiography. Consideration should therefore be given to CC stabilization with two pins during LCL to prevent this rotatory subluxation.

Do We Really Need to Worry About Calcaneocuboid Subluxation During Lateral Column Lengthening?

Brittany Hedrick MD, Jacob Zide MD, Danielle Thomas MD, Claire Shivers BS, Matthew Siebert BS, Bill Pierce BS, Mitchell Harris MD, Anthony Riccio, MD

SCOTTISH RITE HOSPITAL FOR CHILDREN · UTSouthwestern Medical Center

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The Authors Have No Pertinent Financial Disclosures

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The Flatfoot

- Very Common
- 10-20% of Adults[1]
- 44% Age 3-6 years
- Majority are Flexible
- Wide Range of severity and symptoms

3

Landmark Article: Evans (*JBJS 1975*)

- Defined 2 Columns in the Foot
- Clubfoot: Long Lateral Column
- Flatfoot: Short Lateral Column

Lateral Column Lengthening: Calcaneal Osteotomy Proximal to Calcaneocuboid Joint

4

Mosca (*JBJS 1995*)

- Evans Osteotomy
- Potential for CC Subluxation with Distraction
- Recommended Steinmann Pin Stabilization

5

Purpose

To Determine if Performing a Lateral Column Lengthening Leads to Subluxation of the Calcaneocuboid Joint

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Methods

- **Fresh Frozen Cadaveric Feet**
- **7 Matched Pairs**
- **Average age: 60.7 years (range 48y-74y)**
- **Male/Female: 5:2**
- **Exclusion Criteria:**
  - Previous Foot Surgery
  - Severe Osteoporosis

7

Radiographic Analysis

- **X-Ray**
- **Computed Tomography**

8

Methods: Lateral Column Lengthening

- Standard Sinus Tarsi Approach
- Osteotomy:1.5 cm Proximal to CC Joint
- Single Smooth Pin Fixation: 1 Foot per Pair
- Osteotomy Distraction: 12mm Porous Titanium Wedge

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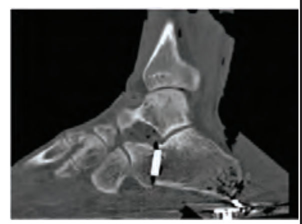
Final Radiographic Analysis

X-Ray

CT Scan



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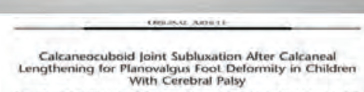
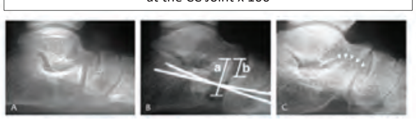
Plain Radiographic Measurements



Ratio of Dorsal Height of Calcaneus Over the Cuboid (b) ÷ Total Length of the Articular Surface of Calcaneus (a) at the CC Joint x 100



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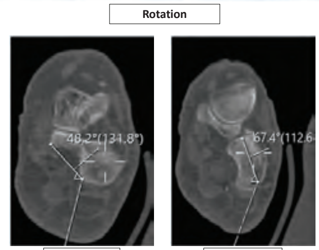
CT Measurements

Translation

Rotation

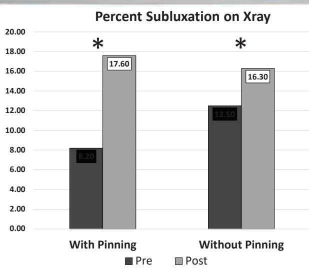


Calcaneus

Cuboid

12

Results: Plain Radiographic Measurements

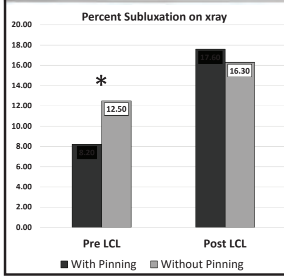


Percent Subluxation on Xray

	Pre	Post	Mean Difference (post-pre)	P value
with pinning	8.2	17.6	9.4	**0.018**
without pinning	12.5	16.3	3.8	**0.043**

13

Results: Plain Radiographic Measurements

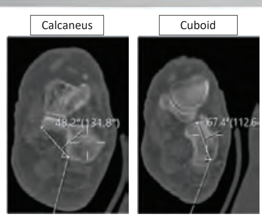


Percent Subluxation on X-Ray

	with pinning	without pinning	Mean Difference	P value
Pre	8.2	12.5	-4.3	**.028**
Post	17.6	16.3	1.2	.499

14

Results: CT scan



Change in Rotation

	Mean (degrees)	Std. deviation	p-value
Pin	7.6	5.6	**.01**
No Pin	17.0	12.3	**.01**

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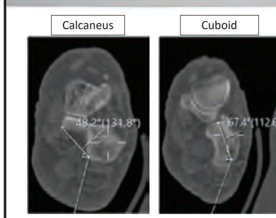
Results: CT scan



Change in Rotation

	Mean (degrees)	Std. deviation	p-value
Pin	7.6	5.6	**.01**
No Pin	17.0	12.3	**.01**

No Difference in Degree of Rotation Between Cohorts (*p=0.28*)

16

Limitations

- Cadaveric Feet
- Osteopenic
- Not Flatfoot
- Novel Way of Measuring CC Joint Rotation
- Bias of Measurement

17

Conclusion

CC Joint Subluxation Occurs as a Result of Lateral Column Lengthening

Pinning of the Calcaneocuboid Joint Does not Prevent Subluxation

18

Conclusion

CC Joint Subluxation Occurs as a Result of Lateral Column Lengthening

Pinning of the Calcaneocuboid Joint Does not Prevent Subluxation

This is a ROTATIONAL Phenomenon

19

References

1. DuMontier et al (2005). Calcaneal Lengthening: Investigation of Deformity Correction in a Cadaver Flatfoot Model. *FAI*. 26(2).
2. Pfeiffer, et al (2006). Prevalence of Flat Foot in Preschool-Aged Children. *Pediatrics*. 118 (2)
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Thank you!

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The Effect of Lateral Column Lengthening on Subtalar Motion: Are We Trading Deformity for Stiffness?

Jacob Zide, Brittany Hedrick, Claire Shivers, Anthony Riccio
jrzide@gmail.com

What was the question?
While lengthening of the lateral column through a calcaneal neck osteotomy is an integral component of flatfoot reconstruction in younger patients with flexible planovalgus deformities, concern exists as to the effect of this intra–articular osteotomy on subtalar motion. The purpose of this study is to quantify the alterations in subtalar motion following lateral column lengthening (LCL).

How did you answer the question?
The subtalar motion of 14 fresh frozen cadaveric feet was assessed using a three–dimensional motion capture system and materials testing system (MTS). Following potting of the tibia and calcaneus, optic markers were placed into the tibia, calcaneus and talus. The MTS was used to apply a rotational force across the subtalar joint to a torque of 5Nm. Abduction/adduction, supination/pronation, and plantarflexion/dorsiflexion about the talus was recorded. Specimens then underwent LCL via a calcaneal neck osteotomy which was maintained with a 12mm porous titanium wedge. Repeat subtalar motion analysis was performed and compared to pre–LCL motion using a paired t–test.

What are the results?
No statistically significant differences in subtalar abduction/adduction (10.9° vs. 11.8° degrees, p=.48), supination/pronation (3.5° vs. 2.7°, p=.31), or plantarflexion/dorsiflexion (1.6° vs 1.0°, p=.10) were identified following LCL.

What are your conclusions?
No significant changes in subtalar motion were observed following lateral column lengthening in this biomechanical cadaveric study. While these findings do not obviate concerns of clinical subtalar stiffness following planovalgus deformity correction, they suggest that diminished postoperative subtalar motion may be due to soft tissue scarring rather than alterations of joint anatomy.

The Effect of Lateral Column Lengthening on Subtalar Motion: Are We Trading Deformity For Stiffness?

Brittany Hedrick MD, Jacob Zide MD, Danielle Thomas MD, Claire Shivers BS, Matthew Siebert BS, Bill Pierce BS, Mitchell Harris MD, Tony Riccio MD

SCOTTISH RITE HOSPITAL FOR CHILDREN
UTSouthwestern Medical Center

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The Authors Have No Pertinent Financial Disclosures

Grant provided Arthrex, Inc.

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DuMontier (*FAI 2005*)

"the method of correction and three dimensional effect of this procedure are not fully understood. The **correction occurs in three dimensions**, but radiographic measurements made in two."

Lack of Studies Investigating Effect of Lateral Column Lengthening on Subtalar Motion

3

Purpose

Evaluate Subtalar Motion Before and After Lateral Column Lengthening and Determine Biomechanical Changes Using a Material Testing Machine (MTS)

4

Methods

- **Fresh Frozen Cadaveric Feet**
- **7 Matched Pairs**
- **Average age: 60.7 years (range 48y-74y)**
- **Male/Female: 5:2**
- **Exclusion Criteria:**
  - Previous Foot Surgery
  - Severe Osteoporosis

5

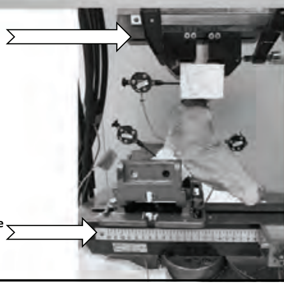
Methods: Specimens

1. Thawed to Room Temperature
2. Amputated 6" Above the Tibiotalar Joint
3. Soft Tissues Removed
   - Proximal Aspect of Tibia/Fibula and Posterior Calcaneus
4. Potted
   - 2 Port Polyurethane Resin
   - 2 Sheet Rock Screws in Calcaneus

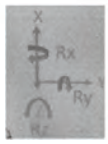
6

Methods

Linear Actuator



Torque/Force Generator



X: IR/ER or Abduction/Adduction

Y: Supination/Pronation

Z: Dorsiflexion/Plantarflexion

7

Biomechanical test

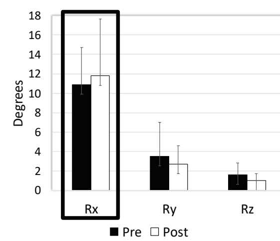
8

Methods: Lateral Column Lengthening

- Standard Sinus Tarsi Approach
- Osteotomy: 1.5 cm Proximal to CC Joint
- Osteotomy Distraction
  - Placement of 12mm Porous Titanium Wedge

9

Results: Biomechanical Test



	Rx		Ry		Rz	
	Pre	Post	Pre	Post	Pre	Post
Avg. (degrees)	10.9	11.8	3.5	2.7	1.6	1.0
Std. deviation	3.8	5.84	3.5	1.9	1.2	0.7
Paired t test	0.48		0.31		0.10	

Image from: https://cascadedafo.com/

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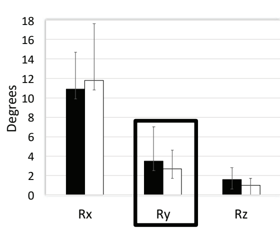
Results: Biomechanical Test



	Rx		Ry		Rz	
	Pre	Post	Pre	Post	Pre	Post
Avg. (degrees)	10.9	11.8	3.5	2.7	1.6	1.0
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Image from: https://cascadedafo.com/

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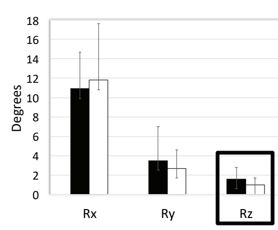
Results: Biomechanical Test



	Rx		Ry		Rz	
	Pre	Post	Pre	Post	Pre	Post
Avg. (degrees)	10.9	11.8	3.5	2.7	1.6	1.0
Std. deviation	3.8	5.84	3.5	1.9	1.2	0.7
Paired t test	0.48		0.31		0.10	

Image from: https://cascadedafo.com/

12

Discussion

Majority of Motion in the Subtalar Joint is Abduction/ Adduction

No Statistical Difference in Subtalar Motion as a Result of Lateral Column Lengthening

13

Limitations

- Cadaveric Feet, Some Osteoporotic
- Small Sample Size
- Not Flatfoot
- Unable to Simulate Weight Bearing
- Bias of Measurement
- Novel Way of Measuring Subtalar Motion

14

Conclusion

Majority of Motion in the Subtalar Joint is Abduction/ Adduction

No Statistical Difference in Subtalar Motion as a Result of Lateral Column Lengthening

15

References

- 1. DuMontier et al (2005). Calcaneal Lengthening: Investigation of Deformity Correction in a Cadaver Flatfoot Model. *FAI*. 26(2).
- 2. Pfeiffer, et al (2006). Prevalence of Flat Foot in Preschool-Aged Children. *Pediatrics*. 118 (2)
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- 5. Adams et al (2009). Calcaneocuboid joint subluxation after calcaneal lengthening for planovalgus foot deformity in children with cerebral palsy. *J Pediatr Orthop*. 29(2):170-4

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Thank you!

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Subtalar Joint Deformity Correction and Arthrodesis

Douglas Beaman, Cassandra Tomczak

What was the question?
What are effective hexapod ring external fixation frame configurations to manage severe subtalar joint deformity? What is the fusion healing success and complications of subtalar joint arthrodesis with staged internal fixation following gradual deformity correction?

How did you answer the question?
Retrospective clinical and radiographic assessment of patients with severe subtalar deformity that underwent re–alignment followed by subtalar arthrodesis with internal fixation. Inclusion criteria was subtalar joint deformity that required gradual correction due to inability of acute correction to achieve anatomic hindfoot alignment. Patients were excluded if neuropathic bone fragmentation was present, or if partial deformity correction was present on preoperative physical examination.
The ability of specific frame constructs were evaluated with respect to the achievement of complete deformity correction. The need for frame modifications, fusion healing, complications, residual acute corrections required, and time to re–alignment were assessed.

What are the results?
Between 2016–2019, six patients met inclusion criteria. There were five females, and one males with an average age of 62 yrs. Five patients had neuropathic, irreducible, and chronic dislocations, with ulcerations. One patient had a severe calcaneal malunion with 2.5 cm of hindfoot height loss. Patients with dislocations were managed with the Taylor Spatial frame miter construct, and the calcaneal malunion was managed with a talar ring within hexapod construct. CT scan and plain radiographs confirmed anatomic re–alignment in all patients. Average time to correction was 5.7 weeks (range 3–10 weeks). Two complications occurred during the correction phase: one metatarsal fracture and one required additional stabilization of the ankle.
All patients underwent successful subtalar fusion with internal fixation. All fusions healed with a neutral hindfoot alignment. There were no deep infections, and all preoperative ulcerations healed.

What are your conclusions?
Severe subtalar deformity can be completely re–aligned using hexapod methods. The miter frame construct is effective in subtalar joint dislocations. There is typically associated transverse tarsal joint mal–alignment in this cohort. Maintaining ankle mortise position is crucial, and often required trans–articular pinning. Severe subtalar joint collapse requires talus stabilization, which can be achieved with a talar ring within the hexapod construct. Staged internal fixation for subtalar arthrodesis is a successful procedure following gradual deformity correction.

Subtalar Joint Deformity Correction and Arthrodesis

Doug Beaman

Cassandra Tomczak

Summit Orthopaedics, Portland, OR

1

Disclosure

- Acumed
- Smith-Nephew
- Extremity Medical

2

Introduction

- Purpose to assess effectiveness of TSF to correct severe subtalar joint deformity and evaluate results with staged arthrodesis with internal fixation
- Prior work
  - characterized subtalar motion in a hexapod configuration in a cadaver model (subtalar joint motion better in an unconstrained forefoot model)
  - clinical success of integrated fixation methods around the foot and ankle

3

Characterization of Subtalar Joint Motion with Spatial Frame-Based Deformity Correction

Doug Beaman MD Paul Fortin MD Erin Baker, MS; Todd Irwin, MD; Kevin Baker, PhD

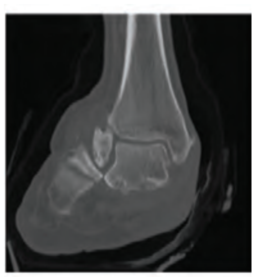
LLRS July 2014
Montreal

Summit Orthopaedics, Portland, OR. University of Michigan, Ann Arbor, MI. Beaumont Health System and OUWB School of Medicine, Royal Oak, MI

4

Methods

- Retrospective clinical review of patients treated with gradual realignment then arthrodesis with internal fixation for severe subtalar joint deformity
  - Fixed chronic dislocation
  - Greater than 2 cm deformity
  - Soft tissue comprimise with acute anatomic realignment



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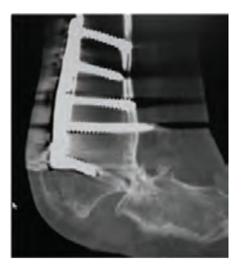
Treatment Protocol

- Subtalar capsular release
- TAL for dislocations
- Ankle joint pinned in dislocations
- Taylor spatial frame
  - Miter (6 X6) if midfoot deformity present
  - Talar ring within frame for isolated subtalar defomity
- Gradual correction (confirmed by CT, rate per soft tissues)
  - Parameters : length then parameters based on CT
- Open arthrodesis with internal fixation
- Frame modification or removal with casting



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Demographics

- 6 patients (2016-19)
- 5 females, 1 male with ave age 62 (56-71)
- F/U 13 mn (6-22 mn)
- Diagnosis: 5 neuropathic fixed rigid dislocations, 1 post-traumatic calcaneal malunion with 2.5 cm axial collapse

7

Results

- 100% Fusion healing within 5 months
- Time to subtalar joint anatomic re-alignment: 5.7 weeks (3-10)
- Frame time
  - modified at fusion in 5 : 174 days (91-245)
  - removed at fusion in 1 : 4 weeks
- Frame constructs:
  - 5 Miter (all had midfoot deformity)
    - 4 valgus, 1 varus dislocation
  - 1 talar ring within hexapod (isolated subtalar)

8

Results

- Radiographic analysis
  - HFA
    - Preop : 32 valgus→51 varus
    - Postop: 0-3 valgus
  - Lateral
    - Preop: 20 degrees
    - Postop: 1.5 degrees
- Other procedures
  - 4 Talonavic fusions, 4 TAL,

9

Results- clinical outcome

- Reinker/Carpenter Scale (JPO, 1997)
  - 2: Excellent (plantigrade, painless, no limitations)
  - 3: Good (plantigrade, mild pain after extensive ambulation)
  - 1: Fair (mild deformity and some functional limitations)

10

Results- complications

- Complications:
  - No deep infections
  - 1 metatarsal fracture during correction (healed without sequlae)
  - 1 talar tilt during correction→ required OR to pin ankle (no sequlae)
  - 1 ankle charcot required fusion (2 years after subtalar fusion)

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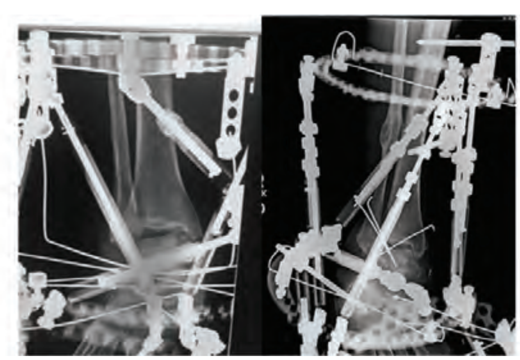

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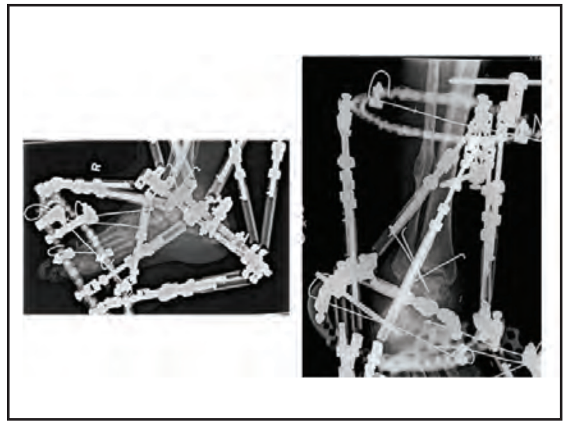

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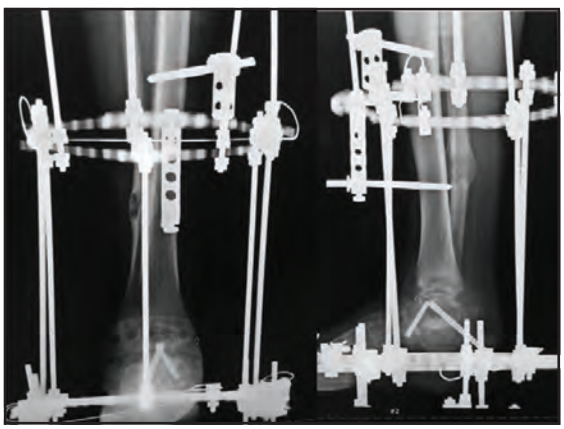

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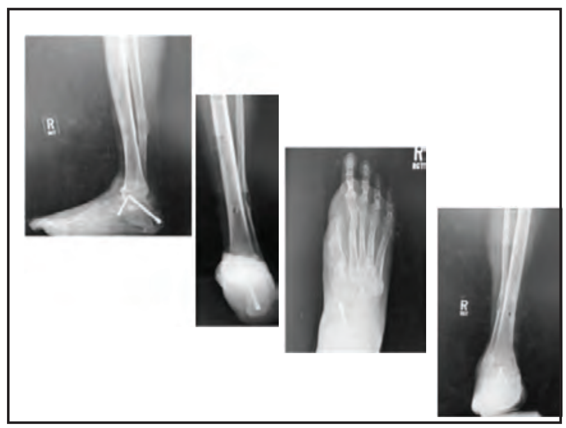

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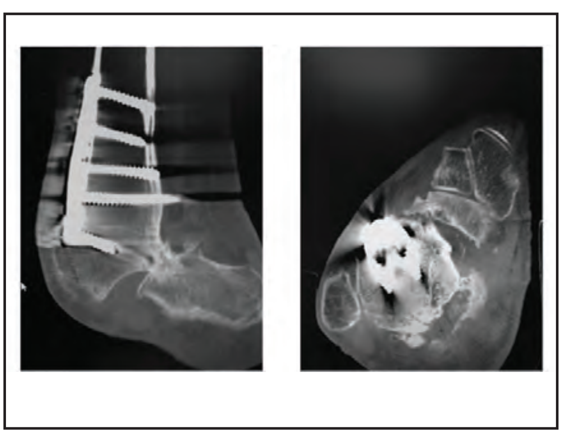

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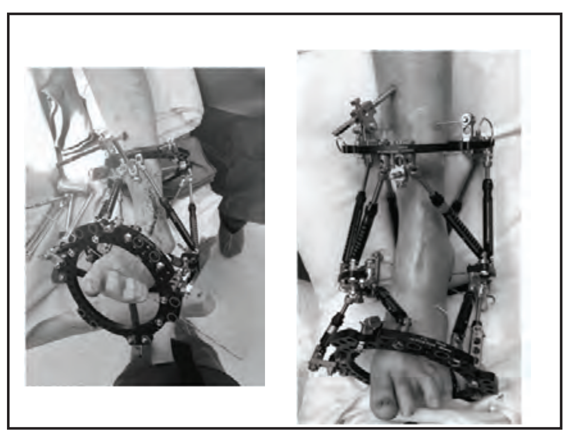

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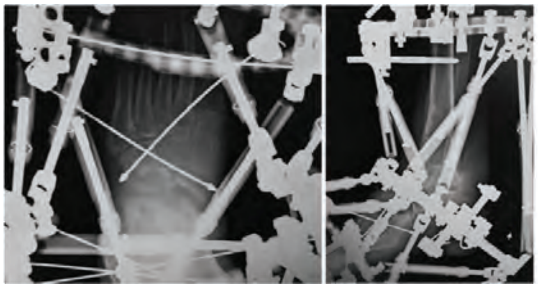

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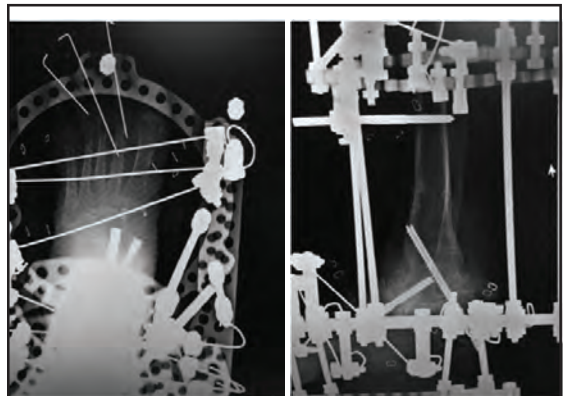

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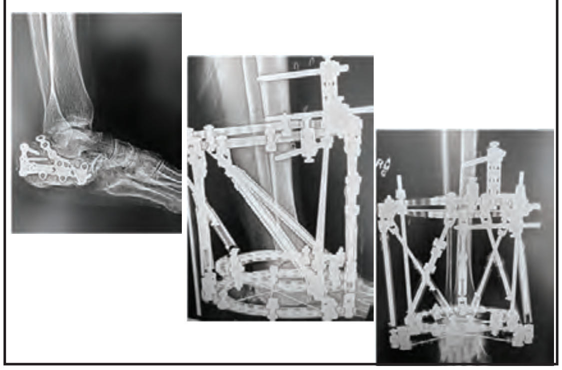
Calcaneal malunion



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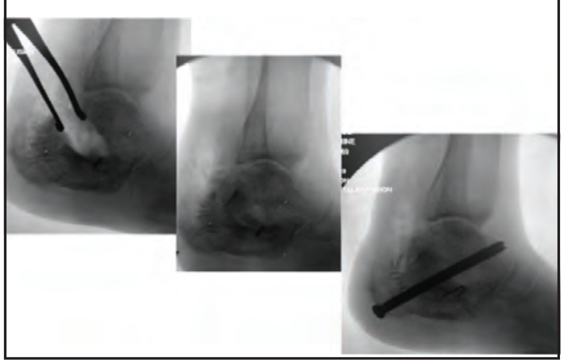
Staged subtalar arthrodesis



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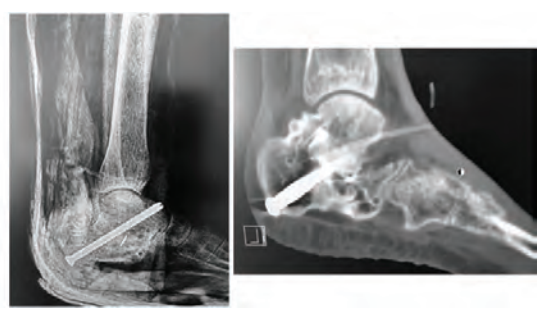

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Summary

- Gradual hexapod re-alignment of severe subtalar deformity followed by staged arthrodesis with internal fixation provides reliable healing with minimal complications in this small patient series
- Adds to our body of work on integrated re-alignment methods around the foot/ankle
- Frame configurations utilized in this study were successful in subtalar re-alignment

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Summary

- Developing a body of work that helps with the decision on when and how to do gradual corrections in the foot

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Session 4: Limb Deformity

Comparison and Validation of Pre–operative Planning Techniques for Distal Femoral Osteotomies and Proximal Tibial Osteotomies

David T. Zhang, Austin T. Fragomen, S. Robert Rozbruch
davidtz123@gmail.com

What was the question?
Pre–operative planning is important for accurate intraoperative execution in many surgical fields. Planning for distal femoral osteotomies (DFOs) and proximal tibial osteotomies (PTOs) consists of choosing the level of the osteotomy, measuring the angle of the osteotomy based on hip–knee–ankle alignment, and choosing a proper osteotomy wedge size. Medical imaging IT solutions company Sectra has implemented a new osteotomy tool in their radiographic system that is simpler than the accepted standard of modified center of rotation of angulation (mCORA) technique, yet unvalidated. In this study, we aim to compare the Sectra osteotomy tool versus the mCORA technique to measure the osteotomy angles as well as wedge sizes in both DFOs and PTOs in order to validate this new tool.

How did you answer the question?
We enrolled n=30 consecutive patients with DFOs and n=30 PTOs from the last year. The Pearson correlation coefficient (PCC) along with descriptive statistics were used to evaluate for similarity between the two techniques. We also compared interobserver and intraobserver reliability using intraclass correlation coefficients (ICC).

What are the results?
The PCC for osteotomy angles in DFOs and PTOs were both 0.998 ($p<0.001$ for both). For wedge sizes, the PCC in DFOs was 0.993 and 0.980 in PTOs ($p< 0.001$ for both). ICCs were high for both interobserver measurements in osteotomy angles and wedge sizes (range 0.989–0.999) as well as intraobserver measurements (0.994–0.999).

What are your conclusions? The Sectra osteotomy tool is a validated tool for preoperative measurements of distal femoral osteotomies and proximal tibial osteotomies. It is reliable and simpler than the current practice of the mCORA technique. We suggest future studies to analyze this Sectra osteotomy tool in other settings as to incorporate it into widespread clinical use.

Comparison and Validation of Pre-operative Planning Techniques for Distal Femoral Osteotomies and Proximal Tibial Osteotomies

David T. Zhang, MD, Peter S. Principe, BS,
Austin T. Fragomen, MD, S Robert Rozbruch, MD.

July 30, 2020

HSS HOSPITAL FOR SPECIAL SURGERY

1

Disclosures

- I have no conflicts of interest or financial incentives to disclose.

2

2

Background | Objective | Methods | Results | Conclusion | Discussion

Background (1 of 2)

- Pre-operative planning is important for accurate intra-operative execution in many surgical fields, including general surgery, otolaryngology, neurosurgery, plastic surgery, and orthopedic surgery
- Specifically in orthopedics, pre-operative planning can be used to achieve proper alignment in lower extremity osteotomies to help patients improve and regain functionality whether for daily living, work, or sport
- A precise pre-operative plan of the magnitude of correction and the height of the opening or closing wedge helps the surgeon perform the realignment with precision during surgery

3

3

Background | Objective | Methods | Results | Conclusion | Discussion

Background (2 of 2)

- Pre-operative planning for distal femoral osteotomies (DFOs) and proximal tibial osteotomies (PTOs) consists of choosing the level of the osteotomy, measuring the angle of the osteotomy based on hip-knee-ankle alignment, and choosing a proper osteotomy wedge size
- Traditionally, the senior authors (ATF, SRR) have used a modified center of rotation of angulation (mCORA) to create such an osteotomy in their pre-surgical planning, avoiding any translation at the osteotomy
- Useful for DFO and HTO opening and closing wedge osteotomies that require an intact hinge cortex at a defined level
- Recently, medical imaging IT solutions company Sectra (Linköping, Sweden) has implemented a new osteotomy tool within their Picture Archiving and Communication System (PACS) that is simpler yet unvalidated

4

4

Background | Objective | Methods | Results | Conclusion | Discussion

Objective

- Currently, this tool has yet to be validated despite its implementation already into clinical use
- The current gold standard is the mCORA technique
- In this study, we aim to compare the Sectra osteotomy tool versus the mCORA technique to measure the osteotomy angles as well as wedge sizes in both DFOs and PTOs

5

5

Background | Objective | Methods | Results | Conclusion | Discussion

Methodology (1 of 3): Study Design

- Analyzed the last 30 consecutive DFOs and PTOs treated at our institution in the last year (late 2018-early 2019)
- All of our measurements were done in Sectra PACS (Sectra IDS7), where the angle of the osteotomy to a tenth of a degree and the wedge height to a tenth of a millimeter were recorded
- Two reviewers' responses were used to compare interobserver reliability
- After 1 week, the measurements for the 60 patients were repeated by the primary observer to assess intraobserver reliability

6

6

Methodology (2 of 3): Measurement Technique

Figure 1: Measuring DFO angle of 6.7 degrees using mCORA technique

Figure 2: Measuring PTO angle of 9.8 degrees using mCORA technique

Figure 3: Measuring osteotomies using the Sectra osteotomy tool

7

Methodology (3 of 3): Statistical Analyses

- To compare the two different techniques, we use the Pearson correlation coefficient, r
- Power analysis assuming r > 0.9 resulted in a sample size of n = 8
- Intraclass correlation (ICC) was performed for interobserver and intraobserver reliability using the two-way mixed-effects model with absolute agreement, with 95% confidence intervals (CIs) reported
- Classification of ICCs: above 0.90 is excellent, 0.75-0.90 good, 0.50-0.75 moderate, and below 0.50 poor
- We hypothesize that all PCCs and ICCs will be excellent

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Table 1: Demographics of patients receiving DFOs and PTOs*

	DFO (n=30)	PTO (n=30)
Age (years)	42.6 (17-64)	37.3 (15-62)
BMI (kg/m^2)	28.0 (19.4-41.9)	28.5 (18.9-69.2)
Female (%)	60%	33.3%
Laterality (% left/right)	43.3%/56.7%	46.7%/53.3%

*All values reported are in the form of "mean (range)"

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The new Sectra osteotomy tool was excellent compared to mCORA

Table 2: Comparison of mCORA technique versus Sectra osteotomy tool technique for measurement of osteotomy angle*

DFO (n=30)				PTO (n=30)			
mCORA	Sectra osteotomy tool	Pearson r	p-value	mCORA	Sectra osteotomy tool	Pearson r	p-value
7.59° (4.46°)	7.62° (4.41°)	0.998	<0.001	11.15° (8.68°)	10.85° (8.10°)	0.998	<0.001

Table 3: Comparison of mCORA technique versus Sectra osteotomy tool technique for measurement of wedge size*

DFO (n=30)				PTO (n=30)			
mCORA	Sectra osteotomy tool	Pearson r	p-value	mCORA	Sectra osteotomy tool	Pearson r	p-value
6.97 mm (4.44 mm)	6.88 mm (4.26 mm)	0.993	<0.001	12.39 mm (12.88 mm)	11.52 mm (9.47 mm)	0.980	<0.001

*All values reported are in the form of "mean (standard deviation)"

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Intraobserver and interobserver reliability were excellent

Table 4: Comparing interobserver reliability using ICC and 95% confidence intervals*

	DFO (n=30)		PTO (n=30)	
	mCORA	Sectra osteotomy tool	mCORA	Sectra osteotomy tool
Angle	0.997 (0.994-0.999)	0.998 (0.996-0.999)	0.999 (0.999-1.000)	0.995 (0.989-0.997)
Wedge size	0.990 (0.979-0.995)	0.989 (0.977-0.995)	0.998 (0.996-0.999)	0.992 (0.977-0.997)

Table 5: Comparing intraobserver reliability using ICC and 95% confidence intervals*

	DFO (n=30)		PTO (n=30)	
	mCORA	Sectra osteotomy tool	mCORA	Sectra osteotomy tool
Angle	0.999 (0.997-0.999)	0.999 (0.998-1.000)	0.999 (0.999-1.000)	0.998 (0.996-0.999)
Wedge size	0.997 (0.993-0.995)	0.994 (0.988-0.997)	0.999 (0.998-1.000)	0.997 (0.994-0.999)

*All values reported are in the form "ICC (95% confidence interval)". All ICCs were statistically significant with p-value < 0.001.

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Conclusions

- The goal of this study was to validate the Sectra osteotomy tool as compared to the gold standard of the mCORA technique
- We found very high correlations between the two techniques for angles and wedge sizes in both DFOs and PTOs
- ICCs were excellent for interobserver and intraobserver reliability in all comparisons
- Sectra has created an osteotomy tool that simplifies the measurement of osteotomy angles and wedge sizes even more, further reducing planning time

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Discussion

- Given the results of our study, we recommend embracing this innovative technology to expedite pre-operative planning in distal femoral osteotomies and proximal tibial osteotomies
- Limitations: enrolled patients were at a single institution (specifically a high-volume academic center), osteotomy site may depend on surgeon preference though ours were consistent across patients, differences in measurements between the two techniques are well within the range of the measurement error
- Suggest future studies to analyze this Sectra osteotomy tool in other settings as to incorporate it into widespread clinical use

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Pin Site Care – Updates on an International Multicentre Pin Site Infection Study

Anthony Cooper, Jero Abad, Harpreet Chhina, MPSIS Study Group
anthony.cooper@cw.bc.ca

What was the question?
What are the factors influencing the rates of pin and wire site infection in external fixator devices? External fixator devices (EFDs) have been widely used in the treatment of various limb deformities. Pin site infections have been the most commonly reported complication of EFDs with a reported incidence rate between 11 and 100%. With the increasing use of EFDs and potentially high pin site infection rates, it becomes imperative to document the pin site care and the rate of pin site infections across different surgical practices.

How did you answer the question?
We are conducting a prospective, observational, multicentre study to measure and document the pin site infection rate and pin site care across Canada, US and UK with the primary site being in Canada. The multicentre database collects data on pin/wire site infections including the type of EFD, EFD manufacturer, type of pin coating, total number of pins and wires, number of infection episodes, and pin site care.

What are the results?
An international MPSIS group has been established with 14 sites enrolled. Seven out of these 14 sites have ethics approval and data transfer agreements. At present, data is being collected on 98 EFDs at these 7 sites (9 surgeons). There is complete data on 77 EFDs at 6 sites. There are 64 total hexapod frames. A frames have 162 fully hydroxyapatite–coated pins, while B and C have 111 and 55 partially hydroxyapatite–coated pins, respectively. There are 8 total monolateral frames; 1 drive rail, 5 ALRS, and 1 Modular Rail System. There are 5 Ilizarov ring fixators. The primary site has complete data for 33 EFDs with 180 pins and 40 wires. Thirty EFDs are hexapod, including 26 A and 4 B and 1 Ilizarov. Two EFDs are monolateral. The average number of pin site and wire site infection episodes per EFD is 2.48 and 0.70 respectively. Nine of these EFDs have foot rings with an average of 0.67 foot infection episodes. The primary cleaning solution is water (sterile or non–sterile). The cleaning frequency is predominantly weekly. Pin/wire site dressing is Mepilex Ag. The primary medication used to treat pin and wire site infections is Cephalexin (QID).

What are your conclusions?
We report the interim results of the multicentre pin site infection study. The primary site currently has the largest number of cases reported and as such the study design and data collection methods have been refined. As we continue to collect data and invite other limb reconstruction surgeons to participate, this study will provide important information for limb lengthening and reconstruction services across the world, as well as parents/primary caregivers of children in external fixation devices by identifying the factors contributing to the pin site infections.

Pin Site Care
Updates on an International Multicentre Study

Dr. Anthony Cooper FRCS, MBChB [1,2,3]
Abad J [1,4], Chhina H [1,2], MPSIS Study Group

1

Disclosures

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Background: MPSIS Group

- Site Recruitment: 2016 - Present
- International MPSIS Group: 14 sites enrolled across Canada, USA, and UK
  - Seven of the 14 sites (9 surgeons) are in the patient recruitment phase
  - The other 7 sites are in the ethics approval and data transfer agreement phase

3

JA1

Background: Recruitment to Date

Site	Total EFDs Enrolled	Total EFDs w/ Complete Data	Complete Data: Hexapods	Complete Data: Monolateral	Complete Data: Ring Fixators
BCCH	39	33	30	2	1
Site 2	13	8	8	0	0
Site 3	1	1	1	0	0
Site 4	12	8	7	0	1
Site 5	20	19	16	2	1
Site 6	11	8	2	4	2
Site 7	2	0	0	0	0
Total	**98**	**77**	**64**	**8**	**5**

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Background: Data Collection

- Multicentre pin site infection study (MPSIS) database was built on REDCap
- Each centre will document:
  - Demographics
  - EFD Details
  - Pin Details
  - Cleaning Methods
  - Medication
  - Infection Details
  - Details of Frame Removal

Data Collection Instrument	Status
Demographics	
External Fixator Device	
Pin Details	
Cleaning Protocol	
Medication	
Hexapod Infection Details	
Monolateral Infection Details	
Ring Fixator Infection Details	
Foot Frame Infection Details	
Frame off	

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Results: Overall

- 7/14 sites have ethics approval
- 98 EFDs across these 7 sites (9 surgeons)

# of EFDs	# of Pins	# of Wires
77	408	113

- Complete data on 77 EFDs across 6 sites

# of EFDs w/ Foot Rings	# of Foot Pins	# of Foot Wires
17	10	73

Pin Site Infection Rate	18.38%
Wire Site Infection Rate	18.58%
Avg. # of Pin Site Infection Episodes per EFD	1.55
Avg. # of Wire Site Infection Episodes per EFD	0.62
Foot Pin Infection Rate	0%
Foot Wire Infection Rate	10.96%
Avg. # of Foot Pin Infection Episodes per EFD	0
Avg. # of Foot Wire Infection Episodes per EFD	0.52

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Slide 4

JA1 Results presented in the abstract: 1) Total EFDs, 2) Breakdown by Frame Type, 3) # of HA coated pins for hexapods.
Jero Abad, 6/29/2020

Results: Primary Site (BCCH)

# of EFDs	# of Pins	# of Wires
33	180	40

# of EFDs w/ Foot Rings	# of Foot Pins	# of Foot Wires
9	1	37

Pin Site Infection Rate	**24.70%**
Wire Site Infection Rate	31.30%
Avg. # of Pin Infection Episodes per EFD	2.48
Avg. # of Wire Infection Episodes per EFD	0.70
Foot Pin Infection Rate	0%
Foot Wire Infection Rate	13.50%
Avg. # of Pin Site Infection Episodes per EFD	0
Avg. # of Wire Site Infection Episodes per EFD	0.67

7

Challenges and Improvements

- **Missed reporting of pin site infections**
  - Dedicated research assistant assigned to the study
  - In-clinic data collection checklist
  - Pin site reporting contact cards
  - Phone call check-ins once a month
  - Verification of prescription filling
- **Incomplete and unverified data**
  - Monthly data quality checks
  - Data quality reports discussed with individual sites
- **Wire Tracking**
  - Defined wire nomenclature
  - Reference Model implemented in database and manual

8

Next Steps

- Continue regular communication with MPSIS Study Group to improve data quality
  - Use input to improve study design and data collection methods as necessary
- Enroll additional centres
- Interested centres please contact externalfixators@cw.bc.ca

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The Effect of Silver–Plated Dressing on Pin Site Complication in Patients Undergoing Limb Lengthening and Deformity Correction using a Circular Frame

Elaine Tran, MD, Alexander Cherkashin, MD, David Podeszwa, MD, Mikhail Samchukov, MD
etran739@gmail.com

What was the question?
Pin site infections are the most common complication of external fixation with reports ranging from 20 to 100% in trauma patients, and reported rates of 42% in children undergoing limb deformity correction with use of the Ilizarov Technique. Pin sites are susceptible to infection due to the broken skin barrier that is created by the pin. Furthermore, excess skin tension may result in increased inflammation, and altered wound healing. Silver is recognized for its antimicrobial effects due to its ionizing capabilities. Studies comparing dry sterile dressings to 1% silver sulfadiazine impregnated dressings for external fixator pin sites have shown a significant decrease in pin tract infection in the study cohort. The purpose of this study was to look at the rate of pin site infections associated with the use of a new silver–plated dressing in pediatric patients undergoing limb lengthening and deformity correction using a circular frame, and to compare this to rates of pin site infections reported in the literature.

How did you answer the question?
A retrospective analysis of patients undergoing limb lengthening and deformity correction using a circular frame, was performed at a single pediatric orthopedic institution over a 14–month period from May 2018 to June 2019. Patients had once–weekly pin–site dressing changes with a sterile, multi–layer, non–adherent silver–plated wound pad dressing (Silverlon catheter dressings by Argentum Medical, Geneva, IL). Demographic data including age at the time of surgery, sex, BMI, and underlying diagnosis was collected. Surgical factors such as number of wires and half pins, number of limb segments spanned, and duration of frame treatment were also retrospectively collected. Pin site infection was defined by documentation of pin site drainage with or without erythema and or purulence, and associated treatment with oral antibiotics. Lastly, the number of pins removed due to a pin site infection was recorded.

What are the results?
There were 23 patients with 24 limbs that were included in this study. 13 patients were female, and 10 were male. The underlying diagnosis was congenital, acquired, or the sequelae of an infection in 4, 17, and 3 patients respectively. Diagnoses included fibular hemimelia, congenital pseudoarthrosis of the tibia, recurrent clubfoot, infantile Blount's, linear scleroderma, partial growth arrest following a physeal injury, chronic osteomyelitis, and others. The average age at time of frame application was 12.2 years (range 18 months to 18.7 years). The average BMI at time of frame application was 27.8 kg/m2 (range 13.9 kg/m2 to 72.5 kg/m2). The frame spanned 1 limb segment in 15 patients and 16 limbs, and 2 segments in 8 patients. Average time in the frame and number of procedures was 3.8 months (range 2 to 9 months) and 2.5 (range 2 to 5) respectively. The average number of wires and half pins was 2.6 and 3.5 per frame respectively. The total number of pin sites was 211 in this cohort. There were 43 pin site infections, while included multiple recurrent infections. There was a 20.4% pin site infection rate. Patients with a BMI greater than 30 kg/m2 had a 38.2% rate of pin site infections versus 14.1% in patients with a BMI less than 30 kg/m2. Two patients had a total of 3 pins removed for infection.

What are your conclusions?
In our cohort of 24 limbs, 20.4% of pins sites were complicated by an infection requiring oral antibiotic treatment, and 1.4% of pins required removal in the operating room. This rate is lower than what has been previously reported in the literature. Also, patients with a BMI greater than 30 kg/m2 had an elevated rate of pin site infections. Difficulty with defining a true pin site infection may have overestimated the number of true infections. In conclusion, the once weekly Silverlon dressing may be a good alternative to more cumbersome daily dressing changes, as it is simple for patients and families, and is effective in reducing the rate of pin site infections.

The Effect of Silver-Plated Dressings on Pin Site Complications in Patients Undergoing Limb Lengthening and Deformity Correction using a Circular Frame

Elaine Tran, MD, David Podeszwa, MD,
Mikhail Samchukov, MD, Alexander Cherkashin, MD

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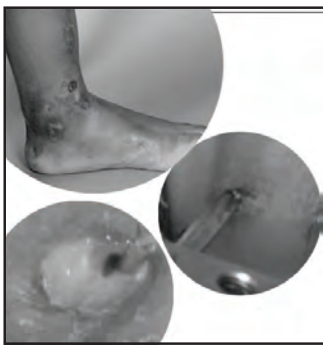
Author(s) have something to disclose:

Consultant Orthofix, Inc

Royalties through Texas Scottish Rite Hospital for TrueLok Circular Fixation system

2



Introduction

- Pin site infections are the most common complication of external fixation
  - Trauma: 20 to 100%
  - Pediatric Limb deformity: 42%
- Pin site infection
  - Broken skin barrier
  - Excess skin tension

3

Introduction

- Silver is recognized for its antimicrobial effects due to its ionizing capabilities.
- Studies comparing dry sterile dressings to 1% silver sulfadiazine impregnated dressings for external fixator pin sites have shown a significant decrease in pin tract infection.

4

Hypothesis

- The purpose of this study was to look at the rate of pin site infections associated with the use of a new silver-plated dressing in pediatric patients undergoing limb lengthening and deformity correction using a circular frame, and to compare this to rates of pin site infections reported in the literature.
- Our hypothesis was that the use of the silver-plated dressing would result in lower pin site infection rates than what has been reported in the literature

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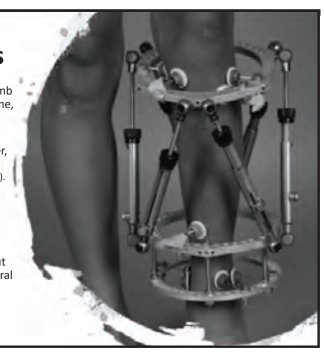
Materials and Methods

- A retrospective analysis of patients undergoing limb lengthening and deformity correction using a frame, at a single pediatric orthopedic institution was performed over a 14-month period
- Weekly dressing changes with a sterile, multi-layer, non-adherent silver-plated wound pad dressing (Silverlon catheter dressings by Argentum Medical, Geneva, IL).
- Demographics: age, sex, BMI, and underlying diagnosis
- Surgical factors: # of wires and half pins, # limb segments, duration of treatment
- Pin site infection: pin site drainage with or without erythema and or purulence and treatment with oral antibiotics.
- # of pins removed due an infection was recorded.



6

Results

- 23 patients with 24 limbs
  - Female: 13, Male: 10
  - Congenital: 4, Acquired: 17, Infection: 3
- Age: 12.2 years (range 18 months to 18.7 years)
- BMI: 27.8 kg/m^2 (range 13.9 kg/m^2 to 72.5 kg/m^2)
- Segments spanned: 1 segment: 15 pts; 2 segments: 8 pts
- Time in the frame: 3.8 months (range 2 to 9 months)
- \# of procedures: 2.5 (range 2 to 5)

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Results

- \# of wires: 2.6
- \# of half pins 3.5
- Total # of pin sites: 211
- Pin site infections: 43
  - 20.4% infection rate
    - BMI > 30 kg/m^2 : 38.2%
    - BMI < 30 kg/m^2 : 14.1%
- Pin removal
  - 2 patients, 3 pins

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Conclusion

- In our cohort of 24 limbs, 20.4% of pins sites were complicated by an infection requiring oral antibiotic treatment
- 1.4% of pins required removal in the operating room.
- This rate is lower than what has been previously reported in the literature.
- Patients with a BMI greater than 30 kg/m2 had an elevated rate of pin site infections.
- Difficulty with defining a true pin site infection may have overestimated the number of true infections.
- In conclusion, the once weekly Silverlon dressing may be a good alternative to more cumbersome daily dressing changes, as it is simple for patients and families, and is effective in reducing the rate of pin site infections.

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Thank You!

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12

Integrated Limb Lengthening is Superior to Classical Limb Lengthening: A Systematic Review and Meta–analysis of the Literature

Gerard A. Sheridan, Austin T. Fragomen, S. Robert Rozbruch
sheridga@tcd.ie

What was the question?
Limb lengthening has classically been performed with circular frames alone utilising the Ilizarov method. In more recent times, additional methods of stabilisation have been integrated with circular frames to improve time to union, reduce patient time in frame, reduce the risk of regenerate refracture and improve patient function. We systematically review studies comparing these two methods of limb lengthening to investigate whether integrated limb lengthening methods are superior to classical limb lengthening methods.

How did you answer the question?
After an initial analysis of 120 studies, 10 studies were deemed eligible for inclusion. Two studies reported on the lengthening and then nail (LATN) technique, 6 reported on lengthening over nail (LON) and 1 reported on lengthening and then plating (LATP). One study reported on all 3 methods. A total of 457 patients had classical limb lengthening while 488 underwent integrated limb lengthening.
The primary outcome measures were total length achieved (cm), external fixator index (EFI) (month/cm) and bone healing index (BHI) (month/cm). Problems, obstacles and sequelae as described by Paley et al. were compared using a random–effects meta–analysis of all available cases. The relative risk (RR) for the relevant outcome was calculated with 95% confidence intervals. The effects of small studies were analysed using a funnel plot and asymmetry was assessed using Egger's test. Kaplan–Meier curves were generated to compare the time spent in frame for both methods of limb lengthening. Deep infection rates were compared between the classical and integrated cohorts also.

What are the results?
Integrated methods of limb lengthening show a significantly superior EFI (p=0.0001) and BHI (p=0.0146) when compared with classical methods. The mean time spent in frame for integrated lengthening was significantly shorter at 16.3 weeks (SD=8.02, 95I 8.89–23.73) compared to 32.5 weeks in classical patients (SD=8.43, 95I 24.77–40.36) (p=0.0015). There were significantly fewer problems (p=0.000) and sequelae (p=0.001) with integrated lengthening. There was no significant difference in the frequency of obstacles encountered (p=0.621). Egger's test demonstrated no small study effects (p=0.829).Deep infections were more common in the integrated cohort. Within the integrated cohort, the LON group was the only group to report any deep infections. This LON deep infection rate was significantly higher than with the LATN and LATP techniques (p=0.005).

What are your conclusions?
For all outcome variables, all integrated methods of limb lengthening confer a significant advantage over classical limb lengthening methods. We suggest the integration of plates and nails with circular frames, while avoiding contact between the two structures, to improve outcomes in patients undergoing limb lengthening procedures.

Integrated Limb Lengthening is Superior to Classical Limb Lengthening: A Systematic Review and Meta-analysis of the Literature

Gerard A. Sheridan, Austin T. Fragomen, S. Robert Rozbruch

Limb Lengthening and Complex Reconstruction Service, Hospital for Special Surgery, New York, NY, USA

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Disclosures

Gerard A. Sheridan

None

Austin T. Fragomen

Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant; Paid presenter or speaker
Smith & Nephew: Paid consultant; Paid presenter or speaker
Synthes: Paid consultant; Paid presenter or speaker

S. Robert Rozbruch

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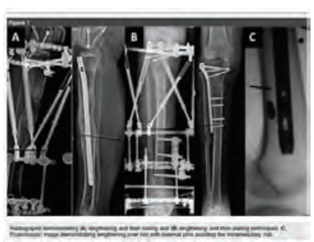
Background

- In 1905, Professor Codivilla began an investigation into the lengthening of bone to treat deformity and malunion (1)
- External fixation alone has since become the gold standard for providing stability with the 'classical method' or 'Ilizarov method'
- <u>Disadvantages - pin tract infections, skin pain, soft-tissue tethering, and joint stiffness</u>

- **Integrated fixation techniques combining internal and external fixation such as:**

A. ***lengthening and then nailing (LATN)***
B. ***lengthening and then plating (LATP)***
C. ***lengthening over a nail (LON)***



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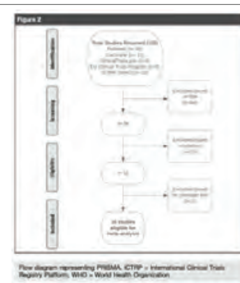
Methods



- Included only comparative studies of classical limb lengthening vs integrated limb lengthening

- *<u>Minimum dataset:</u>*
- External fixation index (EFI) (month/cm)
- Bone healing index (BHI) (month/cm)
- Total lengthening (cm)
- Total time in frame (weeks)
- All-cause revision details

- The PRISMA guidelines were adhered to throughout this study (8)

4

Methods

<u>MeSH terms:</u>

- 'limb lengthening', 'Ilizarov', 'lengthening and then nail', 'LATN', 'lengthening over nail', 'LON', 'lengthening and then plate', 'LATP', 'external fixator index', 'bone healing index'

<u>Sources:</u>

1. PubMed
2. Cochrane Library
3. ClinicalTrials.gov
4. EU clinical trials register
5. International Clinical Trials Registry Platform (World Health Organisation)

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Methods - Statistics

- **<u>Primary outcome measures:</u>**
1. Total length achieved (cm)
2. Time in frame (weeks)
3. All-cause revision
4. EFI (month/cm)
5. BHI (month/cm)

- Kaplan-Meier curves - time spent in frame (Two-sample T-test with equal variances used to detect a significant difference)

- Boxplot graphs to demonstrate the interquartile distributions of EFI and BHI (using a Two-sample T-test with equal variances)

- **<u>Secondary outcome measures:</u>**
- Problems, obstacles and sequelae (compared using a random-effects meta-analysis of all available cases)

- The contribution of potential inter-study heterogeneity analysed using the chi-squared test and the I^2 statistic
- To assess the funnel plot for statistically significant asymmetry, Egger's test for small-study effects was used (11)

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Results

457 limbs - classical techniques
488 limbs - integrated techniques

LON (n=317)
LATN (n=133)
LATP (n=38)

Minimum follow up from 9-29 months
Classical - 60% male
Integrated - 54.3% male

Lan et al. and Park et al. - exclusively for constitutional short stature (13, 15)

Bernstein et al. - exclusively for post-traumatic bone loss (21)

The 7 other studies all had combinations of congenital, developmental and post-traumatic indications for limb lengthening

Table 1

Minimum Data Set

Study	Journal	Total Classic Limbs	Total Integrated Limbs	Integration Technique	Minimum Follow-up (months)
Rozbruch et al[12]	*Clinical Orthopaedics and Related Research*	34	39	LATN	11.4
Lan et al[13]	*International Orthopaedics*	88	78	LATN	12
Paley et al[14]	*The Journal of Bone and Joint Surgery (Am)*	32	32	LON	24
Park et al[15]	*The Journal of Bone and Joint Surgery (Am)*	32	56	LON	29
Sun et al[16]	*The Journal of Bone and Joint Surgery (Br)*	146	140	LON	14.9
Guo et al[17]	*International Orthopaedics*	23	51	LON	22
El-Husseini et al[18]	*Strategies in Trauma and Limb Reconstruction*	16	15	LON	12
Burghardt et al[19]	*Bone and Joint Research*	19	19	LON	9
Harbacheuski et al[20]	*Clinical Orthopaedics and Related Research*	27	27	LATP	25
Bernstein et al[21]	*Clinical Orthopaedics and Related Research*	30	28	1 LON 16 LATN 11 LATP	12

Continued

BHI = bone healing index, EFI = external fixation index, LATN = lengthening and then nailing, LATP = lengthening and then plating, LON = lengthening over nail

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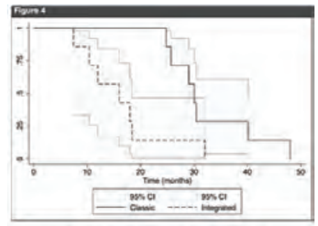
Results

Mean time spent in frame

- Classical group - 32.6 weeks (σ=8.43, 95% CI 24.7-40.3)
- Integrated group - 16.3 weeks (σ=8.02, 95% CI 8.9-23.7)
- (p=0.0015)



Time in frame (weeks) (Kaplan-Meier curve). CI = confidence interval

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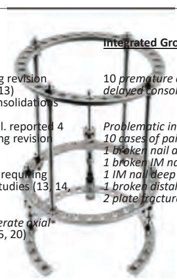
Results – All-cause revision



Classical Group:

1. *Delayed consolidation*
Lan et al. reported 6 cases needing revision surgery with iliac crest autograft (13)
Paley et al. reported 5 delayed consolidations requiring revision (14)
Park et al. reported 5 and Sun et al. reported 4 delayed consolidations, all requiring revision surgery (15, 16)

2. Ten *premature consolidations* requiring revision surgery were noted in 3 studies (13, 14, 16)

3. There were 11 cases of *regenerate axial deviation* requiring revision (14, 15, 20)

Integrated Group:

10 *premature consolidations* (14, 15) and 12 *delayed consolidations* (16)

Problematic internal hardware (n=18):
10 cases of painful hardware (12)
1 broken nail and prominent locking screw (14)
1 broken IM nail (17)
1 IM nail deep infection (18)
1 broken distal screw and 1 loose screw (19)
2 plate fractures

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Results – External Fixation Index

Table 1 (continued)

Minimum Data Set

Study	Mean Age (Classic: Integrated)	Length Achieved (Classic: Integrated)	Classic EFI (months/cm)	Integrated EFI (months/cm)	Classic BHI (months/cm)	Integrated BHI (months/cm)
Rozbruch et al[12]	30: 35	3.9 cm: 5.4 cm	1.9	0.5	1.9	0.8
Lan et al[13]	25.7: 26.8	9.3 cm: 8.5 cm	2.5	0.7	2.53	1.44
Paley et al[14]	25: 26	5.2 cm: 5.8 cm	1.7	0.7	1.7	1.4
Park et al[15]	23.4: 22.3	5.9 cm: 6.4 cm	2.2	0.5	2.1	1.7
Sun et al[16]	21.2: 23	7 cm: 7.95 cm	1.3	1.1	1.8	1.5
Guo et al[17]	22.7: 25.4	7.2 cm: 7.4 cm	1.3	0.58	1.35	1.36
El-Husseini et al[18]	28.4: 31.3	4.98 cm: 4 cm	1.2	0.4	1.2	1.4
Burghardt et al[19]	27: 27	4.8 cm: 5.2 cm	2.3	0.7	2.3	1.4
Harbacheuski et al[20]	41.1: 41.3	3.5 cm: 3.6 cm	2	1.3	2.2	2.1
Bernstein et al[21]	43: 48	5.3 cm: 4.4 cm	2.5	2	—	—

BHI = bone healing index, EFI = external fixation index, LATN = lengthening and then nailing, LATP = lengthening and then plating, LON = lengthening over nail

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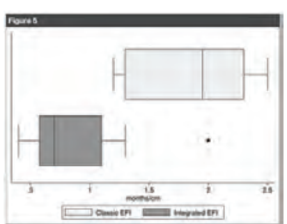
Results

- *External Fixator Index*
- Integrated cohort - 0.88 months/cm (σ=0.476, 95% CI 0.547-1.22)
- Classical cohort - 1.89 months/cm (σ=0.497, 95% CI 1.53-2.25)
- (p=0.0001)



Box plots illustrating classic and integrated external fixation index (EFI) values.

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Results – Bone Healing Index

Table 1 (continued)

Minimum Data Set

Study	Mean Age (Classic: Integrated)	Length Achieved (Classic: Integrated)	Classic EFI (months/cm)	Integrated EFI (months/cm)	Classic BHI (months/cm)	Integrated BHI (months/cm)
Rozbruch et al[12]	30: 35	3.9 cm: 5.4 cm	1.9	0.5	1.9	0.8
Lan et al[13]	25.7: 26.8	9.3 cm: 8.5 cm	2.5	0.7	2.53	1.44
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Sun et al[16]	21.2: 23	7 cm: 7.95 cm	1.3	1.1	1.8	1.5
Guo et al[17]	22.7: 25.4	7.2 cm: 7.4 cm	1.3	0.58	1.35	1.36
El-Husseini et al[18]	28.4: 31.3	4.98 cm: 4 cm	1.2	0.4	1.2	1.4
Burghardt et al[19]	27: 27	4.8 cm: 5.2 cm	2.3	0.7	2.3	1.4
Harbacheuski et al[20]	41.1: 41.3	3.5 cm: 3.6 cm	2	1.3	2.2	2.1
Bernstein et al[21]	43: 48	5.3 cm: 4.4 cm	2.5	2	—	—

BHI = bone healing index, EFI = external fixation index, LATN = lengthening and then nailing, LATP = lengthening and then plating, LON = lengthening over nail

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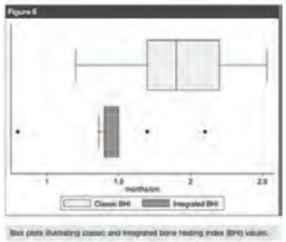
Results

- *Bone Healing Index*
- Integrated cohort - 1.45 months/cm (σ=0.340, 95% CI 1.194-1.716)
- Classical cohort - 1.90 months/cm (σ=0.437, 95% CI 1.56-2.23)
- (p=0.0146)



Box plots illustrating classic and integrated bone healing index (BHI) values.

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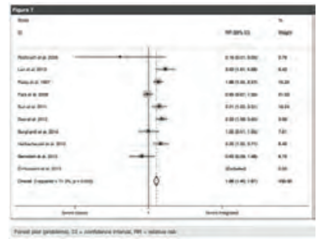
Results - Problems

- Random-effects meta-analysis analysing 'problems'
- Higher relative risk of problems with classical lengthening techniques
- (RR=1.66, 95% CI 1.40-1.97, p=0.000)



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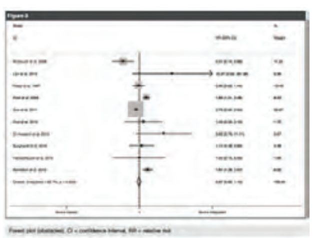
Results - Obstacles

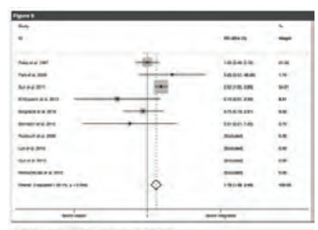
- Random-effects meta-analysis analysing 'obstacles'
- No difference
- (RR=0.97, 95% CI 0.85-1.10, p=0.621)



15

Results - Sequelae

- A random-effects meta-analysis analysing 'sequelae'
- Higher relative risk of sequelae with classical lengthening techniques
- (RR=1.79, 95% CI 1.28-2.49, p=0.001)



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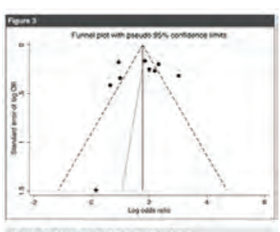
Limitations

- Included retrospective comparative cohort studies
- Missing data was a minor issue with a number of studies
- There was limited data available regarding objective joint range of motion and subjective patient-reported functional outcome measures (these outcomes could not be included in the final results)
- Funnel plots and Egger's test were used to confirm the absence of any bias due to small-study effects



Funnel plot diagram illustrating no small study effects.

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Conclusion

- For all outcome variables, integrated methods of limb lengthening confer a significant advantage over classical limb lengthening methods
- Radiographic outcomes, time to union and time in frame were all improved
- The incidence of complications was also reduced significantly in the integrated group
- This was true on subgroup analysis for all techniques including LATN, LON and LATP techniques
- We suggest the integration of plates and nails with circular frames to improve outcomes in patients requiring limb lengthening procedures

LLRS Limb Lengthening and Reconstruction Society

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Correction of Tetratorsional Malalignment Improves Patient Reported Outcomes

Taylor J. Reif, Nathan Khabyeh–Hasbani, S. Robert Rozbruch, Austin T. Fragomen, Tom Jonggu Shin
reift@hss.edu

What was the question?
When patients present with axial malalignment of the bilateral femurs and tibias, so called 'miserable' malalignment now renamed tetratorsional malalignment (TTM), does correction of the axial plane deformity improve patient reported outcomes?

How did you answer the question?
A retrospective review of patient charts was performed identifying patients who underwent rotational correction of the bilateral femur and tibias. Computerized tomography (CT) was used to measure the preoperative rotational profile and plan the surgical correction. The primary outcome measure was the Limb Deformity – modified Scoliosis Research Society (LDSRS) score, a validated patient reported outcome measure. The degree of correction, union rate, change in joint orientation angles, MAD, and complications of the procedures were also evaluated.

What are the results?
Thirteen patients (10 female, 3 male) with average age of 23.5 years old (7.0 SD) were identified. The average femoral deformity was 19.0 deg (10.0 SD, range 4–37) and the average correction was 25.0 deg (6.2 SD). The average tibial deformity was 21.7 (8.1 SD, range 10–40) with average correction of 21.5 (5.3 SD). The average total LDSRS score significantly improved from 3.50 (0.61 SD) to 4.34 (0.48 SD) ($p = 0.003$). The LDSRS sub–scores for Pain and Self–image also significantly improved, while functional improvement was very close to significant ($p=0.065$). In patients not undergoing concurrent coronal deformity correction (n=8/13), the LDFA, MPTA, and MAD were not significantly different. There were no additional procedures performed to obtain bone union. Three patients required subsequent peroneal nerve decompression following the index procedure, and all neurologic symptoms resolved.

What are your conclusions?
Correction of tetratorsional malalignment leads to patient reported improvements in function, pain and self–image. There were minimal complications and no iatrogenic deformity associated with the procedures. The new name, TTM, is descriptive of this debilitating condition and does not communicate a negative patient image. The name change was felt to be an important leadership action in line with current psychosocial culture.

LDSRS Score	Average Preoperative Score (Std Dev)	Average Postoperative Score (Std Dev)	P value
Total	3.5 (0.61)	4.4 (0.46)	**0.003**
Function	3.5 (0.85)	4.5 (0.75)	0.065
Pain	3.3 (1.0)	4.5 (0.61)	**0.03**
Self Image	3.2 (0.57)	4.27 (0.74)	**0.016**
Mental Health	4.0 (0.82)	4.3 (0.66)	0.55

Table 1: Preoperative and Postoperative (> 6 months) Limb Deformity-Scoliosis Research Society scores (1 minimum, 5 maximum)

Correction of Tetratorsional Malalignment Improves Patient Reported Outcomes

Taylor Reif M.D., Nathan Hasbani B.S., Tom Jonggu Shin M.D.,
S. Robert Rozbruch M.D., Austin T. Fragomen M.D.

Limb Lengthening and Complex Reconstruction Service

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Disclosures

- I have no disclosures related to this work

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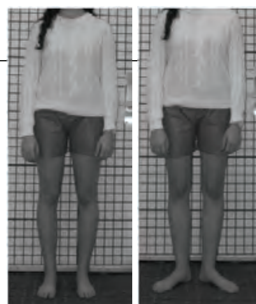
Tetratorsional Malalignment

- Previously known as "Miserable Malalignment"
  - Lacks diagnostic information
  - Promotes negative self image by labeling "miserable"
  - Unfitting of current psychosocial medical culture
- Classically-
  - Excessive anteversion of femur
  - Excessive external torsion of tibia
- Other rotational profiles possible but less common



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Tetratorsional Malalignment

- To maintain foot progression angle of 0 knees internally rotate
  - Squinting patella on gait exam
- Present with hip and knee pain
  - Muscular compensation
  - Worse with activity/fatigue
- Surgically corrected with rotational osteotomy

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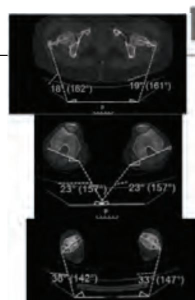
Tetratorsional Malalignment

- Hypothesis
  - Patients who undergo rotational correction of bilateral femur and tibia will experience improvement in limb deformity outcomes measures
- Methods
  - Retrospective review
  - CT used to measure preoperative rotational profile and plan correction
  - Limb Deformity modified Scoliosis Research Society (LDSRS) score obtained preoperatively and 1 year after final correction
    - Validated Patient Reported Outcome measure



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Tetratorsional Malalignment

- Results
  - 10F and 3M patients, age 23.5 (7.0 SD)

	Femur	Tibia
Anteversion/ External Rotation (range)	**39.00°** (25 – 57)	**51.7°** (40 – 70)
Ave Deformity (Std dev)	**24.00°** (10.0)	**21.7°** (8.1)
Ave Correction (Std dev)	**25.03°** (6.2)	**21.5°** (5.3)

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Tetratorational Malalignment

- Main Outcome Measure:

LDSRS Score	Preop Score (SD)	Postop Score (SD)	p value
Total	3.50 (0.6)	4.49 (0.3)	**<0.001**
Function	3.54 (0.9)	4.55 (0.4)	**0.005**
Pain	3.34 (1.0)	4.5 (0.4)	**0.005**
Self Image	3.21 (0.6)	4.26 (0.5)	**<0.001**
Mental Health	4.04 (0.8)	4.44 (0.6)	0.26

- All domains except mental health significantly improved

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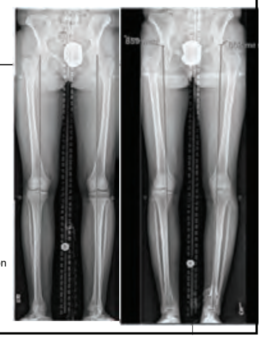
Tetratorsional Malalignment

- Other results:
  - Prophylactic peroneal nerve decompression – 4 / 13
  - Fibular osteotomy – 6 / 13
  - Bone Union 100%
- Complications
  - 3 patients required peroneal nerve decompression after index procedure (15º, 20º, 25º correction)
  - Neurologic symptoms resolved in all cases without permanent deficit
- In patients not undergoing concurrent coronal plane correction (8/13) no change in MAD, LDFA, MPTA



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Tetratorsional Malalignment

- Discussion
  - Clinically significant improvement in patient reported:
    - Pain
    - Function
    - Self Image
  - Minimal complications
- Limitations
  - Limited cohort
  - Rotational correction of 1-3 segments not examined
- New diagnostic moniker
  - Better description of condition
  - More medically and culturally appropriate than labeling patients "miserable"

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Thank You

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Epidural Anesthesia May Increase Opioid Consumption in Adult Gradual Correction Patients

John E. Herzenberg, Wayne A. Wilkie, Nequesha S. Mohamed, Philip K. McClure
jherzenb@lifebridgehealth.org

What was the question?
Gradual deformity correction is often the optimal choice for large limb deformities. Common anesthetic options include general anesthesia, peripheral nerve blocks, and epidural anesthesia. The current study evaluated the 1) demographics and 2) immediate outcomes of adult patients undergoing gradual limb correction utilizing general, nerve block, or epidural anesthesia. Based on previous experience in pediatrics, we hypothesize that epidural anesthesia will present worse overall in–hospital outcomes compared to the other modalities.

How did you answer the question?
Adults who underwent a gradual correction procedure between 2014 and 2018 were identified through retrospective review (n=33). Further stratification based upon anesthesia was applied: general (n=18); nerve block (n=11); epidural (n=4). Demographic data included age, race, sex, American Society of Anesthesiologists (ASA) physical status class, and body mass index (BMI). Outcome data included length of surgery, length of stay (LOS), eight–hour visual analog pain scale scores, pain intensity, total daily opioid consumption, and complications. Categorical variables were assessed with chi–square while continuous variables were assessed with one–way analysis of variance.

What are the results?
Age, sex, race, ASA score and BMI did not vary significantly among the groups. Analyses did not demonstrate any significant differences in length of surgery (p=0.157), LOS (2.56 vs. 1.36 vs. 2.75 days, p=0.295) VAS scores (all p>0.05), and 24–hour (p=0.460) and 48–hour pain intensity (p=0.762) between the groups. Epidural patients did consume significantly more opioids on postoperative day 0 (285.87 vs. 109.75 vs. 948.95, p=0.009) and 1 (151.47 vs. 37.91 vs. 784.38, p=0.009) in comparison to general and nerve block patients.

What are your conclusions?
Although sample sizes were small, our study suggests that patients undergoing gradual limb correction with epidural anesthesia may consume more opioids than those utilizing general or nerve block anesthesia. Further investigation into the optimal anesthetic is warranted to advise patients in the setting of the national opioid epidemic.

Epidural Anesthesia May Increase Opioid Consumption in Adult Gradual Correction Patients

Nequesha S. Mohamed, MD, Wayne A. Wilkie, DO, Ethan A. Remily, DO, Sahir S. Pervaiz, MD, Scott J. Douglas, MD, Nancy Campbell, DO, Noelle C. DiGioia, DO, Philip K. McClure, MD, and John E. Herzenberg, MD

Sinai Hospital, Baltimore, Maryland
International Center for Limb Lengthening
Rubin Institute for Advanced Orthopedics

SINAI HOSPITAL

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Disclosures

- I (and/or my co-authors) have something to disclose
- John Herzenberg, MD: Consultant: Smith + Nephew , OrthoPediatrics, NuVasive, Orthofix, Wishbone, OrthoSpin, Bonus BioGroup.
- Philip McClure, MD: Smith + Nephew (teaching consultant), Orthofix (teaching consultant), Novadip (consultant)

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Gradual Limb Lengthening

- A reliable method to treat congenital and acquired limb deformities/LLD
- Consists of gradually distracting the callus that is formed after the initial subperiosteal osteotomy
- Can be performed in various long bones throughout the body
  - Tibia, femur, humerus, forearm

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Gradual Limb Lengthening Methods

- Intramedullary lengthening nails & external fixation
  - The former has become the preferred method in recent years
    - Increased ROM, decreased pain, and decreased complication rates
- We've optimized limb lengthening from a fixation standpoint
  - **Are there other ways we can further reduce pain levels and complication rates?**

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Anesthesia and Limb Lengthening

- One facet of limb lengthening that has not been explored
- Options: general anesthesia (GA), peripheral nerve blocks (PNB), and/or epidural anesthesia (EA)
- Success has been noted with all of these methods
  - However, the most efficacious method remains unknown

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Objectives

- This study explored demographics and outcomes in adult limb lengthening patients undergoing their procedure with either general anesthesia, peripheral nerve blocks, or epidural anesthesia

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Methods

- Patients undergoing limb lengthening procedures were reviewed from 2014-2018 at a single institution
- Patients must have been older than 18 and underwent gradual correction
- Resulted in three cohorts:
  - GA (n=18)
  - PNB (n=11)
  - EA (n=4)

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Methods

- **Demographics**
  - Age (years)
  - Sex
  - Race
  - American Society of Anesthesiology (ASA) Class
  - Mean Body Mass Index (BMI)

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Methods

- **Outcomes**
  - Length of surgery (minutes)
  - Length of stay (days)
  - Mean visual analog scale scores
  - Pain Intensity (Area-Under-Curve)
  - Total Opioid Consumption
    - In morphine milliequivalents (MMEs)
    - Broken down by day
  - Complications
    - Yes/No

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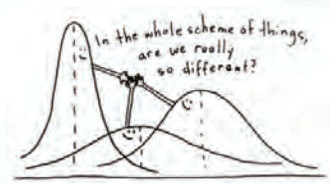
Methods

- **Statistical Analyses**
  - Chi-square: categorical
  - ANOVA: continuous
- Significance
  - $p<0.05$
- Software
  - SPSS v.25



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Results - Demographics

- Age, sex, race, ASA, and BMI were not significantly different among groups ($p>0.05$)

Parameter (N) (%)	GA	PNB	RA	p-value
Number of Patients	18	11	4	
Mean Age (years) (SD)	35.74 (14.12)	35.52 (15.72)	43.87 (14.18)	0.582
Sex				0.728
Male	12 (66.7%)	6 (54.5%)	2 (50.0%)	
Female	6 (33.3%)	5 (45.5%)	2 (50.0%)	
Race				0.977
White	9 (50.0%)	5 (45.5%)	2 (50.0%)	
Black	6 (33.3%)	4 (36.4%)	1 (25.0%)	
Asian	2 (11.1%)	1 (9.1%)	1 (25.0%)	
Other	1 (5.6%)	1 (9.1%)	0 (0.0%)	
ASA Class				0.185
1	2 (11.1%)	5 (45.5%)	1 (25.0%)	
2	13 (72.2%)	6 (54.5%)	3 (75.0%)	
3	3 (16.7%)	0 (0.0%)	0 (0.0%)	
Mean BMI (kg/m^2) (SD)	31.21 (9.80)	29.90 (5.55)	31.50 (8.38)	0.907

SD: Standard Deviation; ASA: American Society of Anesthesiologists; BMI: Body Mass Index

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Results - Outcomes

- Length of surgery, length of stay, postoperative VAS scores, pain intensity were all non-significantly different ($p>0.05$)
- **Opioid consumption on postoperative days 0 and 1, as well as complication rates were significantly different ($p<0.03$)**

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Results - Outcomes

Parameter (N) (SD)	GA	PNB	EA	p-value
Mean Length of Surgery (min)	335.73 (115.82)	237.43 (104.25)	293.75 (67.64)	0.157
Mean Length of Stay (days)	2.56 (1.38)	1.36 (3.14)	2.75 (0.50)	0.295
Mean VAS Score				
Preoperative	1.13 (2.55)	1.00 (1.73)	1.75 (3.50)	0.866
8-Hour	3.41 (2.90)	2.46 (2.70)	2.50 (2.38)	0.635
16-Hour	4.06 (2.72)	1.73 (2.20)	3.25 (2.22)	0.074
24-Hour	4.31 (2.94)	3.18 (1.72)	4.00 (2.94)	0.537
32-Hour	4.63 (2.42)	2.60 (2.59)	3.25 (0.96)	0.113
40-Hour	4.53 (2.00)	3.73 (2.94)	3.50 (1.29)	0.594
48-Hour	3.07 (1.87)	4.22 (2.59)	5.00 (2.45)	0.226
Pain Intensity (AUC)				
24-Hour	85.33 (60.68)	58.91 (44.15)	78.00 (52.41)	0.460
48-Hour	83.56 (43.23)	76.36 (41.63)	94.00 (34.79)	0.762
Total Opioid Consumption (MME)				
Postoperative Day 0	285.87 (345.83)	109.75 (196.50)	948.95 (1045.05)	**0.009**
Postoperative Day 1	151.47 (310.55)	37.91 (27.65)	784.38 (982.68)	**0.009**
Postoperative Day 2	60.30 (83.97)	46.36 (28.03)	75.63 (84.42)	0.755
Complications (%)				**0.029**
Yes	6 (33.3%)	3 (27.3%)	4 (100.0%)	
No	12 (66.7%)	8 (72.7%)	0 (0.0%)	

SD: Standard Deviation

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Limitations

- **Sample Size**
  - This niche surgery makes analyzing large sample sizes difficult
- **Single Institution**
  - Data may lack generalizability
- **Retrospective Design**
  - Lacks randomization, and standardization of anesthetic administration among groups

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Conclusions

- Epidural anesthesia appears to be related to increased postoperative opioid consumption
- This increased opioid consumption may have an effect on complication rates
- Further investigations with more patients are needed to fully elucidate the effect of anesthesia on limb lengthening patients

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Thank You

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Accuracy and Safety of Distal Femoral Valgus Correction: Comparison of Three Techniques

Christopher Iobst, Mohammed Waseemuddin, Anirejouritse Bafor, Molly Duncan, Satbir Singh
christopher.iobst@nationwidechildrens.org

What was the question?
For skeletally mature patients with distal femoral valgus deformity, there are several options for correcting the alignment without using an external fixator as definitive management. Three of the most commonly used techniques are: fixator–assisted plating, fixator–assisted nailing, and reverse planning. Which of these three methods is the most accurate and produces the least number of complications?

How did you answer the question?
After obtaining IRB approval, a retrospective review of a single surgeon's experience correcting distal femoral valgus deformity was performed. Between March 2017 and February 2020, 27 limbs in 24 skeletally mature patients with distal femoral valgus deformities underwent correction. Nine limbs in 8 patients had correction using the reverse planning method, 12 limbs in 12 patients had fixator assisted nailing while 6 limbs (4 patients) had fixator assisted locked plating. In the reverse planning group of patients, 5 limbs underwent correction only, while 4 had correction and lengthening. In the FAN group, 10 patients had correction and lengthening, while 2 had correction only.
For summary of statistics, see Table 1.
The chart review included: pre–operative and final post–operative measurement of the mechanical lateral distal femoral angle (mLDFA), surgical time, range of motion (ROM), and any associated complications.
Statistical analysis: The Excel statistical package was used for analysis. The student's t–test and Single factor ANOVA were used where indicated, to compare means with significance level set at a confidence level of 95% and p–value <0.05.

What are the results?
The mean pre–operative and post–operative mLDFA in the reverse planning group was 80.1o and 87.9o (p < 0.0001). In the FAN group the values were 80o and 87.4o (p < 0.0001) while in the FALP group, the values were 82o and 88o (p < 0.001). With the exception of two patients in the FAN group, all patients had restoration of the mLDFA to within normal range of 85–90°. There was no statistically significant difference in the final mLDFA or surgical time between the groups (p = 0.7769 and p = 0.6375 respectively). There was no statistically significant difference in the final ROMs across the groups (p = 0.6593). (See Table 1) There were no post–operative infections in any group. There was one post–operative fracture in the fixator assisted group and all six of plates were eventually removed from the FAP group due to hardware discomfort.

What are your conclusions?
This review found no statistically significant difference in the accuracy of distal femoral valgus deformity correction between fixator–assisted plating, fixator–assisted nailing or the reverse planning method. There was also no difference in surgical time, range of motion, or risk of infection.
However, one patient from the FAN group required additional surgery due to a fracture through a fixator pin site, and all patients required plate removal for discomfort in the FAP group. The reverse planning method group did not require any additional surgeries. While all three techniques demonstrate excellent accuracy and outcomes, the reverse planning method appears to have less risk for return to surgery than the fixator–assisted techniques.

Table 1: Summary statistics

	Rev Planning (n=9)*	FAN (n=12)	FAP (n=6)**	P value
Age	16.4 ± 1.7 yrs	17.3 ± 5 yrs	15.7 ± 2.2 yrs	
Age range	14 – 18 years	12 – 32 years	13 – 18 years	
LDFA Pre-op	80.1 ± 3.6 degrees	80 ± 3.2 degrees	82 ± 1.1 degrees	0.3967
LDFA range pre-op	75 – 86 degrees	75 – 85 degrees	80 – 83 degrees	
LDFA Post-op	87.9 ± 1.4 degrees	87.4 ± 2.3 degrees	88 ± 1.7 degrees	0.7769
LDFA range post-op	86 – 90 degrees	83 – 92 degrees	86 – 90 degrees	
BMI	34.7 ± 20.9	29.4 ± 7.7	28.7 ± 3.2	0.5956
Duration of surgery	141.2 ± 35.5 mins	156.9 ± 38.9 mins	139.8 ± 62.4 mins	0.6375

*n=9 limbs in 8 patients

**n=6 limbs in 4 patients

Accuracy and Safety of Distal Femoral Valgus Correction: Comparison of Three Osteotomy Techniques

2020 LLRS Annual Scientific Meeting

Christopher Iobst, MD
Anirejuoritse Bafor, MD
Mohammed Waseemuddin, MD

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Disclosures

- Consultant: NuVasive, Orthofix
- Speaker's Bureau: Smith and Nephew

- I will not be discussing "off-label" or investigational uses for products or devices.

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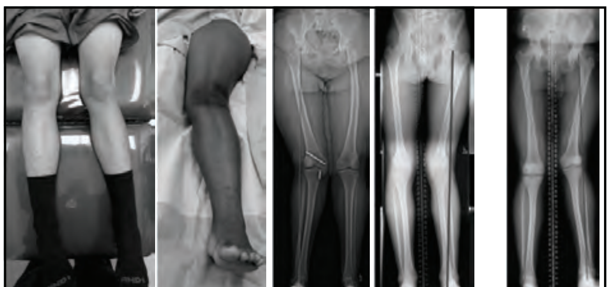

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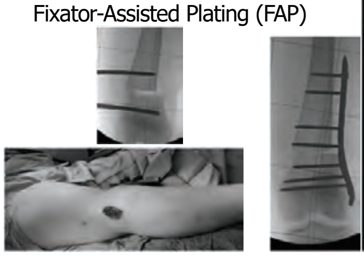
Fixator-Assisted Plating (FAP)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Fixator-Assisted Nailing (FAN)




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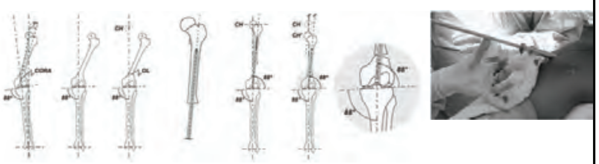
Reverse Planning Method



Baumgart R. The reverse planning method for lengthening of the lower limb using a straight intramedullary nail with or without deformity correction. A new method. *Oper Orthop Traumatol*. 2009;21:221–233

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Study Goals

- #1) Compare the accuracy of restoring the mechanical lateral distal femoral angle (mLDFA) of the three techniques in patients with distal femoral valgus deformity
- #2) Compare the operative time and the complication rate of the three techniques

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Methods

- Institutional review board approval
- Retrospective review of single surgeon between March 2017 and February 2020

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Methods

- Decision to perform either plating or intramedullary nailing was based on patient preference
- Fixator assisted plating was only offered to patients as an option if they did not require lengthening
- For intramedullary nail cases, fixator assisted nailing done consecutively until 2019, then reverse planning used in remaining cases

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Methods

- Data points:
  - Pre-operative and final post-operative mLDFA measured
  - Knee range of motion
  - Operative time
  - Body mass index (BMI)
  - Complications associated with the procedure

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Results

- 27 limbs with distal femoral valgus deformities underwent correction
  - 11 limbs FAN (10 correction and lengthening)
  - 10 limbs reverse planning method (4 correction and lengthening)
  - 6 limbs FAP

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Results

	Reverse Planning (n=10) *	FAN (n=11)	FAP (n=6)**	P value
Age	15.7 ± 2.2 years	16.4 ± 5 years	15 ± 2.4 years	
mLDFA Pre-op	80.6 ± 3.7 degrees	79.5 ± 2.9 degrees	82 ± 1.1 degrees	0.2897
mLDFA Post-op	88.3 ± 1.8 degrees	87.3 ± 1.3 degrees	88 ± 1.7 degrees	0.3440
BMI	34.4 ± 19.8	28.9 ± 8.4	28.7 ± 3.2	0.5832
Duration of surgery	113.2 ± 26.6 mins	150.6 ± 20 mins	110.7 ± 12.7 mins	0.0006
Range of Motion	117.4 ± 14.6 degrees	119.8 ± 18 degrees	115 ± 8.4 degrees	0.8190

*n=10 limbs in 9 patients
**n=6 limbs in 4 patients
FAN (fixator assisted nailing), FAP (fixator assisted plating), mLDFA (mechanical lateral distal femur angle), BMI (body mass index)

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Complications

- No infections in any group
- No delayed unions or non-unions in any group
- One patient in the reverse planning group had distal screw irritation

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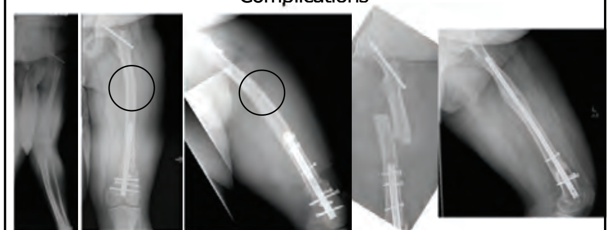
Complications



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Complications

- FAP group: all six plates removed after union per patient request due to localized hardware discomfort

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Discussion

- Each method accurately restores alignment
- No infections, delayed unions, or non-unions in any group
- No statistically significant difference in final knee ROM between the groups

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Discussion


Comparison of Fixator-assisted Plating versus Fixator-assisted Nailing for Distal Femoral Osteotomy
Journal of Limb Lengthening & Reconstruction | Volume 3 | Issue 1 | January-June 2017
Sherif Galal

Accuracy of Distal Femoral Valgus Deformity Correction: Fixator-Assisted Nailing vs Fixator-Assisted Locked Plating

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Discussion

- FAP/FAN utilize an intra-operative fixator as a tool to obtain the correction
- Reverse planning uses pre-operative illustration, rigid reamers, blocking screws

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Discussion

- Surgical time longest for FAN (p = 0.0006)
- Additional surgeries
  - FAP = 6
  - FAN = 1
  - Reverse planning method = 0

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Limitations

- Retrospective
- Non-randomized
- Small sample size
- No patient reported outcome measures
- Number of patients undergoing correction and lengthening not identical in the two nail groups

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Conclusion

- All three methods (FAN, FAP, and reverse planning) accurately correct distal femoral valgus deformity in skeletally mature patients
- Each method results in similar final knee range of motion and union rates

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Conclusion

- Reverse planning method had the best combination of surgical outcomes in this study:
  - Faster than the FAN technique
  - Allowed for both deformity correction and lengthening
  - Avoided the additional surgeries seen in the FAP and FAN patients

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Thank You For Your Attention

Questions or comments?
Contact me at:
christopher.iobst@nationwidechildrens.org

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Session 5: Internal Lengthening Nail

Nails for Femur Lengthening

Sherif Hassan, Tom Shin, Austin T. Fragomen, S. Robert Rozbruch
hassans@hss.edu

What was the question?

Femoral lengthening with internal lengthening nails (ILNs) has been used to avoid complications associated with external fixation. The A ILN has been in use since 2011 but had severe limitations (30–70 pounds) in post–operative weight bearing. The B ILN is the 3rd generation nail that allows 150– 250 pounds of post–operative weight bearing. The aim of this study is to compare the outcomes of using B vs. using C ILN for both unilateral and bilateral femoral lengthening.

How did you answer the question?

A single–center, retrospective cohort study was conducted in which patients records in the period from January 2017 to March 2020 were reviewed. A total of 76 femurs in 34 patients were included in the study, they were divided into 2 groups, B group (16 patients, 30 femora) and A group (18 patients, 36 femora).
Outcomes assessed were the 6–months Limb Deformity–Scoliosis Research Society (LD–SRS) Score, adjacent joints range of motion, average distraction rate, bone healing index (BHI), and complications.

What are the results?

The patients' age in the B group was 31 years (range, 17–65) and was 33 years (range, 19–54) in the A group. The lengthening in the B group was 7.1 cm (range, 4.1–8 cm) and was 6.8 cm (range, 4–8 cm) in the A group. The mean BHI was 0.84 months/cm (range, 0.53–1.5 months/cm) in the B group and was 0.67 months/cm (range, 0.44–1.2 months/cm) in the A group. The mean distraction rate for the B group was 0.67 mm/day (range 0.35–0.94) and was 0.86 mm/day (range 0.6–1) for the A group. For the B group, the mean pre–operative (LD–SRS) score group was 4 (range 3.2–4.8) and the mean 6–months (LD–SRS) score 4 (range, 3.5–4.9); For the A group the mean pre–operative LD–SRS score was 4 (range, 2.9–4.9) and the mean 1–year LD–SRS) score 4.4 (range, 3.8–4.8). For the B group, the mean Loss of hip ROM was 1.67° (range 0–30) and the mean Loss of knee ROM 1.78° (range, 0–10); For the A group there was no loss of hip ROM and the mean Loss of knee ROM 1.66° (range, 0–10). No patients in the B group had mechanical nail complications compared to 3 patients in the A group that had breakage & required exchange nailing. One patient in the A group needed BMAC injection compared to 4 patients in the B group.

What are your conclusions?

The B ILN yield comparable functional results to those of A ILN, shows fewer mechanical nail complications and quicker return to work. However, they are associated with slower healing rate (larger BHI) which explains the surgeons' tendency to distract at a slower rate when using B ILN.

Stainless Steel VS. Titanium Magnetic Internal Lengthening Nail for Femur Lengthening

Limb Lengthening and Complex Reconstruction Service (LLCRS)
Hospital for Special Surgery
New York

Sherif G. Hassan MD, PhD
Tom J. Shin MD
Peter S. Principe BS
Nathan Khabyeh-Hasbani BS
S. Robert Rozbruch MD
Austin T. Fragomen MD

1

Disclosure

No Disclosure

2

Background

- External fixation, has been traditionally used for bone lengthening
- It provokes an array of complications due to soft tissue tethering
- Internal lengthening nails were introduced to evade such complications
- Mechanically activated first generation internal lengthening nails (ILN) showed difficulty controlling rate & rhythm of distraction which led to complications (e.g. run-away nails)

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Background

- The Titanium Magnetic Internal Lengthening Nail (T-MILN), introduced in 2011, has perfect control of rate & rhythm but limited weight bearing ability.
- The Stainless Steel Magnetic Internal Lengthening Nail (SS-MILN) allows 150-250 pounds of weight (a 400% increase in the weight-bearing tolerance compared to T-MILN)
- The aim of this study is to compare the outcomes of using SS-MILN vs. T-MILN for femoral lengthening.

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Methods

- IRB approved, single-center, retrospective cohort study
- Patients who underwent femoral lengthening before 9/2019 using a SS-MILN:
  - etiology: congenital short femur
  - lengthening goal of 8 cm
  - no associated deformity
  - no medical co-morbidities
- T-MILN cases were matched for age, lengthening goal, nail size and etiology to maximize homogeneity between groups.

5

Methods

Outcomes assessed were

- 6-months post-op Limb Deformity-Scoliosis Research Society (LD-SRS) score
- length achieved
- nail size
- distraction rate
- bone healing index (BHI)
- Near by joints (hip & knee) range of motion (ROM)
- Lateral distal femoral angle (LDFA)
- complications

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Results

Demographics

- 30 femoral SS-MILN (16 patients), 36 femoral T-MILN (18 patients).

	SS-MILN	T-MILN	P-Value
Age (years)	31 (17–65)	33 (19–54)	0.46
Gender (F/M)	2F, 14M	3F, 15M	0.99
Length achieved (cm)	7.1 (4.1–8)	6.8 (4–8)	0.51
Nail size (mm)	11.1 (10-13)	10.7 (8.5-12.5)	0.14

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Results

Outcomes

	SS-MILN	T-MILN	P-Value
Distraction rate (mm/day)	0.67 (0.35–0.94)	0.86 (0.6–1)	0.003*
Bone healing index (month/cm)	0.84 (0.53–1.5)	0.67 (0.44–1.2)	0.04*
Loss of hip ROM (degrees)	1.67 (0-30)	0	0.06
Loss of knee ROM (degrees)	1.78 (0-10)	1.66 (0-10)	0.90
Pre-op LD-SRS score	3.94 (3.2-4.8)	4.08 (2.9-4.58)	0.09
Post-op LD-SRS score	4.13 (3.5-4.87)	4.39 (3.8-4.8)	0.07
Change in LD-SRS score	0.19 (1 improvement-1 worsening)	0.37 (0.78 improvement -0.47 worsening)	0.50
Pre-op LDFA (degrees)	87.4 (85-93)	87.4 (84-93)	0.33
Post-op LDFA (degrees)	88.8 (84-94)	87.8 (84-92)	0.09
Change in LDFA (degrees)	1.6 varus (3 valgus-5 varus)	0.25 varus (5 valgus-4 varus)	0.08

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Results

Complications

- In the T-MILN group, 3 nails had mechanical failure that required exchange nailing and 3 other nails had minor mechanical failure (e.g. crown break) that didn't require exchange nailing.
- In SS-MILN group 3 femora required BMAC injections, 2 eventually consolidated & 1 needed exchange nailing .Only 1 patients in the T-MILN group needed BMAC injection.

	SS-MILN	T-MILN
Mechanical with Return to OR	0	3
Mechanical without Return to OR	0	3

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Conclusion

- SS-MILN; had comparable functional results with fewer mechanical nail complications compared to T-MILN.
- However, SS-MILN are associated with slower healing rate (larger BHI), which explains surgeons' tendency to distract at a slower rate when using this device.

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Case Examples

SS-MILN

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Case Examples

SS-MILN

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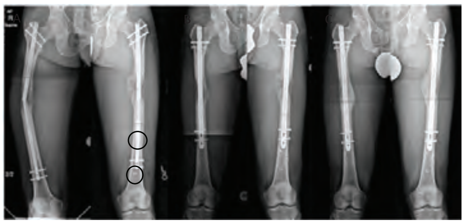
Case Examples

HSS



T-MILN

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THANK YOU

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Humerus Lengthening: A Comparison of the Internal Lengthening Nail to External Fixation

Sherif Hassan, Tom Shin, S. Robert Rozbruch, Austin T. Fragomen
hassans@hss.edu

What was the question?
Humerus lengthening with internal lengthening nails (ILNs) has been used to avoid difficulties and complications associated with the use of external fixators. Are the outcomes different with the use of the ILN?

How did you answer the question?
A single–center, retrospective cohort study was conducted that was IRB approved. A total of 22 humeri (18 patients) were included in the study, they were divided into 2 groups, ILN group (7 patients, 7 humeri) and mono–lateral fixator group (11 patients, 15 humeri). This was staged treatment and not randomized. Outcomes assessed were the 1–year Disabilities of the Arm, Shoulder and Hand (DASH) Score, adjacent joint range of motion (ROM), bone healing index (BHI) and complications.

What are the results?
The patients' age in the ILN group was 28 years (range, 19–38) and 24 years (range, 8–50) in the fixator group. The lengthening in the ILN group was 5.2 cm (range, 5–6 cm) and 7 cm (range, 4–9 cm) in the fixator group. The lengthening percentage in the ILN group was 19% (range, 17%–22%) and 41% (range, 23%–52%) in the fixator group. The BHI was 0.94 month/cm (range, 0.67–1.3 month/cm) and 0.99 month/cm (range, 0.72–1.5 month/cm) in the ILN and fixator groups respectively. The distraction rate in the ILN group was 0.66 mm/day (range 0.49–0.8 mm/day) and 0.86 mm/day (range 0.47–1.2 mm/day) in the fixator group. In the ILN group the pre–operative DASH score was 40.5 (range, 23.3–65) and the 1–year DASH score was 13.6 (range, 1.5–58.3). In the fixator group the pre–operative DASH score was 14 (range, 2.5–42.5) and the 1–year DASH score was 6 (range, 1.7–33). The change in DASH score was 26.8 (6.7–23.3) and 8 (0.84–8.6) in the ILN and fixator groups respectively. The loss of elbow ROM was 5° (0°–23°) in the ILN group and was 7° (0°–15°) in the fixator group. The change of shoulder abduction ROM was 5° loss (20° loss–30° improvement) in the ILN group and was 15° loss (80° loss–30° improvement) in the fixator group. The change of shoulder flexion ROM was 9° improvement (10° loss–30° improvement) in the ILN group and was 6° loss (30° loss–30° improvement) in the fixator group. The time to full recovery of elbow ROM was 39 days (range, 27–53 days) days for shoulder ROM was 122 days (range, 102–136) for the ILN group. In the fixator group there were 4 events of complications (1 radial nerve palsy and 3 refractures after frame removal) requiring return to operating room (OR); while there was only 1 event (deep infection requiring exchange nailing with antibiotic coated nail) in the ILN group.

What are your conclusions?
Humeral lengthening using ILN allow for early full recovery of joint ROM with comparable functional & radiographic outcomes compared to using external fixators. Complications seem less prevalent in the ILN group. The subjective impression of the authors is that the patient experience including pain and recovery of adjacent joint ROM is better with the ILN.

HSS

Humerus Lengthening: A Comparison of the Internal Lengthening Nail to External Fixation

Limb Lengthening and Complex Reconstruction Service (LLCRS)
Hospital for Special Surgery
New York

Sherif G. Hassan MD, PhD
Tom J. Shin MD
Peter S. Principe BS
Nathan Khabyeh-Hasbani BS
Austin T. Fragomen MD
S. Robert Rozbruch MD

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Disclosure

No Disclosure

2

Background

- External fixation, has been traditionally used for humeral lengthening & deformity correction
- It's associated with complication due to soft tissue tethering, such as loss of elbow & shoulder motion.
- Internal lengthening nails (ILN) have been successfully used in lower limbs with better patient experience compared to fixator
- ILN can be used to correct small deformities acutely.

3

Background

- Humeral ILN were not commercially available
- That led to the creative off-label use of the commercially available ILN to lengthen the humerus, most commonly the antegrade femoral nails.
- The aim of this study is to report outcomes of humeral lengthening using PRECICE® ILN and to compare the outcomes to those of external fixation.

4

Methods

- IRB approved, single-center, retrospective cohort study
- A total of 22 humeri (18 patients) were included in the study
- Divided into 2 groups, PRECICE® ILN group (7 humeri, 7 patients) and mono-lateral fixator group (15 humeri, 11 patients)

5

Methods

Outcomes assessed were

- length achieved
- distraction rate
- bone healing index (BHI)
- Near by joints (Shoulder & Elbow) range of motion (ROM)
- complications

6

Results

Patient's Demographics

	PRECICE	EX. Fix.	P-Value
Age (years)	27.9 (19-38)	24 (8–50)	0.45
Gender (F/M)	2F, 5M	5F, 6M	0.76
Lengthening done (cm)	5.2 (5–6)	7 (4–9)	<0.0001*
Length %	19% (17%–22%)	41% (23%–52%)	<0.0001*

Due to original bone length, nails used had a max lengthening capacity of 5 cm

Results

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Outcomes

	PRECICE	EX. Fix.	P-Value
Distraction rate (mm/day)	0.66 (0.49–0.8)	0.86 (0.47–1.2)	0.04*
Bone healing index (month/cm)	0.94 (0.67–1.3)	0.99 (0.72–1.5)	0.73
Change of Shoulder flexion ROM (degrees)	9° improvement (10° loss–30° improvement)	6° loss (30° loss–30° improvement)	0.06
Change of Shoulder Abduction ROM (degrees)	5° loss (20° loss–30° improvement)	15° loss (80° loss–30° improvement)	0.25
Loss of Elbow ROM (degrees)	5° (0–23)	7° (0-15)	0.05*

	Pre-op Elbow ROM	Post-op Elbow ROM	P-Value
PRECICE	123° (100–130)	120° (100–130)	0.21
EX. Fix.	114° (0–140)	110° (0-140)	0.0009*

Results

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Complications

- Fixator group: 4 events of complications (2 transient radial nerve palsy and 2 refractures) requiring return to operating room (OR)
- ILN group: only 1 event (deep infection requiring exchange nailing with antibiotic coated nail).

	PRECICIE	EX. Fix.
Return to OR	1 (infection & Exch. AB nail)	4 (2 transient radial nerve + 2 refracture)
Return to OR	0	2 (loss of elbow terminal extension)

Conclusion

HSS

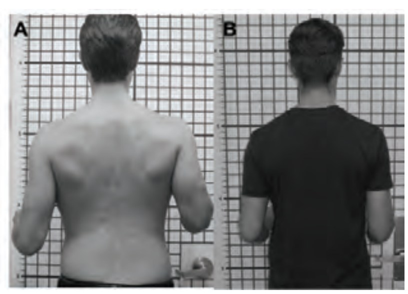
- Humeral lengthening using ILN shows full recovery of joints ROM, fewer complications.
- The impression of the authors is that patient experience including pain and recovery of adjacent joint ROM is better with the ILN.

Case Examples

HSS

Case Examples

HSS



THANK YOU

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Magnetically Driven Intramedullary Limb Lengthening in Patients with Pre–Existing Implanted Programmable Devices: A Case Series

Christopher A. Iobst, MD
christopher.iobst@nationwidechildrens.org

What was the question?
The magnetically driven intramedullary lengthening nail has guidelines warning surgeons to avoid using the device in patients with medically implanted programmable devices such as pacemakers. However, there are clinical situations where patients with implanted programmable devices could potentially benefit from an intramedullary limb lengthening device. Can the device be utilized safely in patients with implantable medical devices?

How did you answer the question?
Between 2017–2019, four skeletally mature patients presented to our institution for limb reconstruction surgery with a pre–existing implanted programmable medical device. The devices consisted of three different types: programmable ventriculoperitoneal shunt (two patients), gastric pacemaker (one patient), and cardiac pacemaker (one patient). Each patient had limb length discrepancy (2.5 cm, 3 cm, 5 cm and 5 cm respectively) and two patients had additional distal femoral angular deformity (6 degrees and 13 degrees, respectively). After prolonged consultation with the patient, their families, and their medical teams, each patient consented to proceeding with the magnetically powered intramedullary limb lengthening device. A retrospective chart review of each patient's clinical course was performed.

What are the results?
All four patients had placement of a magnetically driven femoral intramedullary lengthening nail (three retrograde and one antegrade). All patients reached their goal length and had restoration of a normal mechanical axis. There were no infections, no regenerate healing issues, no range of motion issues, and no unplanned surgeries required. Two patients have had planned removal of the lengthening nail after consolidation. During the course of treatment, no adverse events occurred in any of the four patients related to their pre–existing implanted programmable devices. In the two patients with pacemakers, pre–operative testing was done to confirm that the implanted devices would not be affected by the magnets in the external remote controller (ERC).

What are your conclusions?
To date, there are no published clinical studies demonstrating whether it is safe to use a magnetically driven intramedullary lengthening nail in patients with pre–existing implanted programmable devices. This case series is the first evidence that, when appropriate precautions are undertaken, limb reconstruction can be safely performed in these patients using a magnetically driven intramedullary lengthening nail. Clinical tips to increase the safety for your patient include: using a retrograde femoral nail to keep the magnet (and ERC) as far away from the implanted device as possible, using a weaker version of the ERC (avoid the ERC 4), keep the ERC away from the patient's torso/head at all times, and using a smaller diameter implant (smaller magnet), if possible.

Magnetically Driven Intramedullary Limb Lengthening in Patients with Pre-Existing Implanted Programmable Devices: A Case Series

Christopher Iobst, MD

2020 LLRS Annual Scientific Meeting

Nationwide Children's | Center for Limb Lengthening and Reconstruction

1

Disclosures

- Consultant: NuVasive, Orthofix
- Speaker's Bureau: Smith and Nephew

- I will not be discussing "off-label" or investigational uses for products or devices.

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PRECICE System

- Telescoping intramedullary rod

- FDA clearance received August 23, 2011

Confidential

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PRECICE System

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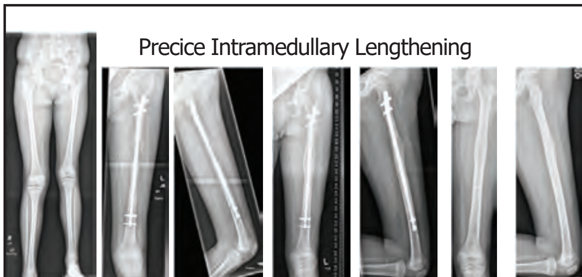
Precice Intramedullary Lengthening



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Warnings

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Magnetic Resonance Imaging Compatibility

Magnetic Intramedullary Lengthening Nails and MRI Compatibility

Charles Gomez, MD,* Scott Nelson, MD,* Joshua Speirs, MD,† and Samuel Barnes, PhD†

J Pediatr Orthop 2018;38:e584–e587

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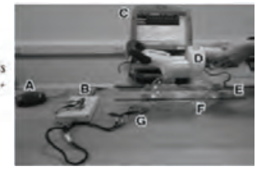
Magnetic Growing Rods and Pacemakers

Recommendations for Lengthening of Magnetically Controlled Growing Rods in Children With Pacemakers

J Pediatr Orthop 2017;37:e250–e254



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Hypothesis

- Can intramedullary limb lengthening using a magnetically driven nail be performed safely in patients with implantable programmable devices?

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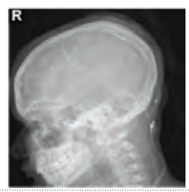
Case 1 – Programmable Ventriculoperitoneal Shunt

- 18 year old female with Dandy Walker Syndrome



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Case 1 – Programmable Ventriculoperitoneal Shunt

- Manufacturer's Guidelines:
- MRI systems of up to 3.0 Tesla may be used
- All products with magnets used in daily lives to be kept a minimum of 5cm away from the site where the valve is implanted
- Approximately 53 cm distance between nail magnet and valve

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Case 1 – Programmable Ventriculoperitoneal Shunt

10.7 X 335

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Case 2 – Gastric Pacemaker

- 18 year old male with chronic intestinal pseudo-obstruction

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Case 2 – Gastric Pacemaker

- Manufacturer's Guidelines:
- Keep external magnetic field bone growth stimulator coils 45 cm away from the neurostimulation system
- Approximately 66 cm between nail magnet and pacer

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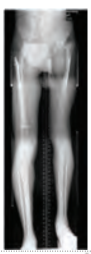
Case 2 – Gastric Pacemaker



10.7 X 190

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Case 3 – Cardiac Pacemaker

- 20 year old male born with a double inlet left ventricle, transposition of great arteries, and sub-valvar pulmonary atresia

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Case 3 – Cardiac Pacemaker

- Manufacturer's Guidelines:
- Recommended to keep the cardiac device at least 30 centimeters away from wireless communication devices, such as demagnetizers
- Approximately 63 cm between nail magnet and pacemaker

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Case 3 – Cardiac Pacemaker

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Case 3 – Cardiac Pacemaker

12.5 X 190

19

Discussion

- First clinical case series demonstrating use of a magnetically driven intramedullary lengthening nail in patients with pre-existing implanted programmable devices
- With appropriate precautions, limb reconstruction can be safely performed in these patients

20

Discussion

- Clinical tips:
  - Use a retrograde femoral nail to keep the magnet (and ERC) as far away from the implanted device as possible
  - Use a weaker version of the ERC (avoid the ERC 4)
  - Keep the ERC away from the patient's torso/head at all times
  - Use a smaller diameter implant (smaller magnet), if possible

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Thank You For Your Attention

Questions or comments?
Contact me at:
christopher.iobst@nationwidechildrens.org

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Cost Comparison of Tibial Distraction Osteogenesis with External Lengthening and Then Nailing (LATN) Versus Internal Magnetic Lengthening Nail (MLN)

Aleksey Dvorzhinskiy, David T. Zhang, Austin T. Fragomen, S. Robert Rozbruch
dvorzhinskiya@hss.edu

What was the question?
Tibial lengthening can be performed by distraction osteogenesis via lengthening and then nailing (LATN) or by using a magnetic lengthening nail (MLN). MLN avoids the complications of external fixation while providing accurate and easily controlled lengthening. Still, concerns exist regarding the high upfront cost of the magnetic nail which serves to limit its use in resource–poor areas and decrease adoption among cost–conscious surgeons. The purpose of this study was to compare the hospital, surgeon, and total cost between LATN and MLN when used for tibial lengthening.

How did you answer the question?
A retrospective review was performed comparing consecutive tibial lengthening procedures using either LATN (n = 17) or MLN (n = 15). The number of surgical procedures and time to union were compared. Surgeon and hospital payments were used to perform cost analysis after adjusting for inflation using the Consumer Price Index (CPI).

What are the results?
The total length of tibial distraction was similar between groups. Patients treated with MLN underwent fewer surgeries (3.6 versus 2.7; $p = 0.01$) but had a longer time to union as compared with patients treated with LATN (19.79 vs. 27.91 weeks; $p = 0.002$). Total costs were similar ($50,345 versus $46,558; $p = 0.7$) although surgeon fees were lower for MLN as compared with LATN ($6,426 versus $4,428; $p < 0.001$).

What are your conclusions?
Although implants are more expensive for MLN, this cost appears to be offset by fewer required procedures in this method as compared with LATN. Overall, LATN and MLN had similar costs while MLN was associated with fewer procedures but a longer time to union.

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Cost Comparison of Tibial Distraction Osteogenesis with External Lengthening and Then Nailing (LATN) Versus Internal Magnetic Lengthening Nail (MLN)

Aleksey Dvorzhinskiy, MD; David T. Zhang, BA; Austin T. Fragomen, MD; and S Robert Rozbruch, MD

Hospital for Special Surgery New York, NY USA

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Disclosures

- Dr. Fragomen or an immediate family member is a member of a speakers' bureau or has made paid presentations on behalf of NuVasive, Smith & Nephew, and DePuy Synthes; serves as a paid consultant to Globus Medical, NuVasive, Smith & Nephew, and DePuy Synthes; and serves as a board member, owner, officer, or committee member of the Limb Lengthening Research Society.
- Dr. Rozbruch or an immediate family member has received royalties from Stryker; is a member of a speakers' bureau or has made paid presentations on behalf of and serves as a paid consultant to NuVasive, Smith & Nephew, and Stryker; and serves as a board member, owner, officer, or committee member of the Limb Lengthening Reconstruction Society.
- The other authors have no disclosures relevant to this presentation.

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Introduction

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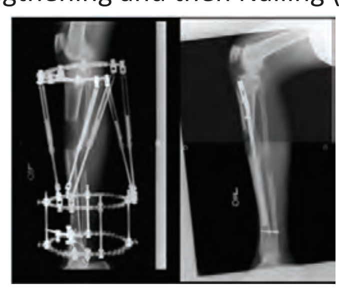
Ilizarov Method

- Powerful method for limb lengthening and deformity correction
- Basic procedure remains unchanged:
  1. Osteotomy
  2. Distraction
  3. Consolidation

4

Lengthening and then Nailing (LATN)



First Procedure → Second Procedure

5

Lengthening and then Nailing (LATN)

- Decreased time in an external fixator provided theoretically:
  - Decreased fixator-associated complications
  - Increased patient satisfaction
  - Decreased chance of regenerate fracture

1. Kim, 2011
2. Wan 2013

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Motorized Lengthening Nails

- Obviate the need for external fixation in certain clinical scenarios
  - Eliminate pin tract infections
  - Decreased risk of knee stiffness

1. Rozbruch, 2014
2. Fragomen, 2017
3. Horn, 2015

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Motorized Lengthening Nails

- Obviate the need for external fixation in certain clinical scenarios
  - Eliminate pin tract infections
  - Decreased risk of knee stiffness
- **Concerns about cost**

1. Rozbruch, 2014
2. Fragomen, 2017
3. Horn, 2015

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Number of Procedures

LATN	MLN
1. Osteotomy and frame application	1. Osteotomy and nail Insertion
2. Removal of frame and insertion of intramedullary nail	2. Removal of nail
3. Removal of nail	

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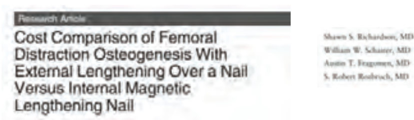

Research Article

Cost Comparison of Femoral Distraction Osteogenesis With External Lengthening Over a Nail Versus Internal Magnetic Lengthening Nail

Shawn S. Richardson, MD
William W. Schairer, MD
Austin T. Fragomen, MD
S. Robert Rozbruch, MD

- Retrospective review of consecutive femoral lengthenings using lengthening over a nail versus magnetic lengthening nail
- **Results:** No difference in total costs between LON versus MLN; no difference in the length of femoral distraction

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Purpose

To compare the hospital, surgeon, and total cost between lengthening and then nailing (LATN) and the motorized lengthening nail (MLN) when used for tibial lengthening

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Methods

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Methods

- Retrospective review comparing consecutive tibial lengthenings using either LATN (n=17) or MLN (n=15)
- Number of surgical procedures and time to union was compared
- Surgeon and hospital payments were used to perform cost analysis after adjusting for inflation using the Consumer Price Index (CPI)

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Standard Protocol

LATN

1. Osteotomy and frame application
2. Removal of frame and insertion of intramedullary nail
3. Removal of nail

MLN

1. Osteotomy and nail Insertion
2. Removal of nail

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Cost Calculation

- Total cost = Hospital Cost + Surgeon Cost
- Hospital cost obtained by compiling the total payments received by our instution for all care related to the patient for this clinical episode
- Surgeon cost were calculated by obtaining all billed CPT codes and calculating an expected surgeon fee using the Medicare Physician Fee Schedule

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Results

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Demographic and Clinical Comparisons

Parameters	LATN	MLN	P Value
Patients	17	15	-
% Female	35	60	0.162
Age (yr)	35.2 +/- 13.49	38.73 +/- 12.61	0.45
% Cases Bilateral	65%	13%	0.003
Length Distracted	5.51 +/- 1.73	4.52 +/- 1.40	0.08
Time To Union (weeks)	19.79 /- 1.73	27.91 +/- 8.30	0.002

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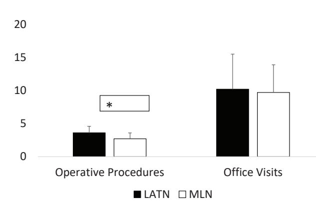
Operative Procedures and Office Visits



Parameters	LATN	MLN	P Value
Operative Procedures	3.6 +/- 1.0	2.7 +/- 0.9	0.01
Outpatient Office Visits	10.2 +- 5.3	9.7 +/- 4.2	0.78

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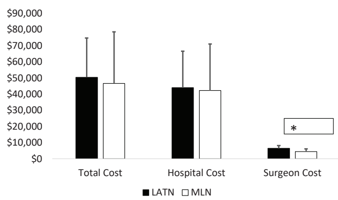
Cost Comparisons



Parameters	LATN	MLN	P Value
Hospital Costs ($)	43,919 +/- 22,601	42,130 +/- 28,882	0.85
Surgeon Costs ($)	6,426 +/- 1752	4,428 +/- 1687	<0.001
Total Cost (hospital + surgeon, $)	50,345 +/- 24,353	46,558 +/- 31,946	0.70

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Discussion

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Cost Comparison

- No difference in total cost between LATN and MLN
  - Only difference seen in surgeon cost which was a minor part of total cost
- Similar results to previous study in the femur comparing lengthening over a nail with magnetic lengthening nail.

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1. Richardson, 2018

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Time to Union

- Time to union was significantly higher in the MLN group as compared with LATN (28 vs. 20 weeks)
  - Reaming may have a detrimental effect on regenerate formation but a positive effect on ultimate union after a regenerate has been created

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1. Rozbruch, 2008
2. Ryu, 2016

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Weaknesses

- Retrospective review: inherent biases as two groups underwent treatment during different time periods
- LATN group had significantly more patients undergoing bilateral procedures
- Our study did not examine indirect costs

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Conclusions

- Despite increased upfront costs, MLN was not shown to increase the cost of tibial lengthening at our institution
  - This can likely be attributed to the additional procedures and hospital care required for the LATN technique

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26

THANK YOU

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27

Evaluating the Utility of the Pixel Value Ratio in the Determination of Time to Full Weight Bearing in Patients Undergoing Limb Lengthening Using an Intramedullary Device

Christopher A. Iobst, MD, Anirejuoritse Bafor, Molly Duncan
christopher.iobst@nationwidechildrens.org

What was the question?
The decision when to allow full weight bearing (FWB) following distraction osteogenesis with an intramedullary lengthening nail does not have well established objective criteria. The pixel value ratio (PVR) assessment has shown good correlation with DEXA scanning in determining the state of mineralization of regenerate bone. Can the pixel value ratio provide an objective method for determining when it is safe to allow full weight bearing in patients undergoing limb lengthening with an intramedullary nail?

How did you answer the question?
Following IRB approval from our institution, a retrospective review of all patients undergoing unilateral lower extremity intramedullary long bone lengthening between May 2017 and December 2019 was performed. Forty–six (46) patients were identified (45 femurs and one tibia). The mean LLD was 4.3 ± 2.1 cm with a range of 1.5 – 11 cm. The pixel value ratios (PVR) of the lateral, medial, anterior and posterior regions of the regenerate bone were assessed for each patient. The measurements were taken from standard anteroposterior and lateral view digital radiographs obtained at routine follow–up visits during the distraction and consolidation phase using the 'region of interest' program in GE Centricity PACS version 4.0.11E software. The schedule for the follow–up visits and image capture were weekly during the distraction phase and every 3 – 4 weeks during the consolidation phase. Statistical analysis: The mean as a measure of central tendency was calculated where required using excel statistical package with variance expressed as standard deviation. Scatterplots were designed to represent the trend of change of PVR over time. The mean PVR at the time of commencement of full weight bearing was determined from the trendline of the charts for each cortex.

What are the results?
The mean length obtained was 3.8 ± 1.3 cm with a range of 2 – 6.7 cm. The mean time taken to achieve FWB was 126.7±30.4 days with a range of 60 – 199 days. The mean PVR at the time of commencement of FWB was 1.0986, 1.0639, 1.1062 and 1.1153 for the lateral, medial, anterior and posterior cortices respectively with an overall mean PVR of 1.096. (See table 1)
There were no cases of pain, fractures or hardware failure following commencement of full weight bearing.

What are your conclusions?
This review found that the mean PVR at commencement of full weight bearing for all cortices was 1.096 and that mineralization is fastest in the medial cortex. There were no patient complications when full weight bearing commenced at this level of healing. The PVR can be a relatively quick and easy tool for objective assessment of regenerate bone mineralization and clinical decision making in patients undergoing distraction osteogenesis with an intramedullary lengthening nail.

Table1: Mean Pixel Value Ratio (PVR) for the various cortices at time of commencement of full weight bearing

Cortex	**Mean PVR**
Lateral	1.0986
Medial	1.0639
Anterior	1.1062
Posterior	1.1153
All cortices	**1.0960**

PVR: Pixel Value Ratio

Evaluating the Utility of The Pixel Value Ratio in The Determination of Time to Full Weight Bearing in Patients Undergoing Intramedullary Limb Lengthening

Anirejuoritse Bafor, MD
Molly Duncan, BS
Christopher Iobst, MD
2020 LLRS Annual Scientific Meeting

Nationwide Children's | Center for Limb Lengthening and Reconstruction

1

Disclosures

- Consultant: NuVasive, Orthofix
- Speaker's Bureau: Smith and Nephew

- I will not be discussing "off-label" or investigational uses for products or devices.

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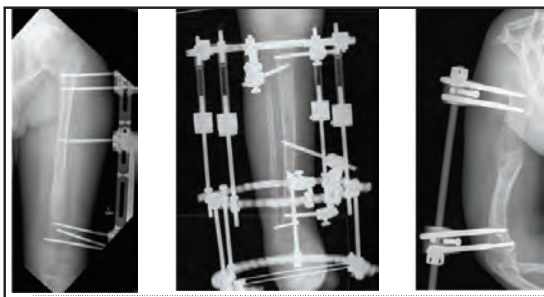

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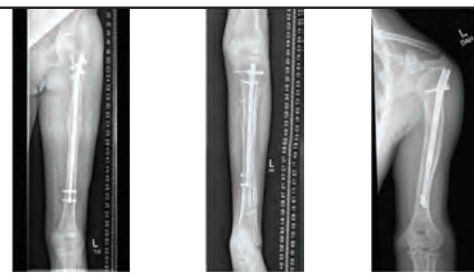

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Regenerate Maturation

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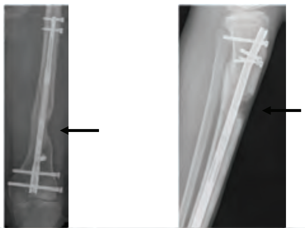
Partial Regenerate Deficiency



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7

BASIC RESEARCH

Objective Guidelines for Removing an External Fixator after Tibial Lengthening Using Pixel Value Ratio

Archives of Orthopaedic and Trauma Surgery, 131, 1333–1340(2011)

Comparative study of callus progression in limb lengthening with or without intramedullary nail with reference to the pixel value ratio and the Ru Li's classification

Serial bone mineral density ratio measurement for fixator removal in tibia distraction osteogenesis and need of a supportive method using the pixel value ratio

J Ped Orthop B 2012, 21:137–145

Assessment of Bone Healing During Antegrade Intramedullary Rod Femur Lengthening Using Radiographic Pixel Density

J Am Acad Orthop Surg 2018;26: e388-e394

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Hypothesis

- Determine if the pixel value ratio could be used to make a correlation between the amount of mineralization of regenerate bone and the timing of full weight bearing in patients undergoing intramedullary limb lengthening

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Methods

- IRB approval
- Retrospective, single surgeon series
- May 2017- December 2019
- 46 patients with intramedullary limb lengthening

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Methods

- Mean age: 15.7 ± 4.7 years (range of 9 – 33 years)
- Mean LLD: 4.3 ± 2.1 cm
- Latency 6 – 7 days
- Distraction rate of 0.75mm per day
- Weekly radiographs during distraction phase
- Radiographs every 3 to 4 weeks during the consolidation phase

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Decision to Allow Full Weight Bearing

- Clinically: painless, partial weight-bearing with a minimum knee range of motion (ROM) of 0 – 90°
- Radiographically: bridging regenerate bone (i.e. a continuous column of bone) was visible on 3 out of 4 cortices

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Radiographic Analysis

13

Pixel Value Ratio (PVR)

- PVR = $\left(\frac{0.5(PVp+PVd)}{PVr}\right)$

- PVR = 1 (similar density between regenerate bone and the adjacent normal bone)

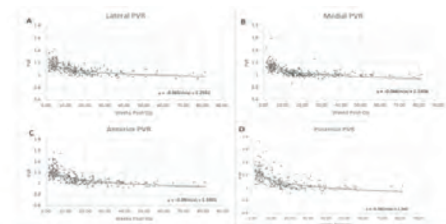
14

Results

- Mean length obtained = 3.8 ± 1.3 cm
- Mean time taken to achieve full weight bearing was 126.7±30.4 days

15

Results



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Results

Cortex	Mean PVR
Lateral	1.071
Medial	1.040
Anterior	1.070
Posterior	1.077
All cortices	**1.065**

PVR: Pixel Value Ratio

17

Discussion

- Decision to allow full weight bearing largely subjective

- Objective measures expensive, inconvenient
  - DEXA scan
  - Quantitative CT

18

Discussion

- PVR method can be done in clinic
- Measure using the 'ROI' tool in PACS
- Full weight bearing = 3 out of the 4 cortices had PVR 1.071

19

Discussion

- Vulcano et al. *J Am Acad Orthop Surg* 2018

Assessment of Bone Healing During Antegrade Intramedullary Rod Femur Lengthening Using Radiographic Pixel Density

- ▪ Measured all 4 cortices not just two
- ▪ Commencement vs. completion of distraction

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Limitations

- Unable to establish a PVR threshold
- May be too conservative
- Soft tissue or hardware can interfere with measurement

21

Conclusion

- PVR practical, reproducible objective measurement of regenerate bone healing
- Full weight bearing = 3 out of the 4 cortices had PVR 1.071
- Formula included in Multiplier App?

22

Thank You For Your Attention

Questions or comments?
Contact me at:
christopher.iobst@nationwidechildrens.org

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Paediatric Femoral Lengthening Using Intramedullary Versus External Fixator Devices: A Single Surgeon Matched Cohort Series

Laura Tillotson, Connor Maddock, Catharine Bradley, Simon Kelley
laura.tillotson@sickkids.ca

What was the question?
Distraction osteogenesis using external fixation is a well–established treatment strategy for children with large femoral length discrepancies (and deformities with length discrepancies) but is associated with a very high rate of complications. The recent introduction of the Precice intramedullary lengthening device offers perceived advantages over external fixation systems and as such we instituted a clear transition from external fixation to intramedullary femoral lengthening, yet evidence supporting its widespread adoption is currently lacking for the paediatric population. We aimed to compare the outcomes of femoral lengthening using intramedullary and external fixation methods in children using a matched cohort of comparable cases.

How did you answer the question?
After obtaining REB approval, our institutions' EMR system (EPIC) was surveyed to collect data on all paediatric patients who had undergone femoral lengthening using a Precice intramedullary lengthening device. A matched cohort of concurrent cases was then obtained to identify children who had undergone comparable procedures using external fixation (TSF or MRS). All surgeries were performed by the senior author. Each group was matched for age, gender and underlying condition. Data collection and statistical analysis was performed to compare femoral length desired/achieved, consolidation index, length of inpatient stay, post operative complications, and follow up between the two groups.

What are the results?
Twenty–eight children who had undergone femoral lengthening (+/– deformity correction) between 2010 and 2019 were identified. One patient was excluded as they refused consent for inclusion. Of the available 27 patients for study, 13 underwent femoral lengthening with the Precice nail (15 femurs in 13 patients, 4 retrograde, 9 antegrade), and 14 with external fixation (17 femurs in 14 patients, TSF n=4 patients, MRS n=10 patients). The groups were well–matched by age (Precice mean 13.6 yrs, TSF/MRS mean 12.3 years, p 0.42), gender (Precice M:F 9:4, TSF/MRS M:F 6:8), and condition (matched lengthening for congenital deficiency, post–traumatic growth arrest, neuromuscular diseases and skeletal dysplasias). There were no statistically significant differences in length achieved (Precice mean 43mm (20–80mm), TSF/MRS mean 42mm (10–70mm), p 0.98) or consolidation index (Precice 24.05days/cm, TSF/MRS mean 28.47days/cm, p 0.275). Follow–up to date is comparable (Precice – 19 months (8 – 35) and TSF/MRS –34 months (7 – 72). Significant differences were found in length of stay (Precice mean 2.2 days (1–4 days), TSF/MRS mean 4.1 days (2–10 days), p 0.02). There was a significantly increased rate of post–operative complications in the external fixation group, (TSF/MRS 71.4% vs Precice 0%). Complications in the External fixator group included pin site infections (n=7, 50%) and return to OR (n=4, 28.6% – joint contracture, loss of alignment, fixator adjustment, scar revision). There were no post–operative complications in the Precice group.

What are your conclusions?
Femoral lengthening (+/– concomitant deformity correction) using the Precice intramedullary device in a paediatric population resulted in excellent outcomes regarding target length and alignment but with a significantly reduced length of inpatient stay, unplanned return to the OR and rate of minor and major complications when compared to a matched cohort of children undergoing lengthening with circular and monolateral fixators.

Paediatric Femoral Lengthening using Intramedullary versus External Fixator Devices: A Single Surgeon Matched Cohort Study

Laura Tillotson, Connor Maddock, Catharine Bradley, Simon Kelley

SickKids

Toronto Orthopaedics

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Disclosures

- None

2

Introduction

- Femoral lengthening well established in paediatric population
- External fixator devices predominant method to date
  - Associated with high rate of complications
  - Limited by patient tolerance
- Precice nail offers possible advantages over external fixator devices
- Literature review – limited comparison series between two methods have been done in adult population, but none to date in children

3

Aim

- Compare outcomes of femoral lengthening in children
- Intramedullary vs external fixation methods
- Matched single-surgeon cohort of comparable cases

4

Method

- REB approval obtained
- EPIC used to collect data on all paediatric patients undergoing femoral lengthening with Precice nail
- Matched cohort of concurrent cases using TSF or MRS
  - Age, Gender, Aetiology
- All surgeries performed by senior author

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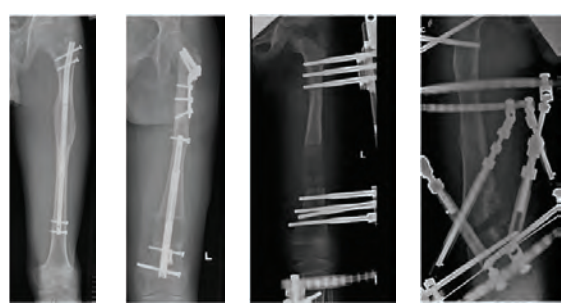

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Method

- Data collection and statistical analysis
  - Femoral length achieved
  - Consolidation index
  - Length of inpatient stay
  - Post-operative complications
  - Follow up

7

Demographics

	Precice	MRS/TSF
Total	13 patients (2 bilateral)	14 patients (3 bilateral) 4 TSF; 10 MRS
Age	Mean 13.6 years (9 – 16)	Mean 12.3 years (8 – 16)
Gender	M= 9, F 4	M = 6, F = 8
Aetiology:		
Congenital	6 (46%)	7 (50%)
Post traumatic	4 (31%)	3 (21%)
Skeletal Dysplasia	2 (15%)	3 (21%)
Other	1 (8%)	1 (8%)
Simultaneous deformity correction	3 (23%)	4 (29%)

8

Results

- 27 patients eligible and gave consent for inclusion
- 13 pts (15 femurs) - Precice nail (11 antegrade, 4 retrograde)
- 14 pts (17 femurs) – External Fixation - TSF (n = 4) or MRS (n = 13)
- Matched for age, gender and aetiology

9

Results

	Precice	TSF/MRS	Significance
Length achieved (mean)	43mm (20-80mm)	42mm (10 – 70mm)	p=0.98
Consolidation index (mean)	24.05days/cm	28.47days/cm,	p=0.275
Follow up to date (mean)	19 months (8-35)	34 months (7-72)	N/A

10

Results

- Significant difference in length of inpatient stay
  - Precice - mean 2.2 days (1-4 days)
  - TSF/MRS - mean 4.1 days (2-10days)
  - p = 0.02

11

Results

- Significant increased rate of post-op complications in Ex-Fix group:
  - External fixator group complication rate 71.4%
  - Precice group complication rate 0%
- Complications in Ex-Fix group included:
  - Pin site infection (n=7, 50%)
  - Return to OR (n=4, 28.6%)
    - Joint contracture requiring manipulation
    - Loss of alignment/fixator adjustment
    - Scar revision

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Discussion

- Only matched cohort series of paediatric femoral lengthening
- Favourable results compared to literature
- Retrospective analysis
- Small patient numbers
- No PROMs
- Awaiting cost analysis

13

Conclusions

- In paediatric femoral lengthening (+/- concomitant deformity correction)
- Precice **equivalent** to external fixation
  - Target length
  - Consolidation index
- Precice offers **advantage**s over external fixation
  - Significantly **reduced length of stay**
  - Fewer **unplanned return to OR**
  - Lower rate of **major and minor complications**

14

- Thank you

15

Session 6: Pediatric Limb Deformity

Does an Osteotomy Performed in Congenital Pseudarthrosis of the Tibia Heal?

Nickolas J. Nahm, Christopher A. Makarewich, Katherine Rosenwasser, John E. Herzenberg, Philip K. McClure
nickolas.nahm@gmail.com

What was the question?
What is the outcome of elective osteotomy performed in congenital pseudarthrosis of the tibia (CPT)?

How did you answer the question?
We performed an IRB–approved retrospective review of ten consecutive patients with CPT who underwent treatment from 2010 through 2019. Patients who underwent tibial realignment osteotomies were included in this study.

What are the results?
Ten patients (11 tibial osteotomies, 6 proximal metaphyseal and 5 diaphyseal) with a median age at osteotomy of 9.5 years (range, 4–39) were included. Etiologies included NF–1 (6), idiopathic (3), and cleidocranial dysplasia (1). Five osteotomies were performed for deformity correction, three to allow intramedullary instrumentation, and three for lengthening. Nine were fixed with a rod supplemented with external fixation (7) or locking plates (2). One osteotomy was stabilized with locked intramedullary nailing alone, and one osteotomy was stabilized with hexapod external fixator alone. Bone morphogenic protein–2 was utilized in only one osteotomy. Median time to healing was 199.5 days (range, 127–304 days). One osteotomy (locked IMN) required grafting at 5.5 months and then healed uneventfully. Median healing index for patients undergoing lengthening was 57.9 days/cm (range, 35–81 days/cm). All three osteotomies performed for lengthening required a second osteotomy for pre–consolidation (fibula only or both bones) at a mean of 34 days. Other complications included compartment syndrome requiring fasciotomy (2), tibial osteomyelitis (1), and fracture distal to cross–union (1).

What are your conclusions?
Contrary to conventional wisdom, tibial osteotomies may be safely performed in CPT for various indications. In our series, all healed with only one requiring secondary bone grafting. Although time to healing of the osteotomy was generally prolonged, this study suggests, somewhat surprisingly, that pre–consolidation can occur frequently in lengthening procedures.

Does an osteotomy performed in congenital pseudarthrosis of the tibia heal?

Nickolas Nahm MD, Christopher Makarewich MD,
Katherine Rosenwasser MD, John E. Herzenberg MD, Philip K. McClure MD
International Center for Limb Lengthening
Ruben Institute for Advanced Orthopaedics
Sinai Hospital of Baltimore
Baltimore, MD, USA

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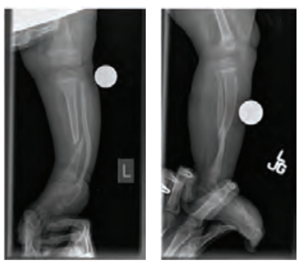
Disclosures

- I (and/or my co-authors) have something to disclose
- John Herzenberg MD: Consultant: Smith + Nephew , OrthoPediatrics, NuVasive, Orthofix, Wishbone, OrthoSpin, Bonus BioGroup.
- Philip McClure MD: Smith + Nephew (teaching consultant), Orthofix (teaching consultant), Novadip (consultant)

2

Introduction

- Congenital pseudarthrosis of tibia (CPT) is characterized by abnormal periosteal biology (Codivilla JBJS-A 1906)
- Treatment of fracture in CPT is challenging but cross-union offers promising results (Choi et al JPO 2011)
- Deformity and limb length discrepancy are common sequalae of treatment of CPT (Kristiansen et al CORR 2003)



18 month old with NF-1 and CPT

3

Introduction

- Osteotomies in CPT are useful for lengthening and deformity correction and may be necessary for intramedullary instrumentation
- Traditional wisdom dictates avoiding osteotomies to address limb length discrepancy and deformity correction (Inan et al JPO 2006)
- Hypothesis: osteotomies performed in CPT reliably heal

4

Materials and Methods

- Retrospective review of consecutive patients with CPT undergoing an elective osteotomy (exclusive of nonunion repair)
- Patients treated 2010-2019
- Patient and surgical variables and healing outcomes collected

5

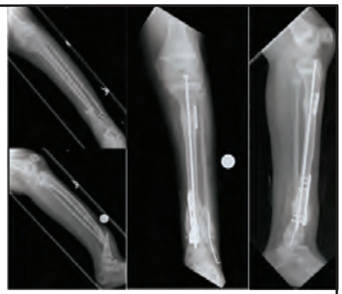
Results

- Ten patients with median age 9.5 years (range 4-39 years)
- 11 osteotomies
- Associated syndromes: Neurofibromatosis-1 (n=6), cleidocranial dysplasia (n=1), and idiopathic (n=3)

6

Results

- Indications for osteotomy
  - Deformity correction (n=5)
  - Facilitate passage of intramedullary instrumentation (n=3)
  - Lengthening (n=3)
- Location of osteotomy
  - Proximal metaphyseal (n=6)
  - Diaphyseal (n=5)



12 year old with NF1 underwent crossunion and proximal tibial ostetomy to facilitate passage of SLIM nail

7

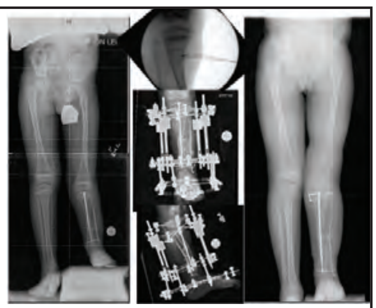
Results

- Zalendronate administered prior to five osteotomies
- Instrumentation
  - Intramedullary nail supplemented with external fixation (n=7) or locking plates (n=2)
  - Locked intramedullary nail alone (n=1)
  - Hexapod external fixator alone (n=1)

8

Results

- Autologous bone graft utilized in four osteotomies
- Bone Morphogenic Protein-2 (Infuse, Medtronic, Memphis, TN) utilized in three osteotomies
- Median time to healing: 199.5 days (range 127-304 days)
- Median healing index for patients undergoing lengthening: 57.9 days/cm (35-81 days/cm)



6 year old with NF-1 and prior crossunion with 8.5 cm LLD. He underwent tibial osteotomy for lengthening over Ilizarov frame

9

Results

- One osteotomy stabilized with locked IMN required additional grafting at 5.5 months
- Premature consolidation in patients undergoing lengthening requiring repeat tibial osteotomy in two patients and proximal tibial-fibular stabilization with wire in one patient
- Compartment syndrome requiring fasciotomy (n=2)
- Tibial osteomyelitis (n=1)
- Fracture distal to crossunion (n=1)

10

Discussion

- No nonunions for tibial osteotomies in CPT – 10/11 osteotomies healed after index procedure with only one osteotomy requiring additional bone grafting procedure
- More time is required for union
  - Median time to healing 199.5 days
  - For lengthening, median healing index 57.9 day/cm
  - 63.1 day/cm reported by Zhu et al BMC Musculoskeletal Disord 2015
  - 89 day/cm reported by Cho et al JPO 2007

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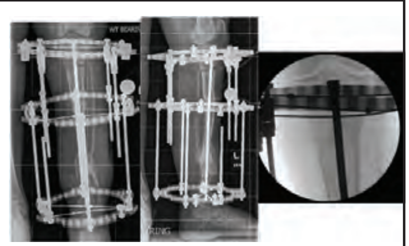
Discussion

- Risk factors for delayed healing or nonunion: dysplastic bone in area of osteotomy or previous lengthening (Cho et al JPO 2007)
- Premature consolidation (2 tibia and 1 fibula)
  - 2 patients had repeat tibial osteotomy
  - Third patient had less fibular distraction concerning for premature fibular consolidation. Addressed with wire stabilization of proximal tibial-fibular joint



15 year old with idiopathic CPT and 5 cm leg length discrepancy underwent proximal tibial osteotomy for lengthening with Ilizarov frame. She had premature consolidation 6 weeks after surgery requiring a second corticotomy

12

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Proximal Femoral Guided Growth for Dysplastic Hips in Children with Cerebral Palsy

Jacob R. Carl, James McCarthy
JacobCarl.MD@gmail.com

What was the question?
The overall prevalence of hip dysplasia in patients with cerebral palsy, ranges from 17% to 35%. Guided growth techniques allow for angular correction without the increased morbidity of bony osteotomy. However, the effect on head shaft angle (HSA), neck shaft angle (NSA), migration index (MI) and articular trochanter distance (ATD) is still not fully understood. We sought to answer the following question: what are the effects of percutaneous screw proximal femoral medial hemiepiphysiodesis on the radiographic outcomes of hip development in patients with cerebral palsy?

How did you answer the question?
A query of hospital databases and medical charts was performed for skeletally immature patients with cerebral palsy (CP) who underwent percutaneous screw proximal femoral medial hemiepiphysiodesis for treatment of hip dysplasia at a tertiary academic medical center. A total of twenty–one (21) patients and twenty–eight (28) hips that underwent PPFMH from September 2010–September 2019 were queried. All Gross Motor Function Classification System (GMFCS) levels were included. Exclusion criteria included follow up less than 2 years and/or lack of post–operative radiographs. Surgical procedures were performed by a single surgeon using the same technique. Standard anterior–posterior (AP) radiographs were obtained to minimize variability in proximal femoral rotation. Pre–operative and postoperative radiographs were reviewed and measurements were made on a picture archiving and communication system (PACS) to assess neck shaft angle (NSA), head shaft angle (HSA), migration index (MI), and articular trochanter distance (ATD). A one tailed t–test was performed comparing preoperative and postoperative radiographic measurements.

What are the results?
Seven (7) patients and twelve (12) hips were included in the preliminary analysis. Fourteen (14) patients were excluded from analysis due to inadequate follow up (less than 2 years). The average age at time of surgery was 7.7 years old. Average follow up of post–operative radiographs was 2.6 years. In our group of patients, NSA decreased from an average of 146.8 to 136.8 degrees ($p < 0.01$), HSA decreased from an average of 158.7 to 145.3 degrees ($p < 0.01$), ATD changed from an average of 22.5 to 15.6 ($p < 0.01$). Migration index decreased from an average of 20.5 to 17.5, however this did not reach significance ($p = 0.2$).

What are your conclusions?
Our early results suggest that guided growth of the proximal femur by percutaneous screw hemiepiphysiodesis significantly decreases neck shaft angle, head shaft angle, and articular trochanter distance in skeletally immature patients with cerebral palsy at 2 years follow up. Percutaneous screw hemiepiphysiodesis may be a useful adjunct in treatment or prevention of proximal femoral deformity in select children with cerebral palsy.

Proximal Femoral Guided Growth for Dysplastic Hips in Children with Cerebral Palsy

Jacob R. Carl, MD
Clinical Fellow Pediatric Orthopaedic Surgery

James McCarthy, MD MHCM
Chair of Pediatric Orthopaedic Surgery

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Disclosures

- The authors have no financial disclosures

2

Background

- Overall prevalence of hip displacement in patients with cerebral palsy (CP), ranges from 17% to 35%[1]
- Progressive displacement may lead to frank hip dislocation
- Hip dislocation in the CP population can lead to pain, difficulty with personal hygiene and chair positioning

3

Can we prevent this?

4

Background

- Hemi-epiphysiodesis, aka guided growth
  - Uses differential growth across a physis to correct angular deformities
  - Used at the knee and ankle for decades.
    - Recently has been successfully used at the hip
  - These techniques allow for angular correction without the increased morbidity of bony osteotomy [2-4]

5

Objective

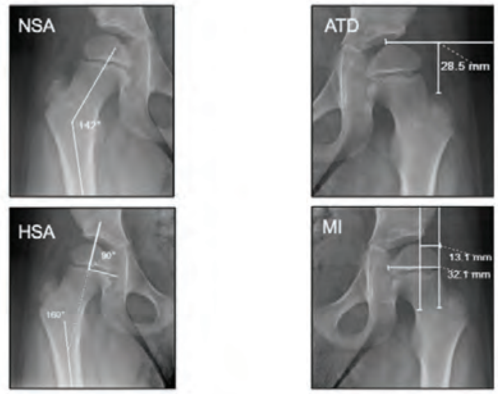
- To assess the impact of percutaneous proximal femoral medial hemi-epiphysiodesis (PPFMH) on the radiographic outcomes of hip development in patients with CP

6

Materials & Methods

- Retrospective chart review of children with CP and hip dysplasia who underwent a PPFMH screw placement for treatment of hip dysplasia
  - Exclusion criteria: less than 2 years follow up
- Pre-operative and postoperative AP radiographs were reviewed
- Neck shaft angle (NSA), head shaft angle (HSA), migration index (MI), and articular trochanter distance (ATD)

7



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Results

- 7 patients and 12 hips were included in the preliminary analysis
- 14 patients were excluded from analysis due to inadequate follow up of less than 2 years
- Average age at time of surgery was 7.7 years old
- Average follow up of post-operative radiographs was 2.6 years.

9

Results

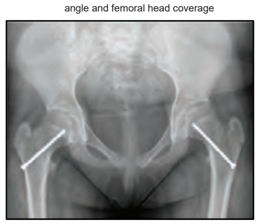
Average Measurements	Pre-op	Post-op	p-value
NSA	146.8 º	136.8 º	p < 0.01*
HSA	158.7 º	145.3 º	p < 0.01*
ATD	22.5	15.6	p < 0.01*
MI	20.5%	17.5%	p = 0.2

10

Case Example

- Pre-operative AP pelvis radiograph of patient with migration of bilateral hips.

- Post-operative AP pelvis radiograph after proximal femur guided growth showing improved neck shaft angle and femoral head coverage



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Conclusions

- In skeletally immature patients with cerebral palsy at 2 years follow up, guided growth of the proximal femur by percutaneous screw hemi-epiphysiodesis significantly decreases
  - neck shaft angle
  - head shaft angle
  - articular trochanteric distance
- Percutaneous screw hemi-epiphysiodesis may be a useful adjunct in treatment or prevention of proximal femoral deformity in select children with cerebral palsy.

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13

Modernization of Bone Age Assessment: Comparing the Accuracy and Reliability of an Artificial Intelligence Algorithm and Short Hand Bone Age to Greulich and Pyle

Mina Gerges, Hayley Eng, Harpreet Chhina, Anthony Cooper
minagerges@live.ca

What was the question?
Bone age is a radiographical assessment used in pediatric medicine due to its relative objectivity in determining biological maturity compared to chronological age and size.1 Currently, Greulich and Pyle (GP) is one of the most common methods used to determine bone age from hand radiographs. 2–4 In recent years, new methods were developed to increase the efficiency in bone age analysis such as the shorthand bone age (SBA) and the automated artificial intelligence algorithms.1,5
The aim of this study is to evaluate the accuracy, reliability and time taken to perform these two methods, in comparison to the gold standard.

How did you answer the question?
213 males and 213 females were selected. Each participant had their bone age determined by two separate raters using the GP (M1) and SBA methods (M2). Three weeks later, the two raters repeated the analysis of the radiographs. The raters timed themselves using an online stopwatch while analyzing the radiograph on a computer screen. De–identified radiographs were securely uploaded to an automated algorithm developed by a group of radiologists in Toronto. The gold standard was determined to be the radiology report attached to each radiograph, written by experienced radiologists using GP (M1). For intra–rater variability, intraclass correlation analysis between trial 1 (T1) and trial 2 (T2) for each rater and method was performed. For inter–rater variability, intraclass correlation was performed between rater 1 (R1) and rater 2 (R2) for each method and trial.

What are the results?
Intraclass correlation between each method and the gold standard fell within the 0.8–0.9 range, highlighting significant agreement. The median time for completion using the GP method was 21.83 seconds for rater 1 and 9.30 seconds for rater 2. In comparison, SBA required a median time of 7 seconds for rater 1 and 5 seconds for rater 2. The automated method had no time restraint as bone age was determined immediately upon radiograph upload. The correlation between the two trials in each method and rater (i.e. R1M1T1 vs R1M1T2) was excellent (κ= 0.9–1) confirming the reliability of the two new methods. Similarly, the correlation between the two raters in each method and trial (i.e. R1M1T1 vs R2M1T1) fell within the 0.9–1 range. This indicates a limited variability between raters who may use these two methods.

What are your conclusions?
Most of the comparisons showed a statistically significant difference between the two new methods and the gold standard; however it may not be clinically significant as it ranges between 0.25–0.5 years. A bone age is considered clinically abnormal if it falls outside 2 standard deviations of the chronological age; standard deviations are calculated and provided in GP atlas.6–8
The shorthand bone age method and an artificial intelligence automated algorithm produced values that are in agreement with the gold standard Greulich and Pyle, while reducing analysis time and maintaining a high inter–rater and intra–rater reliability. Both of these methods are validated, reliable and quick methods of assessing bone age at the point of care. The use of artificial intelligence in the interpretation of medical imaging represents an exciting new chapter in radiographic analysis which will likely have a profound and positive effect on the way that orthopaedic surgeons are able to deliver care.

Modernization of Bone Age: Comparing the Accuracy and Reliability of Artificial Intelligence Algorithm and Short Hand Bone Age to Greulich and Pyle

Mina Gerges[1]
Hayley Eng[2], Harpreet Chhina[1,3], Anthony Cooper [1,3,4]

[1]Faculty of Medicine, University of British Columbia;
[2]Faculty of Science, University of British Columbia;
[3]Department of Orthopaedics, BC Children's Hospital;
[4]BC Children's Hospital Research Institute;

Cooper Lab is supported by research funds from BCCHF

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Disclosure

I, Mina Gerges declare that in the past 3 years:

I have not received support from any company

I have not done consulting work for any company

I have not done speaking engagements for any company

I do not hold individual shares in the following:
[16 bit]

2

Background

- Gruelich and Pyle (GP) is one of the most commonly used methods to obtain bone age
- A radiologist examines the patient's X-ray and compares it to an atlas of radiographs and matches it to the most similar standardized radiographs.

Image from https://www.slideshare.net/gauravacharya1/skeletal-age-assessment-odan, adopted from Gruelich and Pyle (1959)

3

Background: Short Hand Bone Age (SBA)

- Developed in Boston's children's hospital by Heyworth et al. (2013).
- Restricted age range: 12.5-16 for males and 10-14 for females.
- Relies on high yield landmarks in GP method without examining the whole hand leading to shorter analysis times.
- In typical age range for epiphysiodesis

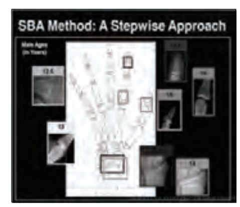

Image with permission from: Heyworth BE, Osei DA, Fabricant PD, et al. The shorthand bone age assessment: a simpler alternative to current methods.J PediatrOrthop. 2013 Jul-Aug;33(5):569-74. doi: 10.1097/BPO.0b013e318293e5f2.

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Background: automated algorithms

- Developed by a group radiologists in Toronto
- This method employs a deep learning algorithm that was built on the principles of GP.
- Fully automated: physician can upload an X-ray and the algorithm will estimate the bone age of the patient.
- https://www.16bit.ai/#bone-age

5

Objectives

- The aim of this study was to evaluate the accuracy of the two methods compared to the gold standard
- We hypothesize that the SBA method performed by inexperienced raters and the algorithm by 16 bit will produce values in agreement with GP performed by an experienced radiologist

6

Methods and Design

- 213 M and 213 F radiographs were recruited from BC children's hospital data base.
- The gold standard was defined as the radiology report written by experienced pediatric radiologists using GP.
- 2 raters with limited prior knowledge in bone age analyzed each radiograph via GP and SBA. 3 weeks later, the process was repeated
- The raters timed themselves using an online stopwatch
- De-identified Jpeg versions of the radiographs were uploaded to the automated algorithm

Exclusion criteria
Ipsilateral fracture within last 2 years
Growth hormone deficiency
Congenital adrenal hyperplasia
Elevated sex hormones
Hypothyroidism
Malnutrition
Skeletal dysplasia

7

Results

Rater/Method/Trial	Intraclass correlation coefficient (κ)	Median (IQR) difference in years	Z score (two tailed) Wilcoxon Signed ranks test
R1M1T1	0.825 ± 0.028	0.5000 (1.00)	0.224
R1M2T1	0.855 ± 0.024	0.5000 (1.00)	**0.000**
R2M1T1	0.871 ± 0.022	0.5000 (1.00)	**0.016**
R2M2T1	0.862 ± 0.023	0.5000 (1.00)	**0.000**
R1M1T2	0.839 ± 0.026	0.5000 (1.00)	**0.001**
R1M2T2	0.851 ± 0.024	0.5000 (1.00)	**0.006**
R2M1T2	0.876 ± 0.020	0.2500 (1.00)	**0.000**
R2M2T2	0.860 ± 0.023	0.5000 (1.00)	**0.000**
Automated Algorithm	0.880 ± 0.020	0.3300 (0.50)	**0.032**

Table 1**: Intraclass correlation, median difference and IQR between the various methods and raters and the gold standard.* ***Statistically significant differences are in bold.
R1: rater 1, R2 rater 2, Method 1(M1): GP, M2: SBA, T: 1st or 2nd round of radiograph analysis.

8

Results

Rater/method/Trial	Intra class correlation coefficient (κ)
R1M1T1 vs R1M1T2	0.942 ± 0.011
R1M2T1 vs R1M2T2	0.958 ± 0.008
R2M1T1 vs R2M1T2	0.955 ± 0.004
R2M2T1 vs R2M2T2	0.972 ± 0.005
R1M1T1 vs R2M1T1	0.914 ± 0.015
R1M2T1 VS R2M2T1	0.945 ± 0.009
R1M1T2 vs R2M1T2	0.919 ± 0.017
R1M2T2 VS R2M2T2	0.953 ± 0.009

***Table 2**: intra-rater (first half table) and inter-rater (second half table) variability.*
R1: rater 1, R2 rater 2, Method 1(M1): GP, M2: SBA, T: 1st or 2nd round of radiograph analysis.

9

Discussion

- Correlation between SBA method, the automated algorithm and the gold standard ranged between 0.8-0.9.
- Statistically significant difference between these two methods and the gold standard. 0.3-0.5 years.
  - This difference may not be clinically relevant as bone age is considered clinically abnormal if it falls outside 2 SDs of the chronological age
- The correlation between the two trials in each method and rater (i.e. R1M1T1 vs R1M1T2) was excellent (κ= *0.9-1*).

10

Discussion

- GP relies on an atlas that is difficult access and use.
- SBA does not require the use of atlas or comparing a variety of morphological features in each radiograph.
  - Maybe sufficient for pediatric orthopedic surgeons performing epiphysiodesis for smaller LLDs, but it does not provide a total replacement to GP.
- The automated algorithm used in this study showed a median error from gold standard within 4 months.
  - It has no age restriction and provides an opportunity to automate the entire process

Image from: https://www.worthpoint.com/worthopedia/radiographic-atlas-skeletal-1790566296

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Thank you!

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Dr Mark Cicero and Dr. Alexander Bilbily from 16 Bit inc. The algorithm adopted in this study is the intellectual property of 16 Bit Inc. Members of the company assisted with the use of the algorithm for the purpose of the study however none of the authors are affiliated with the company, nor there are any financial association with the study.

The Cooper Lab is supported by research funds from BC Children's Hospital Foundation.

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Limitations

- The gold standard used in this study did not account for variability between radiologists.
- The efficacy of the automated algorithm was tested within a constricted age range defined by SBA.
- The raters timing themselves could have also created a bias which could have been minimised using a software for timing, however this was not possible due to resource limitation.
- Only 2 methods were utilized in this study and compared to GP.
  - Tanner white house III (TW) is another method that is widely used to assess hand bone age.
  - Originally, TW was included in this study however the original text describing this method is out of print and inaccessible, therefore it was removed.

14

What Matters Most to Children with Lower Limb Deformities – An International Qualitative Study Informing the Development of a New Patient Reported Outcome Instrument – LIMB–Q Kids

Harpreet Chhina, Anne Klassen, Jacek Kopec, Anthony Cooper
hchhina@cw.bc.ca

What was the question?
What matters most to children with lower limb deformities? Our aim was to identify concepts important to children with lower limb deformities and develop items that will form the basis of a new Patient reported outcome (PRO) instrument for children with lower limb deformities.

How did you answer the question?
Individual, in person semi–structured qualitative interviews were performed with children between the ages of 8–18 years with lower limb deformities and their parents. Participants were recruited from high income (Canada –two sites and US), lower–middle income (India) and low income (Ethiopia) countries. Our goal was to elicit concepts of interest (COI) important to patients in multiple countries in order to develop an internationally applicable Health Related Quality of Life (HRQOL) instrument (LIMB–Q Kids). Interviews with children and parents were conducted separately, recorded, transcribed verbatim, translated and coded using a line–by–line approach. Interviews were conducted in English (Canada and US), French (Canadian French speaking site), Amharic (Ethiopia), Hindi and Punjabi (India). We used an interpretive descriptive methodology to analyze the interview data.

What are the results?
Seventy–nine interviews were conducted (39 patients, 40 parents). The COI important to children with lower limb deformities included physical, social and psychological health, appearance and school. Data from parent interviews also supported these COI as identified from interviews with children.
In terms of physical function, children were able to do their day to day activities and participate in some sports. However, due to the physical limitations posed by their limb deformity, they made adjustments or chose less demanding activities. Children described experiencing a range of emotions including anger, frustration, fear and helplessness. Social life was affected due to the inability to fully participate in activities with their peers. School life was also impacted due to restricted participation in physical and social activities at school. Children were self–conscious about their limping, shorter legs, scars and the appearance of their limbs. They also faced restrictions in physical and social activities due the treatment related devices they had to wear such as shoe–lifts, splints, braces and external fixator devices. Their experience of care was influenced by the type and severity of the deformity, type of treatment, their socio–economic status and access to healthcare.

What are your conclusions?
This study demonstrates that lower limb deformities have a substantial impact on the HRQOL of children. This is further influenced by health inequities including low socio–economic status and access to healthcare in lower–middle and low income countries. Nonetheless, the COI identified were similar across children from all countries. The in–depth information about what matters most to these children provided a rich dataset which was used to develop items for the new PRO instrument. Six individual scales for LIMB–Q kids including appearance, physical health, social health, psychological health, distress and school have been developed. Ongoing work includes cognitive debriefing interviews with children and health care professionals for their feedback on the items. Future work will include an international field test study and psychometric testing. Creating a PRO by this method will ensure that the instrument created is sensitive enough to demonstrate changes in the concepts of interest which are most important to children in order to quantify improvement in quality of life before and after treatment.

What matters to children and adolescents with lower limb deformities: An international qualitative study informing the development of the LIMB-Q Kids

Harpreet Chhina, Anne Klassen, Jacek Kopec, John Oliffe, Anthony Cooper

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Dr. Reggie Hamdy and Dr. Noemi Dahan-Oliel – Shriners Hospitals for Children, Montreal, Canada
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Cooper Lab is supported by research funds from BC Children's Hospital Foundation

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  - Orthopaedics Research and Excellence Funds, Department of Orthopaedics, University of British Columbia
  - Canadian Orthopaedics Foundation
- Harpreet Chhina is supported by a graduate student award from the University of British Columbia
- Limb Lengthening and reconstruction research program is funded by the BC Children's Hospital Foundation

2

Background and Objectives

- Understand the impact of lower limb deformities on the HRQL of children with lower limb deformities
- To identify concepts important to children with lower limb deformities
- To develop a conceptual framework of HRQL to guide the development of scales for a new PROM called LIMB-Q Kids

3

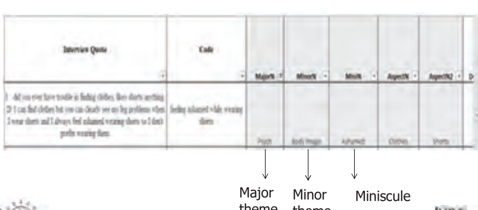
Methods

- 79 face-to-face semi-structured interviews with children and parents
- 5 languages/4 countries/5 sites
- Qualitative analysis was conducted using an approach called interpretive description

4

Results

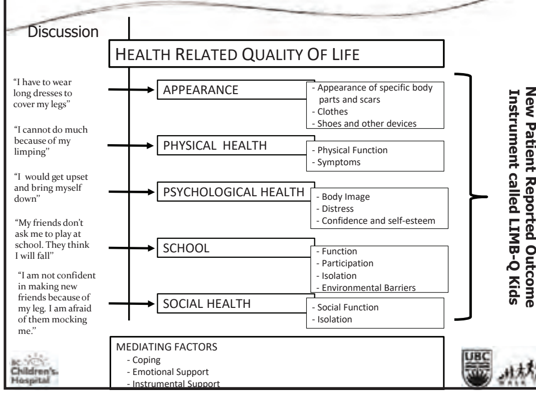
- Qualitative interviews confirmed the impact of lower limb deformities on the HRQL of children
- Qualitative analysis generated 4279 child codes/6279 parent codes representing concepts of interest



Coding process followed for all 4279 child codes/6279 parent codes

5

Discussion



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Next Steps

- International Field Test Study
- 200 completed surveys per country
- If you are interested in participation, please email

externalfixators@cw.bc.ca

BC Children's Hospital

UBC

WALK TALL

7

Estimating Skeletal Maturity using Knee Radiographs during Pre–adolescence—The Epiphyseal:Metaphyseal Ratio

Alex Benedick, Bailyn Hogue, Naveen K. Uli, Raymond W. Liu
axb709@case.edu

What was the question?
Though skeletal maturity is most relevant around puberty and adolescence, skeletal age still has applications in younger age ranges in more specialized settings. Currently, the most widely used skeletal maturity systems utilize radiographs of the left hand and wrist, even when treating conditions of the lower extremity or axial skeleton. Accurate estimation of skeletal maturity using a knee radiograph during pre–adolescence would be useful in the treatment of limb length discrepancy and other general medical conditions. Currently, a quick, accurate and reproducible method of estimating skeletal maturity in this age range is lacking. The purpose of this study was to determine if skeletal maturity can be accurately predicted during pre–adolescence using three simple radiographic knee parameters.

How did you answer the question?
Serial knee radiographs leading up to the chronological age associated with 90% of final height (an enhanced skeletal maturity gold standard compared to peak height velocity) were analyzed in 75 children. The epiphyseal and metaphyseal widths of the distal femur, proximal tibia, and proximal fibula were measured (Figure 1) and the epiphyseal:metaphyseal ratio was calculated. Greulich and Pyle bone ages (GP) were also assigned using left hand radiographs. Correlational analysis was performed to evaluate the relationship between each ratio and the years away from the chronologic age associated with attaining 90% of final height. Linear regression was used to compare the ability of demographics (age, sex), epiphyseal:metaphyseal ratios, GP bone age, and combinations of these variables to predict the years away reaching 90% of final height.

What are the results?
258 left knee radiographs from 39 girls (mean age 8.6 years, range 2.9 to 13 years) and 36 boys (mean age 10.6 years, range 3.8 to 15 years) were included. There was a strong positive correlation between the epiphyseal:metaphyseal ratio value and years away from reaching 90% of final height, with Pearson R values of 0.80, 0.84, and 0.84 for the femur, tibia, and fibula, respectively (all p1 year off from the actual age at which 90% of final height was attained compared to 8.6% using demographics and GP. The mean discrepancy between predicted and actual years away from 90 inal height was not significantly different when using demographics and ratios (0.49 years) compared to demographics and GP (0.48 years) (p=1.0).

What are your conclusions?
This large analysis of a simple and reproducible knee skeletal maturity system demonstrates that with only three discrete radiographic knee parameters, skeletal maturity can be predicted with a high degree of accuracy during the pre–adolescent age range. Given the relative ease of measurement and avoidance of additional hand radiographs, this system might offer a practical alternative to use of the Greulich and Pyle bone age system in younger children with limb length discrepancy.

Estimating Skeletal Maturity using Knee Radiographs during Preadolescence: The Epiphyseal:Metaphyseal Ratio

Alex Benedick MD[1], Bailyn Hogue BS[2], Naveen Uli MD[3], Raymond Liu MD[1]

[1]Department of Orthopaedics, Case Western Reserve University SOM, Cleveland, OH, USA
[2]Case Western Reserve University SOM, Cleveland, OH, USA
[3]Department of Pediatrics, Endocrinology, Case Western Reserve University SOM, Cleveland, OH, USA

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Disclosures

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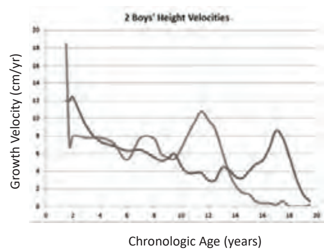
2

Background – Why Skeletal Age?

- Adolescent growth spurt begins at wide range of chronologic ages
  - Timing of growth spurt not well correlated to chronologic age
- However, timing of growth spurt determines when growth will ultimately (begin to) end



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Background – Chronologic Age

- Works better than skeletal age in pre-adolescence
- Does not work as well closer to adolescence
- However, prior skeletal age systems are imperfect and largely qualitative/subjective

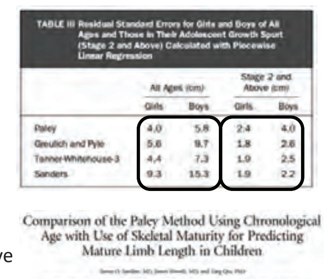


TABLE III Residual Standard Errors for Girls and Boys of All Ages and Those in Their Adolescent Growth Spurt (Stage 2 and Above) Calculated with Piecewise Linear Regression

	All Ages (cm)		Stage 2 and Above (cm)	
	Girls	Boys	Girls	Boys
Paley	4.0	5.8	2.4	4.0
Greulich and Pyle	5.6	9.7	1.8	2.6
Tanner-Whitehouse-3	4.4	7.3	1.9	2.5
Sanders	9.3	15.3	1.9	2.2

Comparison of the Paley Method Using Chronological Age with Use of Skeletal Maturity for Predicting Mature Limb Length in Children

4

Background – Skeletal Maturity Gold Standard

- Old Gold Standard: Peak Height Velocity
  - Difficult to measure due to annual growth measurements
- New Gold Standard: Age at 90% Final Height
  - Excellent proxy for age at Peak Height Velocity
- If we can predict age at 90% final height, we can predict remaining growth

5

Background

- Primarily concerned with skeletal maturity around puberty/adolescence, but still has applications in younger age ranges in more specialized settings
- Would be useful in treating limb length discrepancy, early onset scoliosis, other general medical conditions

6

Purpose

- Develop a quick, accurate, reproducible knee skeletal maturity system that outperforms current systems in the pre-adolescent age range

7

Methods – Bolton Brush Collection

- World's most extensive source of longitudinal human growth data
  - Source of knee radiographs
- Serial knee x-rays up to chronologic age associated with 90% final height analyzed in **75 children**

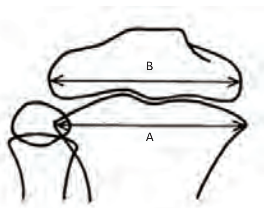

The Brush Foundation

Charles Francis Brush

8

Methods – Epiphyseal:Metaphyseal Ratio

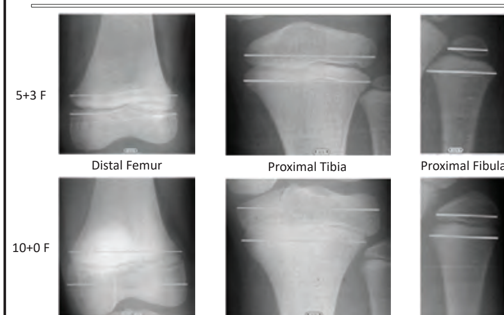
- Draw Line A from widest medial to lateral point of metaphysis
- Draw Line B parallel to Line A from widest medial to lateral point of epiphysis
- Measurements made using distal femur, proximal tibia, and proximal fibula
- Simple, reproducible, quantitative method



$$Ratio = \frac{B}{A}$$

9

Methods – Epiphyseal:Metaphyseal Ratio



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Methods – Correlational Analysis

- Epiphyseal:metaphyseal ratios measured on 258 knee radiographs
- Correlational analysis performed to evaluate relationship between each ratio and years from age at 90% final height

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Methods – Regression Analysis

- Simple and multiple linear regression analysis was used to create models using various combinations of demographics + ratios to predict years away from reaching 90% of final height
  - Estimates of years from 90% final height produced by regression models compared to true years away from 90% final height for each subject
  - % of subject where estimates were >1 year off calculated for each regression model

12

Results – Final Cohort

	N	XR	Mean Age	Age Range
Male	36	106	10.6 yrs	3.8 - 15 yrs
Female	39	152	8.6 yrs	2.9 - 13 yrs
Total	75	258	9.4 yrs	2.9 - 15 yrs

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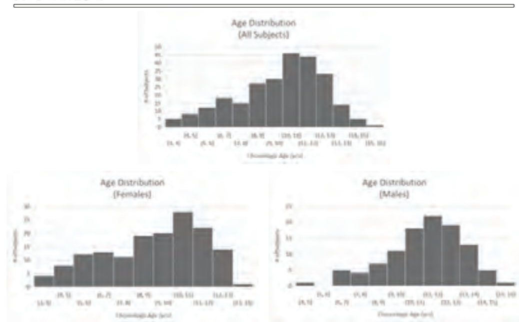
Results – Age Distribution



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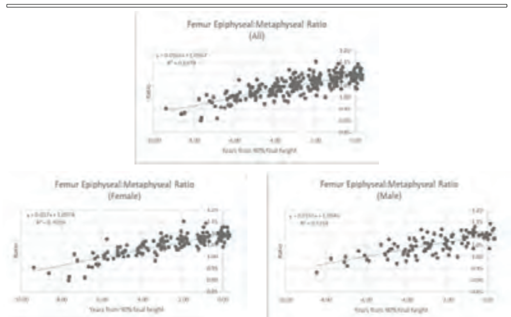
Results – Correlation Femur



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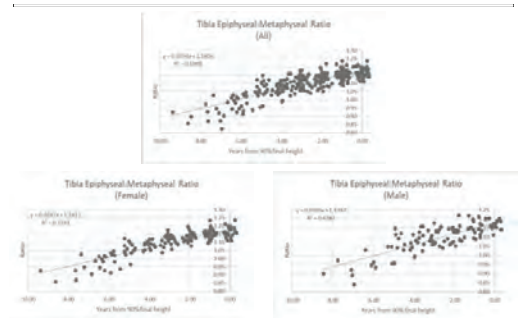
Results – Correlation Tibia



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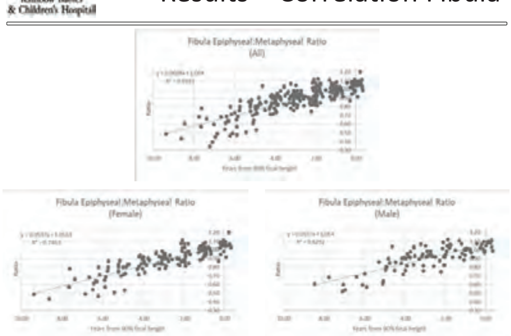
Results – Correlation Fibula



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Results – Correlation Summary

Correlation w/ Yrs from 90*	Fem	Tib	Fib
All Patients	0.799	0.838	0.837
Female	0.838	0.868	0.864
Male	0.732	0.799	0.793

*Pearson R

- Overall, strong positive correlation between Epi:Met ratio value and years away from 90% final height
  - Relationship slight stronger for girls
  - Weakest relationship seen with distal femur

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Results – Multiple Linear Regression

	Age	Ratios	Sex + Ratios	Age + Ratios	Age + Sex	Age + Sex + Ratios	Age + Sex + GP
Discrepancy	0.87	0.78	0.78	0.60	0.55	0.49	0.48
P-value vs. Age + Sex + Ratios	<0.001	<0.001	<0.001	0.041	0.463	--	1.00
> 1 year	37.9%	31.3%	31.3%	20.2%	16.5%	11.1%	8.6%
R squared	0.770	0.796	0.796	0.867	0.895	0.916	0.915

- The Age + Sex + Ratios model performed similarly to Age + Sex + GP
  - Only 11.1% of predictions using age + sex + ratios were >1 year off from actual age at 90% final height compared to 16.5% for age + sex alone
  - Mean discrepancy between predicted and true years from 90% final height was lower for age + sex + ratios than age + sex alone, but not significantly so

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Conclusion

- We found that with just 3 discrete radiographic knee parameters, skeletal maturity can be predicted with a high degree of accuracy during the preadolescent age range
- Addition of epiphyseal:metaphyseal width ratios to age + sex did not produce a statistically superior model, though it could be argued that this model is clinically superior

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Skeletal Maturity using Knee X–rays: Understanding the Resilience of Eight Radiographic Parameters to Rotational Position

Julio Cesar Castillo Tafur, Alexander Benedick, Raymond W. Liu
jcc184@case.edu

What was the question?
We have recently developed a skeletal maturity system using knee radiographs named the modified RWT system, which can significantly outperformed the Greulich and Pyle atlas. This study aimed to quantify how skeletal maturity determinations in the same subjects are affected by rotational variation of the knee radiograph.

How did you answer the question?
We retrospectively obtained normal knee CT scans of 12 male children ages 10 to 16 years and eight female children ages 8 to 14 years, converted them into 3D reconstructions, and then simulated knee radiographs in five different rotational positions. The amount of rotation was based on patella positioning, with a central image with the patella centered, one each with the medial and lateral patellar edges meeting the medial and lateral femoral condyles, and positions between the first three. One hundred images were analyzed using the eight discrete knee radiographic parameters which constitute the modified FELs system. A one–way repeated measures ANOVA was used to compare skeletal age in the patella centered view versus the other positions. We next retrospectively found 85 pediatric patients with both bilateral standing antero–posterior hip to ankles as well as a knee radiographs within six months of each other. The skeletal maturity of 39 males between the ages of 10 and 16 years and 46 females between 8 and 14 years of age was determined using the modified FELs system. Additionally, patellar centering was quantified on each radiograph.

What are the results?
On the CT scan based images, there was no statistically significant effect of rotational position on the modified FELS score using repeat measures ANOVA ($p = 0.43$). Of the eight individual parameters used in the modified FELS system, only the width ratio of the tibial epiphysis and metaphysis (TibA) and the width ratio of the fibular epiphysis and metaphysis (FibA) were statistically different between rotational positions ($p < 0.05$). Post–hoc analyses showed that the most statistically significant difference in TibA was between the most medially placed patella and the centered patella, while FibA was statistically different between the centered patella versus the most medial placed patella, the most laterally placed patella, and partial lateral placement. Comparing clinical full length versus knee radiographs, we found a non–statistically significant trend towards a difference using non–parametric Friedman Test ($p = 0.065$). While a raw difference of 0.055 years was estimated, this difference is clinically insignificant. There was no significant correlation between the difference in patellar centering and the difference in predicted age ($r=0.197$, $p = 0.071$).

What are your conclusions?
This retrospective study supports the resilience of the FELs model to rotational variation. The data reassures clinicians that bone age estimation can be performed in a slightly rotated knee x–ray within a reasonable margin of error. These results can minimize the number of radiographs needed before surgical intervention limiting radiation exposure and expediting clinical flow.

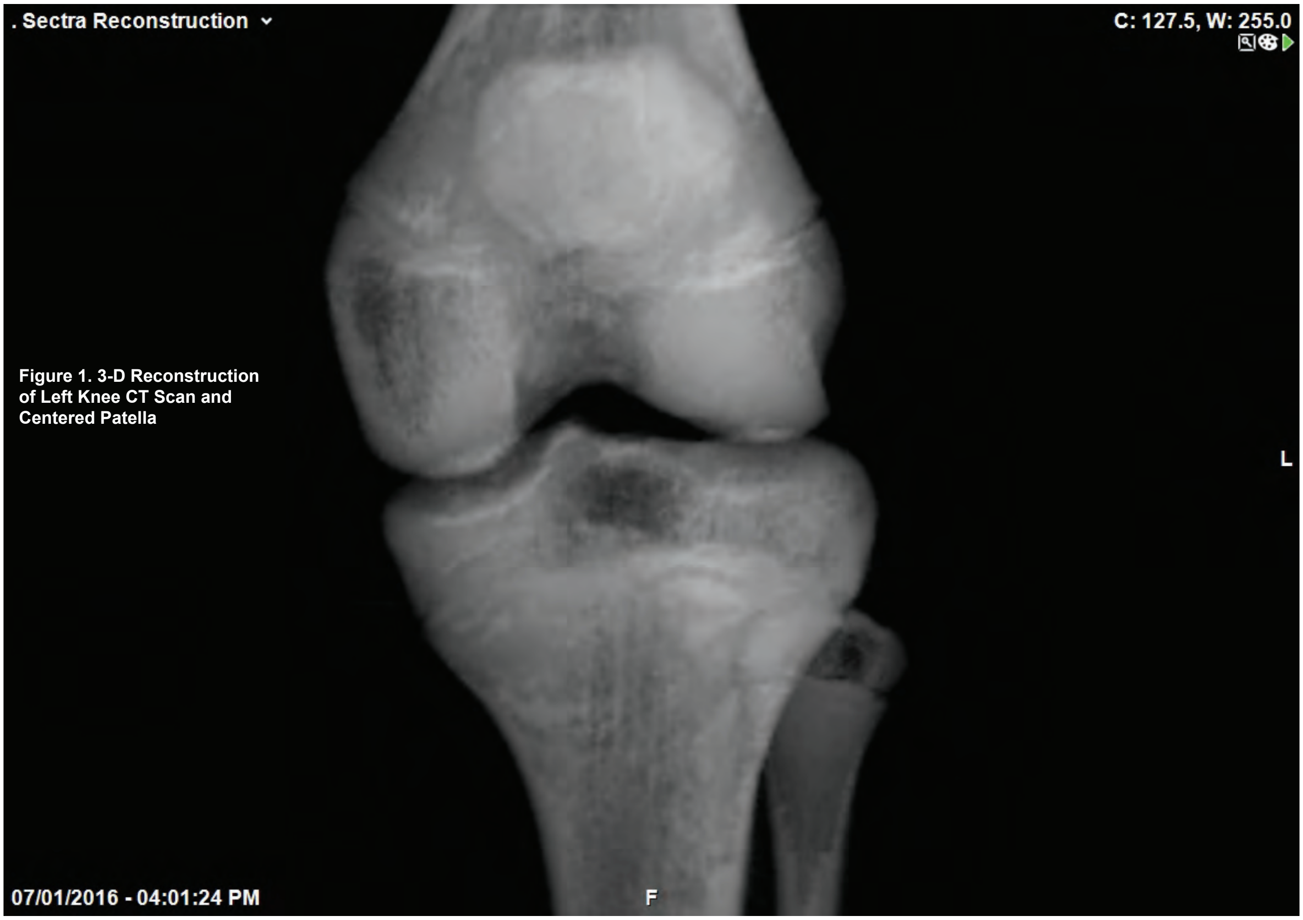

Figure 1. 3-D Reconstruction of Left Knee CT Scan and Centered Patella

Figure 2. Simulated Knee X-ray with Medial Patellar Edge Aligned with Medial Femoral Condyle

Figure 3. Simulated Knee X-ray with Slight Medial Patellar Deviation

Figure 4. Simulated X-ray with Centered Patella

Figure 5. Simulated X-Ray with Slight Lateral Patellar Deviation

Figure 6. Simulated X-Ray with Lateral Patellar Edge Aligned with Lateral Femoral Condyle

Skeletal Maturity using Knee X–rays: Understanding the Resilience of Eight Radiographic Parameters to Rotational Position

Julio C. Castillo Tafur, B.S[1]., Alexander Benedick, M.D[1,2], Raymond W. Liu, M.D[1,2].

Case Western Reserve University School of Medicine[1]
Rainbow Babies and Children's Hospital[2]

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Disclosures

- The authors have no relevant disclosures for this study

2

Introduction

- We have develop a modified RWT that significantly outperforms the Greulich and Pyle system

3

The Modified RWT Model

- Eight discrete radiographic parameters :
  - Three continuous, quantitative parameters
    - TibA, FibA and TibHMed
  - Five categorical parameters:
    - FemL, TibQ, TibN, TibP, and FemK

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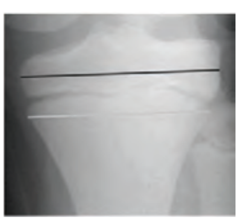
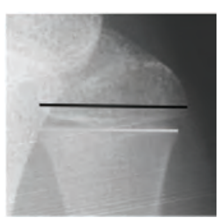
TibA and FibA: Width Ratios



TibA



FibA

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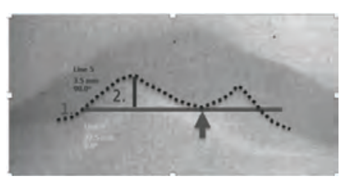
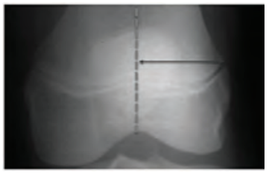
TibHMed: Height



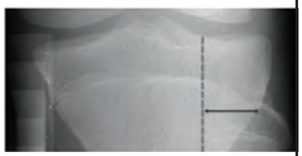
The height of medial tibial spine (mm)

6

FemL and TibQ: Lateral Fusion



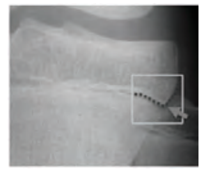
FemL



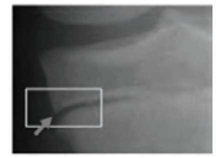
TibQ

7

TibN and TibP: “Capping”



TibN: Lateral ”Capping”



TibP: Medial “Capping”

8

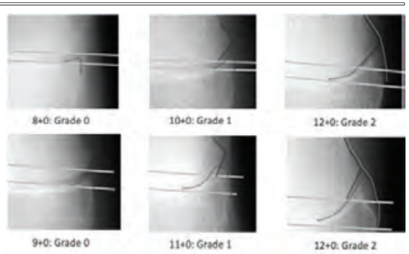
RWT: FemK

“Capping”

- Lateral distal Femoral epiphysis over metaphysis

Grade:

- 0 – Absent
- 1 – Incomplete
- 2 - Complete



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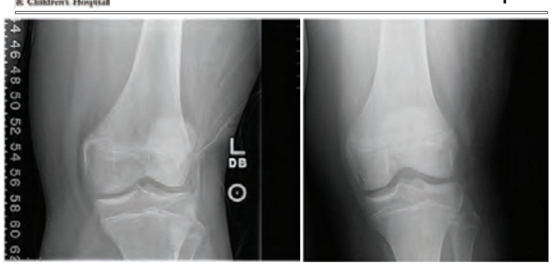
Introduction: RWT question

- In contrast to the standardized hand-wrist radiographs, AP knee radiographs can have substantial rotational variation

10

Rotational Variation: Example



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Statement of Purpose

To evaluate the resilience of the modified RWT model to rotational variation by:

1) Comparing simulated AP radiographs of the knee in five different rotational positions

2) Comparing AP radiographs of the knee versus standing hips-to-ankle bone-length radiographs

12

Part 1: CT Reconstructions

Normal knee CT scans:

1. Twelve male children ages 10 to 16 years
2. Eight female children ages 8 to 14 years

→

Reconstruction:

Generation of simulated knee radiographs in **five** different rotational positions

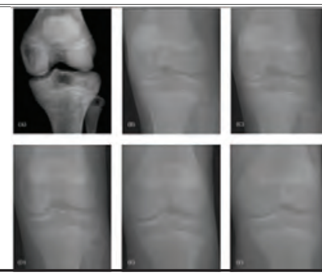
→

Analysis:

Simulations graded using one-way repeated measures ANOVA

13

Simulated Knee Radiographs



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Part 2: Clinical Patients

85 Patients with bilateral standing AP hip to ankles and AP knee radiograph within six months of each other

↓

Estimate the Skeletal Maturity of 39 Males and 46 Females

15

Clinical Patients: Comparison

AP Knee Radiograph


Hip to Knee AP Radiograph

16

Demographics: Both Groups

CT Recon Group (n = 20)	Age	Range
Females	12.7 ± 0.80 Years	11 to 13 Years
Males	13.5 ± 1.1 Years	11 to 15 Years

Clinical group (n = 85)	Age	Range
Females	12.09 ± 1.41 Years	9 to 14
Males	13.82 ± 1.35 Years	11 to 16

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Results: CT Reconstruction

- No statistical difference between the five different rotational views in terms of their overall calculated predicted age using the modified RWT model ($p = 0.43$).
- A statistically significant mean difference of -0.034 ± 0.009 between the most central image with the patella centered and the image with the medial patellar edge meeting the medial femoral condyle ($p = 0.01$).

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Results: CT Reconstruction

FemL & TibQ

19

FemL	Side 1 (Medial Deviation)		
Side 3 (Center)	0	1	2
0	15	0	0
1	0	2	0
2	0	0	3

FemL	Side 2 (Slight Medial Deviation)		
Side 3 (Center)	0	1	2
0	15	0	0
1	0	2	0
2	0	0	3

FemL	Side 4 (Slight Lateral Deviation)		
Side 3 (Center)	0	1	2
0	15	0	0
1	0	2	0
2	0	0	3

FemL	Side 5 (Lateral Deviation)		
Side 3 (Center)	0	1	2
0	15	0	0
1	0	1	1
2	0	0	3

20

TibQ	Side 1 (Medial Deviation)		
Side 3 (Center)	0	1	2
0	16	0	0
1	0	2	0
2	0	0	2

TibQ	Side 2 (Slight Medial Deviation)		
Side 3 (Center)	0	1	2
0	16	0	0
1	0	2	0
2	0	0	2

TibQ	Side 4 (Slight Lateral Deviation)		
Side 3 (Center)	0	1	2
0	15	1	0
1	0	2	0
2	0	0	2

TibQ	Side 5 (Lateral Deviation)		
Side 3 (Center)	0	1	2
0	15	1	0
1	0	1	1
2	0	0	2

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Results: CT Reconstruction

TibN & TibP

22

TibN	Side 1 (Medial Deviation)	
Side 3 (Center)	0	1
0	1	1
1	0	19

TibN	Side 2 (Slight Medial Deviation)	
Side 3 (Center)	0	1
0	1	0
1	0	19

TibN	Side 4 (Slight Lateral Deviation)	
Side 3 (Center)	0	1
0	1	0
1	0	19

TibN	Side 5 (Lateral Deviation)	
Side 3 (Center)	0	1
0	1	0
1	0	19

23

TibP	Side 1 (Medial Deviation)	
Side 3 (Center)	0	1
0	1	0
1	0	19

TibP	Side 2 (Slight Medial Deviation)	
Side 3 (Center)	0	1
0	1	0
1	0	19

TibP	Side 4 (Slight Lateral Deviation)	
Side 3 (Center)	0	1
0	1	0
1	0	19

TibP	Side 5 (Lateral Deviation)	
Side 3 (Center)	0	1
0	1	0
1	0	19

24

Results: CT Reconstruction

FemK

25

FemK	Side 1 (Medial Deviation)		
Side 3 (Center)	0	1	2
0	0	0	0
1	0	2	0
2	0	0	18

FemK	Side 2 (Slight Medial Deviation)		
Side 3 (Center)	0	1	2
0	0	0	0
1	0	2	0
2	0	0	18

FemK	Side 4 (Slight Lateral Deviation)		
Side 3 (Center)	0	1	2
0	0	0	0
1	0	2	0
2	0	0	18

FemK	Side 5 (Lateral Deviation)		
Side 3 (Center)	0	1	2
0	0	0	0
1	0	1	1
2	0	0	18

26

Results: Clinical Group

- A small raw difference of 0.054 years in predicted age which was statistically significant ($p = 0.03$).
- Of the quantitative parameters, only FibA showed a mean difference of 0.014 ± 0.007 which was not statistically significant ($p= 0.11$).
- In comparison, TibA and TibHMed ($p = 0.43$, $p = 0.57$) showed no difference with Wilcoxon-signed rank tests.

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Results: Clinical Group

TibQ	AP Knee		
Bone Length	0	1	2
0	38	2	0
1	4	30	3
2	1	4	3

FemL	AP Knee		
Bone Length	0	1	2
0	39	3	0
1	6	28	1
2	0	2	6

28

Results: Clinical Group

TibN	AP Knee	
Bone Length	0	1
0	3	1
1	0	81

TibP	AP Knee	
Bone Length	0	1
0	16	1
1	1	67

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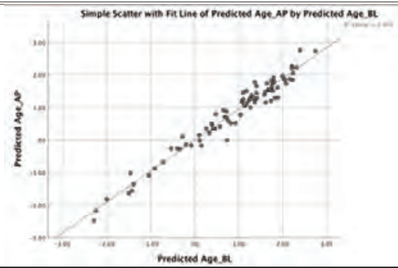
Results: Clinical Group

FemK	AP Knee		
Bone Length	0	1	2
0	3	0	0
1	1	7	0
2	0	1	73

30

Clinical Group: Overall Predicted Age Scatterplot



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Conclusions

1) The modified RWT skeletal maturity system is relatively resilient to rotational variation in knee position.
2) Our findings further validate the use of this system in clinical settings.

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Thank You

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Core Psychosocial Issues for Children and Adolescents in the Context of Limb Lengthening and Reconstruction Surgery Treatment

Amber Hamilton, Peter Principe, Austin Fragomen, S. Robert Rozbruch
amh2030@med.cornell.edu

What was the question?
Psychosocial factors are known to be important in healthcare relating to symptoms, outcomes, and patient experience. Little is known about the psychosocial issues of children and adolescents in the context of limb lengthening and reconstruction treatment. What are the core psychosocial factors that shaped the experience of adolescents who underwent multiple limb lengthening/reconstruction surgeries between the ages of 11 and 18?

How did you answer the question?
A total of 38 patients were enrolled in the study via phone/email. A novel 62–question survey was developed from focused discussions among a pediatric orthopedic surgeon, pediatric/adult limb deformity orthopedic surgeons, orthopedic psychologists, child psychologist, social worker, epidemiologist, several patients, and several parents. It was administered to all enrolled patients from the study institution.
Survey responses were collected from free–response and Likert scale questions that explored topics of medical care, communication/connection to doctor, peer issues, physical space, self–esteem, counseling/clergy, emotional support, school issues, and concerns about future. The survey and other demographic questions were administered retrospectively to young adults (now ages 18–30) who underwent limb lengthening/reconstruction surgery at the study institution between ages 11–18.

What are the results?
A total of 31 patients completed the survey. Respondents valued physician transparency regarding information about their surgery and wanted an experienced surgeon. Majority of respondents found it "very important" to have their questions answered by their surgeon and to have their surgeon speak directly to them instead of to their parents. All responses regarding the role of parents were skewed toward maximizing parent involvement. Patients looked to their parents for emotional, physical, and financial support and assistance in understanding their treatment plan.
Patients were indifferent to the impact of their orthopedic problem on their body image and self–esteem before and after surgery. They found their orthopedic conditions and subsequent treatment plans to be different levels of complicated. They expressed worry about the level of pain they would experience and being able to carry out their activities of daily living (i.e. getting out of bed, showering, dressing self). All patients reported the final result of their orthopedic treatment as positive. Majority of patients were neutral to wanting to speak to a counselor about what they were going through.
Keeping up with friends was not as important to patients during their treatment as it was beforehand. They were indifferent to connecting with peers undergoing similar treatments and preferred not to socialize with others during their hospital stays. Most patients wanted their schools to be made aware of their health and treatment plans. No significant associations between gender and survey responses were found.

What are your conclusions?
These findings call attention to the considerable need for a model by which orthopedic surgeons can assess psychosocial mediators of pain, recovery, and rehabilitation among adolescent orthopedic surgery patients. This patient population valued focused psychosocial support from an integrated team of caregivers including their surgeon, parents, and peers while undergoing limb lengthening/reconstruction surgery. Results will assist orthopedic surgeons in providing holistic care to adolescents. A future prospective study is planned to better understand age specific psychosocial issues.

Core Psychosocial Issues for Children and Adolescents in the Context of Limb Lengthening and Reconstruction Surgery Treatment

Amber A. Hamilton, BA
Peter S. Principe, BS
B. Sue Epstein, PhD
Peter D. Fabricant, MD, MPH
Austin T. Fragomen, MD
S. Robert Rozbruch, MD

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Assessing Psychosocial Needs of Adolescents

- Physical and emotional experience of limb lengthening/reconstruction surgery (LLRS) treatment may decelerate adolescent psychosocial maturation process
- Studies show that orthopedic surgeons are indifferent to screening for psychological factors
- Psychosocial needs and challenges of adolescent patients undergoing LLRS treatment are unclear
- Assess concerns to preserve individuation process and strengthening of self-esteem
- Establish core best practices to improve surgical outcomes, patient experience, and overall patient satisfaction

2

Our objective is to understand the core psychosocial factors that impacted the experience of adolescents who underwent limb lengthening surgery.

This is a retrospective report of the insight of patients currently age 18-30 who underwent multiple limb lengthening and reconstruction surgeries for treatment of a chronic condition between the ages of 11 and 20.

3

Methods

- Collaborative effort between limb lengthening/reconstruction surgeons, pediatric orthopedic surgeons, psychologists, former patients, and parents to create questionnaire
  - 62 questions assessing needs in the areas of self esteem/body image, connection with their doctor, physical and emotional support, role of parent/family, peer relations, spiritual/religious community involvement, academic performance, and concerns about their future.
- Included
  - Patients who underwent more than 1 surgery at HSS including sports medicine, fractures, limb lengthening, and reconstruction due to chronic orthopedic conditions
  - Surgery as adolescent (between the ages of 11 and 20)
  - Currently young adult (between the ages of 18 and 30)
- Primary Outcome: What are the psychosocial challenges, principles, and opportunities when treating children and adolescents ages 11-20 years old?
- Secondary Outcome: Do the challenges expressed by patients fall into a pattern related to gender?

4

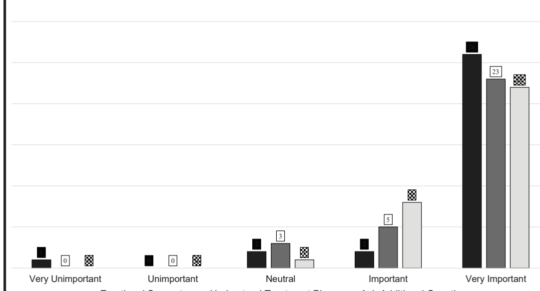
Demographics

Gender	
Male	14
Female	17
Total	**31**

Age at First Treatment	
11-12 years old	9
13-14 years old	4
15-16 years old	11
17-18 years old	6
19-20 years old	1

5

Though adolescents are becoming more independent during this stage of development, they still relied on their parents for much support.



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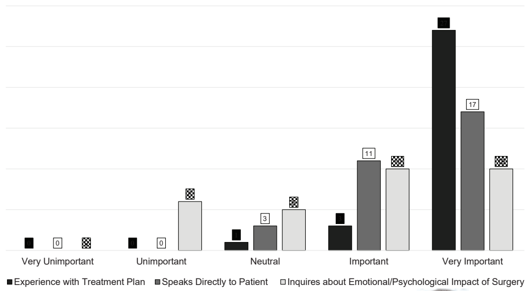
Patients appreciated having an experienced orthopedic surgeon who speaks directly to them as opposed to their parents and who inquires about the emotional and psychological implications of their orthopedic treatment.



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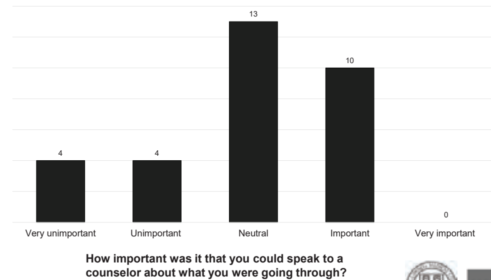
Patients were indifferent to speaking to a counselor about what they were going through.



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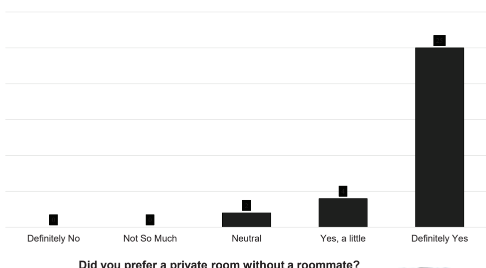
Adolescents wanted privacy while undergoing treatment contrary to the presumptions of orthopedic surgeons.



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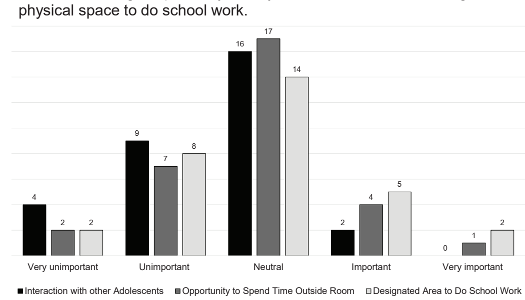
Adolescents were indifferent to socializing and leaving the comfort of their room during hospital stays. They were uninterested in having a physical space to do school work.



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Statistical Analysis

- Association between gender and desire for peer interaction was not found to be significant.
- Association between gender and perception of complicatedness of treatment was not found to be significant.

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Conclusions

- This study has helped us understand the psychosocial issues and preferences of adolescent patients who have undergone LLRS treatment.
- Adolescent orthopedic surgery patients value focused psychosocial support from their surgeon and caregivers. This perceived level of support directly influences their ability to cope with their condition in a healthy manner that does not thwart psychosocial maturation.

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Limitations and Future Directions

- Limitations
  - Recall bias inherent to retrospective study
  - Incentive to complete survey once enrolled
  - Current survey did not address impact of surgery on adolescents who play sports
  - Inability to do meaningful statistical analysis on qualitative data
- These findings will inform the prospective second phase of this study
  - Improve and expand on current questionnaire
  - Identify the psychosocial needs of adolescents before and after surgery for a broader variety of orthopedic conditions (spine, trauma, general pediatric orthopedics, limb lengthening/reconstruction, etc.)
  - Identify the impact of variables such as age at surgery, gender, socioeconomic status, and perceived level of complexity of orthopedic condition

13

Thank you!

14

Limb Lengthening in Russell–Silver Syndrome: An Update Confirming Safe and Speedy Healing

Christine M. Goodbody, S. Robert Rozbruch, Madeleine Harbison, Joshua Buksbaum
goodbodyc@hss.edu

What was the question?
Russell–Silver Syndrome (RSS) is a unique cause of syndromic, and often severe, limb length discrepancy (LLD). RSS causes growth retardation both in utero and postnatally, with asymmetry in limb length more noticeable as growth progresses throughout childhood and adolescent. We aim to present the largest cohort in the literature on limb–lengthening in patients with RSS and to validate previous literature supporting faster bony consolidation in these patients with more robust data. We further aim to establish differences in healing within this cohort based on age, gender, segment lengthened, or type of lengthening procedure performed, to help refine patient expectations and guide practitioners in treating this population.

How did you answer the question?
This was a retrospective study of patients with a diagnosis of Russell–Silver syndrome who underwent a limb lengthening procedure for the purpose of limb equalization. They were compared to a historical control group of patients who underwent limb lengthening for LLD of a non–RSS etiology. The primary outcome measure was bone healing index (BHI).

What are the results?
The RSS group consisted of 24 patients with 29 segments lengthened, and was compared to a historical control group consisting of 20 patients with 22 segments lengthened (Goldman). Patients with RSS had a significantly lower BHI, and therefore faster healing of their lengthening site, than their non–RSS peers ($p = 0.02$). Within the RSS cohort, we did not detect a difference in BHI based on intervention type or gender, but we did find a trend towards faster healing in femurs over tibiae ($p = 0.08$), and established that younger patients tended towards lower BHIs ($p < 0.01$).

What are your conclusions?
Our results confirmed with more robust data the prior finding that patients with Russell–Silver Syndrome may undergo limb lengthening procedures at least as safely as their non–RSS counterparts, and with even faster bony consolidation, especially in younger patients. We hypothesize that concurrent treatment with growth hormone supplementation may contribute to this finding, although further study is necessary. This is the largest cohort of RSS patients treated with limb lengthening for LLD reported in the literature, and these findings will help to guide surgeon decision–making when treating this unique population.

HSS

Safe and Speedy: An Assessment of Bony Consolidation After Limb Lengthening in Russell-Silver Syndrome

Christine M. Goodbody, MD, MBE, Madeleine Harbison, MD,
Austin T. Fragomen, MD, S. Robert Rozbruch, MD

1

DISCLOSURES

HSS

Disclosure:

I do not have a relevant financial relationship.

2

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INTRODUCTION

HSS

- Russell-Silver Syndrome (RSS) is a unique cause of syndromic, and often severe, limb length discrepancy (LLD).
- Causes growth retardation both in utero and postnatally
- Asymmetry in limb length more noticeable as growth progresses throughout childhood and adolescent.

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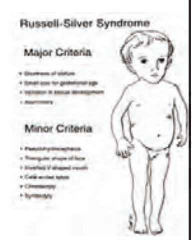
PURPOSE

HSS

- To present the largest cohort in the literature on limb-lengthening in patients with RSS.
- To compare rate of bone healing in patients with RSS to their peers.
- To establish differences in healing within this cohort based on age, gender, segment lengthened, or type of lengthening procedure.



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4

METHODS

HSS

- This was a retrospective study of patients with a diagnosis of Russell-Silver syndrome who underwent a limb lengthening procedure for the purpose of limb equalization.
- They were compared to a control group of patients who underwent limb lengthening for LLD of a non-RSS etiology.
- The primary outcome measure was bone healing index (BHI).

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RESULTS

HSS

- 24 patients with 29 segments lengthened with either an intramedullary nail or a frame.
- Comparison group: 20 patients with 22 segments lengthened.
- Average length of follow up was 27 months (range 3 – 87), and all patients were followed to the primary endpoint of consolidation.

6

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RESULTS

- Patients with RSS had a significantly lower BHI, and therefore faster healing of their lengthening site, than their non-RSS peers (31 days/cm versus 43 days/cm; $p = 0.02$).
- Within the RSS cohort, we did not detect a difference in BHI based on intervention type or gender, but we did find a trend towards faster healing in femurs over tibiae ($p = 0.08$), and established that younger patients tended towards lower BHIs ($p < 0.01$).
- Complication rate was lower in the RSS group as compared to the control group.

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RESULTS

		Average BHI (d/cm)	p value
Intervention type	Nail	31	0.91
	Frame	31	
Gender	Male	32	0.49
	Female	30	
Segment lengthened	Femur	28	0.08
	Tibia	35	
Age (years)	≤13	28	0.04
	>13	36	

Table: Average BHI by intervention type, gender, segment lengthened, and age, within the RSS group

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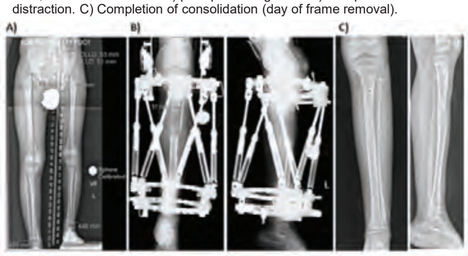
EXAMPLE 1

Example case of tibial lengthening using a TSF in a 6-year-old male with RSS; indirect LLD 51mm. A) pre-op standing films. B) Completion of distraction. C) Completion of consolidation (day of frame removal).



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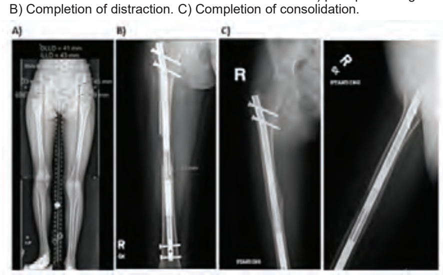
EXAMPLE 2

Example case of femoral limb-lengthening using a Precice nail in a 13-year-old female with RSS with an indirect LLD of 43mm. A) pre-op standing films. B) Completion of distraction. C) Completion of consolidation.



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LIMITATIONS

- Retrospective
- Power
- Variable diagnoses in comparison group
- Not the last word—many will require future lengthenings and must be followed to maturity

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CONCLUSIONS

- Our results confirmed with more robust data that patients with RSS may undergo limb lengthening procedures with even faster bony consolidation than their non-RSS counterparts, especially in younger patients.
- Our results also suggest that limb lengthening in RSS patients is at least as safe as in those without the condition.
- We hypothesize that concurrent treatment with growth hormone supplementation may contribute to this finding, although further study is necessary.
- This is the largest cohort of RSS patients treated with limb lengthening for LLD reported in the literature, and these findings will help to guide surgeon decision-making when treating this unique population.

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THANK YOU!

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Meta–analysis of Limb Lengthening and Related Complications in Osteogenesis Imperfecta

David S. Feldman, MD, Angelika Saribekyan, Troy Rand
dfeldman@paleyinstitute.org

What was the question?
Osteogenesis Imperfecta (OI), commonly referred to as Brittle Bone Disease, is a hereditary condition that causes characteristically more fragile bone with decreased bone mineral density. A number of bone deformities may present in patients with OI, including limb length discrepancies. The purpose of this research was to review and analyze the current literature on limb lengthening in OI to determine the effectiveness of treatment and describe the complications involved.

How did you answer the question?
Pubmed and Google Scholar were searched to identify articles related to OI and lower limb lengthening. Four studies were identified that fit all of the inclusion/exclusion criteria published between 1993 and 2004. The results from the four studies were combined and analyzed to determine 1) The effectiveness of lengthening lower extremities in OI patients, and 2) Rate, type, and severity of complications in OI lower limb lengthening.

What are the results?
Sixteen patients were included in the four studies (N = 9F/7M, Age: 21 years (range 13 – 51 years). The mean planned length was 7.31 cm and mean achieved length was 7.26 cm ($p < .001$, $r = 0.97$). On average patients with OI were able to lengthen their lower limbs to within 0.8 cm of their contralateral lower limb. Three patients were left with a leg length discrepancy due to complications that arose or the magnitude of starting discrepancy. More than half of the complications were considered minor (N = 19) and included pin site infections (N = 8), sensory changes (N = 3), muscle contracture (N = 1), and large quantity of blood loss (N = 1). The major complications (N = 15) required additional correctional surgeries. These included bone fractures (N = 6), migration of the rod (N = 2), loosening or breaking of pins used (N = 2), and loss of mobility in the knee (N = 2).

What are your conclusions?
Lower limb lengthening in OI was successful but involved a high complication rate, with an average of over 2 complications per patient. All of the patients except one experienced some type of complication. This information is important for patients and surgeons when they are considering limb lengthening in OI. Although the procedures are successful it must be understood that both minor and major complications are common, and every effort should be made to mitigate these complications.

META-ANALYSIS OF LIMB LENGTHENING AND RELATED COMPLICATIONS IN OSTEOGENESIS IMPERFECTA

David S. Feldman, MD
Chief of Hip Preservation and Spinal Deformity
Co-Authors: Angelika Saribekyan, BS; Troy Rand, PhD
Paley Institute
West Palm Beach, Florida
LLRS Virtual Conference
July 2020

901 45th Street
Kimmel Building
West Palm Beach, FL 33401
561.844.5255
www.paleyinstitute.org

1

Disclosure

- We have no conflict of interest in relation to the research being presented

2

Background

- Osteogenesis Imperfecta
  - a.k.a. Brittle Bone Disease
- Genetic disease
  - Fragile bones
  - Decreased bone mineral density
- Results in several bone deformities, including leg length discrepancy

3

Methods

- A review and meta-analysis of lower limb lengthening
- 4 studies met the inclusion criteria
  - all studies included individual patient data
- Patients from the 4 studies were pooled to answer 2 questions
  - [N = 16 (9F/7M); mean age = 21 years (range 13 – 51 years)]

  1. Is limb lengthening effective in OI
  2. The rate, type, and severity of complications in lengthening

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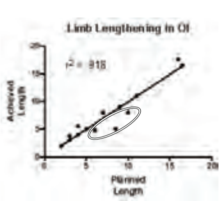
Results - Lengthening



($p < .001$, r = 0.96)

- Planned and achieved length showed a very strong, significant correlation
- 3 patients did not achieve desired length
  - Due to complications or magnitude of starting discrepancy

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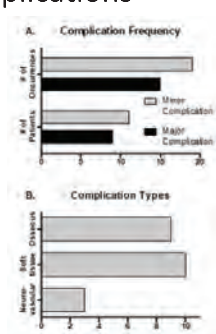
Results – Complications

- 56% minor complications
  - Pin site infection (most common)
  - Sensory changes
  - Muscle contracture
  - Blood loss
- 44% major complications (required follow-up surgery)
  - Bone fractures
  - Rod migration
  - Breaking of pins
  - Loss of mobility in the knee



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Conclusions

- Limb lengthening was successful but had high complication rate
  - Average of 2 complications per patient
  - 15/16 patients had some type of complication
- Extra care should be taken to mitigate complications when lengthening in OI

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Paley Institute
St. Mary's Hospital
901 45th St.
West Palm Beach, Florida 33407

www.PaleyInstitute.org
www.limblengtheningdoc.org

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Treatment Based Classification of Arthrogrypotic Hips and Knees

David S. Feldman, MD, Troy Rand, Michael Beck
dfeldman@paleyinstitute.org

What was the question?
Arthrogryposis Multiplex Congenita (AMC) is a term used to describe idiopathic multiple congenital contractures in multiple body areas. Lower extremity management for AMC patients can be difficult due to the severe combination of hip and knee contractures which disturb normal function, sitting and ambulation. Improving range of motion, not just changing the arc of motion, in AMC is the goal and has often seemed unobtainable. We reviewed the results of range of motion and ambulation improvements in arthrogrypotic patients who were treated based on this new classification.

How did you answer the question?
Patients with AMC were classified into three main groups, each with two subgroups, and a hip modifier: Type 1 – Flexion Type, type 2 – Extension contracture whereby the knee fully extends and does not flex. Type 3 – Stiff Type. Hip modifiers were used for each type: F = hip flexion contracture, E = hip extension contracture, N = normal or near normal hip. Type 1 underwent extensive posterior knee release, multiple neurolyses and proximal femoral shortening, type 2 underwent a Judet quadricepsplasty and anterior release, and type 3 underwent both. Severe Hip flexion and extension contractures underwent soft tissue releases at the same time including when needed flexor/abductor slide, flexor releases, extensor release including Gluteus maximus. Ambulation was classified as either nonambulatory/nonfunctional or ambulatory – home, community, or independent. The clinical and physical therapy charts of arthrogrypotic patients were reviewed to compare hip and knee range of motion before and after surgery guided by this system of classification. Hip and knee range of motion was compared pre– and post–operatively using a Wilcoxon pair–matched rank sign test.

What are the results?
A total of 32 patients were analyzed for each effected hip ($n = 23$) and knee ($n = 60$). There were 16 affected hips and 46 affected knees for type 1, five affected hips and six affected knees for type 2, and two affected hips and seven affected knees for type 3. Overall mean hip range of motion increased ($n = 23$, $p < .0001$) from 51° (SD 31°; range, 0°–90°) to 80° (SD 28°; range, 0°–105°) and overall mean knee range of motion increased ($n = 60$, $p < .0001$) from 42° (SD 23°; range, –5°–100°) to 78° (SD 14°; range, 30°–105°). Type 1 patients increased mean hip range of motion ($n = 16$, $p = .0005$) from 46° (SD 33°; range, 0°–90°) to 77° (SD 33°; range, 0°–105°) and increased mean knee range of motion ($n = 46$, $p < .0001$) from 47° (SD 21°; range, 0°–100°) to 79° (SD 13°; range, 40°–105°). The sample size was not large enough to statistically analyze type 2 hips ($n =5$) and knees ($n = 5$) nor type 3 hips ($n = 2$) and knees ($n = 8$). In type 2 hips, three of the hips did not increase range of motion and two hips increased, one from 30° to 55°and the other from 30° to 65°. In type 2 knees, mean range of motion increased from 24° (range, 0°–90°) to 69° (range, 40°–85°). In type 3 hips, there were increases of 15° and 30°. In type 3 knees, mean range of motion increased from 24° (range, 15°–35°) to 65° (range, 30°–90°). All hip contractures that were not treated surgically were resolved through physical therapy. Pre–surgery 12 out of 32 patients were ambulatory (38%), after surgery all patients were ambulating.

What are your conclusions?
Surgical intervention guided by classification improved function through increased range of motion at the hip and knee and all patients achieved ambulation. No proximal femoral realignment osteotomies were performed in this group of patients. Mild abduction contractures were treated by physical therapy and severe abduction contractures were resolved by performing an abductor slide along with physical therapy.

TREATMENT BASED CLASSIFICATION OF ARTHROGRYPOTIC HIPS AND KNEES

David S. Feldman, MD
Chief of Hip Preservation and Spinal Deformity
Co-Authors: Michael Beck, BS; Troy Rand, PhD
Paley Institute
West Palm Beach, Florida
LLRS Virtual Conference
July 2020

901 45th Street
Kimmel Building
West Palm Beach, FL 33401
561.844.5255
www.paleyinstitute.org

1

Disclosure

- We have no conflict of interest regarding the research being presented

2

Background

- Arthrogryposis Multiplex Congenita (AMC)
  – Idiopathic multiple congenital contractures
  – Most often the cause is unknown
- Lower extremity management is difficult due to combination of hip and knee contractures
- Goal is to change ROM, not just arc of motion

3

Methods - Classification

- AMC patients classified
  - Type 1 – Flexion type
  - Type 2 – Extension type
  - Type 3 – Stiff type
- Hip modifier
  - F – Flexion contracture
  - E – Extension contracture
  - N – Normal or near normal

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Methods - Treatment

- Type 1
  - Extensive posterior knee release
  - Multiple Neurolysis
  - Proximal femoral shortening
- Type 2
  - Judet quadricepsplasty
  - Anterior release
- Type 3
  - Type 1 and Type 2 treatments

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Methods - Treatment

- Hip treatment
  - Severe flexion and extension contractures
    - Soft tissue releases
    - Flexor/abductor slide
    - Flexor releases
    - Extensor release including gluteus maximus
  - Less severe hips were treated with physical therapy alone

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Methods - Comparison

- ROM
  - Hip and Knee ROM was compared pre- and post-operatively using a Wilcoxon pair-matched rank sign test.
  - Ambulation was classified as either non-ambulatory or ambulatory – home, community, or independant

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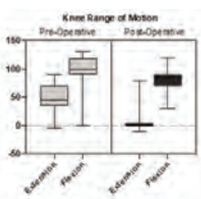
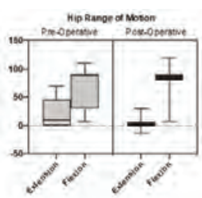
Results – ROM Overall

Knee ROM increased from 42° to 78°



Hip ROM increased from 51° to 80°



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Results – ROM by type

Type 1

Knee (n = 46)	Mean increase from 47° to 79°
Hip (n = 16)	Mean increase from 46° to 77°

Type 2

Knee (n = 5)	Mean increase from 24° to 69°
Hip (n = 5)	3 hips no change (80°, 80°, and 90°)
	2 hips increased (30° - 95° and 30° - 85°)

Type 3

Knee (n = 8)	Mean increase from 24° to 65°
Hip (n = 2)	60° to 90° and 75° to 90°

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Conclusions

- By stratifying treatment by classification the ROM was improved in both the hip and the knee
- Ambulation was achieved by all patients, either independent or assisted
  - Greatly improving quality of life

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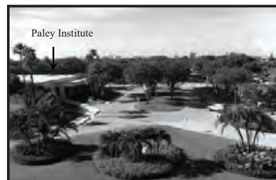

Paley Institute
St. Mary's Hospital
901 45th St.
West Palm Beach, Florida 33407

www.PaleyInstitute.org
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11

Single Stage Surgery for Arthrogrypotic Hip and Knee Flexion Contractures

David S. Feldman, MD, Troy Rand, Michael Beck
dfeldman@paleyinstitute.org

What was the question?
Arthrogryposis Multiplex Congenita (AMC) is a term used to describe idiopathic multiple congenital contractures in two or more joints. Treatment for the lower extremities of AMC patients can be difficult due to a combination of hip and knee contractures which impede function, sitting, and ambulation. Standard treatment for patients with hip and knee contractures is to treat them with separate surgeries and to perform proximal femoral realignment osteotomies as part of the hip and gradual correction of the knee with external fixation. The purpose of this study is to evaluate improvements in hip and knee range of motion and ambulation status when patients were treated for both hip and knee contractures simultaneously without femoral osteotomy and with acute correction of the knee without external fixation.

How did you answer the question?
The clinical and physical therapy charts were reviewed of AMC patients who were treated between 2016 and 2020. If patients presented with a hip flexion and/or abduction contracture of > 25° then a pelvic flexor/abductor slide and flexor release was performed on the hip. The knee flexion contracture was treated using extensive posterior knee release, multiple neurolyses, and proximal femoral shortening. If the hip flexion and/or abduction contracture was < 25° then the knee was treated surgically using the same techniques describe above, and the hip contracture was addressed through physical therapy exclusively. Overall hip and knee range of motion was compared before and after surgery using a Wilcoxon pair–matched rank sign test. Ambulation pre– and post–surgery was classified as non–ambulatory or ambulatory (with or without assistance).

What are the results?
A total of 25 patients of this type were treated (46 legs). Of these, 15 patients (24 legs) had concomitant surgery on the hip and the knee. Sagittal plane ROM data was available pre– and post–operatively for 11 hips and 24 knees in the concomitant group, and 22 additional knees that were treated individually. There was a significant increase in hip ROM ($p = .001$) from 36° (SD 27°; range 0° – 90°) to 70° (SD 37°; range 0° – 104°). There was also a significant increase in knee ROM ($p < .0001$) from 47° (SD 21°; range 0° – 100°) to 79° (SD 13°; range 40° – 105°). All patients achieved a knee within ten degrees of full extension and maintained this at follow up. All patients with mild non–surgical hip/abduction contractures resolved this in the post–operative period. Before surgery 15 out of 25 patients were non–ambulatory (60%), after treatment all patients were ambulating with or without assistance.

What are your conclusions?
Our results indicate that single stage treatment was effective at improving range of motion at both the hip and the knee as well as improving ambulation status. By treating the hip and knee in a single surgery we are reducing the number of surgeries that these patients need, which can have a significant impact on their quality of life, especially when these surgeries are performed during early childhood. Further studies will include long term follow up and quality of life measures before and after surgery.

SINGLE STAGE SURGERY FOR ARTHROGRYPOTIC HIP AND KNEE FLEXION CONTRACTURES

David S. Feldman, MD
Chief of Hip Preservation and Spinal Deformity
Co-Authors: Michael Beck, BS; Troy Rand, PhD
Paley Institute
West Palm Beach, Florida
LLRS Virtual Conference
July 2020

901 45th Street
Kimmel Building
West Palm Beach, FL 33401
561.844.5255
www.paleyinstitute.org

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Disclosure

- We have no conflict of interest regarding the research being presented

2

Background

- Arthrogryposis Multiplex Congenita (AMC) describes two or more congenital contractures in multiple body areas
- Concomitant hip and knee involvement common
- Combination of hip and knee flexion deformities disturb function, sitting, and ambulation

3

Current Standard of Treatment

- Separate surgeries for hip and knee flexion deformities
- Hip flexion contractures:
  - Proximal femoral realignment osteotomies
- Knee flexion contractures:
  - Gradual correction via external fixation

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Study Goal

- Reviewed patients treated for hip and knee flexion deformities simultaneously
  - No femoral osteotomy of the hip
  - Acute correction of the knee without external fixation
- Evaluate improvements in hip and knee ROM and ambulation status

5

Methods – Hip Procedure

- Flexion and/or abduction contracture >25°
  - Pelvic flexor/abductor slide
  - Flexor release
- Flexion and/or abduction contracture <25°
  - Addressed through physical therapy

6

Methods – Knee Procedure

- Flexion contractures (25° or greater)
  - Extensive posterior knee release
  - Multiple neurolyses
  - Proximal femoral shortening

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Methods - Analysis

- Overall hip and knee ROM compared before and after surgery using a Wilcoxon pair-matched rank sign test.
- Ambulation compared pre- and post-operatively.
  - Classified as ambulatory (with or without assistance) or nonambulatory

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Results - ROM

- 15 patients (24 legs) had concomitant surgery on the hip and knee for flexion deformities
  - ROM data was available for 11 hips and 24 knees in this group
  - 22 additional knees were treated individually
- Mean hip ROM increased (p = .001)
  - Pre-Op: 36° (SD 27°; range 0° – 90°)
  - Post-Op: 70° (SD 37°; range 0 – 104°)
- Mean knee ROM increased (p < .0001)
  - Pre-Op: 47°(SD 21°; range 0° – 100°)
  - Post-Op: 79° (SD 13°; range 40° – 105°)

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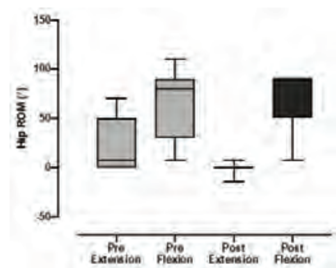
Results – Hip ROM



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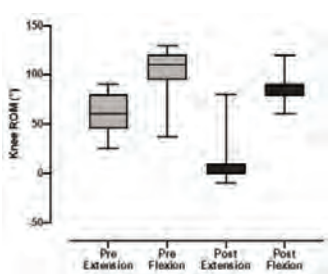
Results – Knee ROM



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Results - Ambulation

- Pre-Op: 15 out of 25 (60%) patients were nonambulatory
- Post-Op: All patients ambulatory with or without assistance

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Patient Case – Radiographs

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Patient Case – Radiographs

14

Patient Case – Pre-Op

15

Patient Case – Post-Op

16

Patient Case – Post-Op

17

Patient Case – Post-Op

18

Conclusions

- Single stage surgery of the hip and knee without external fixation is an effective treatment for flexion deformities in AMC
  - ROM improved at both the hip and knees
  - Improved ambulation status
- Reduces number of surgeries these patients need
  - Major impact on quality of life, especially during early childhood

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Future Investigation

- Long term follow up
- Quality of life measures before and after surgery

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Paley Institute
St. Mary's Hospital
901 45th St.
West Palm Beach, Florida 33407

www.PaleyInstitute.org
www.limblengtheningdoc.org

21

Depression of the Medial Tibial Plateau in Infantile Blount Disease – Can Pathologic Bony Changes be Reversed with Guided Growth Treatment?

Melinda S Sharkey, Christopher Schneble, Jacob F Schulz, Regina Hanstein
msharkey@montefiore.org

What was the question?
Studies have reported success in correcting the mechanical axis of the lower extremity in infantile Blount disease using guided growth technique, but it is not known if guided growth can affect improvement of the bony deformity seen at the proximal tibia. This study assesses whether the pathologic morphological changes at the proximal tibia in infantile Blount disease can be reversed with guided growth treatment.

How did you answer the question?
We performed a retrospective review of patients with a diagnosis of infantile Blount disease who underwent guided growth surgery using a tension band plate–and–screw construct between 2010 and 2018 at two institutions. Radiographic assessment of the severity of deformity of the medial tibial plateau was done using the Langenskiold classification and lower extremity alignment was evaluated by assessing mechanical axis deviation (MAD) of the affected limb before surgery, at removal of hardware (ROH) and at most recent follow–up.

What are the results?
A total of 16 limbs in 10 children who were treated with lateral proximal tibia tension band plate–and–screw construct were evaluated. The average age at surgery was 6.8 +/– 2.2 years old and the average length of retention of the guided growth implant was 1.7 +/– 0.6 years and latest follow–up after surgery was 3.5 +/– 1.5 years. Langenskiold classification ranged from 1 to 5 pre–operatively with 9/16 limbs rated 3 and higher. The pathologic changes at the proximal tibia as classified by Langenskiold improved in 11/16 (68.8%) limbs at ROH and in 15/16 limbs (94%) at latest follow–up. Tibial plateau changes completely resolved in 7/16 (44%) limbs. MAD improved from 34.4 +/– 6.7mm to –0.1 +/– 13.7mm at ROH and 14.5 +/– 10.5mm at latest follow–up. Pre–operatively, the MAD line didn't intersect the central third of the medial plateau in any limb, but did in 12/16 limbs at ROH and 8/16 limbs at most recent follow–up. Only one limb of a 2.6 yo patient had no improvement in Langenskiold classification even though the MAD corrected after 1 year of guided growth treatment.

What are your conclusions?
Even in the presence of advanced pathologic changes at the proximal tibia, guided growth plate treatment was associated with improvement in MAD as well as improvement or resolution of even advanced pathologic bony changes typical of infantile Blount disease in the majority of limbs. Guided growth surgery for infantile Blount disease may be a better first–line treatment option than more invasive surgery such as osteotomy and hemiplateau elevation.

Depression of the Medial Tibial Plateau in Infantile Blount Disease

Can Pathologic Bony Changes be Reversed with Guided Growth Treatment?

Regina Hanstein PhD, Christopher Schneble MD, Jacob F Schulz MD,
Adrienne R Socci MD, Melinda S Sharkey MD

1

DISCLOSURES

All authors declare that they have nothing to disclose.

2

Background: Infantile Blount Disease

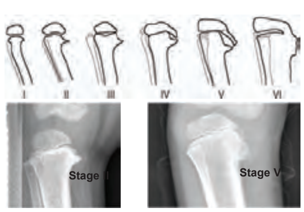
- Disorder of growth of the posteromedial aspect of the proximal tibial growth plate that results in progressive bowing
- Radiographically, proximal tibia shows increasing deformity as the disease progresses:
  - Langenskiöld
  - Lamont

3

Mechanical Axis Deviation Can Improve with Guided Growth

4

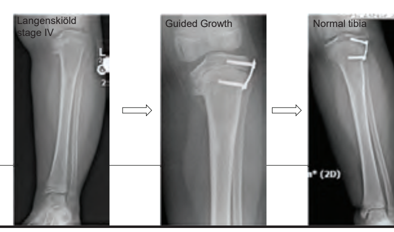
Langenskiöld Classification: Can Guided Growth Reverse Pathologic Bony Changes?



5

HYPOTHESIS

Pathologic morphological changes at the proximal tibia in Infantile Blount Disease can be reversed with Guided Growth surgery



6

METHODS

Inclusion:
- Infantile Blount, Guided growth 1-10yo, F/U to hardware removal or beyond
- 2 institutions, 6 surgeons

Analysis:
- Demographics
- Radiographic Measurements:
  - *- Mechanical axis deviation (MAD)*
  - *- Langenskiöld Classification*
- Complications

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19 limbs in 12 patients

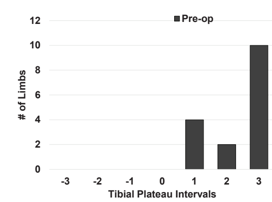
	Age at Surgery (Years)	Sex	Length of Guided Growth (Years)	F/U (Years)	Age @ F/U (Years)	Langenskiöld Pre-op
TOTAL/ MEAN ± SD	6.2 years ± 2.4 years	50% F	1.7 years ± 0.6 years	3.7 years ± 1.5 years	9.9 years ± 3.0 years	Stage I: 2 limbs Stage II: 6 limbs Stage III: 6 limbs Stage IV: 2 limbs Stage V: 3 limbs

8

Results

9

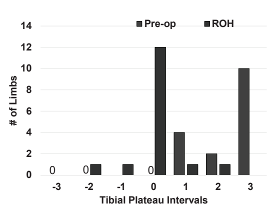
MECHANICAL AXIS DEVIATION (MAD) Pre-Op



❖ Pre-operatively, the MAD line didn't intersect the central third of the tibial plateau in any limb

10

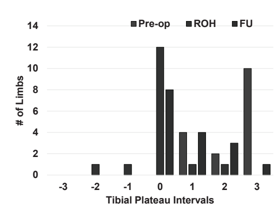
MECHANICAL AXIS DEVIATION (MAD) at ROH



❖ At ROH, MAD had intersected central third of tibia plateau in 12/17 limbs (71%)

11

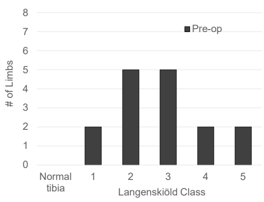
MECHANICAL AXIS DEVIATION (MAD) at Follow-Up



❖ At FU, MAD intersected the central third of the tibial plateau in 8/17 limbs (47%)

12

TIBIAL CHANGES - LANGENSKIÖLD CLASSIFICATION: Pre-Op



❖ Pre-operatively, 11/19 (58%) limbs rated ≥ Langenskiöld stage 3 changes

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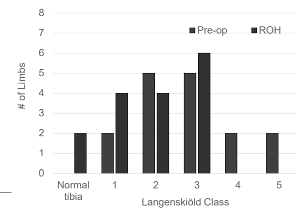
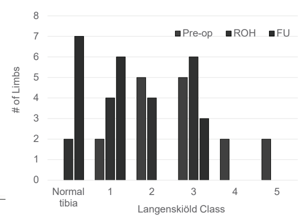
TIBIAL CHANGES - LANGENSKIÖLD CLASSIFICATION: at Removal of Hardware



❖ At ROH, Langenskiöld stage improved in 12/19 limbs (63%)

14

TIBIAL CHANGES - LANGENSKIÖLD CLASSIFICATION: at Follow-up



❖ At most recent F/U, Langenskiöld stage improved in 17/19 limbs (89%) & tibial changes had completely resolved in 7/19 limbs (37%).

15

COMPLICATIONS

- 4/19 limbs have undergone repeat tension-band plating at an average of 3.5 years after original surgery for recurrence of varus deformities
- 1/19 limbs underwent acute tibia and fibula osteotomies and medial hemiplateau elevation 1.2 years after original surgery for worsening of varus deformity (Langenskiöld 5 pre-op)
- 1 screw breakage

16

CONCLUSIONS

Even in the presence of advanced pathologic changes at the proximal tibia in a relatively old population, temporary hemiepiphysiodesis with guided growth plates was associated with:

- Improvement in MAD
- Improvement or resolution of even advanced pathologic bony changes in the majority of limbs
- Pathologic bony changes continued to resolve even as there was rebound of the mechanical axis toward varus deformity
- Need for repeat placement of tension band plates not uncommon

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Thank you

Questions? Contact Melinda Sharkey, MD
msharkey@montefiore.org

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18

Estimating Skeletal Maturity by Segmented Regression Analysis of Key Knee Radiograph Parameters

Joshua T. Yuan, Alexander Benedick, Raymond W. Liu
joshua.yuan@case.edu

What was the question?
We previously compared multiple skeletal maturity systems using the knee and found that a modified and simplified version of the Roche–Wainer–Thissen (RWT) system was optimal, and could potentially outperform the Greulich and Pyle atlas. We now question whether the RWT knee method can be further simplified by reducing the number of parameters while maintaining acceptable predictive accuracy.

How did you answer the question?
Knee radiographs obtained three years before, during, and two years following the chronological age associated with 90% of final height were previously analyzed in 80 children. The number of parameters used in the original RWT method were previously systemically reduced from 34 to 8 by excluding parameters with poor inter–rater reliability and poor correlation with years from 90 inal height. In this study, the remaining 8 parameters were analyzed by segmented regression with radiographs partitioned by chronologic age, sex, and isolated RWT parameters. Prediction error was assessed by cross–validation.

What are the results?
284 left knee radiographs from 38 girls (mean age 10.9 years) and 37 boys (mean age 12.9 years) with known heights were included. Regression analysis showed higher correlation with years from 90 inal height using our model (R–squared = 0.904) versus baseline demographics alone (R–squared = 0.841), and similar correlation compared to the Greulich and Pyle (R–squared = 0.90) and Pyle and Hoerr (R–squared = 0.904) methods. Our model contained six parameters (two femur, four tibia), with assessment of a given patient requiring input from two to five of these parameters, depending on patient demographics.

What are your conclusions?
Our analysis demonstrates that skeletal maturity can be accurately predicted with just two to five radiographic knee parameters. This abbreviated system might be practical for quicker use in the clinic, with the full modified system using eight parameters employed when more detailed surgical planning is done.

Estimating Skeletal Maturity by Segmented Regression Analysis of Key Knee Radiograph Parameters

Joshua T. Yuan, BA, Alex Benedick, MD, Raymond W. Liu, MD

Case Western Reserve University
Rainbow Babies and Children's Hospital

1

Disclosures

- I have no relevant financial relationships with the manufacturer(s) of any commercial product(s) and/or provider(s) of commercial services discussed in this CME activity.
  - Raymond Liu: royalties from Orthopediatrics LLC paid to institution for research fund
- I do not intend to discuss an unapproved/investigative use of a commercial product/device in my presentation.

2

Background

- Accurate estimation of skeletal maturity

ACL

LLD

3

Background

- Greulich & Pyle Atlas
  - Qualitative system
  - Radiographs matched to standards
  - Time intensive
  - Inconvenient for lower limb assessment

13.5 years

14 years

15 years

16 years

4

Bolton Brush Collection

- Annual knee radiographs
- 3 years before, during and 2 years after 90% final height
- Exclusion:
  - Poor quality radiographs
  - Out-of-plane rotation on AP view

5

Final Cohort

	N	XR	Mean Age	Age Range
Male	37	154	12.9 yrs	9 to 17 yrs
Female	41	172	11.1 yrs	7 to 15 yrs
Total	78	326	12.0 yrs	7 to 17 yrs

6

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Roche-Wainer-Thissen (RWT)

- Parameters
  - Femur (12)
  - Tibia (18)
  - Fibula (6)

7

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Roche-Wainer-Thissen (RWT)

- Parameters
  - Femur (~~12~~ 2)
  - Tibia (~~18~~ 5)
  - Fibula (~~6~~ 1)

8

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Knee Parameters in optimized model

Variable	Brief Definition	Value in Equation
FemK	"Capping" of the lateral distal femoral epiphysis over the metaphysis	Absent=0, Incomplete=1, Complete=2
FemL	Fusion of the lateral distal femoral physis	Absent=0, Incomplete=1, Complete=2
TibA	Proximal tibial epiphysis width:methaphysis width	Ratio value
TibH Med	Height of the medial tibial spine	Height value (mm)
TibN	"Capping" of the lateral proximal tibial epiphysis over the metaphysis	Absent=0, Present=1
TibP	"Capping" of the medial proximal tibial epiphysis over the metaphysis	Absent=0, Present=1
TibQ	Fusion of the lateral proximal tibial physis	Absent=0, Incomplete=1, Complete=2
FibA	Proximal fibula epiphysis width:methaphysis width	Ratio value

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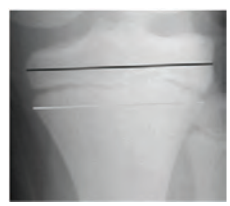
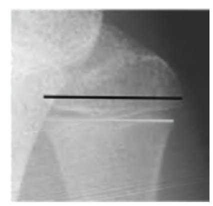
TibA and FibA: Ratios



TibA



FibA

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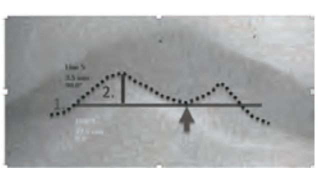
TibHMed: Height



TibHMed

11

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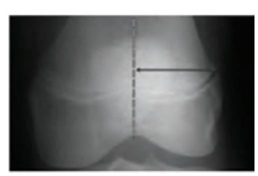
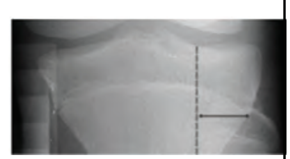
FemL and TibQ: Lateral Fusion



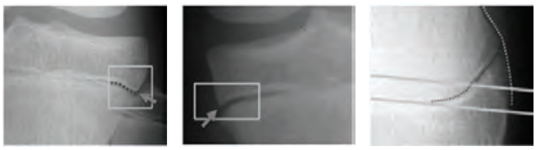
FemL



TibQ

12

TibN, TibP, & FemK: Capping



TibN TibP FemK

13

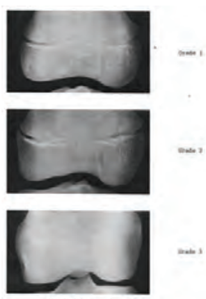
Questions

- Can the optimized RWT knee method be simplified by reducing the number of parameters?
  – Predictive accuracy maintained?
- How does this simplified method compare to currently used methods?
  – Greulich & Pyle Bone Age

14

Segmented Regression

- Partition data by:
  – Age?
  – Sex?
  – Radiograph parameter values?



15

Partitioning by age

- Ordinary least squares (OLS) regression

Sex	0.13	0.0004	0.00085	0.0056	0.37
FemK	0.52	0.015	0.00023	0.038	0.37
FemL	0.2	0.37	0.056	0.076	0.71
TibN	0.1	0.05	0.51	0.73	0.37
TibP	0.07	0.43	0.44	0.0038	0.082
TibQ	N/A	0.32	0.06	0.025	0.73
TibA	0.012	0.16	0.0014	0.98	0.14
TibH Med	0.27	0.69	0.12	0.66	0.34
Fib A	0.083	0.02	0.14	0.5	0.17
	7	9	11	13	15

Chronological Age

16

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Chronological Age

$p < 0.05$

$p > 0.05$

17

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19

Segmented Regression

- Models partitioning by a single variable

	GP + Demo	RWT + Demo	RWT M/F	RWT <12/ ≥12	RWT ≤12/ >12	RWT <13/ ≥13	RWT ≤13/ >13
Parameters	N/A	8	4-6	4-6	5-6	5	3-7
Discrepancy	0.42	0.37	0.36	0.44	0.48	0.45	0.47
> 1 year	6.1%	3.9%	3.5%	7.4%	8.5%	6.7%	7.0%
R squared	0.900	0.925	0.916	0.877	0.871	0.871	0.877

20

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21

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24

Segmented Regression

- Models partitioning by multiple variables

	GP + Demo	RWT + Demo	RWT M/F & FemK	RWT M/F & <12/≥12	RWT M/F & <11/≥11 OR <13/≥13
Parameters	N/A	8	2-4*	2-4	2-5
Discrepancy	0.42	0.37	0.36	0.45	0.42
> 1 year	6.1%	3.9%	2.8%	7.7%	5.6%
R squared	0.900	0.925	0.904	0.849	0.863

*includes FemK

25

Segmented Regression

- Models partitioning by multiple variables

	GP + Demo	RWT + Demo	RWT M/F & FemK	RWT M/F & <12/≥12	RWT M/F & <13/≥13 OR <11/≥11
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26

Segmented Regression

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27

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28

Segmented Regression

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*includes FemK

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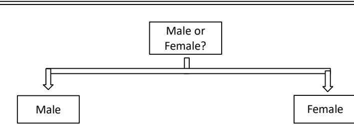
Example: RWT M/F & FemK



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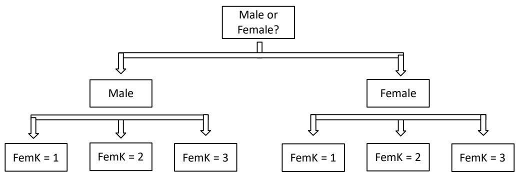
Example: RWT M/F & FemK



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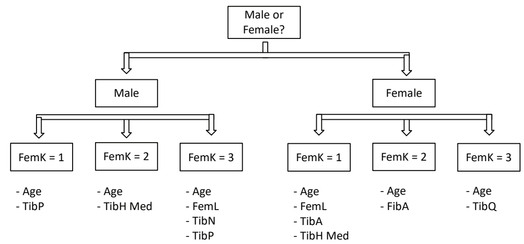
Example: RWT M/F & FemK



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Conclusion

- Skeletal maturity can be predicted with 2 to 4 radiographic knee parameters
- Simplified knee system comparable to Greulich and Pyle
- Abbreviated system for quicker use; full system for more detailed surgical planning

33

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- Abbreviated system for quicker use; full system for more detailed surgical planning

35

Thank You

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Electronic Posters

Femoral Monofocal Sequential Compression–distraction Osteosynthesis Following Closing Wedge Osteotomy Using a Magnetically–controlled Intramedullary Nail: A Case Report

John A. Scolaro, Bryan J Mark
jscolaro@hs.uci.edu

What was the question?
Is it possible to use distraction osteogenesis to correct a recalcitrant, angulated long bone non–union following a closing–wedge resection at the non–union site?

How did you answer the question?
Distraction osteogenesis with a magnetically–controlled nail is commonly used to address congenital or acquired limb length discrepancies. With a concurrent deformity, osteotomies are commonly used to correct alignment at the site of deformity while lengthening is performed at a remote location in the same bone.
To our knowledge, no surgeon has used a magnetically–controlled intramedullary (IM) nail to employ distraction osteogenesis at the same location where a closing–wedge resection was performed to realign bone fragments of a mal–aligned nonunion. In this case, a 65–year–old female with a supracondylar distal femoral nonunion with valgus malalignment, translational offset, and limb length discrepancy presented for treatment. She had concurrent degenerative joint disease of the knee but was not eligible for arthroplasty given her deformity and incomplete osseous union. During a single operative session, we performed a medially–based closing wedge osteotomy and translation realignment, holding the bone fragments in anatomic position with a temporary unilateral external skeletal fixator. We next inserted a retrograde femoral magnetically–controlled IM nail to stabilize the properly aligned femur. We removed the external fixator and utilized the External Remote Controller (ERC) to compress the nail across the non–union/osteotomy site 1.0mm past interfragmentary contact. To ensure ongoing interfragmentary stability, we employed the ERC in clinic to increase compression of the non–union/osteotomy site 0.3mm every week for a total of 4 weeks. Thereafter, we began to slowly lengthen the nail at a rate of 0.5mm and a rhythm of 0.25mm twice a day, continuing at this pace until the limb had been lengthened 32mm.

What are the results?
The patient formed high quality regenerate in the widening distraction zone having the typical radiographic signs of longitudinal striations, uniform width and early, complete corticalization, all features of successful distraction osteogenesis. We did not achieve complete restoration of limb length because the patient asked to have lengthening stopped 5mm short of target length for fascia lata pain.

What are your conclusions?
This case demonstrates that it is possible to first compress and then distract long bone non–unions through a single site, even when a wedge–resection is employed in the zone of an incomplete union to correct malalignment. Our formula of 4 weeks of compression followed by slow (0.5mm/day) distraction proved successful in the metaphyseal portion of the distal femur in this patient. Continued implementation of this technique is needed to further refine the specifics and limits of this protocol. This case provides valuable information to surgeons treating limb deformity in the adult patient as closing wedge osteotomies commonly result in loss of limb length; using this technique, limb length can be regained without an external frame or secondary operative procedure.

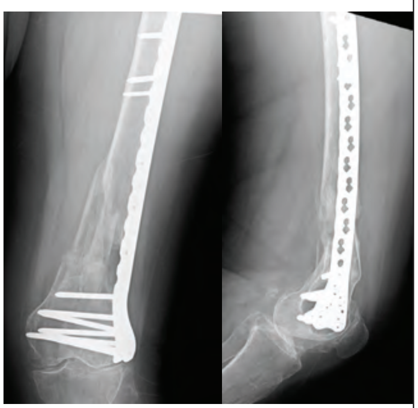
Femoral Monofocal Sequential Compression–distraction Osteosynthesis Following Closing Wedge Osteotomy using a Magnetically–controlled Intramedullary Nail: A Case Report

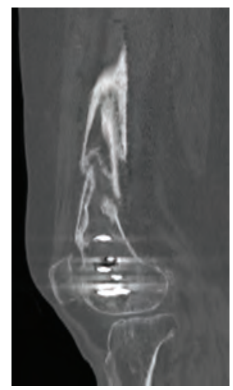
John A. Scolaro, MD, MA
Associate Professor
University of California, Irvine

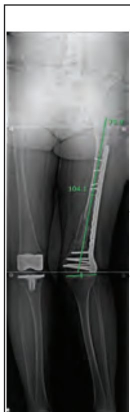
Disclosures

- Nuvasive Specialized Orthopaedics – paid speaker
- Liberal consultation with peers

- 65F
- Hx. L knee DJD
- 10 months s/p ORIF closed supracondylar distal femur fracture
- pain
- gait disturbance







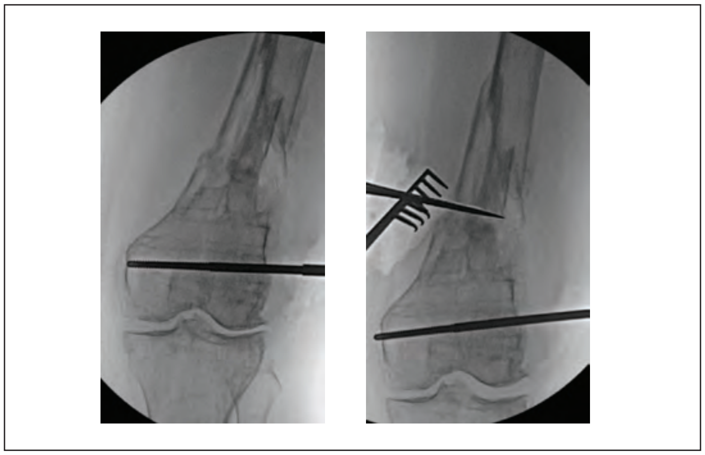
Left:
aLDFA – 75.9º

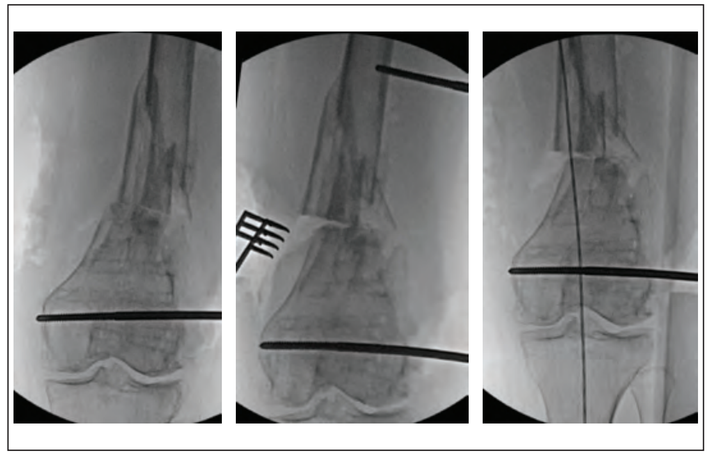
Right
aLDFA – 85º

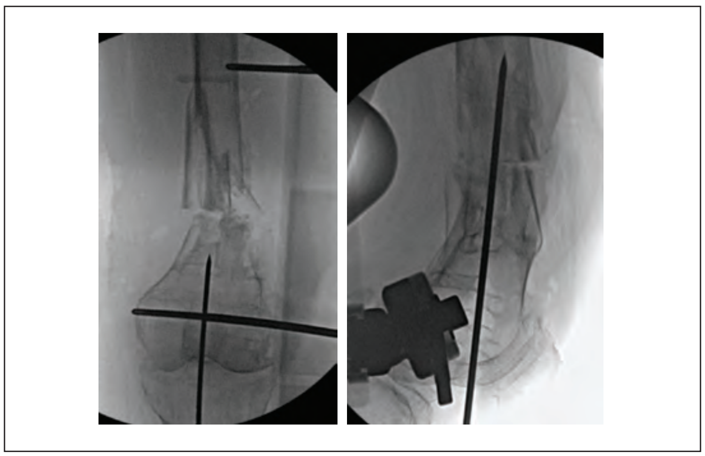
Approx. LLD:
2.5cm

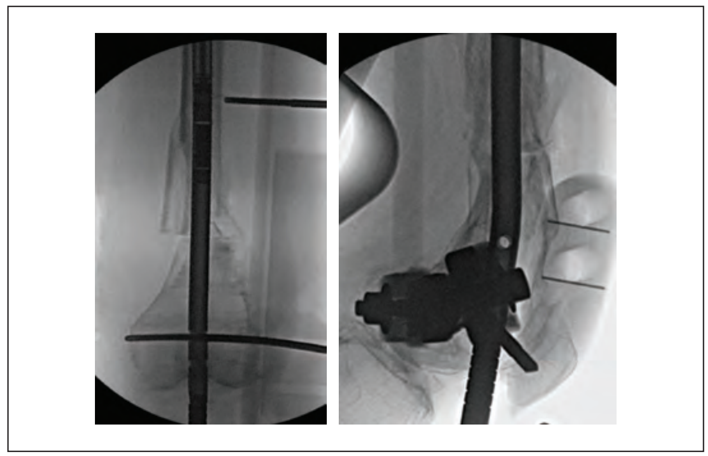
Summary

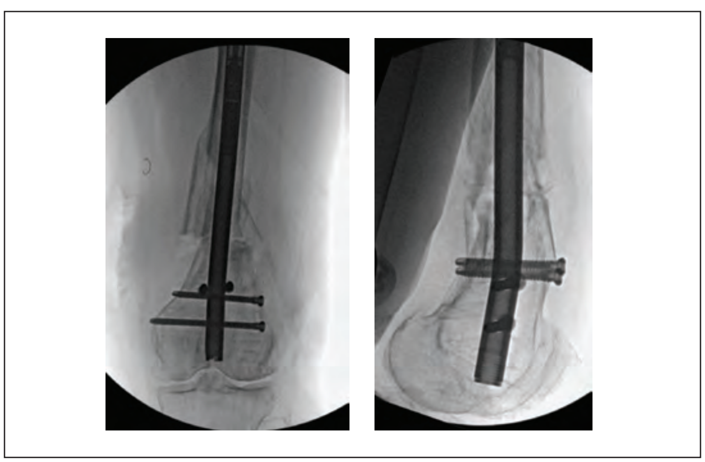
- 65F with left malaligned/nonunited supracondylar distal femur
- Ultimate desire to proceed with L TKA
- Minimize # of surgical procedures
- Arthroplasty consultation → undesirable option given nonunion & deformity



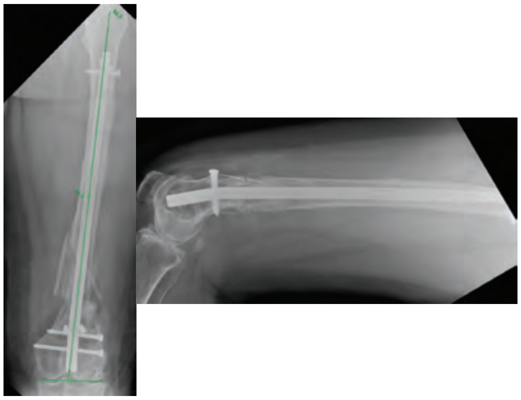






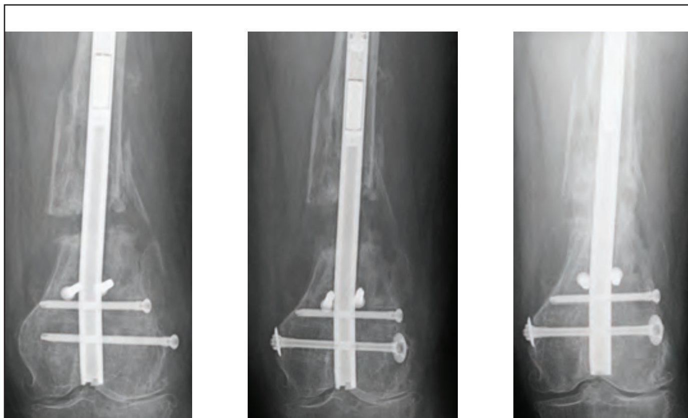



Pre
Post

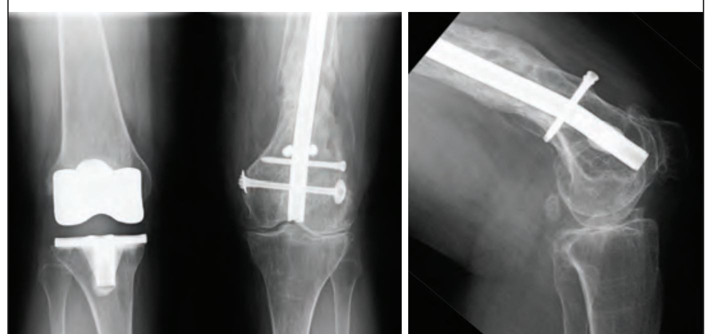


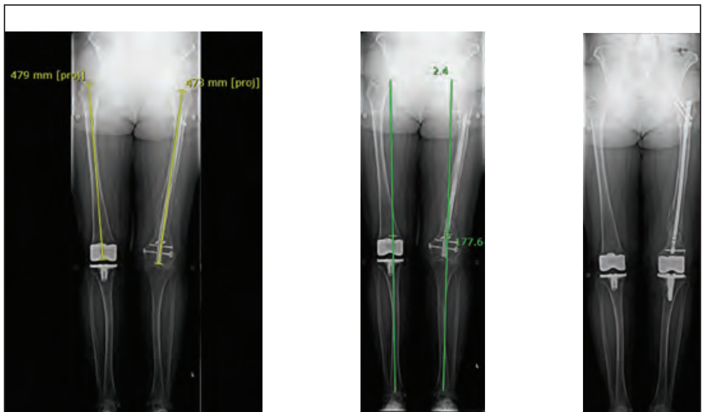
Protocol

- Compression (4 weeks)
  - 50% weight bearing
  - qweek clinic visits – 0.5mm compression
  - 2mm total compression
- Distraction
  - 0.25mm twice daily (0.5mm/day)
  - Stopped just before goal due to knee pain



6 months following program completion





Thank you

jscolaro@hs.uci.edu

Distraction Osteogenesis Using Dual Magnetically Expandable Intramedullary Nails for Large Diaphyseal Femur Defects in the Sarcoma Patient

Steven Magister, MD, Jonathan Copp, Patrick Getty, John Sontich
steven.magister@uhhospitals.org

What was the question?
Following wide resection of a high–grade osteosarcoma of the proximal femoral diaphysis with a resultant large bone void, could a dual magnetically expandable intramedullary nail construct be used to achieve an all–inside distraction osteogenesis?

How did you answer the question?
Following six months of neoadjuvant chemotherapy for biopsy–proven high grade osteosarcoma, with single osseous lesion and absence of skip lesions on advanced imaging, an otherwise healthy 23– year old female presented for resection. Prior to resection, four 5mm Schanz pins were placed from lateral to medial, two distally in the posterior femur and two proximally at the level of the lesser trochanter parallel to one another to set rotation of the femur. Next, a carbon fiber rod was affixed to the pins via pin–to–bar clamps to establish length. The rod and pin to bar clamps were then removed from the pins to provide access to the lateral femur, and for later reattachment during the nail insertion portion of the case at the predetermined length and rotation. With length and rotation accounted for, a standard lateral approach to the femur was undertaken. For further rotational control during reconstruction, parallel etches were made at the proximal and distal osteotomy sites with the microsagittal saw prior to resection. The osteotomies were then made for wide resection and negative margins were obtained resulting in a 12.5 cm bone defect. Reconstruction was then performed using two Precice intramedullary lengthening nails (NuVasive, San Diego CA). (Figure 1) First, the previously constructed external fixation frame was reattached to the previously placed Schanz pins in parallel orientation at original length and with lateral femoral etchings realigned to restore rotation of the limb. Due to the size of the osseous and soft tissue defects and 5cm lengthening capacity of the nail, the limb was then acutely shortened 7cm, using the frame for assistance, for a remaining 5.5cm defect. The antegrade nail, 8.5mm x 165mm, was then lengthened 5cm on the back table, and inserted through standard greater trochanteric entry point, and locked proximally and then distally in the proximal aspect of the distal segment. A second Precice nail, 8.5mm x 165mm, in maximally shortened position was then placed retrograde, and locked distally as well as proximally in the proximal portion of the distal segment with slight overlap with the antegrade nail to enhance stability of the construct. This allowed the antegrade nail to function as a shortening nail while the retrograde nail served as a lengthening nail. Next, a transverse osteotomy was made using a 3.5mm drill and stiletto osteotome in the distal metadiaphysis to create a free distal intercalary segment to be transported proximally. The external fixation frame was then removed and all wounds were irrigated and closed in standard layered fashion. The patient was made non–weight bearing post–operatively for 6 weeks followed by crutch–assisted foot–flat weight bearing.
The patient returned to the operating room for planned second stage reconstruction 2 months post index surgery to revise her construct and complete the remaining distraction. (Figure 2) Both nails were removed, and the original retrograde nail, now maximally lengthened 5cm, was placed antegrade, and a new 190mm x 8mm nail was placed in retrograde fashion for planned 5cm of additional distraction. Lengthening was completed 4 months after index surgery after a total of nearly 10cm of distraction of the distal intercalary segment and 2cm of proximal callous within the resection site. (Figure 3) She remained foot–flat weight bearing for an additional 6 months to allow for the regenerate to consolidate and mature.
Finally, a second planned return to surgery was performed 10 months after the initial operation to replace her dual nail construct with a standard retrograde intramedullary nail in order to promote stability.

Distraction Osteogenesis Using Dual Magnetically Expandable Intramedullary Nails for Large Diaphyseal Femur Defects in the Sarcoma Patient *continued*

Steven Magister, MD

What are the results?
Imaging at most recent follow up at roughly one–year post index surgery demonstrated a stable appearing femur with abundant callus and maturing regenerate. (Figure 4) Overall lengthening was radiographically and clinically determined to be within 1cm of the contralateral leg. Clinically, the patient was able to achieve full knee extension, 100˚ of knee flexion, and the patient had resumed full activity without significant limitations.

What are your conclusions?
Osteosarcoma is the most common primary malignancy of bone. Neoadjuvant chemotherapy, wide resection, and adjuvant chemotherapy for limb salvage is the current standard of care. Resection often leads to large defects requiring complex reconstruction techniques. An all–inside technique was developed in effort to minimize complications of long–term external fixation for distraction osteogenesis of the femur or the need for extensile secondary grafting procedures using induced membrane strategy.

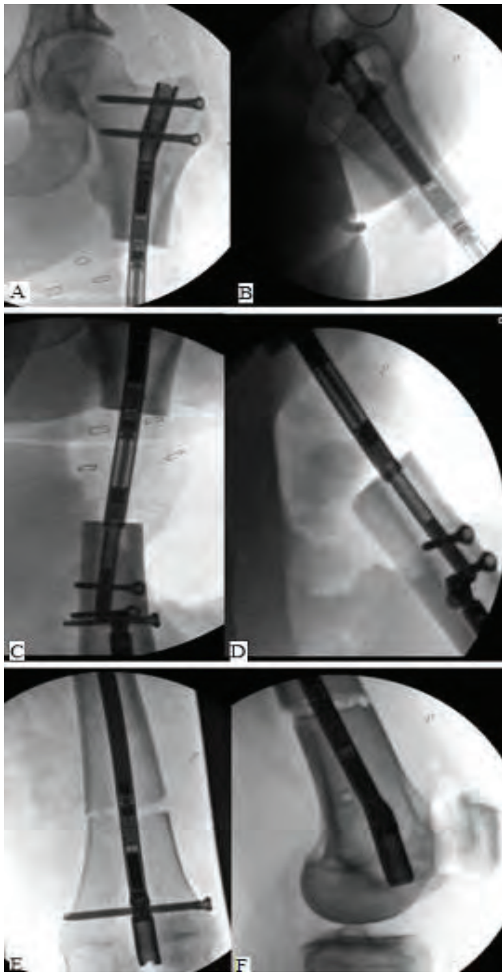


Figure 1

Figure 2

Figure 3

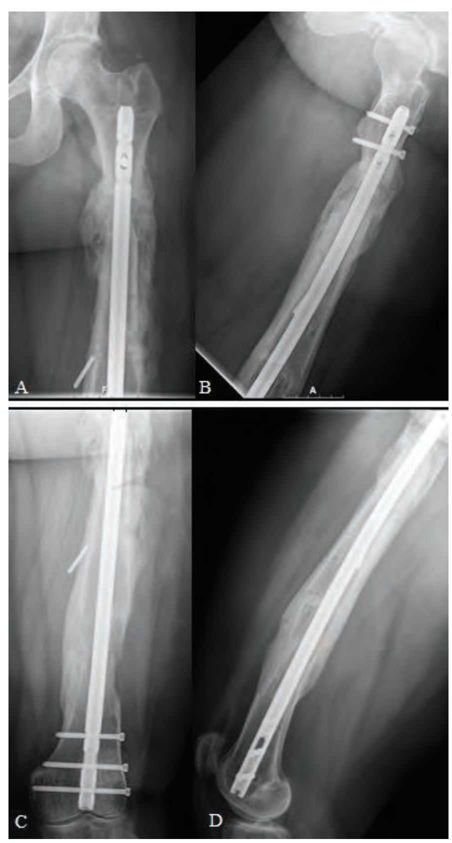


Figure 4

Distraction Osteogenesis Using Dual Magnetically Expandable Intramedullary Nails for Large Diaphyseal Femur Defects in the Sarcoma Patient

Steven Magister[1] MD, Jonathan Copp[1] MD, Patrick Getty[1] MD, John Sontich[1] MD

1 Case Western Reserve University, University Hospitals Cleveland Medical Center, Cleveland, OH

University Hospitals Cleveland Medical Center

1

Disclosures

- Authors SM and JC have no disclosures
- Author PG is a member of the Medical Board of Trustees for the Musculoskeletal Transplant Foundation, and a member of the Question Writing Task Force for ABOS Written Examination
- Author JS accepts royalties from Stryker for the design and use of the Hoffmann LRF Hexapod frame.

2

2

Case

- 23 yo F, high grade osteosarcoma, L proximal femur
- Neoadjuvant chemotherapy → wide resection w/ residual 12.5cm bone void
- Dual Precice intramedullary lengthening nails (NuVasive, San Diego CA)
  - Antegrade + retrograde w/ slight overlap
  - Planned revision dual lengthening nails 2 months status post index procedure to complete lengthening
- Conversion to standard intramedullary nail following lengthening (4 months of lengthening + 6 months callus maturation) 10 months status post index procedure
- Final f/u 18 months s/p index procedure
  - ROM 0-110, 5/5 strength, no reported pain

3

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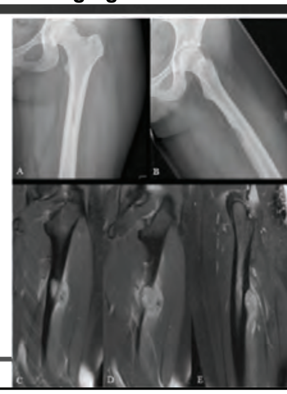
Preoperative Imaging



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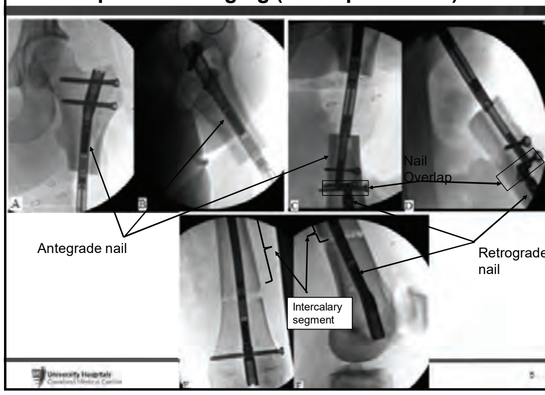
Intraoperative Imaging (index procedure)



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Follow up

10 months post index procedure

18 months post index procedure

6

6

Conclusion

- All-inside dual lengthening nails is a viable option for large bone defects
- Avoids long-term external fixator
- Avoids need for secondary grafting
- Further studies needed to better understand potential complications

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Questions

- Please feel free to reach out to senior author, John Sontich, with any questions regarding this case or its described technique.
  - John.Sontich@UHhospitals.org

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Humeral Lengthening with Intramedullary Retrograde Nailing - A Surgical Technique and a Review of Three Cases

Ulrik Kähler Olesen, Tobias Nygaard, Fuhuan Chen, Peter H. Thaller
ulrik.kaehler@gmail.com

What was the question?
Seeking to improve the treatment for short humerus, we present a modified retrograde surgical technique to correct short humerus length on a congenital or acquired (syndromic, malignant, traumatic, infectious) background.

How did you answer the question?
3 cases were retrospectively reviewed for functional parameters, ROM (flex/ext, abduction) pre- and post-op, complications are presented and discussed. Our suggestions for indications is presented. The surgical technique is presented and discussed, compared to antegrade technique.

What are the results?
Range of motion (flexion/extension/abduction) normalized at 1,5 yr follow-up for all patients. One patient needed nail replacement due to implant failure.All 3 patients experienced excellent results and only mild, temporary complications (temporary parestesias, temporary drophand). Shoulder function improved in two. Consolidation index was <1 for all patients.

What are your conclusions?
The presented cases suggest that the retrograde humeral technique is better because it allows osteotomy below the insertion of the deltoid muscle and thus reduces pressure on rotator cuff and tension on axillary nerve. Additional lengthening is possible. Lengthening over 5 cm requires a more careful approach, monitoring nerve function and range of motion in the affected joints. Smaller defects should only be corrected with specific functional problems.

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Humeral Lengthening with Intramedullary retrograde nailing - a surgical technique and a review of three cases
LLRS (virtual) meeting NYC - July 2020

U. Kähler Olesen, T. Nygaard, Singh UM, F. Chen, P.H. Thaller,

Rigshospitalet Copenhagen
3D-Surgery, Department of General- Trauma- and Reconstructive Surgery, University Hospital Ludwig-Maximilians-University (LMU), Munich, Germany

Ulrik Kähler Olesen
Rigshospitalet, Copenhagen, Denmark
ulrik.kaehler@gmail.com

Copenhagen Limb Lengthening and Bone Reconstruction Unit

1

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Introduction

Indications for humeral lengthening:

- Dwarfism
- Functional problems with excessive length differences
- Steering a car, bicycling, sports, tying shoelaces, improved self-image.

In other words, the indication is relatively limited compared to the femur and tibia, as there is no or very limited impact on joint function (wear) and gait pattern, from a LLD in the upper extremity

____

Disclosures: Nothing to disclose

2

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Shoulder subluxed

Case: LLD Rx humerus & Lx femur after Neonatal sepsis

Planning: Bilateral full length radiographs w.calibration device
LLD: 120 mm. Shortest nail with longest stroke is 150 mm & has **50 mm stroke, so 2. (or more) stages are required**

3

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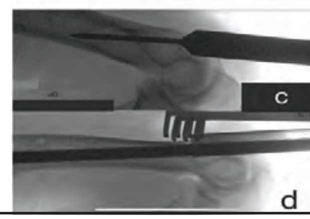
Stage 1 - retrograde humeral access

Arm to be kept flexed at all times

Reamers:
Thin flexible reamers, then
rigid sleeves and reamers (FitBone)

...To get a straight canal in a curved bone...
Note: Shoulder subluxation disappeared



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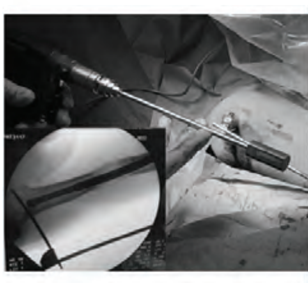
Stage 2:
Re-shortening of nail with "the rapid distractor"
Maintaining length (preventing regenerate collapse) with external fixator.



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Why retrograde and why distal osteotomy ?

- avoiding axillaris nerve
- avoiding deltoid muscle
- no tension on the rotator cuff
- extra-articular insertion

Thin nails allow for retrograde access

Distal (to deltoideus) osteotomy is difficult with antegrade nails

ulrik.kaehler@gmail.com

6

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Results

Case (Hosp)	Age/sex	Pathology	Date of surgery	DI (mm/d)	CI (d/cm)	LLD/ mm	Correction mm	ROM Shoulder	ROM Elbow flex/ext/abduc:	Implant	Notes
1 DK case	25/M	neonatal multifocal osteomyelitis	feb 18	1	25	130	80	Normalized	Normalized	Universal straight femur 150/50/8.5	2-stage technique. Improved shoulder containment. Scoliosis due to lower limb LLD
2 GE case *)	51/M	post trauma, radial palsy	July 14	1	30	40	40	Abduc increase by 10 dgr.	Ext deficit 5 dgr.	Precice 2.0, then 2.1 both retrograde femur, 8.5/215	Implant failure H/W exchange. Temporary radial palsy (drophand)
3 DK case	16/M	Focal osteomyelitis prox. humerus	Okt19	0,83 mm/day	17	100	50	Abd.deficit 10 dgr	Ext. deficit 5 dgr.	Precise Universal straight 10,7/50/160	Sleeping nail. Awaiting stage 2

ulrik.kaehler@gmail.com

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Conclusion

- All 3 patients in this study achieved the planned goal, with no or very limited complications, except for one implant failure, requiring exchange hardware. Shoulder function improved in 2, one had temporary radial palsy.
- We prefer the joint-sparing, retrograde access with limited impact on joint function, axillary nerve, deltoid muscle.
- Nails with short stroke (50 mm) may require two stage surgery to correct larger defects
- Indications are limited compared to the lower extremity as the limb length discrepancy has no impact on native joint-life, axial skeleton (wear) and gait pattern.

ulrik.kaehler@gmail.com

8

Redefining the Juvenile Bunion

Anthony Riccio, Claire Shivers, Kirsten Tulchin-Francis, Jacob Zide
Anthony.Riccio@tsrh.org

What was the question?
The orthopaedic literature is rife with reports of high failure rates following the surgical correction of juvenile bunion deformities. We contend that the reason for these poor outcomes is that although juvenile and adult bunion deformities have similar clinical appearances, the pathophysiology of the two is distinct. As such, successful surgical management of juvenile bunions requires greater understanding of this unique deformity in order to plan appropriate surgical correction. The first step in this process is to redefine the parameters that constitute the juvenile bunion. We propose that the distal metatarsal articular angle (DMAA) is the central defining characteristic of the juvenile bunion and that a higher DMAA may correlate with greater symptomatology in this population.

How did you answer the question?
An IRB approved retrospective analysis of prospectively enrolled patients between 10 and 18 years of age with bunion deformities was performed at a single pediatric institution over a two-year period. Patients with metabolic bone disease, neurologic disorders, and inflammatory arthritis were excluded. Demographic data was recorded and standardized weight- bearing radiographs were used to determine the hallux valgus angle (HVA), intermetatarsal angle (IMA), distal metatarsal articular angle (DMAA), hallux interphalangeus angle, metatarsal cuneiform angle (MCA), cuneiform obliquity, sesamoid position (SP), and joint congruency.
Patient reported outcome measures (PROs) including the Oxford Foot and Ankle Questionnaire (OxAFQ-C), Foot and Ankle Ability Measure (FAAM), Foot and Ankle Outcome Score (FAOS), Pain Numeric Rating Scale Score (PNRS), and Functional Disability Inventory Score (FDI) were administered at initial presentation.
A subgroup of patients also underwent dynamic plantar pressure analysis. Each foot was divided into 11 regions using an automated masking protocol. Peak Pressure, contact area, contact time (% roll over process) and pressure-time integral were evaluated within each region. Bivariate analysis using Spearman's correlation was used to determine the association between individual deformity parameters, as well as the relationship between those parameters, PRO's and/or plantar pressure variables.

What are the results?
32 patients (57 feet) met inclusion criteria (average age of 14 years; range 11-17 years). 48/57 feet (84%) had an elevated DMAA (average 23.1 degrees +/- 7.8 degrees). The DMAA correlated positively with the HVA ($r = 0.734$, $p<0.001$), IMA ($r = 0.439$, $p=0.001$), and SP ($r=0.627$, $p<0.001$). No correlations were identified between deformity parameters and age, gender or BMI percentile. While patients with a greater DMAA and more lateralized SP reported greater functional limitations during play and activities of daily living as determined by OxAFQ-C, FAAM and FAOS sub-scores, those with a higher IMA reported more pain as determined by the FAOS pain sub-score ($r = 0.354$, $p=0.014$). Multivariate analysis revealed that the IMA remained significantly associated with pain after controlling for other deformity and demographic parameters ($p=0.024$). 15 patients (24 feet) underwent plantar pressure analysis. HVA correlated with increased peak pressure ($r = 0.663$, $p=0.001$) and pressure-time integral ($r = 0.604$, $p=0.002$). Overall, the peak pressure and pressure-time integral under the 2nd metatarsal (MT) correlated with lower PRO scores and increased pain-related disability. Conversely, increased 1st MT and 5th MT contact area correlated with improved PRO scores, as did 5th MT peak pressure and pressure-time integral. 5th MT peak pressure also correlated with less pain-related disability

Redefining the Juvenile Bunion *continued*

Anthony Riccio

What are your conclusions?

In contrast to the average adult bunion, the vast majority of juvenile bunions demonstrate elevation of the DMAA. Furthermore, the DMAA correlates significantly with deformity parameters more familiar to a general or pediatric orthopaedic surgeon such as the HVA, IMA, and sesamoid position. While a higher DMAA and more lateral SP seem to be associated with greater functional disability, elevations in the IMA seem to correlate with complaints of pain. Increased pressure under the 2nd MT correlates to greater functional disability and pain, while those patients who were able to maintain pressure spread across both the 1st and 5th MTs had improved PRO scores. These findings corroborate the need for a more detailed understanding of this unique deformity to perhaps improve upon the historically poorer results following operative management of this condition.

Redefining the Adolescent Bunion

Caitin Hardin BA, Claire Shivers BS, Jacob Zide MD, Tulchin-Francis K PhD, Jo CH PhD, Anthony Riccio MD

SCOTTISH RITE HOSPITAL FOR CHILDREN

UTSouthwestern Medical Center

1

Purpose

To Characterize the Radiographic Parameters of Juvenile Bunion Deformities…

…and Determine Which (if any) Correlate to Symptomatology

The Authors Have No Pertinent Financial Disclosures

2

Methods

IRB Approved Retrospective Review of Prospectively Enrolled Patients
Single Tertiary Institution
Two Year Period

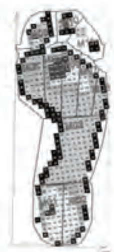
Age 10 to 17+11 Years

Exclusion Criteria:
- Neurologic Disorder
- Congenital Deformity
- Inflammatory Arthritis
- Metabolic Bone Disease

Standardized Weight-bearing Films
- Hallux Valgus Angle (HVA)
- Intermetatarsal Angle (IMA)
- Distal Metatarsal Articular Angle (DMAA)
- Sesamoid Position
- Cuneiform Obliquity
- Joint Congruency
- Metatarsal-Cuneiform Angle

Dynamic Pedobarograph

Patient Outcome Measures:
- Oxford Foot and Ankle Questionnaire (OxAFQ-C)
- Foot and Ankle Ability Measure (FAAM)
- Foot and Ankle Outcome Score (FAOS)
- Pain Numeric Rating Scale Score (PNRS)
- Functional Disability Inventory Score (FDI)



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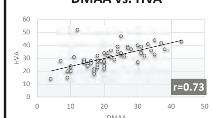
Results

57 Feet (32 Patients) Average Age: 14 Years (11-17) 72% Female 81% Bilateral 50% Skeletally Immature

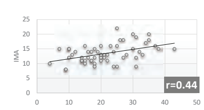
DMAA Elevated in 86% of Feet: 23.1° ± 7.8°

DMAA vs. HVA



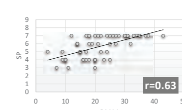
p<0.001

DMAA vs. IMA



p=0.001

DMAA vs. SP



p<0.001

4

Results

HVA

Peak Pressure (r=.663)

Pressure Time Integral (r=.604)

p=0.002

2nd MT Head

5

Pain and Function:

Plain Radiography

Univariate Analysis: ↑ IMA Correlated with Increased Pain (*p=0.014*)

Multivariate Analysis: ↑ IMA Correlated with Increased Pain (*p=0.024*)

↑ DMAA and Sesamoid Position Correlated with Functional Limitations

Pedobarograph

2nd MT Head Peak Pressure Correlated With Worse PRO Scores:
- Oxford Foot and Ankle Physical Disability (r=0.665 *p=0.001*)
- FAOS ADL Disability (r=0.593 *p=0.005*)
- FAOS Quality of Life (r=0.603 *p=0.004*)
- FDI Pain Related Disability (r=0.705 *p<0.001*)

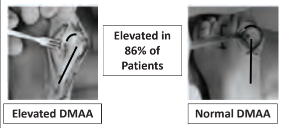
2nd MT Head Pressure-Time Integral Correlated With Worse PROs:
- Oxford Foot and Ankle Physical Disability (r=0.604 *p=0.004*)
- FAOS ADL Disability (r=0.487 *p=0.025*)
- FAOS Quality of Life (r=0.654 *p=0.001*)
- FDI Pain Related Disability (r=0.638 *p=0.002*)

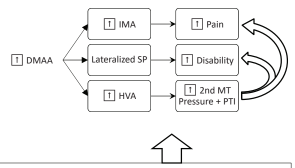
- **1st MT Head Contact Area Correlated with Better Sports and Symptom PRO Scores**

6

That's A Lot of Info on Bunions....So What?

DMAA is the Defining Characteristic of the Juvenile Bunion





The DMAA Correlates to More Familiar Bunion Parameters and Predictors of Pain and Disability

7

The Juvenile Bunion

- DMAA Correlates with More Familiar Deformity Parameters
- These Parameters Are Associated with Pain, Disability and Transfer Metatarsalgia

Surgery Addressing the Elevated DMAA may Improve upon the Historically Poor Results Following Operative Management

8

Eliminating the Pain Generator may be More Important than the Deformity Correction in Calcaneus Fractures

Ainsley Katherine Bloomer, Richard Randall McKnight, David Macknet, Nicholas Johnson, Ziqing Yu, Rachel B. Seymour, Joseph R. Hsu
ainsley_bloomer@med.unc.edu

What was the question?
The initial management of displaced intraarticular calcaneus fractures (DIACFs) is an area of controversy in orthopaedics. The results of open reduction internal fixation (ORIF) have been disappointing, especially when considering the worker's compensation (WC) population. Alternatively, ORIF with primary subtalar arthrodesis (PSTA) has gained increasing interest as an attempt to address the pain component in addition to the deformity of the injury. The purpose of this study is to review patient-centered outcomes of ORIF plus PSTA using screws alone through a sinus tarsi approach.

How did you answer the question?
A retrospective study of all patients from 2013-2019 who underwent ORIF+PSTA for a calcaneus fracture was conducted. The surgical technique consisted of reducing and lagging the posterior facet of the calcaneus to the talus with screws after removing the cartilage through a sinus tarsi approach. The extra-articular portion of the calcaneus was reduced and fixed using large headless screws into the talus and longitudinally into the anterior process of the calcaneus. Allograft was placed in the bone void and in the prepared sinus tarsi (for extra-articular fusion). No plates were applied. Delayed surgeries past 8 weeks were excluded. Demographic data, injury and job information along with relevant medical and radiographic data was collected. In line with similar studies, return-to-work results were delineated by WC status. Plain radiographs were used to assess healing based on 3 zones of fusion: posterior facet on lateral and axial views and sinus tarsi on lateral.

What are the results?
Seventy-nine fractured calcanei underwent PSTA, 60 (75.9%) of which had other associated lower extremity injuries. The most common mechanism of injury was motor vehicle collision (45.6%), followed by fall from at least 10 feet (44.3%), and fall from less than 10 feet (10.1%). Nineteen (24.1%) of patients were smokers at time of index injury, 7 (8.9%) had Type II Diabetes Mellitus, and 16 (20.3%) had an open injury. Overall, 45 (60.0%) patients were able to return to work following injury. Sixty-two (78.5%) achieved ≥2 zones of fusion on radiographs by final follow up and 68 (86.1%) had at least one. Eight patients had a complication and 3 required a return to the operative room: two due to infection and implant removal and one for an equinus contracture. Nineteen patients (24.1%) were classified as having received workers compensation for the injury, including 15 (79%) that had a job as a laborer. Six (31.6%) were able to return to work at same level of function while 7 (36.8%) returned to work at a lower activity level. Median time from surgery to final follow up was 243 (47-566) days for the workers compensation cohort and 159 (26-807) for the remainder (p=0.059). Twenty-nine (48.3%) non-WC patients were able to return to work at the same level as prior to the injury as compared to (31.6%) of WC patients (p=0.002).

What are your conclusions?
DICAFs are complex traumatic injuries with advancing focus on patient-centered outcomes. Screws only primary subtalar arthrodesis through a sinus tarsi approach shows promising results with high rates of return to work and fusion, even in the workers' compensation population.

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Eliminating the Pain Generator may be More Important than the Deformity Correction in Calcaneus Fracture

Ainsley K Bloomer, BS, Nicholas R. Johnson, MD, R. Randall McKnight, MD, David M. Macknet, MD, Ziqing Yu, PhD , Rachel B. Seymour, PhD ,Joseph R. Hsu, MD

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Disclosures

- Joseph Hsu, MD
  - Smith & Nephew – speakers bureau
  - Globus Medical – consulting

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Background

- Morbidity of Calcaneus fractures:
  - Lower SF-36 scores at 10-20 years than population norms (Brauer, Sanders)
- Pain accounts for 80% of variance in poor outcomes
- Poorer outcomes with associated subtalar arthrosis, increased comminution,
- No factors predictive of success in Worker's compensation group
- May have better results after STA with restored anatomy
- No published studies reporting primary STA with sample size > 17

Purpose: **Characterize outcomes of ORIF plus PSTA with screw-only construct via sinus tarsi approach for displaced intraarticular calcaneus fractures**

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Methods

- Retrospective study, 6 years
- Inclusion Criteria:
  - Operatively treated Displaced intraarticular calcaneus fracture
- Single surgeon
- Sinus tarsi approach
  - Cancellous allograft both intraarticular and extraarticular (sinus tarsi)
  - Percutaneous screw-only construct
  - Smaller screws compress articular surface
  - Larger screws maintain fracture length and alignment
- Primary Outcome: Fusion defined as no lucency at subtalar joint at 3 locations
  - Axial view : Posterior facet
  - Lateral view: Posterior facet, sinus tarsi
- Secondary outcomes
  - Complications
  - Return to work
- Multivariable analysis

Candidate variables for risk factors

a.	Age
b.	Gender
c.	BMI
d.	Smoking status
e.	Diabetes status
f.	Worker's compensation status
g.	Preoperative bohler angle
h.	Open fracture
i.	Mechanism of injury

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Results

Population Characteristics

- 79 fractures
- 59 male, 20 female
- Median age (40yo)
- 24% smokers
- 20% open fractures
- 42% laborers
- 24% Workers Compensation
- Mechanism
  - 45% MVC
  - 44% Fall≥10ft

Outcomes

- Achieved radiographic fusion:
  - 2/3 sites : 62 (78%)
  - 1/3 sites: 67 (88%)
- Median days to permission to WB
  - 60 (18-151)
- Return to Work
  - 45 (57%)
- Complications: 8 (10%) total
  - 4 infections (no surgery needed)
  - 1 sural neuritis
  - 3 return to surgery
    - Tibialis anterior lengthening
    - I&D and HWR (acute)
    - I&D and HWR (chronic osteo)

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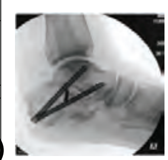
Workers Compensation Analysis

Workers compensation	Yes (N=19)	No (N=60)	P value
Laborer: N (%)	15 (79%)	18 (30%)	0.0002
Injury Mechanism			
MVC	1 (5.3%)	35 (58.3%)	0.0001
Fall ≥ 10 ft	17 (89.5%)	18 (30%)	
Fall < 10 ft	1 (5.3%)	7 (11.7%)	
Open Injury	3 (15.8%)	13 (21.7%)	0.75
Closed	16 (84.2%)	47 (78.3%)	
Sanders (1 missing)			
I	0	0	0.058
II	1	9	
III	6	30	
IV	11	21	
Follow up (days): Median (95% CI)	243 (47-566)	159 (26-807)	0.059
Return to work			
Yes			
Same level	6	29	0.002
Lower level	7	3	
No	0	1	
Unknown	6	14	
N/A	0	11	



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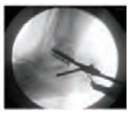
Discussion

Population-based risk factors in our patients

- Fusion: Female sex higher risk for nonunion
- Return to Work:
  - Female gender, smoking, DM, and larger preop Bohler angle independent risk factors against returning to work
- Reoperation: No predictors



Comparison Data

Return to Work/ Workers Compensation:

Busch et al.,1996: Extensile approach
11 of 12 patients returned to work
Huefner et al., 2001 (in FAI): Extensile approach
6 patients, all return to work
Buckley et al, 2014 (OTA) (Sanders IV only)
- RCT ORIF vs ORIF+PSTA
- No report on fusion or RTW

Our Study (N=79):
57% All patients
66% Workers comp

RTW not often review

WC patients tend to do poorly, our patients had comparable outcomes to non-WC

Wound Complications

Kline: 6% minimally invasive group with none requiring surgery
Current: 6% with 2 requiring surgery

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Conclusion

Screw only fixation of displaced intraarticular calcaneus fractures is associated with a high return to work in the worker's compensation demographic and a low complication rate

Limitations:

Retrospective	Small sample size	No CT for fusion
• No PROMs	• No larger series reported	• Include sinus tarsi bone graft for extra-articular fusion

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9

Tandem Use of a Single Magnetic Internal Lengthening Nail for Compound Femoral Lengthening

Harold J.P. van Bosse, Prasad Kanuparthi, Hannah Miravich
HvanBosse@Shrinenet.org

What was the question?
Background: Long bone lengthening traditionally had been performed using external fixators. The advent in 2011 of magnetically actuated intramedullary lengthening nails has dramatically decreased the rate of lengthening complications associated with external fixators. One drawback to the intramedullary devices are their limitations in cases of extreme shortening, topping out at 8 centimeters of length. The purpose of this study was to retrospectively evaluate the experience of using a single implant to perform two sequential lengthenings of the same bone, thereby obtaining more length than ordinarily permitted by the device. We evaluated this lengthening method in terms of healing index, complications, and adjacent joint range of motion.

How did you answer the question?
Between August 2015 and February 2018, we treated two young men with short femurs. The first had a severe injury at 6 years of age resulting in a 124mm length difference between his femurs, the second had a congenitally short femur, that during a previous attempt at lengthening had suffered a partially resolved nerve injury, but with 85mm difference between his femurs. The first patient required more than the 80mm of length obtainable from the implants. For the second, we wanted to more gradually lengthen his femur, in light of the previous neuropraxia. Both patients underwent placement of magnetically actuated intramedullary lengthening femoral nails with osteotomies for lengthening. Both patients underwent the first cycle of lengthening, and when the distraction osteogenesis site healed, had removal of the locking screws. The nail was shortened over several weeks, then the locking screws were replaced, the femurs were re-osteotomized, and the second cycle of lengthening was performed.

What are the results?
The first patient obtained 74mm during the first cycle (lengthening index 1.19mm/day, healing index 0.68 months/cm). Five months after healing, the second osteotomy was performed, having removed the screws and shortened the nail over the 6 weeks previous. In this cycle 38mm were gained (lengthening index 0.18, healing index 14 months/cm). The second patient lengthened 34 mm of lengthening the first cycle (lengthening index 0.6mm/day, healing index 1.9 mos/cm), and 46 mm (L.I. 0.47, H.I. 3.3 mos/cm) on the second, which occurred 4 months after healing. The second patient had premature consolidation of his second cycle femoral osteotomy, requiring repeat osteotomy 2 months later. Both patients developed delayed/non-unions during healing of the second cycle, requiring removal and replacement of the expandable rod with a solid rod, 23 months after the second cycle osteotomy for the first patient, and 16 months for the second. At final followup (62 and 30 months respectively), both have fully healed femurs, are full weight-bearing, without complaints.

What are your conclusions?
Tandem lengthening of the femur using an intramedullary magnetically actuated nail is an option when it is not possible to obtain the necessary length using the available expansion of the device. The technique avoids having to implant two separate lengthening devices. Both of our patients experienced delayed healing of their second cycle regenerates, requiring replacement of the expandable nail with a solid nail. Most likely, the pause between the first cycle healing and the second cycle osteotomy was too short in both of these cases, and should probably be delayed by at least 12 months.

Tandem use of a **Single Magnetic Internal Lengthening Nail** For Compound Femoral Lengthening

LLRS 2020 Virtual Meeting

Harold J. P. van Bosse, MD
Srinivasa Prasad V. Kanuparthi, MD
Hannah Miravich, BA
Shriners Hospital for Children - Philadelphia
Pediatric Orthopaedic Surgery
Philadelphia, Pennsylvania

1

Conflict of Interest Statement

My co-authors and I have nothing to disclose.

I have permission from patients' families to display clinical pictures.

2

Tandem Femoral Lengthening for Large Discrepancies

Background

- External fixators
  - Traditional method
  - Drawbacks – uncomfortable, possibility of pin-site infections
- Magnetically actuated intramedullary nails
  - Since 2011
  - Drawback -limitations in cases of extreme shortening, topping out at 8 centimeters of length.
- Proposal
  - Use a single implant to perform two sequential lengthenings of the same bone
- Objective
  - Retrospectively review of technique on two patients
  - Assess healing index, complications, and adjacent joint range of motion.

Materials and Methods

- Patient Demographics
  - 2 young men with short femurs
  - Patient A
    - 16 years old
    - Acquired 124mm length discrepancy of femur following motor-bicycle accident at 6 years of age.
  - Patient B
    - 18 years old
    - Congenital femoral deficiency with 85mm difference
    - Previous attempt at lengthening resulted in sciatic neuropraxia – so wanted to perform lengthening more gradually

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Tandem Femoral Lengthening for Large Discrepancies

- Treatment Protocol
  - Precice nail placed in femur
    - Retrograde in Patient A due to pre-existing proximal femoral hardware
  - First cycle lengthening performed
  - First distraction callus allowed to heal
  - Locking screws removed
  - Shortening of nail over several weeks with external remote control (ERC)
  - Femur re-osteotomized and locking screws replaced
  - Second cycle of lengthening performed

Results

- Patient A
  - First lengthening 74mm
  - 8 months after nail insertion
    - Locking screws removed
    - Nail shortened over 6 weeks
  - Second osteotomy 10 months after first
  - Second lengthening 38mm
  - Total lengthening 112mm
- Patient B
  - First lengthening 34mm
  - 8 months after nail insertion
    - Locking screws removed
    - Nail shortened over 8 weeks
  - Second osteotomy 10 months after first
  - Second lengthening 46mm
  - Total lengthening 80mm

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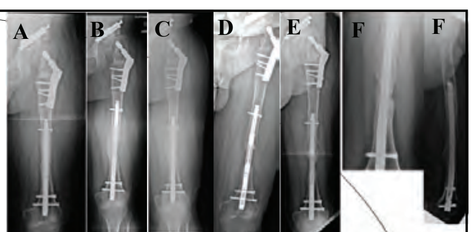
Patient A



A) Immediately after initial insertion of magnetically actuated intramedullary nail at 16 years old
B) 5 months later, 74 mm of length attained (lengthening index (LI) 1.19mm/day, healing index (HI) 0.68 months/cm)
C) 8 months after nail insertion, proximal locking screws removed, and nail shortened at home, followed by re-osteotomy for lengthening 6 weeks later
D) After 5 months of lengthening, 38mm of length attained (LI 0.18mm/day)
E) 23 months after second osteotomy, lengthening nail replaced with static nail for delayed healing
F) Most recent followup, showing progressive healing (HI 14 months/cm)

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Patient B

A) Just prior to initial insertion of magnetically actuated intramedullary nail at 18 years old
B) 5 months after insertion, 34 mm of length attained, lengthening index (LI) 0.6mm/day, healing index (HI) 1.9 months/cm
C) 10 months after insertion, second osteotomy performed (distal locking screws removed 2 months previous for nail shortening)
D) 2 months later, a repeat osteotomy needed, due to premature consolidation
E) After 6 months total lengthening, 46mm of length attained (LI 0.47mm/day)
F) 4 months later, delayed healing, lengthening nail replaced with static nail
G) Most recent followup, 2 years after staring lengthening, showing full healing (HI 3.3 months/cm)

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Tandem Femoral Lengthening for Large Discrepancies

Discussion

- Tandem lengthening of femur
  - Allows for lengthening of femur beyond limitations of expandable intramedullary nail
  - The nail functioned well in both cases
    - Nails shortened appropriately
    - No failure of nail during second lengthening
  - In these two cases, both experienced delayed union after second lengthening
    - Patient B needed a repeat second osteotomy for premature consolidation
  - Both cases required exchange of expandable nail with a solid nail to allow for full healing and full weight bearing

- Lessons learned for future cases
  - Allow for greater regenerate remodeling after first lengthening
    - We waited only 5 months between healing of first regenerate and second osteotomy
    - We now plan a full year after consolidation prior to second osteotomy
  - Second osteotomy at a site different from first regenerate
    - A better regenerate may be possible after the second osteotomy if there is a distance between osteotomy levels
    - Pre-planning the first and second osteotomy to vary levels

7

Regional Nerve Block Decreases Length of Stay in Pediatric Gradual Correction Patients

Philip K. McClure, MD, Nequesha S. Mohamed, Wayne A. Wilkie, John E. Herzenberg
pmcclure@lifebridgehealth.org

What was the question?
General anesthesia, regional blockade, and epidural anesthesia have demonstrated success in children undergoing limb procedures. The present study was undertaken to determine the 1) demographics and 2) outcomes of pediatric patients who received general anesthesia, regional block or epidural anesthesia for gradual limb correction. Our hypothesis is that epidural anesthesia will have no benefit over general anesthesia alone or with peripheral block regarding length of stay (LOS) and pain management.

How did you answer the question?
Pediatric patients that underwent gradual deformity correction between 2014 and 2018 were identified (n=44). Cases were stratified according to anesthesia utilized: general (n=13), regional nerve block (n=15), and epidural (n=16). The variables assessed were: age, race, sex, American Society of Anesthesiologists (ASA) physical status class, body mass index (BMI), length of surgery, LOS, eight-hour visual analog pain scale scores, pain intensity, total daily opioid consumption, discharge destination, and complications. Chi-square analyzed categorical variables, and one-way analysis of variance analyzed continuous variables.

What are the results?
There were no significant differences between general, block and epidural patients in age, sex, race, or ASA class. BMI was slightly higher in general patients. Epidural patients had a longer LOS compared to block patients (3.54 vs. 2.27 vs. 3.13 days, p=0.019), though they had a lower pain score at 40 hours (2.10 vs. 4.31 vs. 1.50, p=0.018). Pain intensity and total opioid consumption were not statistically different between groups. Discharge destination (Home: 84.6 vs. 100.0 vs. 93.8%, p=0.458) and complications (84.6 vs. 53.3 vs. 43.8%, p=0.105) were also not significantly different.

What are your conclusions?
Patients with epidural anesthesia had longer LOS relative to other groups. Patients who had blocks had slight increase in pain score at 40 hours. With all other measures equivalent, blocks may be more advantageous to the economic surgeon to optimize gradual extremity correction. Larger studies may reveal more granular detail regarding opioid consumption.

Dr. Philip K. McClure

Regional Nerve Block Decreases Length of Stay in Pediatric Gradual Correction Patients

Nequesha Mohamed, John E. Herzenberg, Philip K McClure

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Dr. Philip K. McClure

Disclosures

- Novadip (consultant)
- Orthofix (teaching consultant)
- Smith & Nephew (teaching consultant)

- **I will not be discussing "off-label" or investigational uses for products or devices.**

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ANESTHESIOLOGY

Trusted Evidence: Discovery to Practice

From: Predictors of Postoperative Pain and Analgesic Consumption:A Qualitative Systematic Review

Anesthesiology. 2009;111(3):657-677. doi:10.1097/ALN.0b013e3181aae87a

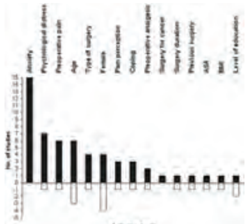

Figure Legend:

Fig. 2. Predictive factors of postoperative pain intensity. ASA = American Society of Anesthesiologists status; BMI = body mass index (kg/m^2); black bars = number of studies with significant correlation;, white bars = number of studies with conflicting results.

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Methods

- Case from 2014-2018
- 44 Pediatric Patients.
  - Anesthesia Choice: general alone (n=13), general with nerve block (n=15) or epidural (n=16).

- Data Points
  - Demographics: Age, Race, Sex
  - ASA class, body mass index (BMI)
  - Length of surgery, length of stay (LOS)
  - Eight-hour visual analog pain scale scores, pain intensity, total daily opioid consumption
  - Discharge destinations.

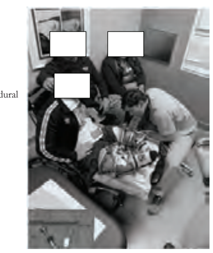

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Table 1: Patient Demographics

Parameter (N) (%)	General	Block	Epidural	p-value
Number of Patients	13	15	16	
Mean Age (years) (SD)	11.50 (2.83)	10.76 (4.40)	9.00 (4.92)	0.265
Sex				0.624
Male	6 (46.2%)	5 (33.3%)	8(50.0%)	
Female	7 (53.8%)	10 (66.7%)	8(50.0%)	
Race				0.676
White	19 (61.3%)	7 (53.8%)	17 (77.3%)	
Black	7 (22.6%)	3 (23.1%)	4 (18.2%)	
Asian	2 (6.5%)	1 (7.7%)	1 (4.5%)	
Other	3 (9.7%)	2 (15.4%)	0 (0.0%)	
ASA Class				0.100
1	7 (53.8%)	7 (46.7%)	12 (75.0%)	
2	4 (30.8%)	8 (53.3%)	4 (25.0%)	
3	2 (15.4%)	0 (0.0%)	0 (0.0%)	
Mean BMI (kg/m^2) (SD)	29.94 (13.29)	23.99 (7.96)	19.10 (6.15)	0.013

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Effect of BMI on Anesthesia Choice?

- Not independently studied
- Likely would require prospective randomized study (multicenter?) in order to neutralize patient factors
- We do not know if block or epidural was "attempted" and "abandoned", or if there is a bias present

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Table 2: Patient Outcomes

Parameter (N) (SD)	General	Block	Epidural	p-value
Mean Length of Surgery (min)	286.00 (57.43)	300.27 (74.51)	334.67 (62.69)	0.307
Mean Length of Stay (days)	3.54 (1.94)	2.27 (0.46)	3.13 (0.72)	0.019
Mean VAS Score				
Preoperative	0.00 (0.00)	0.64 (1.45)	0.33 (1.15)	0.339
8-Hour	1.73 (3.07)	1.20 (1.66)	1.19 (2.71)	0.831
16-Hour	2.00 (3.13)	4.00 (3.57)	2.38 (4.16)	0.358
24-Hour	1.92 (2.87)	1.79 (2.15)	2.36 (2.71)	0.831
32-Hour	2.36 (2.50)	2.86 (2.32)	2.33 (3.22)	0.854
40-Hour	2.10 (2.08)	4.31 (2.18)	1.50 (1.01)	0.018
48-Hour	1.56 (2.19)	2.71 (2.14)	2.20 (3.19)	0.697
Pain Intensity (AUC)				
24-Hour	38.15 (44.32)	52.80 (40.21)	45.00 (63.72)	0.751
48-Hour	37.54 (34.16)	61.33 (30.64)	44.50 (50.17)	0.270
Total Opioid Consumption (MME)				
Postoperative Day 0	675.61 (596.18)	165.20 (221.58)	690.27 (1126.42)	0.116
Postoperative Day 1	494.37 (851.60)	57.84 (118.09)	1430.54 (3810.33)	0.263
Postoperative Day 2	256.35 (404.97)	24.88 (18.58)	181.63 (231.55)	0.064
Discharge Destination (%)				0.458
Home	11 (84.6%)	15 (100.0%)	15 (93.8%)	
Subacute Rehab	1 (7.7%)	0 (0.0%)	1 (6.3%)	
Hospital Facility	1 (7.7%)	0 (0.0%)	0 (0.0%)	
Complications (%)				0.105
Yes	2 (84.6%)	8 (53.3%)	7 (43.8%)	
No	11 (15.4%)	7 (46.7%)	9 (56.3%)	

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Controversy on Block for Tibial Osteotomy

- Combined Sciatic/Popliteal Block
  - Irreversible (short term) in comparison to adjusting rate of epidural to evaluate pain/motor.
- Discharge prior to block resolution?
  - Re-admission, missed complication
  - Offer re-block for severe pain?

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Current Practice

- Adductor Canal block for tibial gradual correction
- Monitor compartments clinically
- No prophylactic fasciotomy
- Tylenol/Toradol for all
- IV/PO opioids as needed

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Conclusions

- For patients undergoing gradual correction
  - Consider limited blocks
    - Close compartment monitoring
  - No added benefit of epidural for pain control or LOS
- Anesthesia choice remains a valuable tool in optimizing short term outcomes
- Robust Randomized Trials Required to further elucidate the role of blocks in optimal care
  - Risks?
  - Costs?
  - Alternatives?

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10

Nonvascularised Fibular Autograft for Reconstruction of Paediatric Bone Defects: An Analysis of 10 Cases

Gerard A. Sheridan, JT Cassidy, A Donnelly, Maria Noonan, Paula M Kelly, David P Moore
sheridga@tcd.ie

What was the question?
Fibular autograft has been utilised for the reconstruction of traumatic and nontraumatic bone defects in both adult and paediatric populations for many years. The use of this technique to reconstruct malignant paediatric tumours has not been well described in the literature to date however. We aim to describe our outcomes using various stabilisation methods for nonvascularised fibular autograft to reconstruct both benign and malignant tumours in a paediatric population in a National Paediatric Centre over the past 14 years.

How did you answer the question?
This was a retrospective review of 10 paediatric cases with non-traumatic primary bone defects in a National Paediatric Centre. Criteria for inclusion were all non-traumatic primary bone defects requiring reconstruction with a non-vascularised fibular autograft in the diaphyseal or metaphyseal regions of the bone. Patients with secondary lesions, lesions located in the epiphysis or lesions reconstructed with vascularised graft were excluded from the analysis.
The primary outcome measures were union and time to union (weeks). Clinical union was defined as a painless graft site. Time to union was illustrated using a Kaplan-Meier curve. Secondary outcome measures included postoperative fracture, infection (deep and superficial), time to full weight-bearing and all-cause revision surgery.

What are the results?
The mean length of follow-up was 63 months for the entire cohort (SD=48.6, 9-168). All patients were followed up until the time of review. Sixty percent of lesions were located in the tibia, 20% were in the femur and the remaining 2 were in the ulna and third metacarpal. Union was ultimately achieved in 8 of the 10 patients using this donor autograft. The mean time to union was 28 weeks (10-99, SD=29.8). Kaplan-Meier curve illustrates that most unions occurred between the 3 and 6 month period. Four patients sustained an infection. Two of these were superficial pin site infections (patient 5,6) and 2 were deep infections (patient 3,8). Two of the 10 patients proceeded to non-union (Patient 8,10). As discussed above, patient 8 developed a deep wound infection and subsequent infected non-union. This was treated with an intercalary endoprosthesis after sterilisation of the infected tissue bed. Patient 10 was a 14 year old female with a diagnosis of aneurysmal bone cyst of the third metacarpal. Patient 8 was the only patient with a lower limb lesion that did not achieve full weightbearing status of that limb.

What are your conclusions?
The use of nonvascularised fibular autograft for the reconstruction of benign and malignant tumours is an effective surgical technique in a paediatric cohort. We report the largest known series of malignant paediatric tumours treated with this technique to date. We also demonstrate good results when using this technique for large bone segmental defects greater than 12cm up to 21.5cm.

Nonvascularised Fibular Autograft for Reconstruction of Pediatric Bone Defects: An Analysis of 10 Cases

Gerard A. Sheridan

Cassidy JT, Donnelly A, Noonan M, Kelly PM, Moore DP

Children's Health Ireland at Crumlin, Dublin, Ireland

1

Disclosures

Gerard A. Sheridan
None

John T. Cassidy
None

Aaron Donnelly
None

Maria Noonan
None

Paula M. Kelly
None

David P. Moore
1. Irish Institute of Trauma & Orthopaedic Surgery
2. Royal College of Surgeons in Ireland: Board or committee member

2

Methods and Sample

Retrospective review of 10 pediatric cases

2005 - 2018

National Pediatric Center

Inclusion Criteria

Non-traumatic primary bone defects

Non-vascularised fibular autograft

Diaphyseal or metaphyseal lesions

Outcomes

- *Union*
- *Time to Union*
- *Fracture*
- *Infection*
- *Revision*
- *Time to Full Weight-Bearing*

Sample

- Gender: 7 Female , 3 Male
- Age: 11 months – 15 years old
- Diagnosis: 5 malignant, 5 benign

Fixation of graft:

- *7 Ilizarov frames*
- *1 locking plate*
- *1 wires*
- *1 other*

3

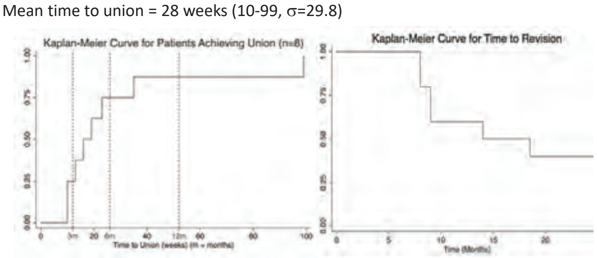
Malignancy — Outcomes

Patient	Age	Gender	Pathology	Location	Donor fibula	Defect Size (cm)	Donor Size (cm)	Fixation type	Union	Time to Union (Weeks)	Postoperative Fracture	Time to Fracture (Weeks)	Infection	Infection (Superficial/Deep)	Time to Full Weight-Bearing (Weeks)	Follow-up Time (Months)
1	14	F	Fibrous Dysplasia - pathological fracture with pseudoarthrosis	Tibia	Bilateral	21.5	23 (x2)	Ilizarov Frame	Yes	35	No	N/A	No	N/A	23	72
2	13	F	Osteosarcoma	Tibia	Ipsilateral	[illegible]	15 (cut into three)	Ilizarov Frame	Yes	21	No	N/A	No	N/A	11	47
3	5	F	Ewings Sarcoma	Femur	Bilateral	[illegible]	14 (x2)	Ilizarov Frame	Yes	10	Yes	6	Yes	Deep - Osteomyelitis Femur	10	[illegible]
4	15	M	Osteosarcoma	Tibia	Contralateral	[illegible]	12 (cut into two)	Locking Plate	Yes	13	Yes	20	No	N/A	13	[illegible]
5	2	F	Chondroblastoma	Tibia	Bilateral	8	10 (x2)	Ilizarov Frame	Yes	10	Yes	17	Yes	Superficial - pin site	5	8
6	7	M	Fibrous Dysplasia	Tibia	Contralateral	10	11	Ilizarov Frame	Yes	16	No	N/A	Yes	Superficial - pin site	16	122
7	11 months	F	Venous infarction and Compartment Syndrome Secondary to Varicella Zoster	Ulna	Contralateral	5	7	Wires	Yes	18	No	N/A	No	N/A	N/A	36
8	13	M	Ewings Sarcoma	Femur	Ipsilateral	[illegible]	20	Ilizarov Frame	No	N/A	No	N/A	Yes	Deep - Wound breakdown	N/A - Conversion to Megaprosthesis	56
9	15	F	Ewings Sarcoma	Tibia	Bilateral	[illegible]	14	Ilizarov Frame	Yes	99	Yes	32	No	N/A	108	52
10	14	F	Aneurysmal Bone Cyst	[illegible] Metacarpal	Contralateral	4	4.5	N/A	No	N/A	No	N/A	No	N/A	N/A	12

4

Union — All-cause revision

Mean time to union = 28 weeks (10-99, σ=29.8)



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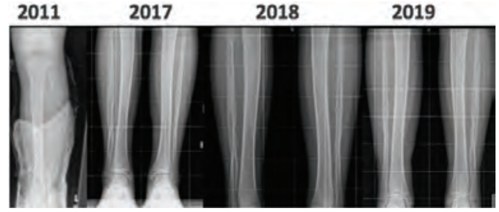
Fibular Regeneration

2011 2017 2018 2019



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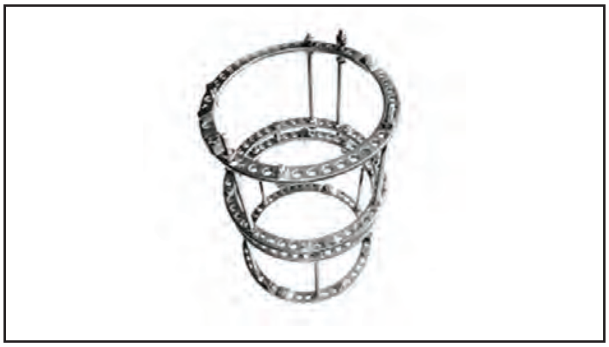

7


Thank You
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CHI
Children's Health Ireland

8

Trends and Practices in Limb Lengthening Over 10 Years – A U.S. Database Study

Ashish Mittal, Rishab Jayaram, Sachin Allahabadi, Sanjeev Sabharwal

What was the question?

Since its inception by Codvilla in 1905 and popularization by Ilizarov in the latter half of the 20th century, limb lengthening has evolved to encompass various techniques. While external fixation remains a mainstay in treatment, intramedullary lengthening has gained popularity as a viable alternative that can avoid certain complications associated with external fixation. In the United States, the Intramedullary Skeletal Kinetic Distractor (ISKD) (Orthofix Inc, Lewisville, TX, USA) was introduced as the first FDA approved internal lengthening device in 2001 followed by the PRECICE nail (Nuvasive, Irvine, CA, USA) in 2011 and the Fitbone nail (Orthofix Inc, Lewisville, TX, USA) in 2017. Due to complications with the Intramedullary Skeletal Kinetic Distractor (ISKD), there was a widespread recall in 2012. We planned to study the trends in utilization of different devices for limb lengthening for the femur and tibia in the United States. We also wanted to assess the variability in limb lengthening techniques based on patient demographics, underlying diagnosis and health insurance status.

How did you answer the question?

Inpatient data was acquired using the Healthcare Cost and Utilization Project database from 2005 to 2014 including NY, CA, FL, NC, UT, NE. Patients with an ICD-9 code for limb lengthening femur, limb lengthening tibia, or both were included. Patients were subdivided based on procedure codes for internal lengthening only, lengthening via external fixation only, or hybrid techniques. Patients were divided into diagnostic subgroups (congenital, developmental, neuromuscular/metabolic, bone dysplasias, post-infectious, post-traumatic, mechanical failure, neoplastic, short stature) and type of insurance (Public, Commercial, Self-pay). Data was analyzed using descriptive statistics, and chi-square test for comparison of subcategories. Linear regression analysis was used to examine trends over time.

What are the results?

4111 patients were identified with limb lengthening procedures between 2005-2014, of which 2073 (50.4%) had sufficient data to be included for analysis. There were 1176 males (56.7%), 856 females (41.3%), and 41 unknown (2.0%) with an average age of 27.2. 876 (42.3%) patients underwent femoral lengthening and 1197 (57.7%) underwent tibial lengthening. 459 patients (22.1%) had lengthening with an intramedullary implant alone, 1191 patients (57.5%) with external fixation alone, and 423 patients (20.4%) with a hybrid technique. Overall, there was a decrease in percentage of intramedullary lengthening devices used for limb lengthening of the femur from 2005 to 2011 ($r=-0.856$; $R2=0.733$), but an increase from 2012 to 2014 ($r=0.961$; $R2=0.923$). There were no significant trends with use of external fixator ($r=0.185$; $R2=0.0342$) or hybrid ($r=-0.440$; $R2=0.0193$) techniques for the femur, or with use of internal lengthening of the tibia ($r=-0.429$; $R2=0.184$). There was a significantly higher rate of external fixator use in patients with an underlying congenital diagnosis in the femur compared to other diagnoses ($p<0.001$; OR 2.42, 95I: 1.80-3.26). There was significantly greater use of internal lengthening devices in patients with an underlying diagnosis of short stature in the femur ($p<0.001$; OR 2.88, 95I: 1.32-6.28) and tibia ($p<0.003$; OR 8.52, 95I: 2.26-32.10). Patients with short stature also had a higher usage of self-pay for procedures compared to other diagnosis groups ($p<0.001$; OR 24.34, 95I: 11.55-51.32).

What are your conclusions?

Techniques for limb lengthening surgery have continued to evolve over time. While external fixation continues to have a predominant role in limb lengthening, our data demonstrates an increased percentage of lengthening via internal devices from 2012 to 2014. Selection of implant depends on various factors, including underlying diagnosis and bone involved. We are currently expanding the study population to include data from more recent years to further assess the trends in limb lengthening in the United States.

Trends and Practices in Limb Lengthening Over 10 Years – A U.S. Database Study

LLRS Virtual Meeting 2020

Ashish Mittal MD, Rishab Jayaram, Sachin Allahabadi MD, Matt Callahan MBA, Sanjeev Sabharwal MD MPH

Dignity Health St. Mary Medical Center

UCSF University of California San Francisco

UCSF Benioff Children's Hospitals

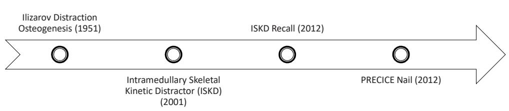
1

Disclosures

- None

2

Background/Goals



- To determine trends in utilization of different devices for limb lengthening for the femur and tibia in the United States
- To assess variability in limb lengthening techniques based on patient demographics, underlying diagnosis and health insurance status

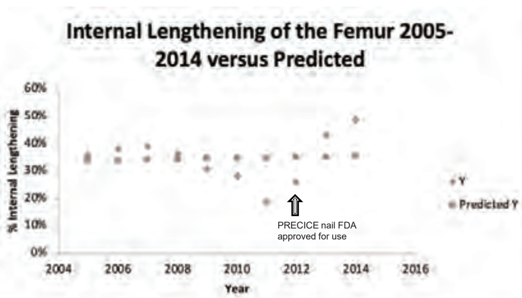
3

Methods

- Healthcare Cost and Utilization Project (HCUP) National Database queried from **2005-2014**
- Data from **43 states** available (non-longitudinal)
- **4,111** limb lengthening procedures
- **2,073** patients with sufficient data
  - **876** femoral (42%)
  - **1,197** tibial (58%)
- Average age **27** yrs.(range 0-97)
- **57%** Male
- ICD-9 codes were used to determine:
  - Diagnoses
  - Procedure performed
- Statistical Analysis was conducted using descriptive statistics and chi-square test with significance p< 0.05

4

Results



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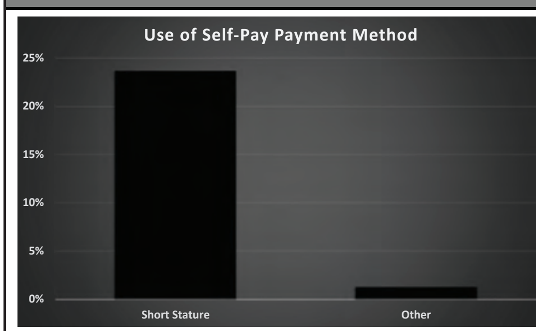
Results



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Results

- No significant trends with use of external fixator or hybrid techniques for the femur
- No significant trend with use of internal lengthening of the tibia
- Higher rate of external fixator in the femur with **congenital** shortening diagnosis compared to other diagnoses (**OR 2.42**, 95% CI: 1.80-3.26, p<0.001)
- Greater use of **internal lengthening** devices in the femur (OR 2.88; p<0.001) and tibia (OR 8.52; p<0.003) in patients with an underlying diagnosis of **short stature**

7

Conclusions

- External Fixation was the predominant modality of limb lengthening from 2005-2014
- Use of internal lengthening of femur decreased from **2004-2012**, and had a relative increase from **2012-2014**
- Patients undergoing limb lengthening with an underlying diagnosis of short stature had a higher rate of **internal lengthening** and **self-pay** payment than patients with other diagnoses

8

Thank You

Ashish.Mittal@dignityhealth.org
Sanjeev.Sabharwal@ucsf.edu

UCSF Benioff Children's Hospitals

Dignity Health
St. Mary Medical Center

LLRS
Limb Lengthening and Reconstruction Society

UCSF
University of California San Francisco

9

Hexapod Education in Developing Nations

Richard Gellman, Douglas Beaman
Rgellman@me.com

What was the question?
In developing nations, with limited surgical capabilities, what is the feasibility of treating problem fractures, osteomyelitis and congenital deformities with the techniques of ring external fixation and computer controlled hexapod frames?
How can US initiated educational platforms be used to facilitate learning in these countries?

How did you answer the question?
In 2010, education in deformity correction began at the annual SIGN Conference in Richland, WA. Starting in 2016, regional deformity courses were held in Tanzania, Cameroon, Nigeria and Kenya, and focused surgical mentorships were initiated in Kenya and The Philippines.
Ring external fixation components for educational purposes and US surgeon teaching visits were supplied by donations from US surgeons and Smith Nephew, Inc.
A recent grant by SIGN is now available to supply the non-reused component of deformity correction (1.8 mm smooth wires and 5 mm half pins).

What are the results?
Supply costs of ring external fixation components are prohibitively high in the developing nations involved in this study.
Training of foreign surgeons in developing countries in the facets of deformity correction such as deformity planning, frame design and appropriate patient application has been successful in certain locations but remains the largest challenge. This has been assessed by review of their cases.
Current SIGN educational courses provide basic and advanced didactics in ring external fixation applications. Deformity planning, understanding of the hexapod parameters and programs as well as bone healing optimization continue to be deficiencies.

What are your conclusions?
The experience at the SIGN organization of creating a worldwide network of 5,000 surgeons in 50 countries to train and supply intramedullary nails for long bone fractures has provided the educational basis for treating problem fractures, osteomyelitis and congenital deformities with computer controlled hexapod ring external fixation.
This preliminary evaluation of the SIGN learning methods has demonstrated the successes and remaining challenges in teaching modern ring fixation methods. Ongoing efforts include expansion of the LLRS Traveling Fellowships to include two additional surgeons sponsored by the SIGN organization.

HEXAPOD EDUCATION IN DEVELOPING NATIONS

- What is the feasibility of treating problem fractures, osteomyelitis and congenital deformities with the techniques of ring external fixation and computer controlled hexapod frames in developing nations?

1

NO DISCLOSURES

2

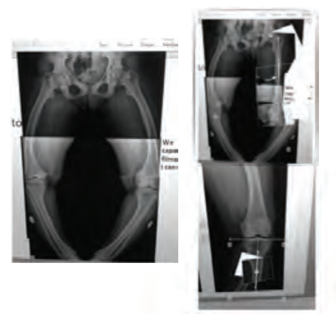
2010: education in deformity correction begins at the annual SIGN Conference in Richland, WA. (signfracturecare.org)

2016-19: regional deformity courses & focused surgical mentorships held in Tanzania, Kenya, Cameroon, Nigeria and The Philippines.

3

Ring external fixation componentry are supplied by donations from US surgeons and Smith Nephew, Inc.

A grant by SIGN is now available to supply the non-reused component of deformity correction (1.8 mm smooth wires and 5 mm half pins).



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RESULTS

Training of surgeons in developing countries in deformity planning, frame design and appropriate patient application has been successful but remains the largest challenge.

Results are assessed by review of cases.

5

SIGN educational courses & surgical mentorships provide basic and advanced didactics in ring external fixation applications.

Deformity planning, understanding of the hexapod programs as well as bone healing optimization continue to be deficiencies.

6

CONCLUSIONS

This preliminary evaluation of the SIGN learning methods has demonstrated the successes and remaining challenges in teaching modern ring fixation methods.

Ongoing efforts include expansion of the LLRS Travelling Fellowships to include two additional surgeons sponsored by the SIGN organization.

7

HOW CAN YOU HELP?

Donate your used external fixation equipment

Donate your time teaching

rgellman@me.com

signfracturecare.org

8

Tiered Team Research: A Novel Concept for Increasing Research Productivity in the Academic Setting

Joseph R. Hsu, MD, Vignesh K Alamanda, Chad A Krueger, Rachel B. Seymour, Daniel J Stinner, Josh Wenke
Joseph.Hsu@atriumhealth.org

What was the question?
Research has become a key pillar of academic medicine and a corner stone of residency training; however, there continue to be significant barriers to ensuring research productivity for residents. We implemented a novel tiered team approach to research and sought to determine the benefits this approach aimed to increase research productivity and promote collaboration during residency training.

How did you answer the question?
This was a retrospective study that evaluated the implementation of a novel tiered team research approach at a single institution between the years of 2009-2013. Analytical software was used to visualize and display the research interconnections amongst the authors of the captured publications. In addition to using Gephi to determine the research interconnections, it was also used to graphically demonstrate the growth in research capability of the tiered team and its individual members.

What are the results?
The research team produced a total of 77 publications during the study period (2009-2013). Significant and frequent collaboration and co-authorship was noted as the years progressed following implementation of tiered team research.

What are your conclusions?
Tiered team research can be readily implemented at most institutions and can lead to increases in productivity of published research. It can also promote collaboration and peer mentorship among those involved.

Atrium Health
Musculoskeletal Institute

Tiered Team Research: A Novel Concept for Increasing Research Productivity in the Academic Setting

Vignesh K. Alamanda, MD[1]; Chad A. Krueger, MD[2]; Rachel B. Seymour, PhD[1]; Daniel J. Stinner, MD[3]; Joseph Wenke, PhD[3]; Joseph R. Hsu, MD[1]

[1]Department of Orthopaedic Surgery, Atrium Health Musculoskeletal Institute; 1000 Blythe Boulevard Charlotte, NC, 28203
[2]Department of Orthopaedics and Rehabilitation, San Antonio Military Medical Center, Ft. Sam Houston, TX
[3]Department of Orthopaedics, United States Army Institute of Surgical Research, Ft. Sam Houston, TX

OrthoCarolina · Carolina NeuroSurgery & Spine Associates · Atrium Health Musculoskeletal Institute

1

Background

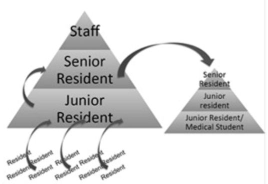
- Research is a key pillar of academic medicine and a cornerstone of residency training. Resident involvement in research has many benefits:
  - Enriches resident training
  - Advances field of research
  - Improves patient care
  - Enhances critical thinking and analytic skills
  - Aids in furthering career in academic medicine
- ACGME requires research experience during residency
- Despite the benefits of research as a part of residency training, barriers to research productivity exist.
- Implemented a novel tiered team approach to research to promote collaboration and increase productivity.

2

Methods

- Retrospective study at a single institution between the years of 2009 – 2013.
- Participants: PGY 1 and 2 of orthopaedic surgery, research resident, attending clinician, support personnel.
- Analytical software used to visualize and display research interconnections

Figure 1



3

Results

- The research team (3 residents and an attending faculty member) produced a total of 77 publications,
- Publications progressively increased as members advanced though the research pyramid.

Table 1

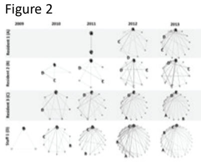
Year	Resident 1	Resident 2	Resident 3	Staff 1
2009	0	0	0	4
2010	0	1	11	18
2011	1	4	8	16
2012	7	6	10	26
2013	6	2	5	13

4

Results

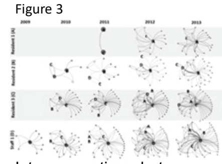
- Tiered teams led to exponential growth in research productivity and interconnections

Figure 2



Significant and frequent collaboration and co-authorship is seen as the years progressed post-implementation.

Figure 3



Interconnections between research team members and the extensions derived from each of the sub projects run by various team members.

5

Discussion

- The tiered team approach:
  - Provides clear, achievable goals
  - Promotes collaboration between residents and faculty
  - Maximizes the total number of publications for the team
  - Facilitates peer mentorship
  - Allows residents to be involved in multiple areas of research through various roles
  - Is generalizable to most academic departments

6

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THANK YOU!

Does Anesthesia Choice Affect in Hospital Outcomes for Adult Acute Deformity Correction Patients?

John E. Herzenberg, Ethan A. Remily, Nequesha S. Mohamed, Philip K. McClure
jherzenb@lifebridgehealth.org

What was the question?
Acute correction of limb deformity can be performed with general anesthesia, peripheral nerve blockade, or epidurals, each with satisfactory outcomes. The present study was undertaken to determine the 1) demographics and 2) outcomes of adult patients undergoing an acute limb correction with general, peripheral nerve block, or epidural anesthesia. Previous internal data with pediatric patients predicts a negative outcome for epidural.

How did you answer the question?
Adults who underwent acute correction between 2014 and 2018 were evaluated (n=50). Further stratification grouped patients by anesthesia type: general (n=38), nerve block (n=7) or epidural (n=5). Collected data consisted of age, sex, race, American Society of Anesthesiologists (ASA) physical status class, body mass index (BMI), length of surgery, length of stay (LOS), visual analog pain scale (VAS) scores, pain intensity, total daily opioid consumption, and discharge destination. Categorical and continuous variables were analyzed with chi-square and one-way analysis of variance respectively.

What are the results?
General, nerve block, and epidural anesthesia were similar in terms of age, sex, race, ASA score, and BMI. There were no significant differences in surgery length (p=0.412) or LOS (p=0.810). Epidural patients had significantly lower pain scores at 8 hours postoperatively (4.37 vs. 4.14 vs. 1.40, p=0.038), but there were no other differences observed in pain scores at any other time point (all p>0.05). Additionally, no differences were found in 24-hour (p=0.080) and 48-hour pain intensity (p=0.292), opioid consumption on postoperative day 0, 1 or 2.

What are your conclusions?
Despise some concerns regarding anesthetic choice, it appears that each type performed adequately against each other. However, some group sizes are quite low, and repeating this investigation with higher numbers will likely give a clearer picture of the best anesthesia. Based on this preliminary data, it seems like there is no clearly superior anesthesia for this type of operation in adult patients; and all fare equally well.

Does Anesthesia Choice Affect Hospital Outcomes for Adult Acute Deformity Correction Patients?

Nequesha S. Mohamed, MD, Ethan A. Remily, DO, Wayne A. Wilkie, DO, Sahir S. Pervaiz, MD, Scott J. Douglas, MD, Nancy Campbell, DO, Noelle C. DiGioia, DO, Philip K. McClure, MD, and John E. Herzenberg, MD

Sinai Hospital, Baltimore, Maryland
International Center for Limb Lengthening
Rubin Institute for Advanced Orthopedics

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Disclosures

- I (and/or my co-authors) have something to disclose
- John Herzenberg, MD: Consultant: Smith + Nephew , OrthoPediatrics, NuVasive, Orthofix, Wishbone, OrthoSpin, Bonus BioGroup.
- Philip McClure, MD: Smith + Nephew (teaching consultant), Orthofix (teaching consultant), Novadip (consultant)

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Objectives

- To determine the demographics of patients undergoing adult limb deformity correction
- To quantify outcomes pertaining to each anesthetic (general, peripheral, epidural)

Hypothesis

- The utilization of general anesthesia or peripheral nerve block leads to superior outcomes compared to epidural anesthesia in acute adult limb deformity correction.

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Methods

- **Patient Selection**
  - A retrospective review of limb correction patients at a single institution between 2014 and 2018
  - Inclusion criteria: age >18; underwent acute correction procedure (n=50)
  - Stratified by anesthesia type
    - General anesthesia (n=38)
    - Peripheral nerve block (n=7)
    - Epidural (n=5)
  - <u>Outcomes</u>
    - Hospitalization
      - length of stay (LOS), discharge destination
    - Pain
      - VAS pain scores, pain intensity, daily opioid consumption

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Results

- **Demographics**
  - Age, Sex, Race, ASA class, BMI
    - <u>No statistical significance between groups</u>

Parameter (N) (%)	General	Block	Epidural	p-value
Number of Patients	38	7	5	
Mean Age (years) (SD)	34.09 (15.19)	43.23 (17.62)	35.44 (9.69)	0.349
Sex				0.301
Male	19 (50.0%)	2 (28.6%)	1 (80.0%)	
Female	19 (50.0%)	5 (71.4%)	4 (20.0%)	
Race				0.241
White	22 (59.5%)	5 (71.4%)	3 (60.0%)	
Black	11 (29.7%)	1 (14.3%)	1 (20.0%)	
Asian	4 (10.8%)	0 (0.0%)	1 (20.0%)	
Other	0 (0.0%)	1 (14.3%)	0 (0.0%)	
ASA Class				0.631
1	4 (10.5%)	2 (28.6%)	1 (20.0%)	
2	28 (73.7%)	4 (57.1%)	4 (80.0%)	
3	6 (15.8%)	1 (14.3%)	0 (0.0%)	
Mean Body Mass Index (SD)	29.12 (9.35)	26.81 (9.29)	27.72 (8.09)	0.810

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Results

- **Hospitalization Outcomes**
  - Length of surgery, length of stay, discharge destination
    - <u>No statistical significance between groups</u>

Parameter (N) (SD)	General	Block	Epidural	p-value
Mean Length of Surgery (minutes)	303.05 (121.79)	359.43 (125.53)	351.20 (119.18)	0.412
Mean Length of Stay (days)	2.63 (1.44)	2.43 (0.53)	2.80 (0.45)	0.810
Discharge Destination (%)				0.536
Home	24 (88.9%)	3 (75.0%)	4 (100.0%)	
Hospital Facility	3 (11.1%)	1 (25.0%)	0 (0.0%)	

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Results • Pain Outcomes

Mean VAS Score	**General**	**Block**	**Epidural**	**p-value**
Preoperative	0.88 (1.82)	1.83 (2.23)	0.00 (0.00)	0.335
8-Hour	4.37 (2.38)	4.14 (2.48)	1.40 (1.95)	0.038
16-Hour	4.81 (2.47)	3.57 (2.88)	3.00 (2.55)	0.210
24-Hour	4.72 (2.79)	3.29 (3.30)	2.60 (1.34)	0.173
32-Hour	4.39 (2.63)	5.71 (1.60)	3.00 (2.23)	0.181
40-Hour	4.58 (2.70)	4.43 (3.41)	3.40 (3.44)	0.700
48-Hour	3.97 (2.70)	5.14 (3.18)	3.80 (2.49)	0.575
Pain Intensity (AUC)				
24-Hour	108.21 (50.42)	88.00 (52.66)	56.00 (38.78)	0.080
48-Hour	88.21 (56.22)	122.29 (53.61)	81.60 (35.96)	0.292
Total Opioid Consumption (MME)				
Postoperative Day 0	389.83 (323.50)	184.36 (186.97)	496.80 (1010.55)	0.387
Postoperative Day 1	180.74 (350.73)	64.36 (75.43)	582.00 (996.85)	0.102
Postoperative Day 2	84.93 (191.37)	62.89 (45.92)	246.06 (288.20)	0.193

- Epidural patients had significantly lower pain scores at 8 hours postoperatively (p=0.038)
- No other differences in pain scores at other times (all p>0.05)
- No statistical significance for all other pain outcomes between groups

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Conclusions

- Each type of anesthetic appears to perform equivalently when compared to each other in acute limb lengthening
- More studies of larger size is necessary to delineate the role of anesthesia in this procedure

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Prevalence of Vitamin D Deficiency in Adult Limb Lengthening and Deformity Correction Patients

John E. Herzenberg, Ethan A. Remily, Nequesha S. Mohamed, Philip K. McClure
jherzenb@lifebridgehealth.org

What was the question?
Low vitamin D levels have been a growing concern in the elective orthopedic world. Limb lengthening and deformity correction surgery requires adequate bone metabolism for healing. It is currently unknown what the vitamin D levels are among this population.

How did you answer the question?
A retrospective review was performed for adult patients, age 18 or older, who underwent an osteotomy surgery for acute or gradual correction of a lower extremity long bone deformity. Patients were identified by screening case logs at one orthopaedics referral center between 2014 and 2018. Data collected included age, sex, race, diagnosis, long bone treated, and peri-operative 25(OH)D level for descriptive statistics.

What are the results?
Of 139 subjects identified as undergoing a lower extremity osteotomy surgery, 96 (69%) underwent peri-operative 25(OH)D peri-operative testing. External fixation patients were most likely to be tested. Of patients with 25(OH)D lab results available, most were male (53/96, 55%) and Caucasian (58/96, 60%) with a mean age of 33.3 ± 15.4 years (range, 18-72 years). Diagnoses treated included idiopathic disorders (28/96, 29%), miscellaneous diagnoses (20/96, 21%), post traumatic deformities (18/96, 19%), congenital limb deficiencies (12/96, 13%), skeletal dysplasias (11/96, 11%), and post-infectious diagnoses (7/96, 7%). The mean 25(OH)D level was 29.5 ± 17.8 ng/mL [range 5.7-95.9 ng/mL]. Deficient levels (20 but < 30 ng/mL) were found in 29/96 (30.2%) subjects, resulting in 63% of subjects having low peri-operative 25(OH)D. A minority of subjects (35/96, 36.5%) had adequate 25(OH)D levels.

What are your conclusions?
A majority of adult limb lengthening and deformity correction patients have deficient or insufficient vitamin D levels peri-operatively. Identifying these patients prior to surgery in order to replenish vitamin D levels may improve bone healing following osteotomy surgery.

LLRS 2020 – Virtual Annual Meeting

Prevalence of Vitamin D Deficiency in Adult Limb Lengthening and Deformity Correction Patients

Jessica C. Rivera, MD
Nequesha S. Mohamed, MD
Iciar M. Dávila Castrodad, MD
John E. Herzenberg, MD, FRCSC

International Center for Limb Lengthening
Rubin Institute for Advanced Orthopedics
Sinai Hospital, Baltimore, MD USA

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Disclosures:

Consultancies:
- Smith Nephew
- NuVasive
- WishBone
- OrthoSpin
- Orthofix
- OrthoPediatrics

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Vitamin D Deficiency – Research:

- Ortho Trauma
  - Smith et al.
    - 75 patients (16-80 years) with ankle fractures
    - 47% of patients had insufficient vitamin D levels
    - 13% had deficient vitamin D levels
- Fractures
  - Gorter et al.
    - 187 pediatric fracture pts
    - 34% were vitamin D deficient
    - 527 adult fracture pts
    - 40% were vitamin D deficient / 11% were severely deficient
- Pediatric deformities & painful conditions
  - Davies et al.
    - 187 children admitted to the orthopedic service
    - 32% had vitamin D insufficiency
    - 8% were vitamin D deficient

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Limb Lengthening

- Osteotomy
- Distraction
- Fixation
  - Bone regeneration
- Need adequate bone metabolism → vitamin D

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Materials

- Retrospective study including patients:
  - 18 years or older
  - Undergoing osteotomy surgery for
    - acute correction and fixation of a lower extremity long bone deformity or for gradual lengthening
    - deformity correction by external fixator or intramedullary lengthening nail
  - Single, referral center between 2014 and 2018

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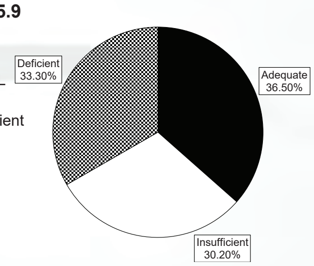
Results

- Mean 25(OH)D level 29.5 ± 17.8 ng/mL [range 5.7-95.9 ng/mL]
- 35 patients (36.5%) > 30 ng/mL adequate for bone health
- 29 (30.2%) < 30 ng/mL insufficient
- 32 (33.3%) < 20 ng/mL **DEFICIENT**



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Results

- **Mean 25(OH)D level 29.5 ± 17.8 ng/mL [range 5.7-95.9 ng/mL]**
- 35 patients (36.5%) ... adequate fo...

63% of adult limb lengthening patients had insufficient or deficient peri-operative vitamin D levels!

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Conclusions

- **Limb lengthening requires optimal bone metabolism for healing of new regenerate bone.**
- **We found a high prevalence of vitamin D deficiency/insufficiency (63%) in adult limb lengthening patients.**
- **Identifying these patients pre-operatively allows for vitamin D “pre-habilitation” to optimize bone health prior to limb lengthening procedures.**

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8

Accuracy of Virtual Surgical Planning and Custom 3D-Printed Osteotomy and Reduction Guides for Acute Correction of Antebrachial Deformities in Dogs

Christina Carolyn De Armond, Daniel Dean Lewis, Stanely Kim, Adam Biedrzycki
cdearmond@ufl.edu

What was the question?
The objective of this retrospective study was to describe our methods for virtual surgical planning and the printing and application of custom osteotomy and reduction guides for antebrachial deformity correction in dogs. Additionally, this study aimed to evaluate the accuracy of executing the pre-operative plan as well as assess the clinical outcomes in a series of dogs in which custom printed osteotomy and reduction guides were used to perform antebrachial deformity correction.

How did you answer the question?
Medical records of dogs which had antebrachial deformity corrections based on computer software planning and acute corrective surgery performed using 3D printed custom radial osteotomy and reduction guides performed between May 2018 through January 2020 were reviewed.
All dogs underwent preoperative CT imaging of both thoracic limbs. Image segmentation, 3D virtual surgical planning, and custom guide design was performed using medical imaging and computer assisted-design software (Materialise, Leuven, Belgium). DICOM images were segmented using a bone algorithm to render 3D sterolithography files. 3D virtual deformity models were then characterized as either uniapical or biapical. Virtual closing wedge ostectomy(ies) were performed and bone segments were rotated and translated until the desired correction was achieved. Both 3D osteotomy and reduction guides were reverse-engineered to achieve the virtual surgical correction in the operating room.
Custom guides and bone models were 3D printed and sterilized for surgery. The guides were then used intraoperatively to execute the virtual plan. All osteotomies were stabilized using plates and screws.
Postoperative CT images were processed in the same manner as described for preoperative imaging. 3D renderings of both the virtual surgical plan and postoperative limb were assessed for frontal plane alignment (FPA) and sagittal plane alignment (SPA). Previous reports established normal ranges for FPA of 0 to 8° and SPA of 21.3 to 31.8° (Fox 2006, Fasanella 2010).
To assess accuracy of guide use, FPA, SPA, and radial torsion was compared between the virtual plan and postoperative result. Results within 5 degrees variation to the virtual surgical plan were considered acceptable execution of the virtual plan.

What are the results?
Population and Deformities –
Ten dogs (eleven forelimb deformities) met the inclusion criteria. Six deformities were categorized as biapical and five were categorized as uniapical deformities (Table 1).
Surgery and Outcome –
Total surgical time ranged from 55 minutes to 6 hours 45 minutes (median = 3 hours 20 minutes). Uniapical correction surgical time ranged from 55 minutes to 2 hours 55 minutes (median = 1 hour 40 minutes). Biapical correction surgical time ranged from 3 hours 50 minutes to 6 hours 45 minutes (median = 4 hours 55 minutes). Cutting and reduction guides were successfully used for nine out of eleven surgeries; however, reduction guides were abandoned in two procedures due to difficulties in aligning the antebrachium as a result of soft tissue constraints. Guide use was often subjectively easy, but some difficulty was encountered for juxta-articular guide placement due to soft tissue constraints.
All cases reached radiographic osseous union of radial osteotomies within 12 weeks of surgery. Following recovery, both clinician and owner assessment of gait and limb alignment were favorable for 9/11 cases.

Accuracy of Virtual Surgical Planning and Custom 3D-Printed Osteotomy and Reduction Guides for Acute Correction of Antebrachial Deformities in Dogs *continued*

Christina Carolyn De Armond

Complications –
One dog had proximal radial fracture two days following surgery. Four deformities had implant-associated soft tissue irritation, three of which underwent implant removal surgery. Confirmed bacterial surgical site infection occurred in one case. Reduced carpal extension occurred in one case and resolved with tenotomy of the flexor carpi ulnaris muscle.
Alignment and Accuracy –
Postoperative CT data was available for eight of eleven limbs. FPA and SPA were measured on the postoperative virtual limbs. According to previously established ranges, two out of eight limbs was under-corrected in the frontal plane and one out of eight was under corrected in the in the sagittal plane (Fox 2006, Fasenella 2010).
Variation of virtual plan and postoperative corrected limb FPA ranged from 0 to 9 degrees (median = 1□). Sagittal plane alignment varied 0 to 4 degrees (median = 1.5□) between the plan and corrected limb. Torsional variation between the virtual plan and corrected limb ranged from 1 to 5 degrees (median = 1□). Twenty-one of twenty-four, or 87.5% of the above measured parameters, were within the defined range of accuracy of 5 degrees variation between corrected limb and virtual plan.

What are your conclusions?
This study reflects the initial experience of virtual surgical planning and printing for limb deformity correction at our institution. To the authors' knowledge, this is the first study to show use of custom reduction guides in addition to osteotomy guides for antebrachial limb deformity correction. It is also the first study to analyze the results of antebrachial deformity correction using postoperative CT. Additionally, it is the first study to describe use of a novel methodology to virtual surgical planning for deformity correction. Our results showed high accuracy of translation of the surgical plan to a postoperative result; however, our experiences also highlight areas of potential improvement for this emerging treatment modality.

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Fasanella FJ, Tomlinson JL, Welihozkiy A, et al. Radiographic measurements of the axes and joint angles of the canine radius and ulna. [Proceedings of the 37th Annual Conference of the Veterinary Orthopedic Society, Breckenridge, CO, February 20– 27,] 2010:21.

Accuracy of virtual surgical planning and custom 3D-printed osteotomy and reduction guides for acute correction of antebrachial deformities in dogs

Christina C. De Armond, MVB (Hons) , Daniel D. Lewis, DVM, Stanley E. Kim, DVM, MS, Adam H. Biedrzycki, BVSc, PhD

UF College of Veterinary Medicine
UNIVERSITY of FLORIDA

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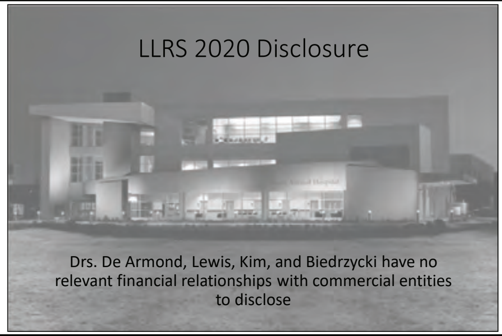

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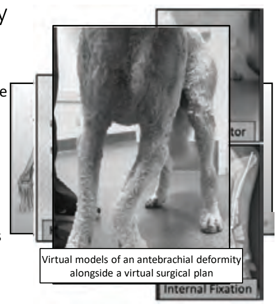
Approach to Limb Deformity Correction in Dogs

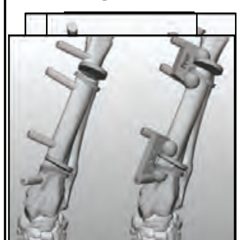
- Antebrachial deformities in dogs are typically complex, multiplanar anomalies, with multiple CORAs
- Traditional approach to deformity characterization and surgical plan is based on radiographic or CT images
- Management usually employs Ilizarov-type fixators ... l fixation
- Under ... ethods is comr
- Virtual ... d custom ... nning and provide accurate results



Virtual models of an antebrachial deformity alongside a virtual surgical plan

3

Methods: 3D-Virtual Surgical Planning and Custom Surgical Guide Design for Deformity Correction



- Retrospective case study
- Acute deformity correction using virtual surgical planning and 3D-printed custom guides for ostectomies and reduction
- Post operative CT used to determine accuracy of guide use

[illegible]

4

Surgical Results

- 12 antebrachial deformity corrections
- Guide use successful in 9
  - Abandoned in 3 cases
  - Difficulty with soft tissue constraints and juxta-articular guide placement
- Fluoroscopy only used during implant placement
- Complications
  - Surgical Site Infection n=1
  - Implant removal n=4

5

Difference Between Virtual Plan and Postoperative Result

Deformity Number	Frontal Plane Alignment (degrees)	Sagittal Plane Alignment (degrees)	Torsion (degrees)	Translation (mm)
1	0.58	1.36	1	1
2	2.3	1.76	1	4
4	1.03	4.25	4	12
5	0.28	0.76	3	1
7	0.65	3.96	2	1
8	0.2	2.2	5	5
9	2.13	0.57	5	3
11	1.52	2.33	7	19
12	2.4	1.58	3	2

Alignment Accuracy

- Postoperative CT available for 9 of 12 limbs
- Acceptable result was defined as alignment within ≤5° or ≤ 5 mm of the virtual surgical plan
- 91.6% of parameters met the criteria of acceptable variation
- Only 3 parameters were outside of the acceptable range

6

Discussion

- Virtual surgical planning provides an *intuitive* technique of deformity correction and application of CORA principles
- Surgical guides facilitate accurate execution of the virtual plan
- Transposing wedge ostectomies more centrally, away from the CORA, simplifies guide and implant placement
- Increasing functional limb length can complicate acute corrections; consider limb segment shortening to mitigate restrictive soft tissue tension

7

Acknowledgements

"Cello" Pre-left forelimb correction

"Cello" Post left forelimb surgery

The authors would like to thank the LLRS for the opportunity to present this study.

8

Clinical Observership Opportunities in North America for International Orthopaedic Surgeons

Sanjeev Sabharwal, MD, Laura Carrillo, Borja Segarra
sanjeev.sabharwal@ucsf.edu

What was the question?
What clinical observership opportunities are available in North America for international orthopaedic surgeons?

How did you answer the question?
Two investigators performed a systematic online search to identify orthopaedic clinical observerships that are available in the United States and Canada for international surgeons. Variables such as host type, geographic location of host site, program type, eligibility criteria, subspecialty focus, application and participation fees, availability of funding, duration of observership, and the quality of online information that is available based on an online content (OC) score were collected.

What are the results?
Of the 113 available observership sponsors in North America, 36 (32%) were professional society-based, 69 (61%) were academic/institution-based, and 8 (7%) were private practice-based. Most observerships were located in the U.S. (n = 85) and, of these, the Northeast was the most common U.S. region (n = 29, $p = 0.008$). Of the observerships with a focus, pediatrics was the most frequent orthopaedic subspecialty ($p < 0.0001$), followed by spine and trauma. Professional society-sponsored observerships offered funding to international surgeons more often than academic/institution-based and privately sponsored programs ($p < 0.0001$). The average OC score for the entire cohort was 2.35 and was similar among the 3 host types ($p = 0.954$). The program structure and requirements such as applicant eligibility, application and participation fees, and duration of observership varied widely.

What are your conclusions?
There are opportunities for international orthopaedic surgeons to participate in clinical observerships in North America. Given the greater funding support and lack of fees for professional society-sponsored observerships, these observerships may pose fewer financial barriers for surgeons from low and middle-income countries (LMICs). The quality of online information was similar among the 3 different host types and can be improved. The relevance and impact of a clinical observership experience in North America for a practicing orthopaedic surgeon from an LMIC need to be explored further.

Clinical Observership Opportunities in North American for International Orthopaedic Surgeons

Laura Carrillo, BA, Borja Segarra, MD,
Sanjeev Sabharwal, MD, MPH

UCSF University of California San Francisco

UCSF Benioff Children's Hospitals

1

Disclosures

- We have no relevant disclosures related to this talk

2

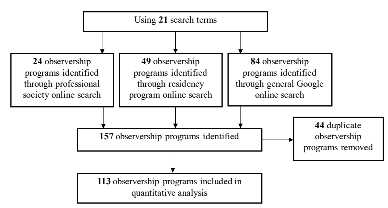
Background

- Clinical observerships provide international orthopaedic surgeons the opportunity to observe, learn, and share various aspects of musculoskeletal clinical care and research.
- The purpose of this study was to assess the spectrum of orthopaedic clinical observerships currently available in North America (Canada and U.S.), which may be found via an internet search, for practicing overseas surgeons.

3

Methods

- Three types of incognito Google searches were performed during April and May 2019.



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Host Type

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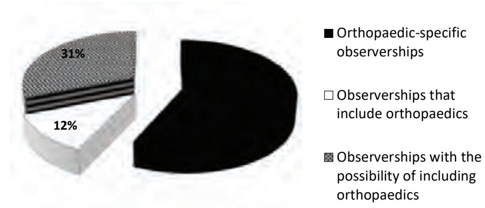
Program Type



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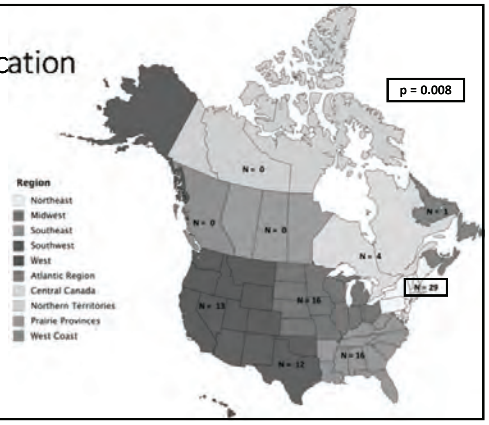
Location



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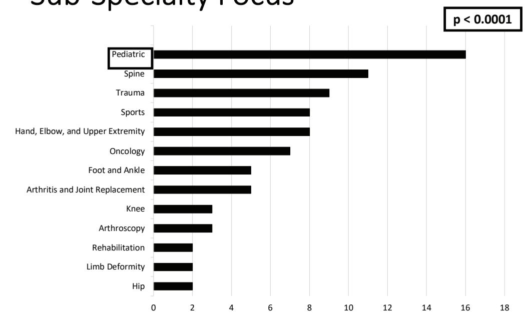
Sub-Specialty Focus



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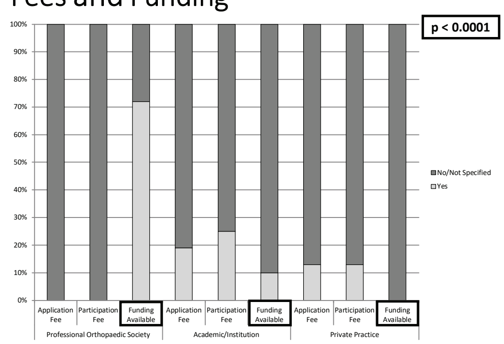
Fees and Funding



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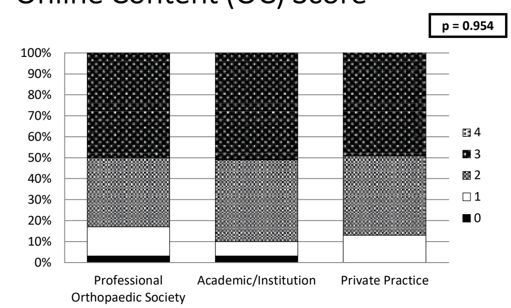
Online Content (OC) Score



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Limitations

- Search strategy
- Lack of program verification
- English advertisements
- OC Score

11

Conclusion

- There are opportunities for international orthopaedic surgeons to participate in North American observerships.
- Given the greater funding support and lack of fees for professional society sponsored observerships, these observerships may pose fewer financial barriers for surgeons from low- and middle-income countries (LMICs).
- The quality of online information was similar amongst different host types and can be improved.
- The relevance and impact of a clinical observership experience in North America for practicing orthopaedic surgeons from LMICs need to be explored further.

12

Thank You

Sanjeev.Sabharwal@ucsf.edu

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University of California
San Francisco

UCSF Benioff Children's Hospitals

LLRS
Limb Lengthening and Reconstruction Society

POSNA
Pediatric Orthopaedic Society of North America

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