33rd Annual Scientific Meeting

Limb Lengthening and Reconstruction Society:

ASAMI–North America

July 12 & 13, 2024

Margaritaville Beach Resort

Hollywood, FL

www.llrs.org

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LLRS: ASAMI–North America

Future Meetings

Essentials of Lower Extremity Reconstruction (ELER)

January 24 & 25, 2025

Dallas, TX

LLRS Specialty Day

March 2025

San Diego, CA

34th Annual Scientific Meeting

Philadelphia, PA

Upcoming AAOS Meeting

March 10–14, 2025

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
2021	New York, NY	Austin T. Fragomen, MD
2022	Portland, OR	Raymond W. Liu, MD
2023	Olympic Valley, CA	L. Reid Nichols, MD
2024	Hollywood, FL	Stephen M. Quinnan, 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

Stephen M. Quinnan, MD, FAAOS

Professor of Orthopaedic Surgery, Florida Atlantic University

Paley Orthopedic & Spine Institute, West Palm Beach, FL

squinnan@paleyinstitute.org

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Christopher A. Iobst, MD

Mitchell Bernstein, MD

Karen R. Syzdek, Executive Director

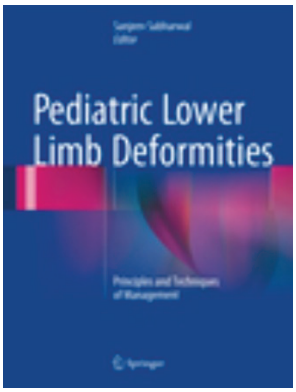
Pediatric Lower Limb Deformities

and

Limb Lengthening and Reconstruction Surgery Case Atlas Series

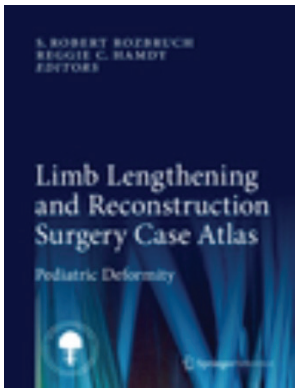
Pediatric Lower Limb Deformities

Sanjeev Sabharwal (Ed.)



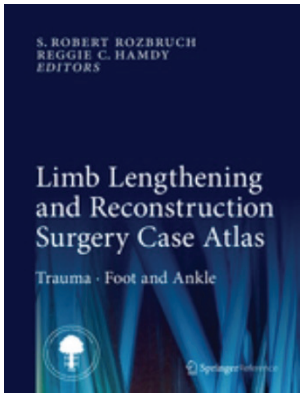
Pediatric Deformity

S. Robert Rozbruch and
Reggie C. Hamdy (Eds.)



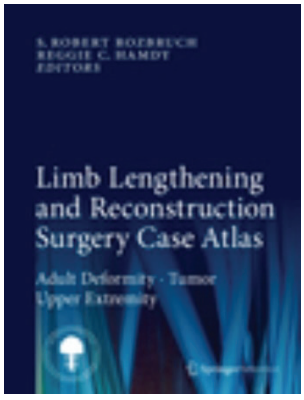
Trauma • Foot and Ankle

S. Robert Rozbruch and
Reggie C. Hamdy (Eds.)



Adult Deformity • Tumor
Upper Extremity

S. Robert Rozbruch and
Reggie C. Hamdy (Eds.)



To order, go to www.springer.com • Search “limb lengthening”

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
ASAMI NORTH AMERICA

34th Annual Scientific Meeting

The Logan Hotel

Philadelphia, PA

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

33rd Annual Scientific Meeting

Objectives

Upon completion of LLRS's 33rd Annual Scientific 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 33rd Annual Scientific 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

The LLRS appreciates its Corporate Partners and Exhibitors

Globus Medical/NuVasive Inc.
Thank you for the generous grant

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Exhibitors

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Thank you for the In–kind Donation

Baltimore Limb Deformity Course

Congenital Limb Deficiencies 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)

The LLRS thanks the following entities for their generous support.

ALM Ortho is focused on supporting surgeons when there are no industry solutions to their patient's complex orthopedic problems. Through our direct collaborations with surgeons, we develop and deliver innovative Orthopedic Implant Solutions for Osseointegration, Limb Lengthening, and Traumatic problems.

LIFEBRIDGE HEALTH
Rubin Institute for Advanced Orthopedics

Baltimore Limb Deformity Course – Register for an intensive course covering deformity correction planning and limb lengthening. An internationally renowned faculty will provide didactic and hands–on lab instruction. Learn about fellowship opportunities. 410–601–9798; click here for the BLDC website

Biocomposites® At Biocomposites, we are distinct in that our team of specialists is singularly focused on the development of innovative calcium compounds for surgical use. Our innovative products are at the forefront of calcium technology and range from bone grafts to matrices that can be used in the presence of infection. We are proud to be driving improved outcomes across a wide range of clinical applications, in musculoskeletal infection, trauma, spine and sports injuries, for surgeons and patients alike. https://www.biocomposites.com/

BONESUPPORT™ BONESUPPORT is the innovator of CERAMENT G with Gentamicin, the first and only FDA authorized combination antibiotic–eluting bone graft indicated for bone infection. As the first injectable combination antibiotic bone graft substitute, CERAMENT G can be delivered in a single–stage procedure to simultaneously support bone remodeling and locally elute Gentamicin to protect bone healing. It can help significantly reduce the recurrence of infection while improving patient outcomes and quality of life and reducing healthcare costs. The CERAMENT technology has the largest amount of pre–clinical and clinical data to prove bone remodeling and is the only bone graft substitute technology supported by a Level I randomized controlled trial. www.bonesupport.com

CONGENITAL LIMB DEFICIENCIES/DEFORMITIES LIVE SURGERY COURSE
THE PALEY FOUNDATION

The annual Congenital Deficiencies & Deformities Live Surgery Course (West Palm Beach, FL) will present comprehensive exposure to assessment, planning, surgery, and rehabilitation of patients with Congenital Femoral Deficiency, Congenital Pseudarthrosis of the Tibia, Fibular and Tibial Hemimelia, Congenital Pterygium of the Knee, Radial Club Hand, and Congenital Dislocation of the Patella. Participants will get to see patients before, during, and after surgical treatment as well as live surgery demonstrating procedures such as SUPERhip, SUPERknee, SUPERankle, SHORDT, X-UNION, and Ulnarization. Please visit: www.ThePaleyFoundation.org for more information.

DePuy Synthes Companies, part of the Medical Devices & Diagnostics (MD&D) segment of Johnson & Johnson, offers an unparalleled breadth of products, services, programs and research and development capabilities, that are designed to advance patient care and deliver clinical and economic value to health care systems throughout the world. Click here to go to the DePuy Synthes website.

At Integrum, we transform the lives of amputees by giving them an alternative, innovative treatment solution to traditional socket solutions. The OPRA™ Implant System is the only FDA-approved bone-anchored prostheses which directly connects the prosthetic leg to the patient's musculoskeletal system allowing for greater range of motion, a more stable attachment, and improved sensory feedback.

International Limb Differences Network is a global network of orthopedic surgeons, researchers and allied healthcare professionals with a common goal to improve the health related quality of life of patients with limb differences.
https://www.limbnetwork.com/

Globus Medical offers innovative technologies and industry-leading clinical support to help surgeons and healthcare providers deliver better care around the globe. Providing one of the most comprehensive offerings of musculoskeletal solutions and enabling technologies, now including the procedurally integrated portfolio of NuVasive. www.globusmedical.com/uniting

MY01 envisions a world where every disease is quantifiable, enabling precise, personalized care for all patients. Managing limb ischemia and compartment syndrome, our tools provide proactive monitoring and actionable insights through a connected care team benefiting patients, providers, and payers.

The newly merged Orthofix–SeaSpine organization is a leading global spine and orthopedics company with a comprehensive portfolio of biologics, innovative spinal hardware, bone growth therapies, specialized orthopedic solutions and a leading surgical navigation system. Its products are distributed in approximately 68 countries worldwide. The company is headquartered in Lewisville, Texas and has primary offices in Carlsbad, CA, with a focus on spine and biologics product innovation and surgeon education, and Verona, Italy, with an emphasis on product innovation, production, and medical education for orthopedics. The combined company's global R&D, commercial and manufacturing footprint also includes facilities and offices in Irvine, CA, Toronto, Canada, Sunnyvale, CA, Wayne, PA, Olive Branch, MS, Maidenhead, UK, Munich, Germany, Paris, France and São Paulo, Brazil. To learn more, visit Orthofix.com.

Founded in 2006, OrthoPediatrics is an orthopedic company focused exclusively on advancing the field of pediatric orthopedics. As such it has developed the most comprehensive product offering to the pediatric orthopedic market to improve the lives of children with orthopedic conditions. OrthoPediatrics currently markets 46 surgical systems that serve three of the largest categories within the pediatric orthopedic market. This product offering spans trauma and deformity, scoliosis, and sports medicine/other procedures. OrthoPediatrics' global sales organization is focused exclusively on pediatric orthopedics and distributes its products in the United States and over 70 countries outside the United States. For more information, please visit www.orthopediatrics.com.

Paragon 28 is built around principle–driven innovation. Working relentlessly to advance the science behind F&A surgery, P28 passionately blends knowledge from global thought leaders to develop comprehensive, relevant solutions. We're committed to creating surgeon–centric systems, specialty instruments and innovative implants.

Smith+Nephew prides itself on being a partner to the Limb Reconstruction surgeon and an innovator in circular fixation technology. We help you push the boundaries in limb restoration and allow your patients to rediscover the joy of Life Unlimited. Visit www.smith–nephew.com to learn about our products.

Stryker is one of the world's leading medical technology companies and together with our customers, we are driven to make healthcare better. The Company offers a diverse array of innovative products and services in Orthopaedics, Medical and Surgical, and Neurotechnology and Spine, which help improve patient and hospital outcomes. https://www.stryker.com/

Limb Lengthening and Reconstruction Society

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

Meeting Evaluation

The meeting evaluation is online. Please go to the following link and complete the evaluation by **Friday, August 2, 2024**. *Your responses are needed for CME credit to be valid.*

https://www.surveymonkey.com/r/LLRSAM2024

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 live activity for a maximum of 7 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!

34th Annual Scientific Meeting

The Logan Hotel

Philadelphia, PA

Please complete the evaluation online at

https://www.surveymonkey.com/r/LLRSAM2024

on or before **August 2, 2024.**


AUGUST
SAVE THE DATE
21–25, 2024
34th Annual
Baltimore Limb
Deformity Course
LIFEBRIDGE HEALTH
Rubin Institute for Advanced Orthopedics
CARE BRAVELY
Endorsed by:
LLRS
DeformityCourse.com
Four Seasons Hotel, Baltimore, Maryland, USA
Registration will be open by March 1, 2023. Please check the website for updates periodically.


ELER
Essentials of Lower Extremity Reconstruction
Scottish Rite for Children
Dallas, TX
January 25 & 26, 2025
FREE for those who qualify – learn more here

Limb Lengthening and Reconstruction Society

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

Disclosures

Program Committee

Mitchell Bernstein, MD, FAAOS (Canada)
Submitted on: 01/03/2024
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant
NXTSens MY01: Research support
Orthofix, Inc.: Paid consultant
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Smith & Nephew: Paid consultant
Synthes: Paid consultant

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Biocomposites: Paid consultant
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Bayer: Research support
Morison industries: Research support
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International Journal of pediatric Orthopaedics: Editorial or governing board
Journal of Children's Orthopaedics: Editorial or governing board
Journal of Limb lengthening and Reconstruction: Editorial or governing board
Journal of Pediatric Orthopedics: Editorial or governing board
Journal of Pediatric orthopedics B: Editorial or governing board
Limb Lengthening and Reconstruction Society: Board or committee member
Pediatric Orthopaedic Society of North America: Board or committee member
Raising Special Kids: Board or committee member
Springer: Publishing royalties, financial or material support

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Journal of Children's Orthopedics: Editorial or governing board
Orthofix, Inc.: IP royalties

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Nuvasive: Paid consultant
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Smith & Nephew: Paid consultant; Research support
Stryker: Paid consultant; Research support
Synthes: Paid consultant

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Workplace Safety and Insurance Board of Ontario: Research support

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Journal of Bone and Joint Surgery - British: Editorial or governing board
Journal of Orthopaedic EXperience & Innovation: Editorial or governing board
Orthopaedic Trauma Association: Board or committee member
Orthopedics: Editorial or governing board
Ruth Jackson Orthopaedic Society: Board or committee member
Southeast Fracture consortium: Board or committee member
Speak Up Ortho: Board or committee member
Wolters Kluwer Health - Lippincott Williams & Wilkins: Editorial or governing board

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DePuy, A Johnson & Johnson Company: Paid consultant
MHE Coalition: Other financial or material support
Orthofix, Inc.: Other financial or material support; Paid consultant
OrthoPediatrics: Other financial or material support
Pega Medical: Other financial or material support
Reselute Medical: Paid consultant; Stock or stock Options
Smith & Nephew: Other financial or material support
Stryker: Other financial or material support
TRELLIS: Research support
Zimmer: Other financial or material support

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Canadian Orthopaedic Association: Board or committee member
Canadian Paediatric Orthopaedic Trauma Course: Board or committee member
Canadian Pediatric Orthopaedic Society: Board or committee member
European Paediatric Orthopaedic Society (EPOS): Board or committee member
Limb Lengthening and Reconstruction Society: Board or committee member
Orthopediatrics: Paid consultant; Research support
Pediatric Orthopaedic Society of North America: Board or committee member

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DePuy, A Johnson & Johnson Company: Research support
Next Science: Paid consultant; Research support
NSite: Stock or stock Options
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Osteocentric: IP royalties; Paid consultant
Reselute: IP royalties; Paid consultant; Stock or stock Options
Shukla: IP royalties; Paid consultant
SI Bone: Paid consultant; Paid presenter or speaker
Synthes: Paid consultant; Paid presenter or speaker
Wolters Kluwer Health - Lippincott Williams & Wilkins: Publishing royalties, financial or material support

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orthopediatrics: IP royalties; Paid consultant

* The content of the activity is not related to the business lines or products of their employer/company.

All relevant financial disclosures have been mitigated.

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Orthofix, Inc.: Paid consultant

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Synthes: Paid consultant; Paid presenter or speaker

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Limb Lengthening and Reconstruction Society: Board or committee member
Orthofix, Inc.: Paid consultant
Ultragenyx: Paid consultant

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Flower Ortho: Paid consultant
Genesis Innovations Group: Stock or stock Options
Globus Medical: IP royalties; Paid consultant
Imagen Technologies: Stock or stock Options
Intelligent Implants: Stock or stock Options
Journal of Orthopaedic Trauma: Editorial or governing board
KCI: Paid consultant; Paid presenter or speaker
Metamorphosis AI: Paid consultant; Stock or stock Options
NSite Medical: Stock or stock Options
Orthopaedic Trauma Association: Board or committee member
OsteoCentric: Paid consultant
SI-Bone: IP royalties; Paid consultant
StabilizOrtho: Paid consultant
Stryker: Paid consultant
Synthes: IP royalties; Paid consultant
Wolters Kluwer Health - Lippincott Williams & Wilkins: Publishing royalties, financial or material support

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Limb Lengthening and Reconstruction Society

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

33rd Annual Scientific Meeting

Compass Rose North & East, Level 9

Friday, July 12, 2024

7:00 a.m.	Check–in/Registration Opens – Level 9 Foyer
7:15–8:00 a.m.	Continental Breakfast – Level 9 Foyer **Visit Corporate Partners**
8:00–8:04 a.m.	Welcome/Introduction/Disclosure – *Stephen M. Quinnan, MD*
8:05–8:52 a.m.	**Session I: Nonunion & Bone Defects** Moderator: Mani Kahn, MD
8:05–8:11 a.m.	Impact of Obesity on Inflammatory Markers in Patients with Aseptic Nonunions – *Min Suh, MD*
8:12–8:18 a.m.	Bone Morphogenetic Protein Utilization in Long Bone Nonunions: Is it as Popular as We Think? – *Nainisha Chintalapudi, MD*
8:19–8:25 a.m.	Comparison of Outpatient vs. Inpatient Lower Extremity Nonunion Surgery – *Min Suh, MD*
8:26–8:32 a.m.	Discussion
8:33–8:39 a.m.	Fulcrums in Balanced Cable Bone Segment Transport – Assessing Mechanical Differences – *Stephanie Kaszuba, MD*
8:40–8:46 a.m.	Balanced Cable Bone Transport of the Tibia Using Automated Motorized Struts – *Elizabeth Partridge Wellings, MD*
8:47–8:52 a.m.	Discussion
8:53–9:31 a.m.	**Session II: Trauma Part 1** Moderator: Mitchell Bernstein, MD
8:53–8:59 a.m.	The Impact of Reduction Quality of Tibial Plafond Fractures during Temporizing External Fixation on Final Fracture Alignment and Overall Outcomes – *Roberto C. Hernandez–Irizarry, MD*
9:00–9:06 a.m.	Preventing Deformity in 43C Tibia Pilon Fractures: Revisiting Conventional Wisdom of Implant Placement – *Amber Hamilton, MD*

9:07–9:13 a.m.	Utilization of Short–Segment Temporary Reduction Assisting K–wires (TRAK–wires) for Intramedullary Nailing of Periarticular Fractures: A Technical Trick and Case Series – *Ryan P. Serbin, MD*
9:14–9:20 a.m.	Enhanced Radiographic Union (RUST) Score of Adolescent Tibia Shaft Fractures Treated with Hexapod Circular External Fixation: A Multicenter Study of 38 Consecutive Cases – *Ahmed Thabet–Hagag, MD*
9:21–9:31 a.m.	Discussion
9:32–10:09 a.m.	**Session III: Pediatrics Part 1** Moderator: Jaclyn F. Hill, MD
9:32–9:38 a.m.	Surgical Treatment of Dynamic Valgus in Patients with Fibular Hemimelia: A Radiographic Assessment – *Aaron J. Huser, DO*
9:39–9:45 a.m.	International Field Test of Limb–Q Kids: A New Patient Reported Outcome Measure for Lower Limb Differences – *Harpreet Chhina, PhD*
9:46–9:52 a.m.	Psychological Risk Profile for Pediatric Patients Considering Limb Lengthening and Reconstruction – *Whitney M. Herge, PhD*
9:53–9:59 a.m.	Increasing the Knee Arc of Motion in Patients with Arthrogryposis: Minimum Two–Year Follow–Up – *Michael W. Brown, BS*
10:00–10:09 a.m.	Discussion
10:10–10:38 a.m.	**Session IV: Guided Growth** Moderator: Jill C. Flanagan, MD
10:10–10:06 a.m.	Biomechanical Analysis of a Predictive Mathematical Model for Rotational Guided Growth – *Alexander Chang, BS*
10:07–10:13 a.m.	Go Big or Stay Home? Impact of Implant Selection on Outcomes of Growth Modulation in Blount Disease – *Claire Noyes, MD*
10:14–10:20 a.m.	Sleeper Plates for Guided Growth: Choice of Plate Material Changes Risk of Tethering – *Gourav Jandial, MD*
10:21–10:27 a.m.	Timing of Growth Modulation for Congenital Femoral Deficiency–Associated Distal Femoral Valgus – *John G. Birch, MD*
10:28–10:38 a.m.	Discussion
10:39–11:05 a.m.	Refreshment Break **Visit Corporate Partners**
11:06–11:16 a.m.	Clinician Scholar Career Development Program (CSCDP) Presentation Introduction by Jessica C. Rivera, MD, PhD *Ainsley Bloomer, MD* *Caleb Gottlich, MD*

11:17 a.m.–12:15 p.m.	Presidential Guest Lecture* "How Did We Get Where We Are: Limb Lengthening & Deformity Reconstruction: Some of My Innovations Over the Past 38 Years" *Dror Paley, MD* *Paley Orthopedic & Spine Institute at St. Mary's Medical Center*
12:16–1:10 p.m.	Lunch **Visit Corporate Partners**
1:15–2:01 p.m.	**Session V: Osseointegration Part 1** Moderator: Joseph R. Hsu, MD
1:16–1:22 p.m.	How Well Does Perc OI Work? Comparing Percutaneous vs Open–Exposure Transtibial Osseointegration – *S. Robert Rozbruch, MD*
1:23–1:29 a.m.	Understanding the Impact of Intraoperative Bone Splitting on Patients with Osseointegrated Implants – *Jason D. Gross, MD*
1:30–1:36 p.m.	Osseointegration of the Femur: One Year Outcomes of the Press–Fit Technique – *David Burns, MD, PhD*
1:37–1:43 p.m.	Tibia Osseointegration: Outcomes after a Minimum Follow–up of 1 Year *David Laniado, MD*
1:44–1:50 p.m.	Evaluating Prosthetic Joint Infection Risk in Lower Extremity Osseointegration – *Tyler D. DeSena, MD*
1:51–2:01 p.m.	Discussion
2:02–2:38 p.m.	**Session VI: Adult Limb Deformity Part I** Moderator: Austin T. Fragomen, MD
2:02–2:08 p.m.	Interprofessional Teams in Limb Lengthening and Deformity Clinics *Jessica C. Rivera, MD, PhD*
2:09–2:13 p.m.	A Comparison of Functional Results of Three Different Surgical Techniques in Patients Undergoing Femoral Lengthening – *Ilhan Sulejmani, MD*
2:14–2:20 p.m.	Tibia Deformity Correction Using an Intramedullary Nail *David Laniado, MD*
2:21–2:27 p.m.	Retrograde Femoral Lengthening below a Total Hip Arthroplasty *David Burns, MD, PhD*
2:28–2:38 p.m.	Discussion

2:39–2:59 p.m.	Refreshment Break **Visit Corporate Partners**
3:00–3:15 p.m.	**Traveling Fellowship Presentation** Introduction by Jaclyn F. Hill, MD *Ugochuku Akpati, MBBS* *Stephen Becher, MD* *Gourav Jandial, MD* *Heather Kong, MD*
3:16–4:01 p.m.	**Session VII: Osteomyelitis** Moderator: David B. Frumberg, MD
3:16–3:22 p.m.	Effectiveness of Single–Stage Debridement with High–Dose Medullary Antibiotic Injection for Treating Osteomyelitis – *Amber Hamilton, MD*
3:23–3:29 p.m.	Bacterial Elimination with Dalbavancin Antibiotic Beads *Jessica C. Rivera, MD, PhD*
3:30–3:36 p.m.	Delivery of Dalbavancin from Antibiotic Beads: Is it Toxic to Bone? *Jessica C. Rivera, MD, PhD*
3:37–3:43 p.m.	Bromelain as a Source of Debridement for Infected Orthopaedic Implants *Matthew Bratton, BS*
3:44–3:50 p.m.	Is a Calcium Sulfate Injection during Transition to a Nail After Ring Fixator Associated with a High Rate of Infection? – *Alyssa Barré, MD*
3:51–4:01 p.m.	Discussion
4:15–5:15 p.m.	LLRS Business Meeting* – *LLRS Members Only*
6:30–8:30 p.m.	President's Reception* – License to Chill Terrace, Level 11

Limb Lengthening and Reconstruction Society
Association for the Study and Application of the Methods of Ilizarov–North America

33rd Annual Scientific Meeting

Compass Rose North & East, Level 9

Saturday, July 13, 2024

7:30 a.m.	Check–in/Registration Opens – Level 9 Foyer
7:30–8:15 a.m.	Continental Breakfast – Level 9 Foyer **Visit Corporate Partners**
8:15–8:20 a.m.	Welcome/Introduction/Disclosure – *Stephen M. Quinnan, MD*
8:21–8:59 a.m.	**Session VIII: Internal Limb Lengthening Nails** Moderator: Christopher A. Iobst, MD
8:21–8:27 a.m.	Neck Shaft Angle Deviation in Patients Undergoing Femoral Limb Lengthening – *Akram Al Ramlawi, MD*
8:28–8:34 a.m.	Nail Bending in Femoral Lengthening – *Akram Al Ramlawi, MD*
8:35–8:41 a.m.	Mechanical Angle Deviation Shift during Femoral Limb Lengthening *Akram Al Ramlawi, MD*
8:42–8:48 a.m.	Compression of Intercalary Allografts with Magnetic Lengthening Nails, Mid–term Results with a Comparison of Techniques *Lee Zuckerman, MD*
8:49–8:59 a.m.	Discussion
9:00–9:38 a.m.	**Session IX: Trauma Part 2** Moderator: Jessica C. Rivera, MD, PhD
9:00–9:06 a.m.	Does Intramedullary Nailing Increase Surgical Site Infection Rates for Incomplete Ballistic Tibia Shaft Fractures that Require Operative Debridement? – *Kathryn Dwight, MD*
9:07–9:13 a.m.	How Many Operations Does It Take? Incidence and Risk Factors for Secondary Surgery and Amputation after Lower Extremity Limb Salvage with Free Tissue Transfer – *Roberto C. Hernandez–Irizarry, MD*
9:14–9:20 a.m.	Gradual Reconstruction Algorithm for Distressed Soft Tissues: The GRADIST Method – *Ivan Federico Rubel, MD*

9:21–9:27 a.m.	Evaluating Embolic Load Differences: Medullary Versus Extramedullary Fixation Techniques in Tibia Fracture Surgery – *Amber Hamilton, MD*
9:28–9:38 a.m.	Discussion
9:39–10:30 a.m.	Alessandro Codivilla Guest Lecture* "Greeting Comfortable, Being Uncomfortable" *Rakesh Patel, MD, MBA* *University of Michigan Health System*
10:31–10:50 a.m.	Refreshment Break **Visit Corporate Partners**
10:55–11:31 a.m.	**Session X: Pediatrics Part 2** Moderator: L. Reid Nichols, MD
10:55–11:01 a.m.	Comparing Two Abbreviated Bone Age Assessment Methods to Greulich and Pyle and the Modified Fels Wrist System Using Serial Radiographs *Lauren Huang, BA*
11:02–11:08 a.m.	Post–Operative Outcomes of the Patellofemoral 360° Procedure for Complex Patellofemoral Instability – *Austin T. Fragomen, MD*
11:09–11:15 a.m.	Analysis of Serial Foot Radiographs to Determine Foot Height Multipliers *Raymond W. Liu, MD*
11:16–11:22 a.m.	Limb Length Discrepancy and Osteogenesis Imperfecta: Preventable or Inevitable? – *Jill C. Flanagan, MD*
11:23–11:31 a.m.	Discussion
11:32–12:08 a.m.	**Session XI: Osseointegration Part 2** Moderator: Jason Stoneback, MD
11:32–11:38 a.m.	Periprosthetic Fracture Management in Patients with Transfemoral Osseointegration – *S. Robert Rozbruch, MD*
11:39–11:45 a.m.	Transfemoral Osseointegration for Patients with Amputation to Manage Infected Total Knee Arthroplasty – *Tyler S. DeSena, MD*
11:46–11:52 a.m.	Transcutaneous Osseointegration in Patients with Diabetes Mellitus and/or Peripheral Vascular Disease: A Case Series of 5 Patients with Minimum 3–year Follow–up – *LaYow Christine Yu, MD*
11:53–11:59 a.m.	MRI is Safe for Amputees with Titanium Press–Fit Osseointegration *LaYow Christine Yu, MD*
12:00–12:08 p.m.	Discussion

**No CME awarded*

12:09–12:45 p.m.	**Session XII: Adult Limb Deformity Part 2** Moderator: Kevin Tetsworth, MD
12:09–12:15 p.m.	Frontal Plane Knee Motion Following Surgical Correction of Genu Valgum – *S. Robert Rozbruch, MD*
12:16–12:22 p.m.	Chatbots in Limb Lengthening and Reconstruction Surgery. How Accurate are the Responses? – *Christopher A. Iobst, MD*
12:23–12:29 p.m.	Acute Pelvic Support Osteotomy in Patients Over 70 Years of Age in Failed Hip Arthroplasties – *Leon Gonzalo Mora Herrera, MD*
12:30–12:36 p.m.	Evaluation of How to Determine if a Lateral Ankle View is Acceptable Using Rotated X–rays Generated from CT Scan 3D Models *DreMarcus Ferrell, MS*
12:37–12:45 p.m.	Discussion
12:46–1:00 p.m.	President's Remarks and Introduction of 2024–2025 President *Stephen M. Quinnan, MD* and *Christopher A. Iobst, MD*

Session I: Nonunion & Bone Defects

Moderator: Mani Kahn, MD

Impact of Obesity on Inflammatory Markers in Patients with Aseptic Nonunions

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Anthony Paterno, Bradley Lauck, , Susan Odum, Joseph R Hsu, MD; Rachel B Seymour, PhD; Roman M Natoli, Paul E Matuszewski, MD; William T Obremskey, MD; Sharon Babcock, Robert D Zura, MD; Hassan Mir, Malcolm DeBaun, Lisa Cannada, MD; JD Adams, Anna N Miller, Michael J Gardner, Kristoff Reid, Andrew T Chen

What was the question?
C–reactive protein (CRP), erythrocyte sedimentation rate (ESR), and white blood cell count (WBC) are inflammatory markers routinely used to help diagnose septic nonunions. Evidence suggests these inflammatory markers can be elevated in healthy patients with high body mass index (BMI) levels, decreasing their diagnostic utility and validity. The purpose of this study is to determine the association between BMI and inflammatory markers (CRP, ESR, and WBC) in patients with an aseptic nonunion.

How did you answer the question?
A retrospective series of 1242 nonunions from 13 Level 1 trauma centers was performed. Basic demographic data, as well as CRP, ESR, and WBC were queried. We confirmed that inflammatory markers were elevated in septic nonunions. Then, the n=1031 aseptic nonunions were stratified by four BMI categories (normal: BMI40). A Kruskal–Wallis test was performed to compare the Inflammatory markers between BMI categories Wilcoxon tests with adjusted p–value compared all possible comparisons. Complications (persistent nonunion, DVT, hardware failure, and reoperation) were compared among BMI categories with a Chi–square test.

What are the results?
With the aseptic nonunions median CRP values differed between BMI categories [normal 0.5 (0.5, 0.9); overweight 0.5 (0.5,0.7); obese 0.5 (0.5, 1.0); morbidly obese 0.82 (0.5, 1.6); $p<0.0001$. Median ESR values also differed amongst BMI groups [normal10 (4,22); overweight 11 (5,20); obese 16 (10,29.5), and morbidly obese 26 (11.5, 41); $p<0.0001$]. Pairwise comparisons to normal weight patients indicate that morbidly obese patients had significantly higher CRP and ESR values ($p<0.0002$ and $p<0.0001$). There were no significant differences in WBC levels or prevalence of complications.

What are your conclusions?
Baseline CRP and ESR were elevated in aseptic nonunion patients with high BMIs. This suggests that the higher a patient's BMI, the typical inflammatory biomarkers may not be as reliable in trying to differentiate between a septic or an aseptic nonunion.

Bone Morphogenetic Protein Utilization in Long Bone Nonunions: Is it As Popular as We Think?

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Roman Natoli, William T Obremskey, MD; Andrew T Chen, Sharon Babcock, Hassan Mir, Michael J Gardner, Robert D Zura, MD; Paul E Matuszewski, MD; Anna N Miller, JD Adams, Jarrod Dumpe, MD; Ziqing Yu, Rachel B Seymour, PhD; Joseph R Hsu, MD

What was the question?
Bone morphogenetic protein (BMP) has gained popularity for managing long bone nonunions in spite of controversy/concern for complications. This study aims to evaluate BMP efficacy and impact on patient outcomes/complications, and describe BMP utilization for managing long bone nonunions in trauma centers among orthopedic traumatologists.

How did you answer the question?
We performed a multi–center retrospective review of adults with long–bone (humerii, femurs, tibias) nonunions treated with autograft (iliac crest, RIA, local graft) or allograft, with/without BMP. Inclusion criteria included patients >18 years old requiring long bone nonunion surgical intervention.. Exclusion criteria was follow–up

What are the results?
There were 970 nonunions , 157 BMP cases (33 humerii (21%), 61 femurs (38.9%) and 59 tibias (38%)) and 813 cases without BMP (222 humerii (28%), 247 femurs (29.7%), 344 tibias (42.3%)). >50% of injuries were closed in both groups (57% BMP, 51% non–BMP) and there was a significant association between segmental gap defect presence and BMP utilization as a biologic augment (p=0.016). BMP cohort patients tended to be female (54% vs 40%, p=0.029), older (54 vs 48 years, p=0.0036), and had higher BMIs (31.12 vs 28.44, p=0.0019). No difference in union rate (85% vs 79%, p=0.1266), time to union (197 vs 205 days, p=0.8415) or complication rates (43% vs 40%, p=0.3708). Median length of stay was 2 days.. BMP cohort had greater variability than non–BMP cohort (IQR 1,4 vs 2,4; p=0.0127). BMP utilization significantly increased after 2010 (4% vs 41%), with 3 centers driving 78% of utilization and 4 surgeons driving 42% of cases. When top two BMP utilizers were excluded there was no statistical clinical outcome improvement and statistically significant increase in length of stay (1–4 days in BMP group vs 1–3 days in no BMP group, p=0.0004)

What are your conclusions?
BMP patients tended to be older and female. No significant differences in union rate, time to union or complications between the cohorts. Although it has been increasing since 2010,a limited number of centers and fewer surgeons utilize BMP.

Comparison of Outpatient vs Inpatient Lower Extremity Nonunion Surgery

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What was the question?
Orthopaedic surgery is trending towards emphasizing shorter lengths of stay and aiming to perform more outpatient surgery when safe to do so. While evidence suggests lower complication rates and lower costs for outpatient hip and knee arthroplasty, this benefit is not well described in orthopaedic trauma. The purpose of this study is to assess the outcomes of inpatient versus outpatient surgery in lower extremity nonunion surgery. We hypothesize that there will be no differences in outcomes between the two groups.

How did you answer the question?
A retrospective analysis of 981 patients who underwent surgical fixation of aseptic tibial and femoral nonunions gathered from 14 Level 1 trauma centers was performed. Based on length of stay (LOS), patients were stratified into two groups: outpatient (LOS=0; n=146) and inpatient (LOS>1; n=835) Primary outcomes of complications (post–operative infection, reoperation, and readmission) were compared between inpatient and outpatient cases using Chi–square tests Multivariable logistical regression models were developed to determine the probability of infection, readmission and reoperation after controlling for potential risk factors , e.g. age, BMI, tobacco, ASA classification, insurance, and use of bone graft.

What are the results?
All complication rates were higher among inpatient cases. Of the 835 inpatient patients, 11.5% developed an infection compared to 9.0% of outpatients (p=0.36), 19.0% were re–admitted compared to 11.0% (p=0.03), and 24.5% versus 20.5% required a reoperation (p=0.34). When controlling for confounders such as age, BMI, tobacco, ASA classification, insurance, and use of bone graft, patients who had surgery in an outpatient setting had a reduced odds of infection 0.74 (p=0.39), readmission 0.76 (p=0.35), and reoperation 0.92 (p=0.73) compared to those who had surgery in an inpatient setting, but these were not statistically significant.

What are your conclusions?
There does not appear to be a significant difference in outcomes with inpatient vs outpatient tibial and femoral aseptic nonunion surgery. Further research should be conducted to identify cost savings of outpatient nonunion surgery and what specific patient factors will optimize outcomes.

Fulcrums in Balanced Cable Bone Segment Transport – Assessing Mechanical Differences

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Rhys Richmond, BS; Steven Tommasini, PhD; David B. Frumberg, MD

What was the question?
Multiple options exist for fulcrums in balanced cable bone segment transport (BC–BST) procedures but there is no strong consensus amongst orthopaedic surgeons on best practice. This study investigates the mechanical differences between a variety of fulcrums used to perform this reconstructive technique.

How did you answer the question?
A custom testing rig was designed to assess the tension modifying effects of different fulcrums on the BC–BST system. 8 fulcrums were tested: 5.0mm cortical screw, 4.5mm cortical screw, 4.0mm Ti locking screw, 5.0mm Ti locking screw, 4.0mm peg (smooth and threaded portions), 4.5mm peg, and tensioned wire. Fulcrums were drilled into a Sawbones fragment and a cable was threaded around each fulcrum and through a BC–BST external fixation system. The cable was tensioned to a 400 N force at a constant rate of 0.05 mm/s by an Instron machine. Transported distance of a periosteum–simulating spring was measured and stiffness of each fulcrum–cable system was determined.

What are the results?
With the exception of one fulcrum (5.0 locking screw), there was an observed relationship between stiffness of the system and the displacement of the spring for smooth and threaded/screw fulcrums (Tables 1–3). Overall, larger diameter fulcrums lead to increased spring/segment displacement. Threaded fulcrums had the unique problem of slippage of the cable from thread to thread, leading to inconsistent tension. Tensioned wires were observed to have low stiffness in this closed system.

What are your conclusions?
The diameter and type of fulcrum directly affect the force needed to pull a segment down over a predetermined distance. A more in–depth understanding of the impact that the diameter and the threads of the fulcrum have on the BC–BST system will allow for greater personalization of the pull tension. Further investigation that guides fulcrum choice in surgery can potentially minimize mechanical complications while promoting faster and more effective healing.

Table 1. Fulcrum Stiffness

Fulcrum	Observed Stiffness (N/mm)
3.5 Cortical Screw	32.207
4.5 Cortical Screw	26.348
4.0 Ti Locking Screw	19.129
5.0 Ti Locking Screw	17.290
Fitbone 4.0 Peg - Smooth	18.140
Fitbone 4.0 Peg - Threaded	22.014
Fitbone 4.5 Peg - Smooth	18.023
Tensioned Wire	16.396

Table 2. Instron Pull vs. Spring Displacement

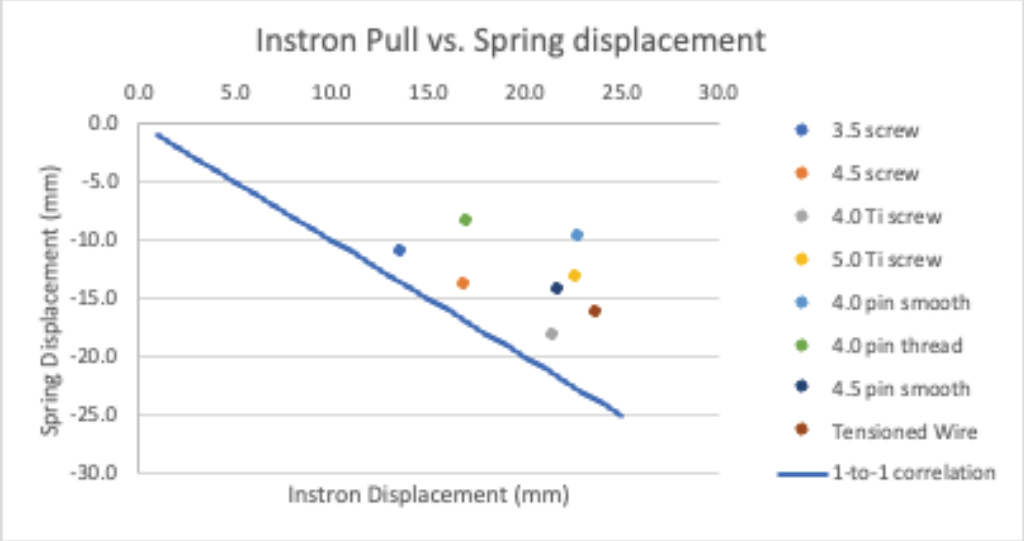
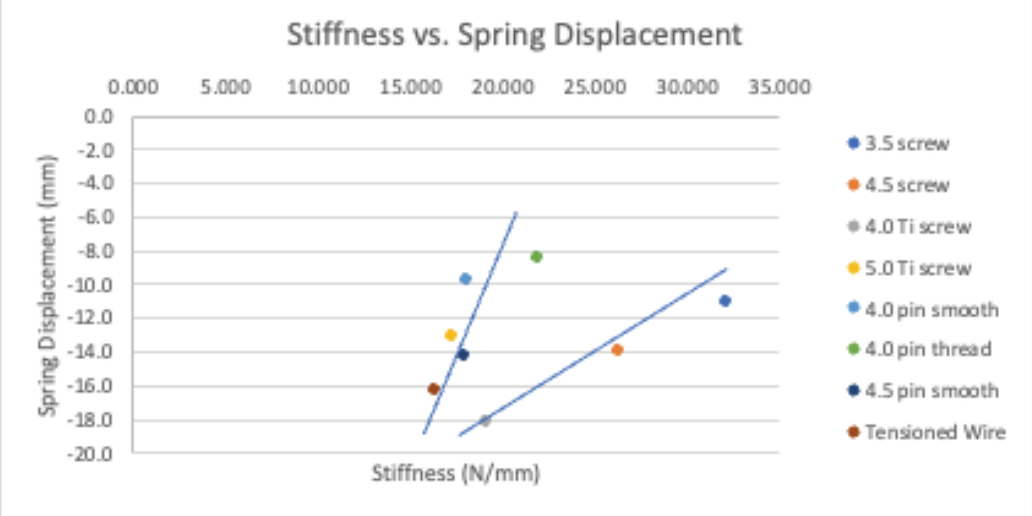


Table 3. Stiffness vs. Spring Displacement



Balanced Cable Bone Transport of the Tibia Using Automated Motorized Struts

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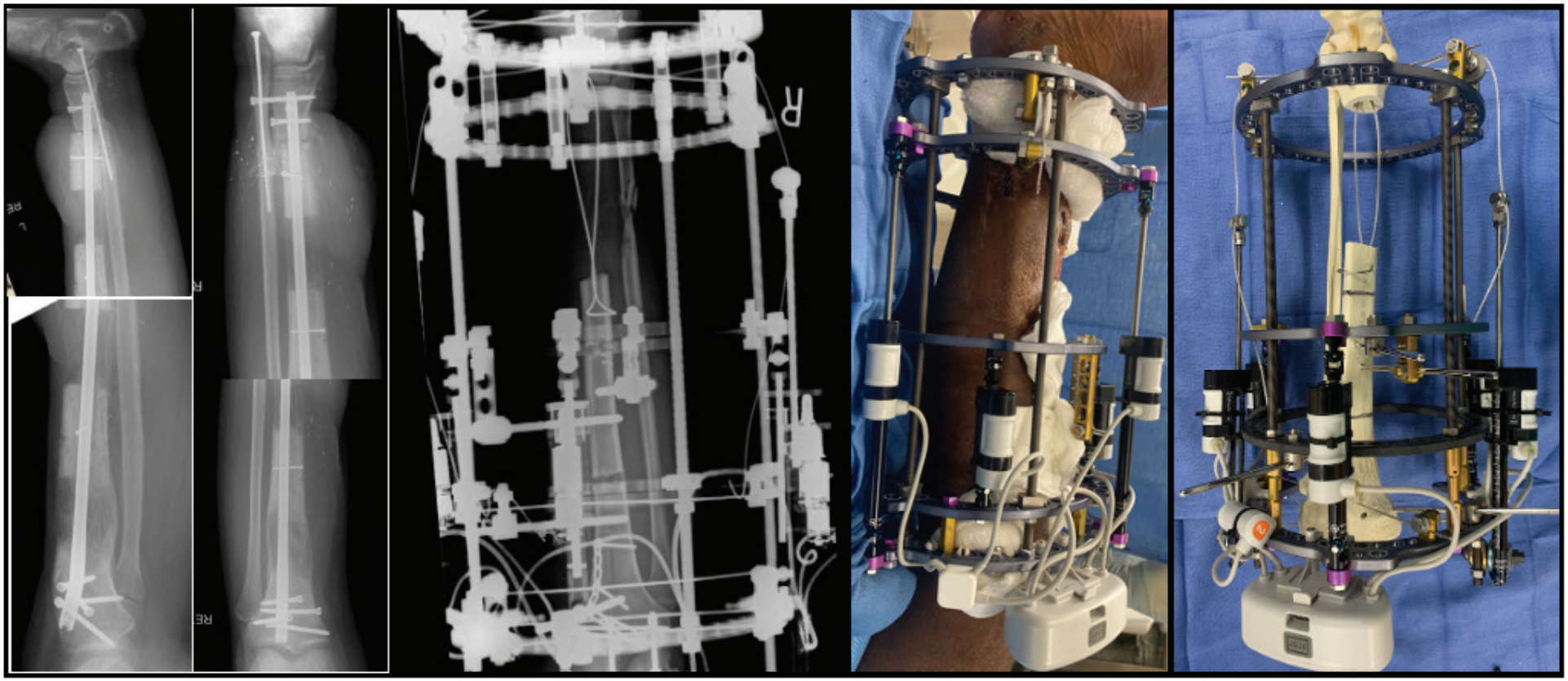
James Alan Blair, MD

What was the question?
The use of automated struts to drive bone transport has recently gained popularity due to its ease of use for the patient and caregiver, however the ability of automated struts to drive a cable transport has not been described. We set to demonstrate the utility of automated struts driving both bifocal and trifocal cable–assisted bone transport to potentially allow for more efficient bone transport of massive defects.

How did you answer the question?
A retrospective analysis of all tibial bone transports performed via circular external fixation utilizing automated struts driving cable transport at a single institution was performed. Outcome measures included union rate, complication profile, external fixation index (EFI), bone healing index (BHI), and final mechanical alignment.

What are the results?
Seven patients were included with a mean age of 34, 71% male, and an average defect of 9.9cm. Tibial defects were distal third (n=5) and middle third (n=2). Constructs included bifocal cable transport (n=3), trifocal tandem hybrid cable transport (n=3), and trifocal bidirectional cable transport (n=1). To date, two patients (one bifocal and one trifocal) have completed transport with subsequent docking procedure and conversion to an intramedullary nail with an EFI of 0.45mo/cm and BHI of 0.58mo/cm for bifocal transport and EFI of 0.23mo/cm and BHI of 0.40mo/cm for trifocal transport. No patient had any change in final mechanical alignment. Throughout the case series, there have been four malfunctions of the Autostrut necessitating unscheduled return to clinic. There have been no complications necessitating return to the operating room.

What are your conclusions?
Automated struts powering balanced cable bone transport is possible. This treatment strategy combines the advantages of automation (ease of use, decreased noncompliance, increased segmentation) with the advantages of cable transport (easier conversion to intramedullary nail, less scarring, decreased potential for pin tract infections). Further research is necessary to determine the optimal daily rate and frequency of transport.



Session II: Trauma Part 1

Moderator: Mitchell Bernstein, MD

The Impact of Reduction Quality of Tibial Plafond Fractures during Temporizing External Fixation on Final Fracture Alignment and Overall Outcomes

Roberto C. Hernandez–Irizarry, MD
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Anna Meyer

What was the question?
Fractures of the tibial plafond are often complex fractures that require an initial surgery with external fixation (ex–fix) to allow for soft tissue rest prior to definitive open reduction and internal fixation (ORIF). Current outcomes in literature regarding plafond fractures focus on the alignment and reduction quality after final fixation but do not account for the alignment of the fracture during the temporizing phase in the ex–fix. Our question was does coronal and sagittal plane alignment of a tibial plafond fracture in the external fixator affect the final alignment of the fracture or lead to increased risk of complications?

How did you answer the question?
All patients with tibial plafond fractures at an urban level–1 trauma center between 2014 and 2021 were retrospectively reviewed. For this study, inclusion criteria was set as: closed AO/OTA 43C tibial plafond fractures treated initially with an ex–fix prior to definitive management with an ORIF. Patient charts were reviewed for injury characteristic, management, complication, and demographic data. Intraoperative fluoroscopy at the time of placement of the external fixation system was analyzed and measurements were taken from AP and Lateral views of anterior–posterior (AP) translation, lateral translation, the anatomic lateral distal tibia angle (aLDTA) to assess varus and valgus angulation, and the anatomic distal tibia angle (ADTA) to measure procurvatum and recurvatum. The same measurements were then repeated on the AP and lateral plain films from the final office visit to determine final fracture alignment. The complications that were considered included unplanned readmission, surgical site infection (SSI) both superficial and deep, radiographic nonunion as defined by clinical notes that returned to the operating room, and post traumatic osteoarthritis. The data was analyzed using descriptive statistics, paired sample t–tests, and logistic regression tests.

What are the results?
153 patients with closed 43C tibial plafond fractures were reviewed for this study. In this cohort there were 105 males, 43 females with an average patient age of 42.5 years. 61 (39.9%) were injured in a motor vehicle collision, 50 (32.7%) were injured from a fall from height, and the rest fell into ground level fall, motor cycle collision, or pedestrian vs auto for mechanism of injury. 111 (72.5%) of patients also had a concomitant ipsilateral fibula fracture. For complications, 9(5.9%) had an unplanned readmission, 15(9.8%) had a superficial SSI, 7(4.6%) had a deep SSI requiring formal irrigation and debridement, 10(6.5%) had a nonunion, and 25(16.3%) developed post traumatic osteoarthritis.

The Impact of Reduction Quality of Tibial Plafond Fractures during Temporizing External Fixation on Final Fracture Alignment and Overall Outcomes *continued*

Roberto C. Hernandez–Irizarry, MD
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What are the results? *continued*
There was a significant difference between the measurements in the ex–fix and the final radiograph measurements for AP translation ($p < 0.001$), lateral translation ($p < 0.001$), and a LDTA measuring varus and valgus ($p = 0.001$). Notably, there was no significant difference between ex–fix and final measurements for the ADTA measuring procurvatum and recurvatum ($p = 0.339$). Patients with larger differences in AP translation were significantly more likely to be readmitted ($p=0.044$), and those with larger differences in a LDTA (coronal plane angulation) were significantly more likely to have a superficial SSI ($p=0.008$), a deep SSI (p

What are your conclusions?
Tibial plafond fractures can be complex injuries. The use of external fixation for temporization is important for soft tissue rest prior to open treatment of the fracture, however, this study shows that the quality of reduction of the fracture when the external fixation system is placed may be just as important of a component of this phase of treatment off these injuries, especially in terms of varus and valgus angulation in the coronal plane. The results of this study suggest that the greater the degree of correction that is required during ORIF, the higher risk the patient is for postoperative complications such as surgical site infections or poor fracture healing that can lead to further hospitalizations, further operations, and overall, a prolonged treatment course.

Preventing Deformity in 43C Tibia Pilon Fractures: Revisiting Conventional Wisdom of Implant Placement

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Roberto C. Hernandez–Irizarry, MD

What was the question?
Tibia pilon fractures are challenging injuries to treat. Surgical goals aim to restore the native axis, joint congruency, while minimizing soft tissue insults. Classic teaching emphasizes critically evaluating the injury film and choosing a primary implant based on the pattern of deformity. Our research question was "does an implant to counteract the initial deforming force prevent malunion or fracture collapse on follow up?"

How did you answer the question?
A retrospective review of all tibia pilon fractures surgically treated in a single Level 1 trauma center from 2014–2021 was done. All 43C tibia pilon fractures were screened. Open injuries, fractures treated nonsurgically or with definite external fixation, and patients with less than 6 months follow up were excluded from analysis. We classified the unsplinted, unreduced injury film in the coronal, sagittal and axial planes based on the presenting deformity. We then measured the aLDTA and aADTA on immediate postoperative imaging and at final follow up for comparison. We defined our primary outcome (malunion) as alignment that changed > 5 degrees based on the deformity parameters on either plane. We compared two groups: patients who had an implant resisting the initial deformity, and patients who did not have an implant to resist the initial deformity.

What are the results?
Our cohort included 143 patients that had complete data and at least 6 months of follow up. The most common injury film deformity was an oblique plane deformity. 49% of patients had a valgus deformity, and 44% had a recurvatum deformity in their initial injury film. 100% of patients had shortening. On final follow up, 27% of our entire cohort had a malunion. When comparing the two groups, patients with an implant resisting the initial deformity in the coronal plane (i.e. medial plate for a varus pilon) had a 19% malunion rate vs 36% for those without ($p=0.02$). In the sagittal plane, the rates of malunion were not statistically different (25% with vs 29% without, $p = 0.53$). Fibula pattern and fixation strategy did not change the results.

What are your conclusions?
Tibia pilon fractures are devastating injuries that are challenging to treat. Complete articular injuries are particularly challenging because they require restoration of the articular surface in addition to restoration of the native axis. Based on our results it seems that the classic teaching of using plates to resist the initial injury film deformity protects from malunion in the coronal plane, with no difference in the sagittal plane. Fixation of the fibula does not seem to have a role in predicting malunion. Our future research efforts will include analyzing the quality of reduction, patient reported outcomes, and full–length weight bearing imaging.

Utilization of Short–Segment Temporary Reduction Assisting K–wires (TRAK–wires) for Intramedullary Nailing of Periarticular Fractures: A Technical Trick and Case Series

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Calvin Chandler, Ziqing Yu, Benjamin Averkamp, Laurence B Kempton, Joseph R Hsu, MD; Kevin D Phelps

What was the question?
Intramedullary nailing of peri–articular fractures has gained popularity, but obtaining and maintaining alignment can be difficult due to deforming forces on the short articular segment. Blocking screws facilitate reduction but may limit subsequent interlock placement when inadequate bone stock is available for fixation. This study introduces Temporary Reduction Assisting K–wires (TRAK–wires) as an alternative technique for obtaining and maintaining alignment when nailing short segment periarticular fractures.

How did you answer the question?
A retrospective review was conducted on adult patients at a level one trauma center presenting with OTA 41A–C and 33A–C fractures treated operatively with IMN from 2018 to 2022. Patients (n=22) were included that had temporary k–wires visualized on fluoroscopy and permanent blocking screws were not used (OTA 33, n = 19; OTA 41, n= 3). Anatomic angles, including aPDFA, aLDFA, aMPTA, and aPPTA , were measured intra–operatively, post–operatively, and at final follow–up to evaluate alignment. Loss of reduction, union, malunion, and all complications were collected. The number and position of TRAK–wires relative to the intramedullary nail (IMN) are reported for all patients (n=22). Outcomes, including alignment, maintenance of reduction, and complications, are reported for patients with over 12 months of follow–up (n=10).

What are the results?
When using TRAK–wires, anatomic alignment was restored intra–operatively in all cases (n=–22). Alignment was maintained after wire removal in all but one patient at final follow–up (n=9). There were no observed neurologic injuries, malunions, or loss of reduction attributable to the technique. The union rate in patients with > 12–month follow–up was 70% (n=7). Two open OTA 33C fractures developed deep infections and nonunions requiring reoperation while one Schatzker VI OTA 41 fracture developed atrophic nonunion.

What are your conclusions?
TRAK–wires facilitated safe, intra–operative alignment correction that was maintained after removal. Outcomes support TRAK–wires as a method to assist with reduction when nailing short segment periarticular fractures. The advantages of TRAK–wires include their ability to correct multi–planar deformities, removability post–fixation, and redirection capability. These findings suggest TRAK–wires are a promising tool in managing complex fractures, warranting further research for broader application.

Enhanced Radiographic Union (RUST) Score of Adolescent Tibia Shaft Fractures Treated with Hexapod Circular External Fixation: A Multicenter Study of 38 Consecutive Cases

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Ibrahim Salama, Christopher A. Iobst, MD; Anirejuoritse Bafor; Kyle Klahs, MD:
Soyoung Jeon, PhD; Dillon Stone, Amr Abdelgawad

What was the question?
Our objective was to evaluate clinical and radiographic outcomes of adolescent tibia fractures treated with hexapod circular external fixators using the RUST score for fracture union. We also wanted to calculate cost for adolescent tibia shaft fractures treated with hexapod external fixators

How did you answer the question?
This is a multi–center retrospective case series which screened adolescent patients with tibial shaft fractures 10–17 years of age. Patients treated non–operatively, through ORIF, or with uniplanar external fixators were excluded. Screen dates were from 2010 through 2021. Patient demographics, radiographic, functional outcomes, and financial data were investigated.

What are the results?
Trauma registry identified 352 cases of adolescent tibia fractures. Further screening showed 38 of cases treated with CEF. The average patient age was 14 years, with 76% (29/38) being male. The average duration of CEF treatment was 4 months, and patients were followed up for 7 months. twelve (31%) were open fractures, and 21 (55%) of the patients with CEF treatment developed pin site infections. The average RUST score was 10. All fractures healed with less than 10 degrees of deviation in all directional planes. Open fractures were associated with higher energy mechanisms of injury ($p<0.001$), additional operative procedures ($p=0.008$), and larger sagittal deviation (10.30 ± 0.42, $n=2$; 4.45 ± 3.35, $n=8$; $p=0.049$). Larger coronal deviation degrees were linked to complications ($5°\pm2$, $n=4$ versus $2°\pm1.$, $n=7$; $p=0.037$). There was a statistically significant difference in RUST scores based on proximal physis maturity, with a mean of 10 in the open fracture group and 9 in the closed fracture group ($p=0.027$). The median and interquartile ranges for the total cost of the procedures were $75 k and $26 k, respectively.

What are your conclusions?
Hexapod circular external fixation for adolescent tibial shaft fractures offers unique advantages for select adolescent patients. Throughout this multi–center study, hexapod fixators were shown to provide full weight bearing and early range of motion of both the ankle and knee joints with minimal complications. Pin site infections were shown to be the most common complication and correlated positively with secondary procedures. Hexapod fixators allowed for minimal angulation or translation in all patients with no cases of nonunion or decreased range of motion.
Hexapod fixators for adolescent tibial shaft fractures resulted in successful pain free osseous union without increased complications or the need for secondary procedures.

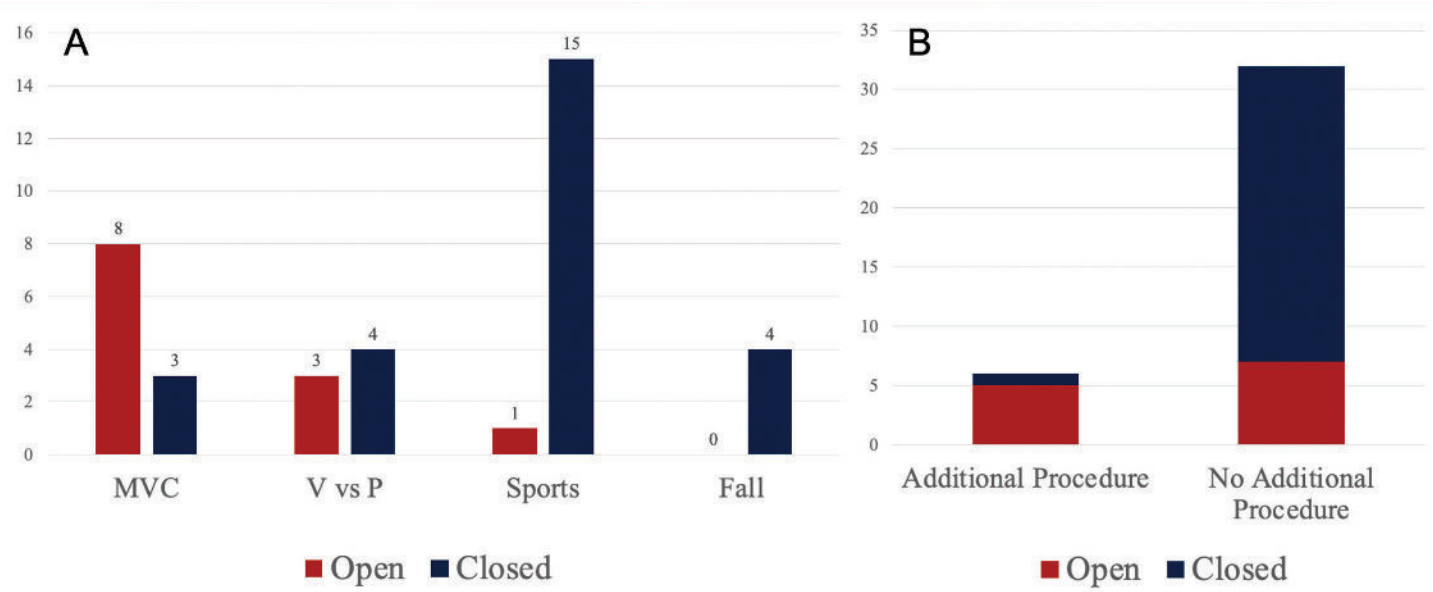

Figure 3a. Effect of mechanism of injury on fracture type. P-value <0.001 **3b.** Correlation between fracture type and additional operations. P-value=0.008

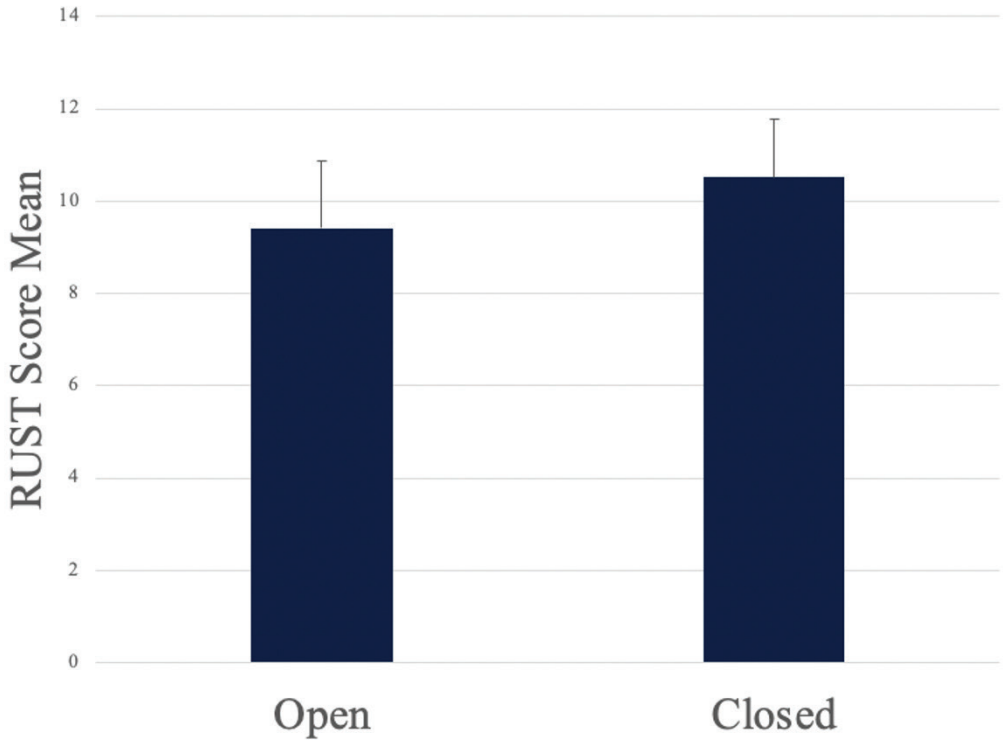

Figure 3c. Fracture type effect on RUST score average. P-value=0.032

Session III: Pediatrics Part 1

Moderator: Jaclyn F. Hill, MD

Surgical Treatment of Dynamic Valgus in Patients with Fibular Hemimelia: A Radiographic Assessment

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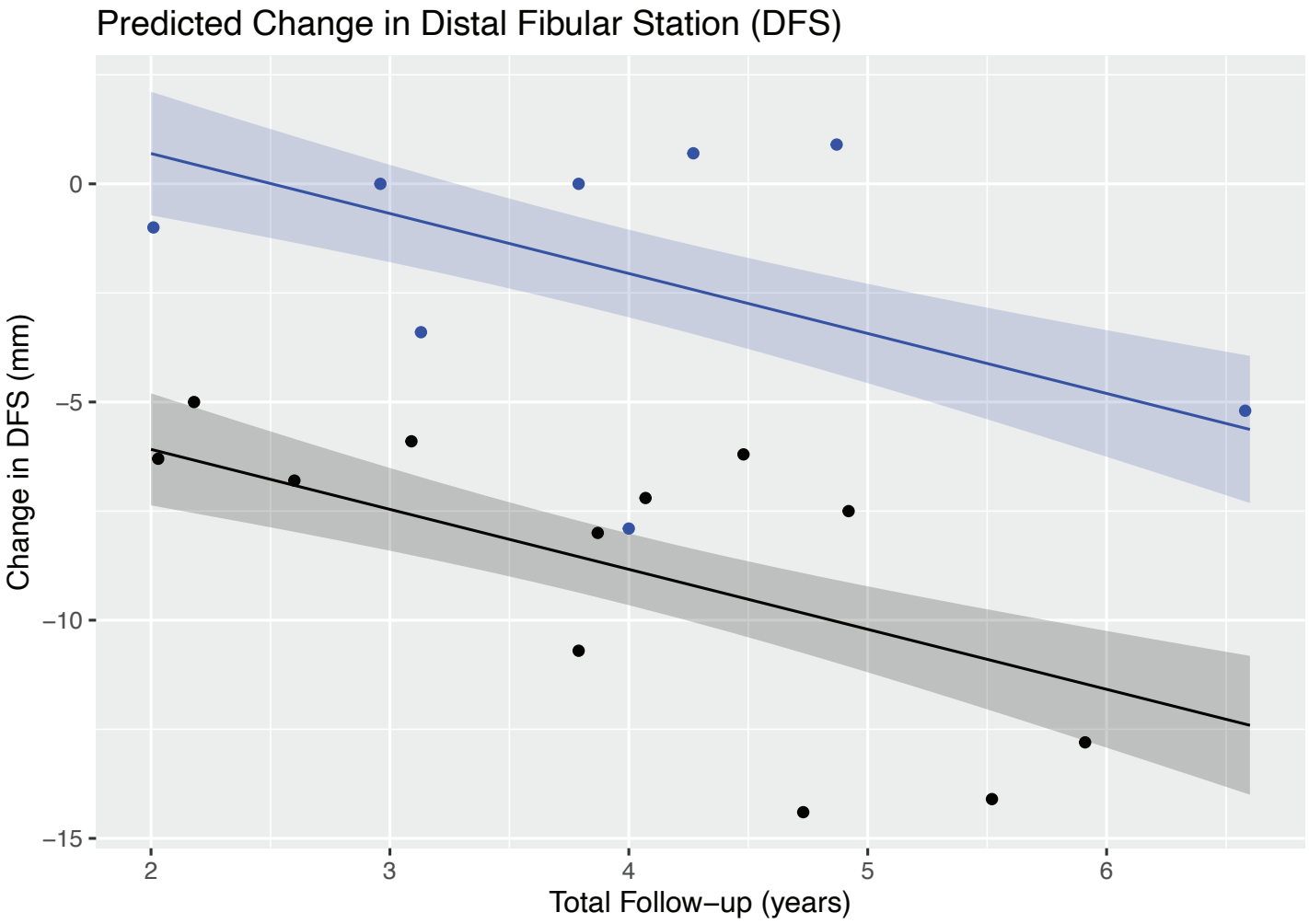
Hans K Nugraha, Katherine E Miller, Dror Paley, MD

What was the question?
Can dynamic valgus in patients with fibular hemimelia be predicted by a radiographic finding? How do the radiographic measurements change with and after surgical treatment of dynamic valgus in patients with fibular hemimelia? Are age, follow–up time and/or a synostosis/tether related to recurrence in patients with fibular hemimelia who've undergone surgery for dynamic valgus?

How did you answer the question?
A retrospective study was conducted on patients with fibular hemimelia who underwent shortening tibial osteoplasty between January 2014 and February 2022. Patients were excluded who had less than 2 years of follow–up, bilateral involvement, fixed valgus deformity, previous rotationplasty, or were skeletally mature at the time of surgery. Radiographic measurements included: lateral distal tibial angle (LDTA), talocrural angle (TCA), anterior distal tibial angle (ADTA), and distal fibular station (DFS). Measurements were compared at preoperative, immediate postoperative, and final follow–up. Multivariate logistic regression was performed to determine if any of the radiologic measurements could predict dynamic valgus. Multivariate linear regression was performed to determine if age, follow–up or synostosis/tether were related to changes in DFS following surgery.

What are the results?
Twenty patients met the inclusion criteria (9 females/11 males). The mean age at surgery was 6.9 years (±3.5 years) and mean follow–up was 4.0 years (±1.3 years).
Logistic regression found preoperative DFS ($p<0.0001$) to be predictive of dynamic valgus. The logistic regression model had a specificity and sensitivity of 0.90. DFS (ICC=.94) at different time points demonstrated a significant change ($p<0.0001$,$W=0.60$) with improvement from preoperative to postoperative measurements ($p<0.0001$), recurrence from postoperative to final ($p=0.0001$) and no difference between the preoperative and final values ($p=1.0000$). Findings were similar for LDTA, TCA and ADTA. The linear regression model found a synostosis/tether ($p<0.0001$) and follow–up duration ($p=0.0155$) were predictive of the recurrence of the DFS radiographic measurement. Figure 1 is the prediction plot using two groups: the group in blue had a synostosis/tether and the group in black did not. The group with the tether had less change in DFS postoperatively compared to the group without.

What are your conclusions?
Distal fibular station can be used to confirm the dynamic valgus of the ankle on clinical exam. Tibial osteoplasty for shortening to re–establish the distal fibular station improves the position immediately postoperatively, but the deformity recurs. The presence of a tibial–fibular synostosis or tether may prevent this recurrence.


Predicted Change in Distal Fibular Station (DFS)
Change in DFS (mm)
0
−5
−10
−15
2
3
4
5
6
Total Follow−up (years)

International Field Test of Limb–Q Kids: A New Patient Reported Outcome Measure for Lower Limb Differences

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Marcel Abouassaly, Alicia Kerrigan, Bjorn Vogt, Jan Duedal Rolfing, Louise Johnson,
Juergen Messner, Mohan Belthur, Melissa Esparza, MD; David Bade, David Podeszwa, MD

What was the question?
LIMB–Q Kids is a new patient–reported outcome measure (PROM) for children with Lower limb differences (LLDs). A mixed method multiphase approach was used to develop LIMB–Q Kids. In phase 1, a systematic review was conducted to identify concepts from existing PROMs used in research with children with LLDs. A preliminary conceptual framework derived from the systematic review informed an international qualitative study. The data from qualitative interviews were used to form the LIMB–Q Kids, which was further refined through multiple rounds of cognitive debriefing interviews (CDIs) with children. Input was obtained from parents and healthcare professionals from Australia, Canada, Ethiopia, India, UK, and the USA. LIMB–Q Kids was rigorously translated into Danish, Finnish, Hindi, and German.
Our research questions were:
• Are the items included in LIMB–Q Kids psychometrically valid and follow the Rasch model?
• Are LIMB–Q Kids scales reliable and valid?
• Do LIMB–Q Kids scale scores correlate with LLRS–AIM index scores?
• Do LIMB–Q Kids scale scores correlate with existing PROMs including PROMIS Pediatrics

How did you answer the question?
An international field test study was conducted where children from several sites completed LIMB–Q Kids, PROMIS Pediatric Short Form v2.0 – Mobility 8a and PedsQL. Demographic and clinical data was collected including the LLRS–AIM index indicating the clinical severity.

What are the results?
In total 800 patients from 16 sites completed LIMB–Q Kids. 580 participants completed LIMB–Q Kids, PROMIS Pediatric Mobility scale and PedsQL at the same time. These data were used to validate LIMB–Q Kids with previously established PROMs. 92 participants completed LIMB–Q Kids twice for the test re–test reliability analysis.
Rasch Measurement Theory analysis (RMT) allowed the scales to be shortened by identifying items that have poor item fit and high residual correlations. The field–test version of LIMB–Q Kids consisted of 11 scales ,159 items total with individual scale items length ranging from 9–32 items. These 11 scales measure appearance, physical function, symptoms (hip, knee, ankle, foot, and leg), leg–related distress, and school, social and psychological function. As a result of the analysis, the current version of LIMB–Q Kids scales ranges from 9–11 items only.
Analysis based on the data from the field test study, indicated that LIMB–Q Kids scales are reliable and valid. Test re–test reliability was high for all LIMB–Q Kids scales (Intraclass correlation coefficient ranges from 0.765 – 0.938). LIMB–Q Kids function scale correlated highly with the PROMIS Pediatric Short Form v2.0 – Mobility 8a (Pearson correlation 0.824) and PedsQL Physical Function Total score (Pearson correlation 0.771). Construct validity was good

International Field Test of Limb–Q Kids: A New Patient Reported Outcome Measure for Lower Limb Differences *continued*

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What are the results? *continued*
based on predefined hypotheses. Patients with higher LLRS–AIM index total score indicating higher complexity/severity of lower limb condition had lower scores on all LIMB–Q Kids scales indicating more impact on the children as expected. LIMB–Q Kids scales scores were not related to age as expected. Girls had lower scores on psychological, social and distress scales of LIMB–Q Kids.

What are your conclusions?
There is currently no rigorously developed and internationally applicable PROM for children with LLDs. RMT analysis allowed for item reduction and generation of smaller version of LIMB–Q Kids scales. LIMB–Q Kids has evidence of construct validity based on the analysis. LIMB–Q Kids will provide a common metric for outcome assessment for children with LLDs internationally. This will also allow health care professionals to provide evidence for the impact of various treatment options on the overall quality of life of patients allowing them to make more informed decision about their treatment choices. This information will also facilitate shared decision making.
The modular design of LIMB–Q Kids with a variety of scales provides flexibility to choose the scales best suited to measure the outcomes of interest in any given study or clinical situation. This will be an important aspect in reducing the patient burden for completing PROMs.

Psychological Risk Profile for Pediatric Patients Considering Limb Lengthening and Reconstruction

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What was the question?
Pediatric limb lengthening and reconstruction (LLR) is a prolonged, complex, and arduous treatment process. Appropriate multidisciplinary assessment of potential patients is critical to ensure that (a) relevant treatment risk factors are proactively identified and understood by the patient, their family, and the medical team and (b) to guide decision making regarding if/when to proceed with treatment. No literature exists, however, comprehensively delineating psychological factors that should be considered when determining risk. As such, our team's question was how to establish a universal psychological risk classification system for pediatric patients considering LLR.

How did you answer the question?
Our well–established LLR team treats nearly 300 potential and actual pediatric LLR patients per year. Based on our collective multidisciplinary experience, our team developed a risk assessment decision–making tree that has been successfully used in determining patients' readiness for treatment.

What are the results?
Please refer to attached table: Psychosocial Risk Classification for LLR Treatment
Of the last 15 pediatric patients seen in clinic for consideration of LLR, one patient fell into the Low Risk category, 11 patients fell into the Moderate Risk category, 2 patients fell into the High Risk category, and 1 patient fell into the Emergent Concerns category. Frequently identified risk factors related to lack of patient interest/motivation for treatment, lack of patient/family appreciation of treatment demands and expectations, patient psychological symptoms/difficulty with emotion regulation, and family stressors.

What are your conclusions?
This universal risk assessment tool is designed to support pediatric LLR teams, particularly teams without an embedded mental health professional, in guiding preoperative decision making. Specifically, this tool allows patient risk to be more easily and consistently assessed, and treatment preparation may be accelerated or slowed based on a patient's risk profile.
For patients in the Moderate Risk, High Risk, and Emergent Concerns categories, treatment preparation should be approached with increasing levels of caution, respectively. Dedicated time, ranging from months to years, will be required to address the patient's specific risk factors; this may include time for the patient to mature and develop motivation for treatment, dedicated meetings with the team nurse and psychologist to better understand treatment demands and expectations, dedicated work with physical therapy / occupational therapy to build up strength, endurance, and/or adherence capability, and referrals out for individual and/or familial therapy to address relevant psychological and psychosocial risk factors. For patients in the Low Risk category, treatment should be approached thoughtfully with ongoing assessment of the variables delineated above, to monitor any potential changes in risk status and associated intervention needs.

	Low Risk	Moderate Risk	High Risk	Emergent Concerns
Individual Factors	• Average to above average cognitive functioning • Average to above average academic functioning • Minimum of 2 to 3 close friendships • Absence of peer victimization • Involved in a variety of activities (e.g., sports, clubs) • Abstinence from nonprescribed substance use	• Average to below average cognitive functioning • Average to below average academic functioning • Minimum of 1 close friendship • Experience and/or history of peer victimization • Limited involvement in outside activities • History of nonprescribed substance use (not current)	• Below average to low cognitive functioning • Below average to low academic functioning / disinterest in school • Lack of close friendships • Experience and history of peer victimization • No involvement in outside activities • Active nonprescribed substance use	• Suspension and/or expulsion from school • Physical aggression towards others • Active, frequent nonprescribed substance use • Police and/or legal involvement
Familial Factors	• Two or more active caregivers • Stable family structure • High familial organization • Flexible work schedule(s) accommodating of frequent medical appointments • Financial resources to support treatment • Access to consistent and reliable transportation • Absence of other significant caregiving demands	• One or more active caregiver • History of fluctuating family structure • Difficulty with familial organization • Rigid work schedule and/or work schedule with lack of available FMLA/PTO • Risk for financial strain during treatment • Inconsistent access to transportation • Presence of other significant caregiving demands	• Single caregiver • Inconsistent family structure • Poor familial organization • Rigid work schedule and/or work schedule with lack of available FMLA/PTO • Financial strain present • Inconsistent to no access to transportation • Presence of numerous other significant caregiving demands	• Lack of access to consistent housing, nutrition, clothing • Active CPS involvement
Psychological Factors	• Absence of current or past significant mood, anxiety, trauma symptoms, etc • Well-developed emotion regulation abilities • Well-developed cognitive and emotional flexibility • Well-developed support system (e.g., family, friends, therapist, etc)	• Presence or recent history of mild to moderate mood, anxiety, trauma symptoms, etc • Inconsistent emotion regulation abilities • Limited cognitive and emotional flexibility • Limited support system or inconsistent access to support system	• Presence of moderate to significant mood, anxiety, trauma symptoms, etc • Poor emotion regulation abilities • Poor cognitive and emotional flexibility • Lack of support system	• Presence of significant and unmanaged mood, anxiety, trauma symptoms, etc • Current and/or historical experience of abuse or trauma
Adherence History	• Demonstrated ability to adhere to treatment expectations generally (e.g., attending appointments as scheduled) • Demonstrated ability to adhere to treatment expectations specifically (e.g., prehabilitation exercises)	• Difficulty adhering to treatment expectations generally (e.g., frequent cancelled or missed appointments; lack of follow through on previous recommendations) • Difficulty adhering to treatment expectations specifically (e.g., lack of completion of prehabilitation program)	• Significant and repeated difficulty adhering to treatment expectations generally (e.g., frequent missed appointments; periods of loss to follow-up) • Significant and repeated difficulty adhering to treatment expectations specifically (e.g., lack of interest in or effort toward any prehabilitation tasks)	• Lack of adherence to life saving care activities (e.g., insulin administration)

Motivation for Treatment	• Patient is independently motivated for treatment and is capable of expressing this • Patient's motivation for treatment is stable over time • Family is motivated for treatment, though they appropriately defer decision making to patient • Family's motivation for treatment is stable over time	• Patient expresses variable interest in / motivation for treatment • Patient's motivation for treatment fluctuates over time • Family expresses variable interest in / motivation for treatment and/or they do not appropriately defer decision making to patient • Family's motivation for treatment fluctuates over time	• Patient expresses disinterest in or aversion towards treatment • Family expresses disinterest in or aversion towards treatment and/or they do not appropriately defer decision making to patient	• Patient unwilling to participate / engage in discussion regarding treatment • Family unwilling to participate / engage in discussion regarding treatment
Goals for Treatment	• Patient's goals are appropriate and consistent with those of the medical team • Family's goals are appropriate and consistent with those of the medical team	• Patient's goals are not fully aligned with those of the medical team • Family's goals are not fully aligned with those of the medical team	• Patient's goals are not aligned with those of the medical team and are inappropriate or unreasonable • Family's goals are not aligned with those of the medical team and are inappropriate or unreasonable	• Patient's goals are completely inconsistent with those of the medical team • Family's goals are completely inconsistent with those of the medical team
Comprehension of Treatment Expectations	• Patient understands treatment expectations at a developmentally appropriate level • Family understands treatment expectations at a reasonable level	• Patient displays underappreciation of treatment expectations • Family displays underappreciation of treatment expectations	• Patient displays poor appreciation of treatment expectations, as demonstrated by lack of knowledge and/or flippancy toward treatment • Family displays poor appreciation of treatment expectations, as demonstrated by lack of knowledge and/or flippancy toward treatment	• Patient is completely disengaged from all discussion of treatment expectations • Family is completely disengaged from all discussion of treatment expectations

Increasing the Knee Arc of Motion in Patients with Arthrogryposis: Minimum Two–Year Follow–Up

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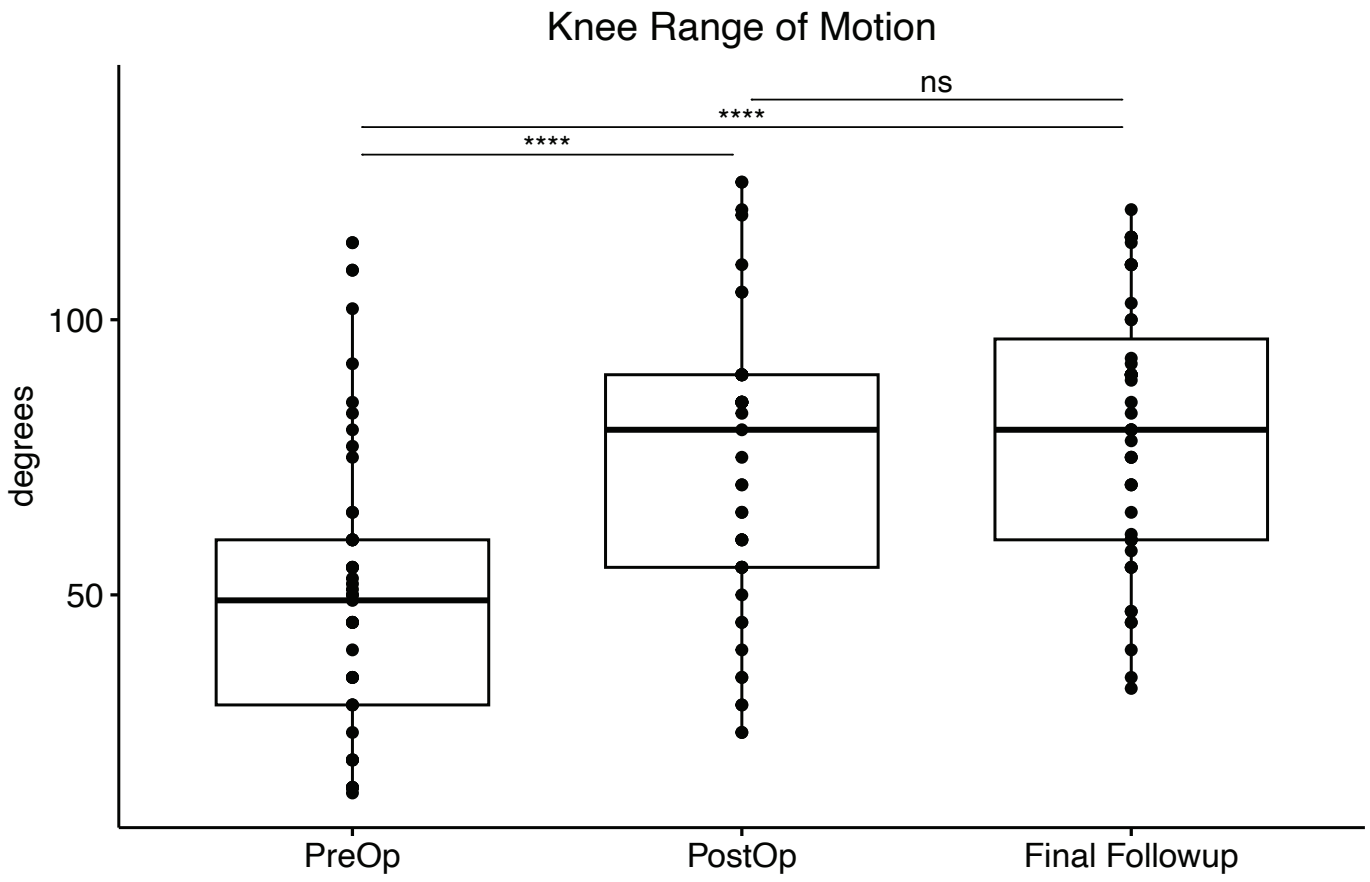
What was the question?
What are the clinical results of proximal femoral shortening, peroneal nerve decompression and posterior knee release in patients with arthrogryposis at a minimum 2 year follow–up?

How did you answer the question?
A retrospective chart review was performed on all patients with arthrogryposis presenting to our institution from January 2015 through June 2023. Patients treated with femoral shortening, peroneal nerve decompression and posterior knee release were included. Patients were excluded if they had less than 2 years of follow–up from the index procedure. Ambulatory status, patient demographics, surgical history, orthotic use and range of motion values were obtained from the office visits and physical therapy notes.
Fisher's Exact test compared categorical variables. Motion measurements were analyzed using a Friedman test and pairwise comparisons performed using paired Wilcoxon signed–rank tests with Bonferroni correction. Effect size was calculated using Kendall's W with Cohen's interpretation. Multiple Spearman Rho correlation coefficients were calculated to determine if any correlation existed between the data points. A p–value of 0.05 was considered significant.

What are the results?
29 patients with 51 knees and a mean age of 5.7 years were included. The mean follow–up was 36.9 months. The median preoperative flexion deformity was 46° and this improved to 10° at the latest follow–up ($p<0.0001$). The median preoperative knee range of motion was 49° and this improved to 80° at the latest follow–up ($p<0.0001$) (See Figure 1)
Preoperatively, 11 patients were ambulators (37.9%) and 18 were non–ambulators (62.1%). At follow–up, 27 were ambulators and (93.1%) and 2 non–ambulators (6.9%). Of the 27 ambulating patients, 15 patients were community ambulators and 12 were home ambulators. Nine patients used AFOS, 16 patients used KAFOS and two did not require an orthosis.
Complications included one intraoperative femur fracture during acute extension. This was fixed with percutaneous wires that were removed at 3 weeks postoperatively. One patient/two limbs required revision posterior capsulotomy.

What are your conclusions?
Clinical outcomes of femoral shortening, posterior knee release and peroneal nerve decompression appear promising at a minimum 2–year follow–up with a continued improvement in ambulatory ability and range of motion. Continued surveillance of this cohort is necessary to determine if these improvements are maintained in the mid– and long–term.



pwc: **Wilcoxon test**; p.adjust: **Bonferroni**

Session IV: Guided Growth

Moderator: Jill C. Flanagan, MD

Biomechanical Analysis of a Predictive Mathematical Model for Rotational Guided Growth

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Raymond W. Liu, MD

What was the question?
Hemiepiphysiodesis has been traditionally used to correct coronal and sagittal plane deformities. However, recent studies on animal models and human patients have shown the application of medial and lateral oblique tension band plating to enact rotational guided growth for the correction of torsional deformities. While initial animal models have utilized rigid plates, a recent clinical study used flexible implants with success. We mathematically modeled rotational correction, used a biomechanical model to determine the effectiveness of flexible tension bands, and assessed variables that influence the total amount and rate of rotational correction.

How did you answer the question?
A mathematical expression for angular correction as a function of femur width, plate length, and plate angle was derived. To validate this model, a custom housing was built to accommodate a sawbone femur model. Two screws with a flexible metal band connecting them were fixed to the distal end of the femur model. The proximal femoral segment was fixed while the distal segment was attached to a custom rig, and longitudinal growth was simulated through distraction. Rotational angular correction was measured using axial photographs measured using ImageJ. Intraclass correlation coefficients (ICCs) between the theoretical and actual rotational changes were calculated using SPSS.

What are the results?
Our experimental model closely followed the predicted incremental angular corrections with ICCs of 0.98 ($p < 0.001$), 0.76 ($p = 0.001$), and 0.98 ($p < 0.001$) for our groups with a 22mm implant length and initial plate offset angles (ϕ) of 30°, 45°, and 60° respectively. Rotational correction was not linear. A smaller φ led to higher initial rates of correction but severely limited the maximum angular correction (ωmax). Increases in the initial φ angle from 30° to 45°, while maintaining a plate length of 22mm, did not drastically change ωmax (20° to 26°). However, changing ϕ from 45° to 60° increased ωmax from to 38°. Implant length also holds a positive correlation with ωmax although the relationship does not appear to be linear.

What are your conclusions?
Rotational guided growth can be used effectively for correction of torsional deformities. Our derived formula had strong correlation with measurements from our biomechanical model. Increasing the length of the wire between the two screws and increasing the angular deviation of the construct from the vertical increase the amount of rotational correction possible, although anatomical constraints need to be considered clinically. The correction was non–linear, with less correction initially, which emphasizes careful clinical follow up of patients treated with this technique.

Figure 1: comparison of experimental results to predictive algorithm in variable initial plate offset angles

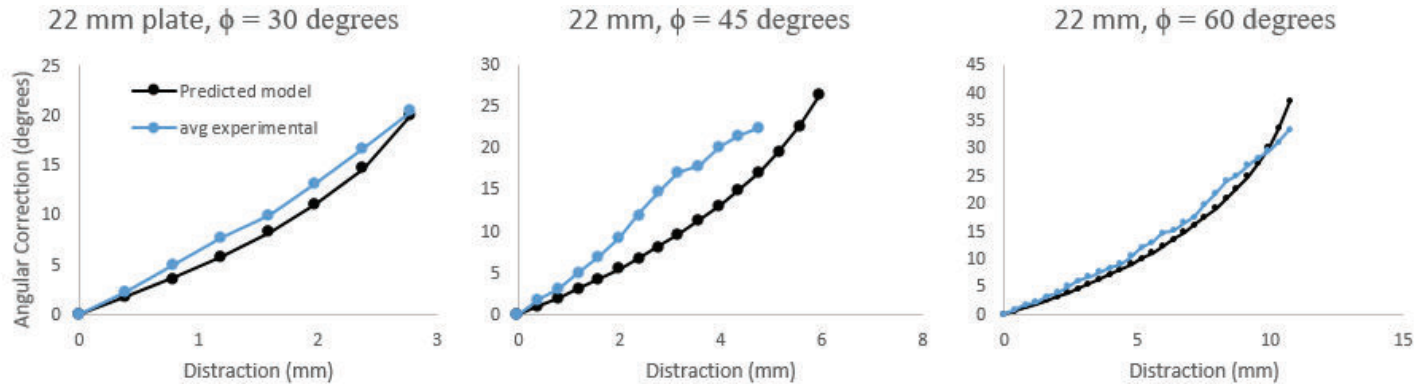
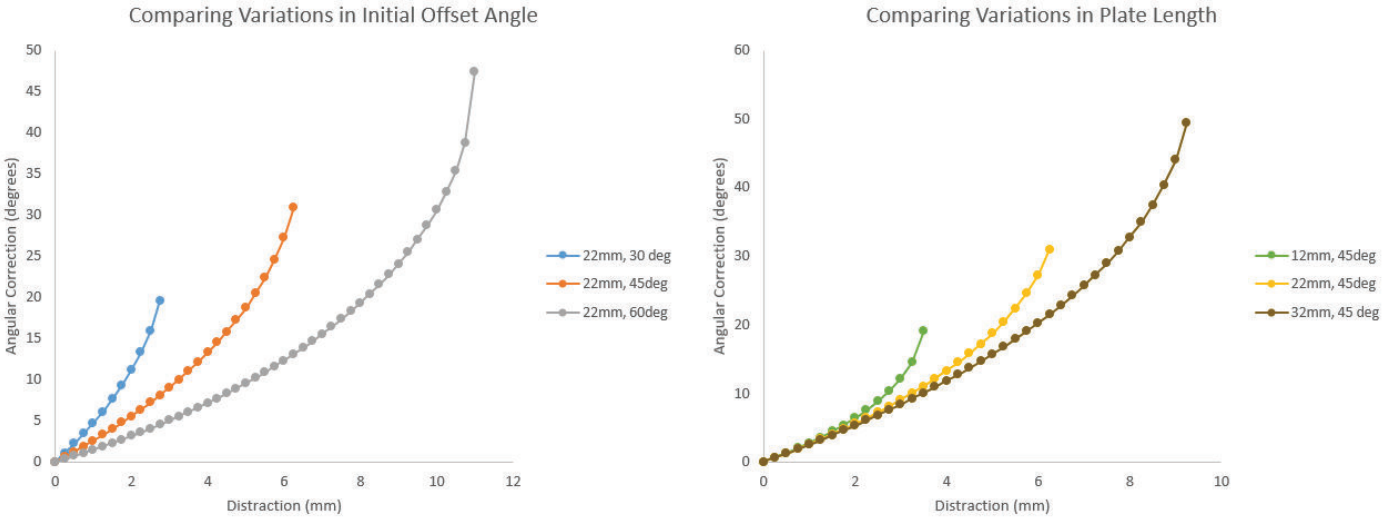


Figure 2: comparison of theoretical models isolating for change in initial plate offset angle (ϕ) or Implant length



Go Big or Stay Home? Impact Of Implant Selection on Outcomes of Growth Modulation on Blount Disease

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What was the question?
Guided growth is an effective way to correct limb deformity in skeletally immature patients. However, significantly higher rates of complications are reported when this technique is used to treat patients with Blount disease. We reviewed patients with Blount disease treated with growth modulation to determine the effectiveness of the implant construct on deformity correction.

How did you answer the question?
All patients who underwent growth modulation for Blount disease between 2010 and 2021 at a single institution were reviewed. Information collected included baseline health and demographic data, duration of growth modulation treatment, treatment location (tibia or femur), and implant type. Implant type was subclassified into staples or tension band plates (TBP). For each TBP, number of screws and screw type (cannulated (C) or non–cannulated (NC)) were recorded. Bilateral lower extremity x–rays were used to measure the LDFA, MPTA, LDTA, and MAD preoperatively, prior to implant removal and at final follow–up. Complications recorded included wound dehiscence, infection, implant breakage, over–correction, under–correction, physeal arrest, repeat surgery and recurrent deformity after implant removal.

What are the results?
Seventy–four patients with Blount disease were treated with growth modulation, 29 for bilateral deformity. Within this group, 100 tibias and 28 femurs were treated (Table 1). Preoperative tibial deformity was similar among all constructs but patients who received 4–hole TBP had worse preoperative femoral deformity and medial mechanical axis deviation (Table 1). The overall complication rate was 81%, with 57% of patients left with residual varus while 20% of patients over–corrected to valgus alignment. Patients treated with 2–hole TBP were significantly more likely to require revision surgery compared to those with 4–hole TBP ($p=0.03$). The incidence of complications was significantly lower and likelihood of achieving a neutral MAD at maturity significantly greater when a 4–hole TBP was combined with NC screws for tibial deformity ($p=0.02$, $p=0.12$) and when NC screws with a TBP were used for femoral deformity ($p=0.01$). Only 3 patients were treated with staples and each ultimately underwent osteotomy for to treat persistent varus.

What are your conclusions?
Patients undergoing growth modulation for Blount disease face substantial risk for perioperative complications, the greatest being failure of deformity correction. While many patient specific factors cannot be modified, implant selection is controlled by the surgeon. Our results suggest that using a 4–hole TBP and non–cannulated screw construct can significantly increase the potential for deformity correction while reducing the incidence of complications and need for implant revision.

Table 1

Location	Patients	Preop Joint Line Angle (MPTA Tibia, LDFA Femur)	Final Joint Line Angle (MPTA Tibia, LDFA Femur)	PREOP MAD (mm)	FINAL MAD (mm)
Tibia	100	77, 92	85, 90	-52	-17
Femur	28	80, 95	85, 90	-68	-22
Construct					
Tension Band Plate	125				
2-hole, cannulated	48	79, 93	87, 90	-46	-10
2-hole, noncannulated	26	79, 91	89, 90	-40	-5
4-hole, cannulated	24	77, 95	85, 81	-79	-28
4-hole, noncannulated	27	77, 93	84, 87	-68	-16
Staple	3	78, 94	83, 90	-58	-28

Sleeper Plates for Guided Growth: Choice of Plate Material Changes Risk of Tethering

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What was the question?
The technique of sleeper plate involving the removal of the only metaphyseal screw from the tension band plate construct after desired correction, has increased in popularity, especially in those with a high risk of rebound. There have been reports of tethering of the plate resulting in unwanted and continued correction post metaphyseal screw removal. We aimed to assess the safety and efficacy of this technique and to investigate if different plate material impacts results (tethering).

How did you answer the question?
We performed a retrospective review of all patients who underwent guided growth with 8 plate constructs for coronal plane deformity from February 2014 to September 2023, operated by a single surgeon (the senior author). 178 plates were inserted in 95 patients; out of which 64 patients were excluded as they were either still in situ with both screws or the whole construct was removed. 29 patients were included in whom the metaphyseal screw was removed after correction was achieved and they were evaluated for tethering and rebound.

What are the results?
The sleeper plate group consisted of 17 males with 24 sleeper plates and 12 females with 17 sleeper plates. Out of the 41 sleeper plates, 22 were stainless steel (SS) and 19 were titanium. The median age at hardware insertion was 9.7 (4.3 – 17.0) years overall with 11.0 (4.3 – 13.3) years and 9.7 (4.9 – 17) years for the SS group and titanium group respectively. 44 % (18/41) maintained the achieved overall correction and 56 % (23/41) rebounded in the direction of the original deformity (rebound was seen in 11/14 fibular hemimelia patients plates). The median age at screw removal was 11.2 (4.8 – 18.2) years with 11.8 (4.8 – 14.0) years for the SS group and 11.2 (5.4 – 18.2) years for the titanium group. The median follow–up time was 4.4 (0.7 – 7.1) years overall, 5.8 (4.9 – 7.1) for titanium and 2.7 (0.7 – 4.6) for stainless steel. Of note, 21 % (4/19) of the titanium plates tethered after a median duration of 1.1 (0.3 – 1.9) years. No plate had to be removed due to difficulty in screw reinsertion.

What are your conclusions?
The sleeper plate is an acceptable treatment strategy for coronal deformities around the knee when rebound is expected. Based on our series, the titanium plates used in sleeper mode have an unacceptably high risk of tethering. In our series, we had no tethering in patients who had stainless steel implants, however longer–term studies with a larger sample size are needed to confirm these results.

Timing of Growth Modulation for Congenital Femoral Deficiency–Associated Distal Femoral Valgus

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Marina R Makarov, MD; Chan–Hee Jo, David A. Podeszwa, MD; Elizabeth Hubbard, MD

What was the question?
We wanted to know the recurrence rate of distal femoral valgus deformity correction in children with congenital femoral deficiency or femoral deficiency–associated congenital fibular deficiency after growth–plate modulation. We also sought to determine demographic risk factors for recurrence.

How did you answer the question?
We reviewed the medical records and radiographs of patients treated at our institution by growth–plate modulation for distal femoral valgus deformity associated with congenital femoral deficiency (with or without associated congenital fibular deficiency). We recorded documented complaints at the time of surgery; sex; chronological age at surgery and at implant removal (if removed); Greulich–Pyle atlas and modified Fels skeletal ages at those time points (if available); maturation status at time of implant removal; and pre–operative and final mechanical lateral distal femoral angles (mLDFA) and mechanical axes.

What are the results?
22 patients with adequate follow up underwent growth modulation for distal femoral valgus between 2011–2022. mLDFA averaged 81° preop (range, 79–85°). Preoperatively, three patients expressed complaints about the extremity (other than shortening) whereas 19 did not. 19/22 patients had the implant removed (17 prior to skeletal maturity). Six patients did not develop recurrence after correction of their deformity whereas 16 did. 16/17 patients who were not skeletally mature at the time of implant removal developed recurrence of deformity; 4 of these had reimplantation of a growth–modulation plate while two had corrective osteotomy in conjunction with intramedullary lengthening. 10 have either accepted recurrent deformity or await further surgery. Mean years of growth remaining at implantation based on chronological age was 3.2 in the 6 patients who did not develop recurrent deformity compared to 4.5 in the 16 patients who did ($p = 0.03$). There were no statistically significant differences between those who recurred and those who did not with respect to gender or etiology. Differences between chronological and skeletal ages varied between 0–2 years; in no patient did a variation in skeletal age from chronological predict a different outcome.

What are your conclusions?
Growth modulation by plate is an effective method of correcting distal femoral valgus deformity associated with congenital femoral deficiency. However, recurrence of deformity is virtually universal if the patient has more than 4 years of growth remaining at the time of implantation and is skeletally immature at implant removal. In the absence of symptoms, such surgery should generally be delayed until the subject has 3 years of growth remaining or completion of epiphysiodesis to prevent recurrence is appropriate.

Clinician Scholar Career Development Program (CSCDP) Presentation

Introduction by Jessica C. Rivera, MD, PhD

Ainsley Bloomer, MD
Caleb Gottlich, MD

Presidential Guest Lecture

"How Did We Get Where We Are: Limb Lengthening & Deformity Reconstruction: Some of My Innovations Over the Past 38 Years"

Dror Paley, MD
Paley Orthopedic & Spine Institute at St. Mary's Medical Center

Session V: Osseointegration Part 1

Moderator: Joseph R. Hsu, MD

How Well Does Perc OI Work? Comparing Percutaneous vs Open–Exposure Transtibial Osseointegration

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Michael Greenstein, Andrew Lopolito, Jason S. Hoellwarth, MD; Taylor J. Reif, MD

What was the question?
Transtibial osseointegration (TTOI) limb replacement is used to manage below–knee amputations, improving function and alleviating shortcomings often associated with traditional socket prostheses. TTOI may be performed via a percutaneous manner when minimal additional work is needed, or via an open exposure to facilitate associated procedures such as nerve reconstruction or tissue refashioning. How does percutaneous vs open TTOI outcomes compare in three areas? The primary comparison is the safety profile: oral or intravenous antibiotic administration, or any relevant return to the operating room. The secondary comparison was the perioperative care: length of operation, estimated blood loss, infusion volume, and length of hospital stay. The tertiary comparison was pre– versus post–operative scores of the Limb Deformity–Modified Scoliosis Research Society (LD–SRS) and PROMIS patient–reported outcome measures.

How did you answer the question?
Retrospective chart review of our osseointegration database was performed of all patients who underwent TTOI limb replacement between July 2018 and September 2023. Patients were excluded if they did not have follow–up through at least six months. Review focused on post–operative complications (primary aim), and perioperative care (secondary aim). Complications were categorized as early (first six months) or late (after six months) to differentiate potentially approach–related issues versus general osseointegration issues. Demographic data were analyzed with descriptive statistics. Fisher's Exact Test compared categorical variables. Welch's unpaired t–test compared continuous variables. Significance was set at $p < 0.05$.

What are the results?
36 patients (37 TTOI procedures) were included: 14 percutaneous (one bilateral) and 22 open. Demographics were statistically similar. Complications are summarized in Table 1. The antibiotic prescription rate was lower in the percutaneous vs open cohort both in the first six months (3/14=21% vs 15/22=68% , p=0.015) and after six months (1/9=11% vs 12/20=60%, p=0.019). Additional surgery was infrequent and similar in both cohorts. Perioperative care was significantly better in the percutaneous cohort regarding operation time (66.9 vs. 169.0 minutes, $p<0.001$), estimated blood loss (40.0 vs. 143.8 mL, $p<0.001$), infusion volume (965.4 vs. 1407.1 mL, p=0.002), and length of hospital stay (2.5 vs. 3.6 days, p=0.003); one patient per cohort was excluded because of unrelated additional procedures during the TTOI. The average LD-SRS and PROMIS patient-reported outcome measures subscores significantly improved in both the percutaneous and open cohorts. Further, the magnitude of improvement was significantly greater for the percutaneous than open cohort for the LD-SRS pain, PROMIS pain intensity, and PROMIS pain interference subscores (other subscores improved similarly between cohorts).

How Well Does Perc OI Work? Comparing Percutaneous vs Open–Exposure Transtibial Osseointegration *continued*

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What are your conclusions?
The percutaneous TTOI approach confers straightforward advantages compared to the open approach: a lower risk of antibiotic use within and after the first six months, shorter operative time, lower estimated blood loss, lower infusion volume, and decreased length of hospital stay. Additional surgery in both cohorts was infrequent and occurred at a similar rate. Both percutaneous and open TTOI significantly improve patient–reported outcomes, with percutaneous patients reporting significantly better pain experiences. While it may not always be an option, percutaneous TTOI should be considered for its apparent advantages.

Table 1 | Complications and Surgical Details

	Open	Perc	P-value
Complications within first 6 months			
N (patients)	22	14	
PO or IV abx	15	3	**0.015**
I&D	1	0	1
Removal/Failure	1	0	1
Other return to OR	1	0	1
Complications after 6 months			
N (patients)	20	9	
IV or PO Abx	12	1	**0.019**
I&D	2	0	1
Removal/Failure	1	1	0.532
Other return to OR	3	1	0.532
Surgical Details			
Length of Operation (min)	169	66.92	**<0.001**
Estimated blood loss (mL)	143.81	40	**<0.001**
Infusion Volume (mL)	1407.14	965.38	**0.002**
Length of stay (days)	3.62	2.46	**0.003**

PO = Oral, IV = Intravenous, I&D = Irrigation and debridement

Supplementary Table 1 | Patient Demographics

	Open	Percutaneous	P-value
N (patients)	22	14	
Sex			0.467
Male	14	11	
Female	8	3	
Ethnicity			0.331
White	21	12	
Black	1	0	
Asian	0	1	
Other	0	1	
Etiology of Amputation			0.198
MVC	6	6	
Trauma	6	2	
Pain	5	0	
Thrombosis	1	0	
Infection	2	3	
Cancer	1	2	
Failed Ankle Fusion	1	0	
Deformity	0	1	
Laterality			0.116
L	9	9	
R	13	5	
B/L	0	1	
BMI	29.85	27.21	0.230
Age at OI Surgery	47.96	45.71	0.661
Follow-up (months)	26.68	18.93	0.113

Understanding the Impact of Intraoperative Bone Splitting on Patients with Osseointegrated Implants

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Matan Grunfeld, S. Robert Rozbruch, MD; Taylor J. Reif, MD; Jason Shih Hoellwarth, MD

What was the question?
Press–fit osseointegration (PFOI) for amputees offers an alternative to traditional limb–loss rehabilitation, successfully addressing many problems associated with socket prostheses. The procedure involves the retrograde insertion of a permanent, transcutaneous intramedullary stem, which acts as a skeletal anchor for an external prosthesis. The insertion may cause a non–propagating longitudinal split in the distal bone, which can raise concern of significance and necessary management. This study is the first to investigate the prevalence, consequences, and risk factors associated with these distal bone splits.

How did you answer the question?
A retrospective review analyzed 100 PFOI procedures (62 femur, 38 tibia) with at least one year of follow–up. Patient charts were reviewed to assess differences in postoperative management for those with distal splits, and to identify complications including implant removal, loosening, fracture, periprosthetic fracture, or infection necessitating operative intervention within the first year after osseointegration. Radiographic evaluations were performed to detect any changes in the implant's position. Factors such as age at osseointegration, sex, body mass index, laterality, amputation etiology, amputation level, time from amputation to osseointegration, implant dimensions, and the sizes of reamers and rasps used were evaluated for their potential influence on the occurrence of bone splitting.

What are the results?
28 cases experienced distal bone splitting (23 femur, 5 tibia) during the implantation process; the remaining 72 cases did not experience any splitting. The patients were divided into two groups for comparison: those with splitting (Split group) and those without (Intact group). All patients followed the same standard immediate postoperative rehabilitation protocol (generally: 4–6 weeks of non–weight bearing, followed by 4–6 weeks of progressive weight bearing with a loading prosthesis, then full prosthesis weight bearing as tolerated). One year post–operation, 28/28=100% Split vs 70/72=97.2% Intact retained their original implant, (p=1.000). Within the Intact group, one implant was removed due to intractable pain, and another was replaced because it was undersized and dislodged two weeks post–operation, with the patient undergoing a revision procedure nine months later. The difference of periprosthetic fracture rate was not significant: 4/28=14.3% vs 3/72=4.2% (p=0.094). Regarding infection, debridement was performed for 1/28=3.6% vs 5/72=6.9% (p=1.000). Radiographic analysis of the Split cohort did not identify any changes in implant position at one year post–operation. Regarding risk factors, a bone split was significantly associated with transfemoral versus transtibial level (p=0.011) and longer implant length (p=0.005). No association was identified with implant diameter (p=0.098), reamer size (p=0.124), or rasp size (p=0.274).

What are your conclusions?
Small contained distal bone splits during PFOI does not appear to confer a risk of clinically apparent negative outcomes. The increased frequency of splits with longer femur implants may suggest that better implant–bone conformation may reduce these occurrences. There does not appear to be a need to provide osteosynthesis for these splits or alter postoperative care to prevent subsequent complications.

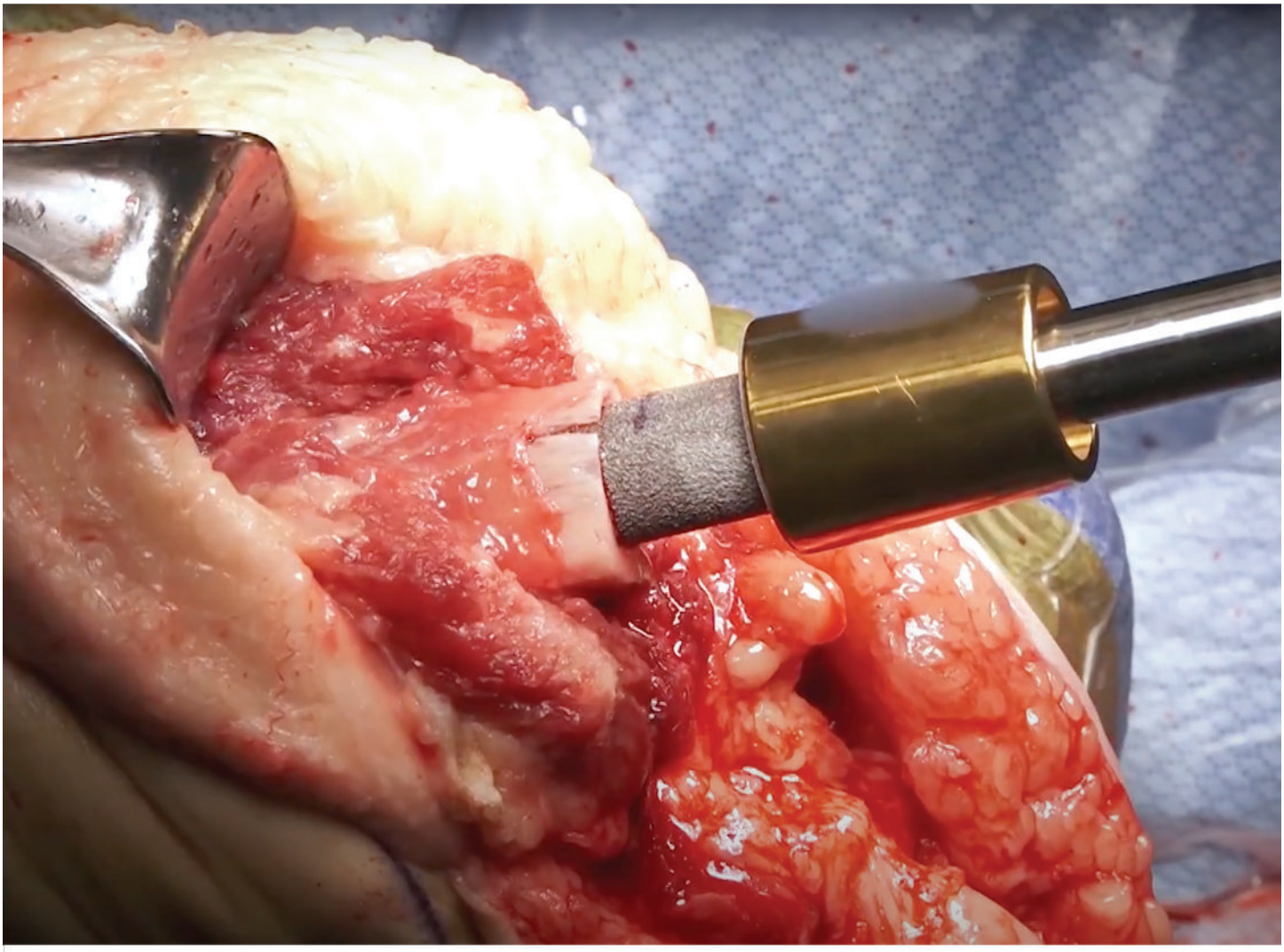

Figure 1. Intraoperative image of an anterior distal bone split during final implant seating. The final implant position was not affected and the implant remained stable.

Osseointegration of the Femur: One Year Outcomes of the Press–Fit Technique

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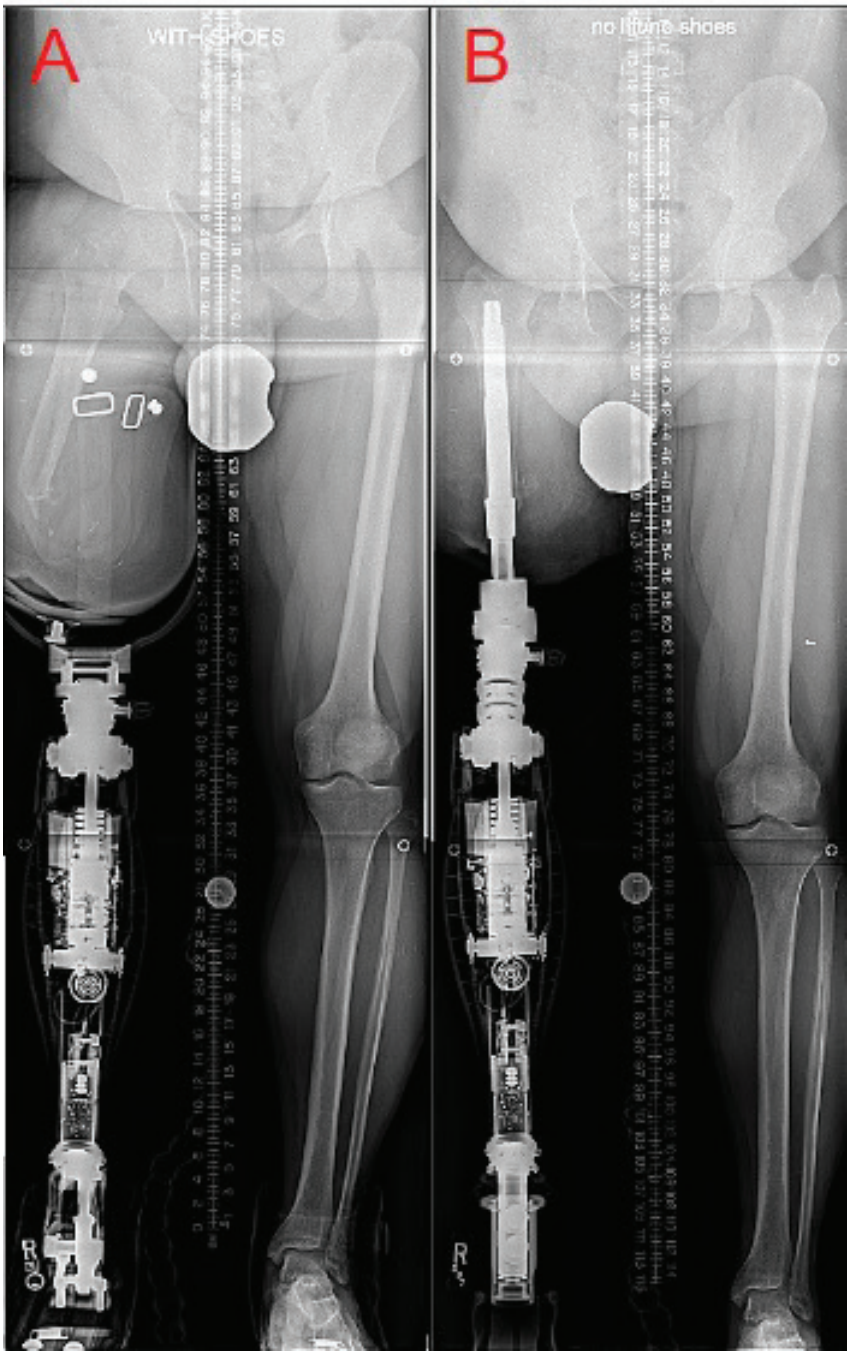
Drew Lopolito, Jason Hoellwarth MD; Taylor Reif MD; S. Robert Rozbruch MD

What was the question?
Press–fit transfemoral osseointegration of the femur allows for a direct transcutaneous skeletal connection between an artificial leg and the residual femur in a single stage procedure that can be performed open or percutaneously. A skeletally anchored prosthesis can offer enhanced mobility, balance, and proprioception to amputees, as well as eliminate problems associated with socket mounted prostheses such as skin problems, ulcers, and pain. The purpose of this research is to describe the clinical and patient reported outcomes for this technique.

How did you answer the question?
We retrospectively reviewed all patients at our institution who underwent press–fit femoral osseointegration between April 2016 and June 2022 (at least two years post–surgery). The primary outcome was adverse events prompting additional surgery. Additional outcomes were changes in mobility (Timed up and go (TUG), 2 minute walk test (2MWT), 6 minute walk test (6MWT) and patient–reported quality of life surveys (LD–SRS, QTFA, and PROMIS).

What are the results?
Sixty-seven integration procedures in 65 patients were included in this cohort. The etiology for the index amputations included trauma (52), infection (8), vascular (1), oncologic (2), deformity (1), and chronic pain (3). Seven patients had osseointegration simultaneous to their index amputation, and 60 patients had revision of a traditional amputation for issues related to socket fitting (36), skin problems (37), pain (34), and mobility (34). Followup data was available for 52 of the 67 procedures and collected up to a mean 2.1 (1.0 - 5.2) years. Infection occurred in 15 (28.8%) of patients; 11 of whom were successfully treated with antibiotics. The total reoperation rate was 25%, including 3 debridements (5.8%) and one removal for infection (1.9%), 4 fracture repairs (7.7%), 7 soft tissue revisions (13.5%), and 0 nerve surgeries. Implant survival was 100% at 1 year, 100% at 2 years, and 98.1% at 5 years. At one year, patients reported increased prosthetic use (9.3 vs. 13.7 hours/day, P=<0.001), improved mobility on the TUG (11.9 vs. 9.8 s, P=0.050), 2MWT (291.3 vs. 416.5 ft, P=<0.001), 6MWT (761.5 vs. 1228.1 ft, P=<0.001) tests, and improved outcomes on the LD-SRS total (domain) score (3.1 vs. 3.7, P=0.003); QTFA prosthetic use (53.8 vs. 80.8, P=0.002), mobility (54.5 vs. 75.4, P<0.001), and global (37.7 vs. 62.9, P<0.001) scores; and PROMIS physical function (35.7 vs. 43.6, P<0.001), global physical health (41.0 vs. 46.3, P=0.012), and global mental health (44.3 vs. 49.6, P=0.012) scores.

What are your conclusions?
Osseointegration of the femur using the press–fit technique is a safe procedure that reliably improves function and quality of life to transfemoral amputees.


A
WITH SHOES
B
no future shoes

Evaluating Prosthetic Joint Infection Risk in Lower Extremity Osseointegration

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What was the question?
Press–fit osseointegration (PFOI) with a solid core implant is a rehabilitation alternative to socket prostheses. One of the most important adverse events is infection. Some amputees seeking PFOI have an existing total joint arthroplasty (TJA), for which a major concern is also prosthetic joint infection (PJI). The risk of PJI for patients with PFOI has never been investigated. This study evaluated the risk of PJI for lower extremity PFOI patients who had pre–existing lower extremity TJA.

How did you answer the question?
All patients who had osseointegration were evaluated for study inclusion if they had knee or hip TJA prior to osseointegration, as documented in history, imaging, or upon subsequent phone call inquiry. Patients were asked and charts were reviewed to determine whether PJI occurred following PFOI, and if so, what management entailed. Mobility data (k–levels) was also reported.

What are the results?
A total of 14 patients each had one pre–existing TJA: 11 contralateral knee, two ipsilateral hip (above a transtibial PFOI), and one contralateral hip. No patients had TJA in the same bone as their PFOI. No patients developed PJI. The average follow–up time after PFOI was 2.4±3.3 years (0.6 to 4.4 years). This amounts to a total of 33.9 patient–years with no PJI following PFOI. Preoperatively, the number of patients achieving K–level 2 or better was 1/14=7%; after PFOI it was 8/14=57% ($p=0.013$).

What are your conclusions?
Lower extremity PFOI does not present an apparent imminent threat of PJI to patients with pre–existing lower extremity TJA. Presumptively, the osseointegration skin portal could be a relative risk of PJI versus patients without this non–anatomic skin opening. However, that risk has yet to become measurable. Patients with TJA seeking PFOI or vice versa likely should be counseled that osseointegration could theoretically represent an increased risk for PJI, but it currently seems reasonable to consider both of these orthopedic reconstructions for patients who would benefit from such care.

Session VI: Adult Limb Deformity Part I

Moderator: Austin T. Fragomen, MD

Interprofessional Teams in Limb Lengthening and Deformity Clinics

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What was the question?
Limb lengthening and reconstruction offers a renewed sense of hope to individuals grappling with limb length discrepancies and deformities. Despite significant growth in the field, there has been little investigation into the clinical models that best serve the needs of limb reconstruction patients. The prevailing model at major tertiary limb deformity clinics employs a comprehensive, multidisciplinary team approach. The extent to which this model is consistently adopted remains uncertain despite the likely benefits to patients, particularly for psychosocial support both pre and post operatively.
The primary objective of this research is to describe various practice models of interprofessional teams involved in the care of limb reconstruction patients. In addition, we aim to shed light on perceived needs and barriers of limb reconstruction surgeons.

How did you answer the question?
We conducted a survey of the surgeon membership of the Limb Lengthening and Reconstruction Society (LLRS). Survey questions aimed to assess practice characteristics, current clinical models, clinical needs, and barriers to implementation. Descriptive statistics were used to report frequency and proportions of categorical data.

What are the results?
26% (n=63/221) of the surgeon membership completed the survey. 6 respondents were excluded due to incomplete surveys. The majority of respondents worked in an academic setting (57.9%, n=33/57). Dedicated fellowship in limb deformity and lengthening was less common (42.1%, n=24/57). Most respondents work exclusively in pediatric care (45.6%, n=26/57). Only 38.6% (n=22/57) of clinics contain a dedicated limb lengthening/deformity service.
Clinical models varied, with midlevel providers (68.4%, n=39/57), physical/occupational therapists (40.4%, n=23/57), and orthotics/prosthetics (29.8%, n=17/57) being the most commonly embedded healthcare professionals. Fewer clinics provide psychosocial support to patients, with 14.0% (n=8/57) of clinics with dedicated mental health professionals, 5.3% (n=3/57) including spiritual support/clergy, and 7.0% (n=4/57) offering peer support groups. Mental health services were the most desired service not already available to respondents (49.1%, n=28/57). Lack of funding emerged as the primary barrier to implementation across desired healthcare services. Embedded services and reported clinical needs did not differ significantly based on the presence of a dedicated limb lengthening service.

What are your conclusions?
This survey of the LLRS provides the first comprehensive description of clinic models for limb lengthening and deformity surgery in the United States. Midlevel providers, physical/occupational therapists, orthotics/prosthetics specialists, and social workers/case managers are commonly embedded in these clinics, but there is a notable deficit in psychosocial support services. However, there appears to be an increasing recognition and desire to integrate these support systems. Funding appears to be the primary barrier to the implementation of these services. However, a lack of significant difference between respondents with access to a dedicated limb lengthening and deformity service indicates the feasibility of maintaining interdisciplinary care even outside of specialized clinics.

A Comparison of Functional Results of Three Different Surgical Techniques in Patients Undergoing Femoral Lengthening

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Halil Ibrahim Balcı, Cengiz Şen, Mehmet Demirel, Türker Şahinkaya

What was the question?
Few studies have compared clinical and radiographic results of three femoral lengthening systems (Lengthening with monolateral external fixator, lengthening over nail (LON) and a newer technique, magnetically driven intramedullary lengthening nail). The effect of these techniques on isokinetic muscle strength around the hip and knee has not yet been investigated to the best of our knowledge.
1) is there any difference in the clinical and radiographic results, in patients who underwent femoral lengthening using the three different methods
2) is there a change on isokinetics, isometric muscle strength and endurance power around the hip and knee periarticular muscle in these three patient groups.

How did you answer the question?
Between 1999 and 2022, 105 patients (125 femurs) underwent three different femoral lengthening techniques due to constitutional short stature and lower extremity limb length discrepancy, were retrospectively identified and included in the study. Based on the surgical technique performed, patients were divided into three groups: the magnetically driven intramedullary lengthening nail group (23 patients, 30 femurs), the monolateral external fixator group (43 patients, 50 femurs), the Lengthening over nail group (39 patients, 45 femurs). For functional assessment, patients were evaluated using ASAMI (Association for the Study and Application of the Methods of Ilizarov), SF–12 (Short Form), and LEFS (Lower Extremity Functional Scale) scores at their final follow–ups. Radiological evaluation and complications during the postoperative follow–up period, bone healing index, regenerate quality, and final lengthened bone amount was noted. Additionally, all patients underwent muscle strength and endurance measurements using a Cybex dynamometer for bilateral knee extensors and flexors, as well as bilateral hip abductors and adductors, at their final follow ups.

What are the results?
There were no significant differences between the three groups in terms of gender, age at operation, amount of shortness, operated side, targeted lengthening amount, amount of bone lengthened, preoperative and postoperative MAD, regenerate quality(p>0.05). The bone healing index was significantly greater in the monolateral external fixator group (p=0.001; p<0.01). while LEFS scoring was significantly lower in the monolateral external fixator group compared to the other two groups (p=0.009; p<0.01). Complication rates were significantly lower in the magnetically driven extensible intramedullary nail group (p=0.006; p<0.01). In the evaluation of isokinetic muscle strength and endurance, knee extensor peak torque (p=0.001; p=0.001; p<0.01), knee flexor peak torque (p=0.001; p=0.001; p<0.01) and hip abductor peak torque (p=0.001; p=0.001; p<0.01) values were the lowest among the three groups in the monolateral external fixator group. Knee extensor (p=0.018; p=0.010), flexor (p=0.586; p=0.386) and hip abductor (p=0.034; p=0.055) muscle strength and endurance values were highest in the magnetically driven extensible intramedullary nail group and lowest in the monolateral external fixator group.

A Comparison of Functional Results of Three Different Surgical Techniques in Patients Undergoing Femoral Lengthening *continued*

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What are your conclusions?
The present study has revealed that the magnetically driven intramedullary lengthening nail technique has shorter consolidation time, better bone healing index and lower complication rates. Although that LON and magnetically driven intramedullary lengthening nail keep isokinetic muscle strength measurements better than external fixation, there were no significant difference between them.

Tibia Deformity Correction Using an Intramedullary Nail

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Drew Lopolito, Jason S. Hoellwarth, MD; Taylor Reif. MD; Austin T. Fragomen. MD;
S. Robert Rozbruch. MD

What was the question?
Tibia deformity in coronal, sagittal, and rotation planes affects the mechanical axis of the lower extremity and the load stresses which can precipitate premature degenerative disease of the knee and ankle. There are various fixation options to correct tibial deformity; intramedullary nails are a durable and widely available option. The aim of this study was to evaluate the radiographic and patient reported outcomes of acute tibial deformity correction using a static intramedullary nail (IMN).

How did you answer the question?
A retrospective review was performed of all patients who underwent tibia deformity correction with static IMN who had a minimum follow up of 1 year. The outcomes evaluated were radiographic and clinical deformity measurements (mechanical axis deviation (MAD), medial proximal tibia angle (MPTA), thigh–foot axis (TFA)), patient–reported outcomes (Limb Deformity–modified Scoliosis Research Society (LD–SRS), Patient–Reported Outcomes Measurement Information System (PROMIS)), knee and ankle motion, and adverse events.

What are the results?
There were 116 tibias (83 patients), 49 female (71 tibias) and 34 male (45 tibias), mean age 28.9±13.2 (11-65) years. 58 (50%) patients had a staged, and 8 (6.9%) patients had bilateral tibias in the same surgical procedure. The tibias were divided in 3 groups based on primary deformity: coronal-only, rotation-only, or coronal+rotational (other dimensions were not represented). The deformities are expressed in magnitude-only (without direction) for word limitation purposes. All alignment measures significantly improved. Specifically, the coronal-only group's MAD (38±25.2 to 7.7±6.4 mm, p=<0.001) and MPTA (7.6±3.4° to 2.7±2.3°, p=< 0.001), rotation-only group's TFA (19.6±7.1° to 3.7±2.2° (away from the normal 15°), p=<0.001), and the the coronal+rotational group's MAD (22.2±19.6 to 9.9±12 mm, p=<0.001) and TFA (15.5±7.6° to 3.7±4.3°, p=<0.001). Postoperative LD-SRS and PROMIS showed statistically significant improvement in all categories except mental health, which improved but not to a statistically significant degree. Preoperative and postoperative knee and ankle motion was unchanged. Non-surgical adverse events included 1 superficial wound infection and 1 fracture after trauma which were managed without surgery. There were 8 unplanned surgeries (7%); 6 delayed unions (managed with bone graft, exchange nailing, or nail dynamization), 1 peroneal nerve palsy (resolved following release), and 1 loss of correction (corrected by conversion to external fixator). No compartment syndromes or vascular injuries occurred.

What are your conclusions?
Acute correction of tibial deformity with an IMN is safe and accurate for coronal and axial deformities. Adverse events were infrequent and non–catastrophic.

Retrograde Femoral Lengthening below a Total Hip Arthroplasty

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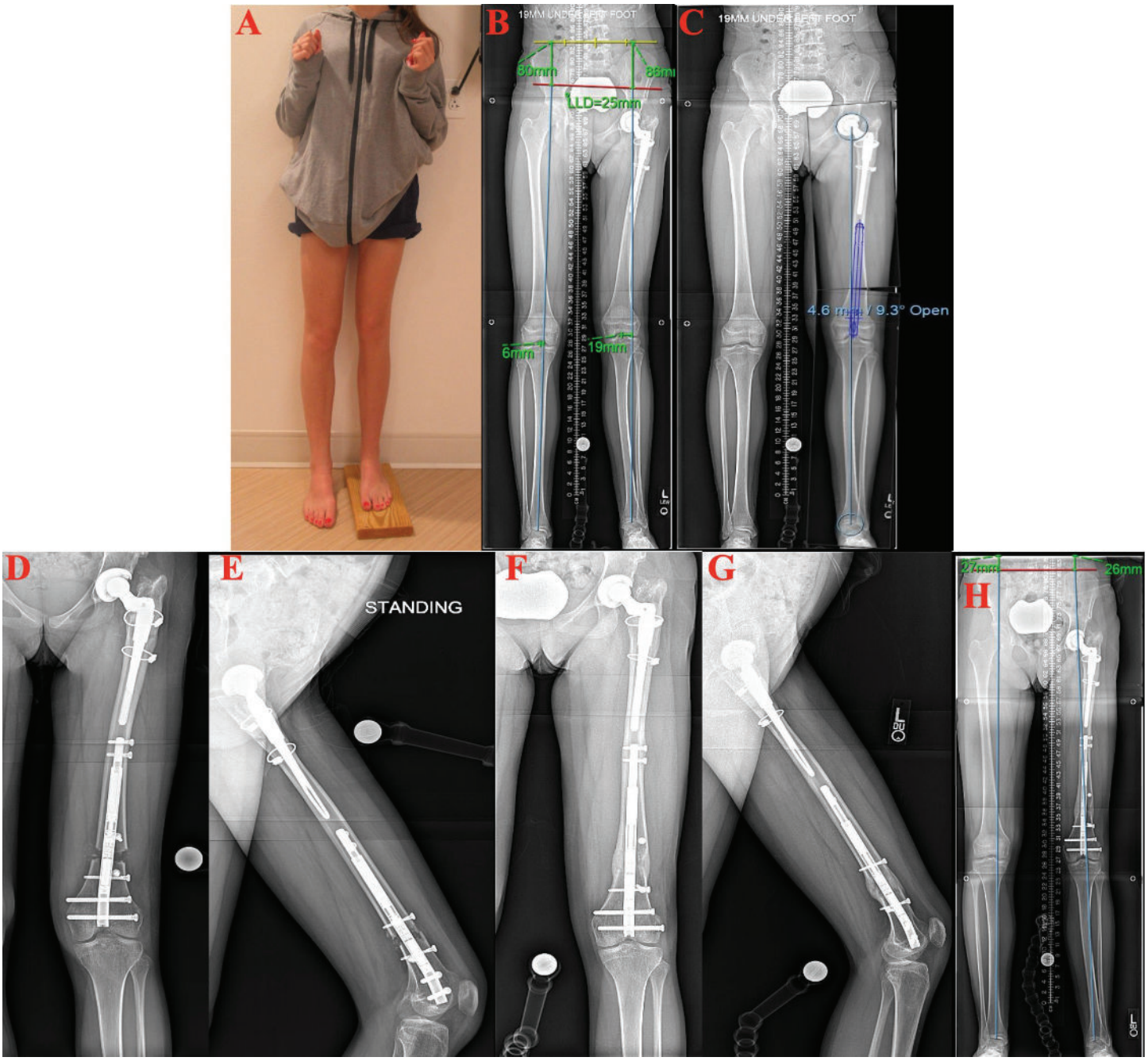
Drew Lopolito, Jason Hoellwarth, MD; Taylor Reif, MD; Austin T. Fragomen, MD;
S. Robert Rozbruch, MD

What was the question?
Limb length discrepancy (LLD) after total hip arthroplasty (THA) is a common occurrence, and can lead to back pain, disordered gait, and decreased functional outcomes. Femoral lengthening ipsilateral to a THA using a retrograde motorized internal lengthening nail (MILN) is a hip sparing option for limb equalization. The purpose of this research is to report on the technique and results of this method.

How did you answer the question?
We retrospectively reviewed all patients at our institution who underwent unilateral femoral lengthening using a retrograde MILN ipsilateral and distal to a THA between April 2016 and June 2022. We describe the technique and considerations for this procedure in detail, and report the patient demographic variables, etiology and magnitude of LLD, concomitant deformity, knee range of motion, time to union, and all adverse events and complications.

What are the results?
Eleven lengthening procedures were included in this cohort. Etiology for LLD included avascular necrosis (4), post–infection (3), and one each of post–trauma, congenital deficiency, hip dysplasia, and iatrogenic secondary to index THA procedure. Mean lengthening was 35.7± 14.7 mm (range 20–70 mm) with a lengthening index of 1.5 ± 1.2 months until union per cm of lengthening. Complications included two patients who required reamed exchange nailing to achieve union, and one interprosthetic fracture treated with removal of the MILN and plate fixation. No adverse effects on THA function were documented.

What are your conclusions?
Femur lengthening using a retrograde MILN ipsilateral to a THA is a safe and reliable hip sparing option for post–THA limb length equalization.


A
B
19MM UNDERHEEL FOOT
80mm
86mm
LLD=25mm
6mm
19mm
C
19MM UNDERHEEL FOOT
4.6 mm / 9.3° Open
D
E
STANDING
F
G
H
27mm
26mm

Traveling Fellowship Presentation

Introduction by Jaclyn F. Hill, MD

Ugochuku Akpati, MBBS
Stephen Becher, MD
Gourav Jandial, MD
Heather Kong, MD

Session VII: Osteomyelitis

Moderator: David B. Frumberg, MD

Effectiveness of Single–Stage Debridement with High–Dose Medullary Antibiotic Injection for Treating Osteomyelitis

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Roberto Hernandez–Irizarry, MD

What was the question?
Osteomyelitis presents a complex challenge in medical treatment due to the unique structure and function of bone and surrounding soft tissues. Treatment is usually multidisciplinary and can include nonsurgical and surgical interventions. Our research question was: Is a single stage debridement and injection of a high dose of medullary antibiotics effective in treating Cierny stage III and IV osteomyelitis?

How did you answer the question?
A retrospective review of surgically managed osteomyelitis at a level 1 trauma center from 2020–2023 was done. We identified cases with Cierny stage III and IV osteomyelitis over this time period. The treatment protocol included a single stage debridement of the osteomyelitis and medullary injection of high dose of antibiotics using calcium sulfate as a carrier. The surgical technique included local debridement and medullary debridement using a reamer irrigator, with injection of 30 mL of calcium sulfate in the canal using a french tube and a tumi syringe, mixed with 9g of Vancomycin and 3.6g of Tobramycin. Intravenous antibiotics were used adjuvantly based on intraoperative cultures. Multiple metabolic panels were obtained in the postoperative period, and the creatinine levels were trended over time.

What are the results?
Our series consisted of 12 consecutive patients. The average age was 46 (range 15–73). There were 4 femur osteomyelitis and 8 tibia shaft osteomyelitis. There were 7 patients with Cierny IV and 5 patients with Cierny III osteomyelitis. 4 patients were type A hosts, and 8 patients were type B hosts. The most common cultured organism was methicillin resistant staph aureus (MRSA, 5/12 patients), followed by streptococcus species and pseudomonas. At final follow up, no patients had a recurrent infection. One patient (8%) had an acute kidney injury at 8 weeks post injection, defined as creatinine >0.3 mg/dL from baseline, which was managed with a change in his oral antibiotic therapy and supportive hydration.

What are your conclusions?
Surgical debridement and high dose antibiotic injection can be an effective and safe way to treat Cierny stage III and IV osteomyelitis. The surgeon must be vigilant for renal function postoperatively when injecting antibiotics in the medullary canal.

Bacterial Elimination with Dalbavancin Antibiotic Beads

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Grant W Lambert, BS; Keenan T Hurst Jr, BS; Janet D Conway, MD

What was the question?
Local administration of antibiotics via cement beads is a method currently employed in the management of traumatic wounds, fracture related infections, and hardware associated infections. However, not all antibiotics can be used with cement and the elution characteristics of cement are not necessarily favorable for prolonged treatments. Dalbavancin, a lipoglycopeptide antibiotic with Staphylococcus coverage and an extended half–life, has been approved for the treatment of acute soft tissue infections caused by gram–positive organisms and may be a novel option for delivering local antibiotic. This study aims to evaluate the elution capacity of dalbavancin from polymethylmethacrylate (PMMA) cement beads and its efficacy against Staphylococcal species in vitro.

How did you answer the question?
Polymethylmethacrylate cement was used to prepare cement beads with 500mg of dalbavancin HCl/40g cement pack. The beads were transferred into separate conical tubes containing 5 milliliters of phosphate–buffered saline (PBS) and subjected to agitation in a shaking incubator at 37ºC. The PBS was sampled and replaced at intervals of 1, 2, 4, 16, 24, 48, 96, 116, and 144 hours. Methicillin–resistant Staphylococcus aureus Rosenbach (BAA–1683; ATCC) and Xen36 Staphylococcus aureus (#119243; PerkinElmer) were expanded separately in tryptic soy broth (TSB). The cultures were separated into conical tubes and mixed with PBS for controls or PBS from the antibiotic elution timepoints followed by shaking incubator at 37ºC for 24 hours. After 24 hours, the samples were evaluated for bacterial density by measuring optical density (OD) at 600nm with a UV–Vis Sectrophotometer (Spectronic Genesys 10 Bio). The collected PBS samples were also analyzed via mass spectrometry for drug amounts in the eluent at an outside institution with results currently pending.

What are the results?
The eluent from the dalbavancin antibiotic beads affected both the MRSA and Xen36 Staph culture densities. OD measurements from the MRSA and Xen36 strains plus blank PBS controls were 0.987 and 0.974, respectively. MRSA cultures densities exposed to the dalbavancin antibiotic beads ranged from 0.029 to 0.015 resulting in a 96–99% decline in culture density compared to controls. Xen36 Staph culture densities exposed to the dalbavancin antibiotic beads ranged from 1.427 to 0.001. At one–hour, the eluent decreased culture density by 32%. Between 2– and 120– hours, eluent decreased culture density by 96–99%. At hour 144, the culture density rebounded to a 46% increase.

What are your conclusions?
Dalbavancin is a novel lipoglycopeptide antibiotic with a long half–life and efficacy against bacterial pathogens commonly implicated in bone and hardware infections that complicate musculoskeletal trauma and orthopedic procedures. Bone cement, such as PMMA, is commonly utilized as a vehicle for the local delivery of antibiotics; however, antibiotics infused into bone cement must be heat stable and should result in effective eluent from the beads for several days. The antibiotics currently used in bone cement have notably shorter half–lives compared to dalbavancin, which may be beneficial if it can effectively elute from cement. Preliminary results from the optical density measurements suggest that dalbavancin is capable of withstanding the temperatures produced by the PMMA reaction and retain activity against two different Staph isolate cultures in vitro for at least five days. Further analysis is required to determine the degree of dalbavancin elution from PMMA. Mass spectrometry evaluation of elution samples is currently in progress.

Delivery of Dalbavancin from Antibiotic Beads: Is it Toxic to Bone?

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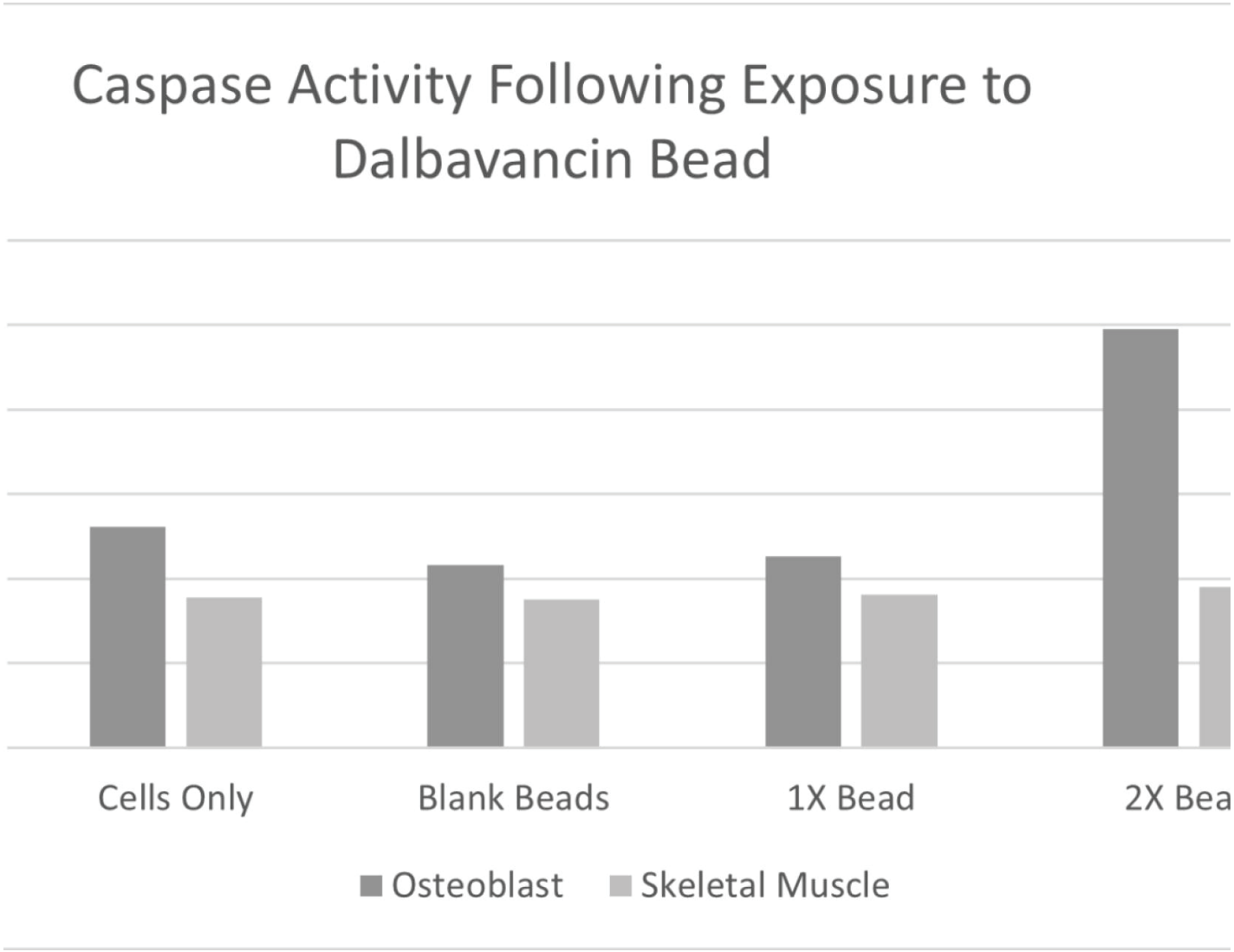
What was the question?
While local antibiotics can be helpful to mitigate or treat infection, the local application of drug which would typically be administered intravenously may have adverse effects on the local tissues. A new lipoglycoprotein antibiotic called dalbavancin has not been extensively studied in terms of safety and efficacy for local delivery. The purpose of this research is to determine if antibiotic beads made with dalbavancin result in a local milieu that adversely affects cultured human cells. Due to the nature of orthopaedic trauma, both bone and soft tissue must be considered for toxic effects. We aim to determine how dalbavancin antibiotic beads affect both cultured human osteoblasts and skeletal muscle cells.

How did you answer the question?
Polymethylmethacrylate Simplex®P cement was used to prepare cement beads with no antibiotic (control), 500mg of dalbavancin HCl/40g cement pack (1X dose), or 1000mg/40g cement pack (2X dose). Human osteoblasts (Cell Applications, Inc) were seeded at 2 x 104 cells/cm2 on 6–well tissue culture plates in Osteblast Growth Media at 37ºC. Human skeletal muscle cells (Cell Applications, Inc) were similarly seeded on 6–well tissue culture plates in Skeletal Muscle Growth Media. Once confluent, culture media was changed and wells then exposed to no bead, a blank (control) bead, a 1X bead or 2X bead in triplicate for four additional days. On the final day, the media supernatant was collected and assayed for caspase–3 fluorescence activity (Sigma–Aldrich), as a measure of apoptosis.

What are the results?
Human osteoblasts in culture did not demonstrate differences in apoptotic activity when exposed to a blank bead ($p=0.3180$) or 1X dose bead ($p=0.9633$) compared to cells not exposed to a bead. However, the 2X bead dose did increase caspase activity compared to unexposed cells ($p=0.0471$). Skeletal muscle cells in culture were not affected by any of the bead exposures compared to unexposed cells. Caspase–3 activities are graphed in Figure 1.

What are your conclusions?
Dalbavancin is a new antibiotic approved to treat gram–positive soft tissue infection and may be helpful in treating gram–positive osteomyelitis. The local delivery of antibiotic, including delivery of antibiotic from cement beads, can be a useful adjunct to treating bone infection. However, high doses of locally delivered antibiotic may be detrimental to the local tissues. This in vitro study suggests a high dose of dalbavancin may affect osteoblast apoptosis as measured by caspase activity. Additional studies can now determine if 1X beads result in an eluent that eliminates bacteria.


Caspase Activity Following Exposure to Dalbavancin Bead
Cells Only
Blank Beads
1X Bead
2X Bea
Osteoblast
Skeletal Muscle

Bromelain as a Source of Debridement for Infected Orthopaedic Implants

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Jaclyn Murphy, Jessica C. Rivera, MD. PhD

What was the question?
The growth of biofilms on orthopedic implants is of major surgical concern, with infection rates estimated to be up to 2 percent for all orthopedic procedures. Currently, manual scrubbing accompanied with a saline wash is the most common method of biofilm eradication. However, enzymatic debridement has emerged as an alternative option. Bromelain is an enzyme derived from pineapple stem and has been previously used in several studies as a method of biofilm dissolution. As a result, the present study aimed to answer the question: "Can bromelain be used to effectively debride biofilm off of infected orthopaedic implants?"

How did you answer the question?
In our study, 10 mm x 3.5 mm surgical grade cortical bone screws were incubated in Methicillin–resistant Staph aureus (MRSA) inoculated broth. Treatment groups were exposed to low dose bromelain solution (200 µg/mL), high dose bromelain solution (1 mg/mL), or bromelain powder (3 U/mg) for 20 minutes. The screws were either rinsed with 1X phosphate buffer saline (PBS) or briefly scrubbed for thirty seconds prior to rinsing. The screws were then stained with 0.25% crystal violet to determine the amount of biofilm remaining. Resultant effluents were analyzed by optical density (OD) at 600 nm. The percent of biofilm dissolution was determined using the following equation: $\%BD = [OD\ Control - OD\ Treated]/ [OD\ Control] \times 100$. OD means were compared between each treatment and controls with Analysis of Variance (ANOVA) with Bonferroni correction.

What are the results?
Six screws were used for each group. The average optical densities of the low dose bromelain solution (0.104 ± 0.047) was no different compared to controls ($p=0.345$). The average optical densities of low dose + scrub bromelain solution (0.068 ± 0.020) and high dose + scrub solution (0.045 ± 0.014) were significantly different from their respective controls ($p=0.012$; $p= 0.001$). The average optical densities for screws in the high dose treatment group (0.056 ± 0.012), powder (0.041 ± 0.010), and powder + scrub (0.032 ± 0.005) were also significantly different than their respective controls ($p=0.003$; $p=0.001$; $p < 0.0001$). The powder + scrub treatment resulted in 91% biofilm dissolution.

What are your conclusions?
Bromelain is a promising alternative option for the debridement of biofilm from orthopedic implants. Future work should be aimed at decreasing the exposure time to increase practicality in the operating room. In addition, this experiment should be replicated in vivo to determine if treating biofilm–infected implants with high dose bromelain yields any toxic side effects to the surrounding tissue.

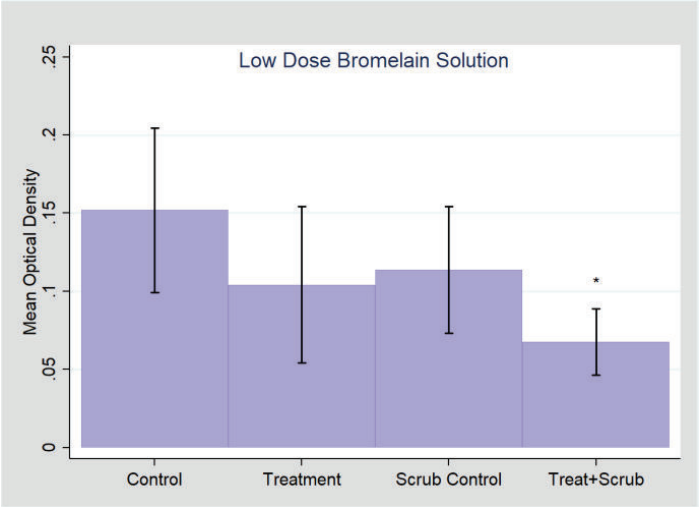

Figure 1: Low dose bromelain solution and low dose plus scrub treatment

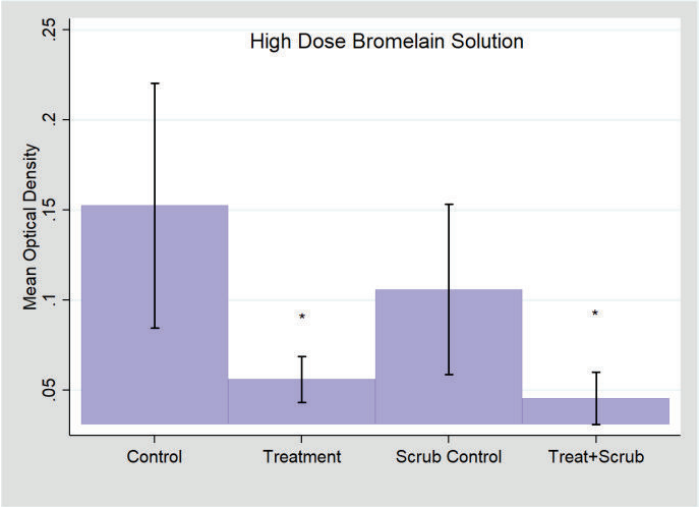

Figure 2: High dose bromelain solution and high dose plus scrub treatment

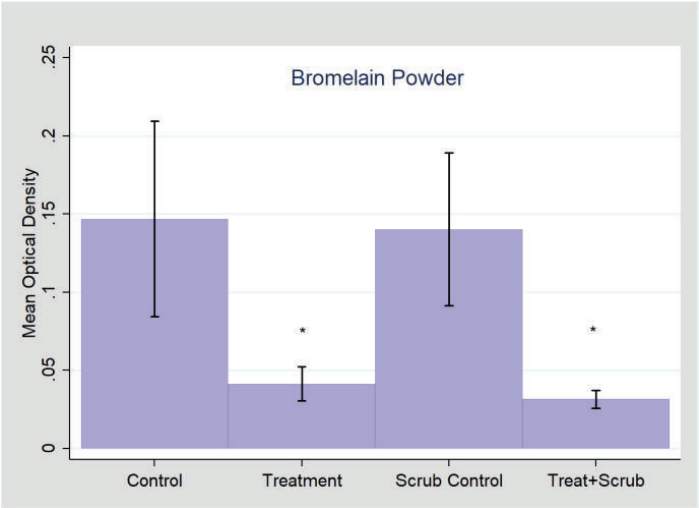

Figure 3: Bromelain powder and powder plus scrub treatment

Is a Calcium Sulfate Injection During Transition to a Nail After Ring Fixator Associated with a High Rate of Infection?

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What was the question?
Transitioning from a ringed fixator to a nail can help prevent complications associated with prolonged external fixator use. Infection after transition to nailing (IMN) is reportedly as high as 43%, with concerns for colonized pin sites increasing risk of osteomyelitis. Techniques such as pin holidays and off–axis pins have been utilized to prevent infection but are not always possible. The purpose of this study was to determine if patients in external fixators transitioned to an IMN with combination antibiotic–laden calcium sulfate injection would result in a decreased infection rate.

How did you answer the question?
A retrospective review was conducted on patients treated at a Level 1 trauma center between 2020 and 2023. Patients with prolonged ringed external fixator placement (>1 month) for multiple diagnoses (limb salvage, segmental defect, deformity, nonunion) who transitioned to an IMN with calcium sulfate antibiotic–laden injection were included. Patients were treated with canal irrigation, and 40–60cc injection of calcium sulfate (Synthecure, Austin Medical Ventures, Memphis, TN) combined with vancomycin/tobramycin prior to IMN. Demographics, time in fixator, secondary procedures, complication, nonunion, and infection were recorded.

What are the results?
Eighteen patients were reviewed, with an average age of 53.5 (range 20–76). Fifteen (83%) underwent limb salvage after traumatic fracture, while three (17%) underwent deformity correction. Average follow up time was 15.5 months (range two days–37 months). Patients had their external fixator on an average of 195 (range 55–393) days. All patients had pin tracts in line with future nail trajectory and a history of at least 1 pin tract infection. One patient (5.5%) had a delayed docking site union which healed after bone grafting and plating. Two patients (11%) had infections, which is less than historical control ($p < 0.05$). Both resolved with nail removal/exchange.

What are your conclusions?
Placement of intramedullary antibiotic–impregnated calcium sulfate at the time of transition to an IMN is associated with lower rates of infection and complication. This represents a promising technique to minimize length of time in a frame, although further study is warranted to thoroughly understand risks of infection.

Session VIII: Internal Limb Lengthening Nails

Moderator: Christopher A. Iobst, MD

Neck Shaft Angle Deviation in Patients Undergoing Femoral Limb Lengthening

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Michael Assayag, MD; Philip K. McClure, MD

What was the question?
What is the relationship between antegrade telescoping ILNs and varus–procurvatum malalignment, along with the relationship between the osteotomy and surgical entry sites?

How did you answer the question?
Preoperative and post–lengthening neck shaft angle (NSA), along with the anatomic medial proximal femoral angle (aMPFA), were compared to assess varus–procurvatum malalignment. Osteotomy level coefficient (OLC) was used to evaluate the relative distance of the osteotomy from the tip of the greater trochanter. Patients' demographic information and surgical entry point were retrospectively sourced from the medical records.

What are the results?
Average age was 19.9 years and mean lengthening was 4.7 cm. Of the 142 nails, trochanteric entry was used in 127 procedures and piriformis entry was used in 74 of them. With pre-op OLC of .3. The preoperative NSA was significantly reduced from 130.6 to 127.4 degrees at the end of lengthening (P <.05). There was no discernible correlation between the OLC and change in NSA. The trochanteric entry point was associated with a greater tendency to reduce the NSA (Mdif = -4.1, SD = 6.5) as compared to the piriformis entry point (Mdif = -3, SD 6.4)(P < .05). No significant change in aMPFA was noted between pre- and postoperative time points, nor between trochanteric and piriformis entry groups.

What are your conclusions?
Antegrade intramedullary limb lengthening was strongly associated with varus deformity of the proximal femur, as shown by an appreciable reduction in NSA. This change was more prominent when using the greater trochanter as the nail's entry point. The level of the osteotomy did not play a significant role in shifting the NSA.

Nail Bending in Femoral Lengthening

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What was the question?
What is the expected and accepted degree of Nail bend during femoral lengthening?

How did you answer the question?
We retrospectively evaluated 130 ILNs in 100 adult patients who underwent limb lengthening. We excluded patients who had concomitant osteotomies, tibial lengthening, malunion, non–union, mechanical failure, or revision surgery for any reason. All nails were inserted through the greater trochanter or piriformis. Patients' age, weight, height, and body mass index (BMI)were extracted. Radiologic assessments involved analyzing long lower limb standing X–rays before, during, and at consolidation for total distraction and nail bend. Nail diameter and patient characteristics were directly sourced from medical records.

What are the results?
Nail bend at consolidation averaged 2.4 degrees (SD 2.4), ranging from 0 to 9. Additionally, total femoral lengthening was assessed, with a mean value of 5.3 cm (SD 2.1). A significant positive association was observed in the nail bend and weight (weight in kg/nail diameter in mm) coefficient (P <.01). Bilateral limb lengthening was also correlated to increase nail bend (P <.05).

What are your conclusions?
Patient's weight to nail diameter ratio and bilateral limb lengthening were found to be significant factors affecting nail bend. These findings advance our understanding of the interrelation between the nail biomechanical profile and the patient's physical attributes, offering important implications for limb lengthening.

Mechanical Angle Deviation Shift during Femoral Limb Lengthening

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Michael Assayag, MD; Philip K. McClure, MD

What was the question?
What is the effect of ILNs on the alignment and mechanical axis of the lower limb?

How did you answer the question?
We retrospectively evaluated records for 154 femoral antegrade ILNs inserted in 122 adult patients for limb lengthening. We excluded patients that underwent concomitant osteotomies or tibial lengthening, or who had malunion, non–union, mechanical failure, or revision surgery for any reason. Long–leg standing X–rays were taken preoperatively, at the end of lengthening, around 3 months postoperative, and at culmination of consolidation (approximately 6 months postoperative). Mechanical angle deviation (MAD) and anatomic mechanical angle (AMA) were assessed as primary outcomes at each X–ray time point for sequential comparison. The Predicted MAD was derived from the trigonometric formula (Predicted MAD = lengthening*sin (AMA))

What are the results?
Preoperative MAD was 2.4mm medial (SD = 10.6), diminishing to 1.9mm (SD = 13.2) medial by the end of lengthening. Upon assessment at consolidation, average MAD had equilibrated back to 2.6mm medial. Our results showed a net shift of .18mm and an absolute shift of 3.4mm, whereas the net predicted MAD was –.7 and the absolute predicted shift was 5.6mm.
Mean preoperative AMA was 5.9 (maximum 9 and minimum 0.1, SD = 1.49). At the end of lengthening the average AMA had decreased to 4.8 (maximum 10.74 and minimum 0.1, SD = 1.4)

What are your conclusions?
Our data indicated minimal to no impact on the mechanical axis or joint alignment of the lower limb after lengthening using a telescoping femoral ILN in a deformity–free femur. Study results showed that the femur typically realigned in a way that minimized mechanical deviation while preserving joint alignment. Further studies are needed to understand the types of forces and factors that lead to this phenomenon.

Compression of Intercalary Allografts with Magnetic Lengthening Nails, Mid–term Results with a Comparison of Techniques

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What was the question?
Using magnetic growing intramedullary nails to compress an intercalary allograft may improve union rates and decreased complications. The purpose of this study is to evaluate union rates, complications, and mid–term results of this technique. In addition to this, a subset analysis of patients who underwent routine compression post–operatively compared to those who did not is presented.

How did you answer the question?
A retrospective review of 16 patients with 33 osteotomy sites on 7 femurs, 9 humeri and 1 tibia was performed. The average age was 36.7 (9–73) with an average follow–up of 47.2 months (7–102). Thirty 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. The average allograft length was 14.8 cm (6.5–29). All nails were compressed intraoperatively. Ten patients did not undergo routine post–operative compression. Eight patients underwent routine compression, including 2 patients who required revision surgery after not undergoing compression due to hardware complications. Radiographs were evaluated to determine union rates, time to union and to evaluate for both early and late complications.

What are the results?
Thirty out of 33 sites (90.9%) were healed at final follow–up, whereas 28 of the sites (84.8) healed with a single surgery. When comparing the union rates of the 2 groups, 14/14 (100%) of routine compression group healed compared to 16/21 (76.2%) who did not undergo routine compression ($p=0.069$), One of the nails failed in a patient who had routine compression compared to 3 that failed in the non–routine compression group. All 4 patients underwent revision surgery. Two of the 3 patients in the non–routine group subsequently underwent routine compression and healed uneventfully whereas the remaining patient did not undergo compression and the revision hardware failed. The patient in the compression group that underwent revision had routine compression and healed uneventfully. No other complications occurred in the routine compression group. Other complications in the non–routine group included 1 fracture through the allograft after a fall, 1 wound dehiscence, the backing out of 4 screws/pegs with one that required removal, and fracture of 1 screw. 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 91% of patients healed at final follow–up with 85% after a single surgery. The use of routine post–operative compression improved the rate of healing to 100% compared to 76% which approached significance. The complications in the routine compression group, including hardware complications were decreased. Routine post–operative compression appears to improve the union rates and decrease the complications of this technique although further study is needed.

Session IX: Trauma Part 2

Moderator: Jessica C. Rivera, MD, PhD

Does Intramedullary Nailing Increase Surgical Site Infection Rates for Incomplete Ballistic Tibia Shaft Fractures that Require Operative Debridement?

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Roberto Hernandez–Irizarry, MD; Adam Boissonneault, Michael Maceroli

What was the question?
Incomplete ballistic tibia shaft fractures often require operative debridement due to wound size and/or exposed bone. After operative debridement of the wound, incomplete tibia shaft fractures may be treated with intramedullary nailing (IMN) or with splint/cast immobilization. Although IMN may allow earlier weight bearing, there is a theoretical risk of increased infection due to hardware burden. The aim of this study was to compare infection rates between patients who underwent operative debridement for a ballistic tibia shaft that were treated with or without IMN.

How did you answer the question?
This study is a retrospective review of a consecutive series of patients that presented to a single urban, academic level I trauma center over a 5–year period with a ballistic tibia shaft fracture. Incomplete tibia shaft fractures were determined based on CT imaging and were defined as those fractures with at least one shaft cortex that was completely intact. Our primary outcome measure was deep surgical site infection (SSI), defined as need for re–operation for irrigation and debridement within six months. Our secondary outcome was superficial SSI, defined as need for local wound care and oral antibiotics but no operative intervention. Deep and superficial SSI rate were compared between groups with and without IMN using logistic regression analyses.

What are the results?
There were 200 ballistic tibia shaft fractures that occurred in the 5–year period reviewed. Of these 200 fractures, 39 fractures (20%) were determined to be incomplete fractures. Of the 39 incomplete tibia shaft fractures, 23 patients (59%) were treated with IMN and 16 patients (41%) were treated with splint/cast application after operative debridement of their traumatic ballistics wounds. No patient in either group developed a deep SSI. There were two patients (9%) that developed a superficial SSI in the IMN group compared to 0 patients who did not receive IMN ($p=0.226$). There was no significant difference in demographics or co–morbidities between groups.

What are your conclusions?
For incomplete ballistic tibia shaft fractures that require operative debridement, our study reveals no increased risk of SSI with IMN versus splint/cast application. This is the first study to compare these treatment options in this patient subgroup and offers useful information to help guide surgeon and patient shared decision making.

How Many Operations Does It Take? Incidence and Risk Factors for Secondary Surgery and Amputation after Lower Extremity Limb Salvage with Free Tissue Transfer

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What was the question?
Traumatic defects of the lower extremity (LE) require robust soft tissue to cover critical structures and facilitate healing. Free tissue transfer (FTT) is often necessary when local tissue is inadequate. While much of the literature emphasizes free flap viability in successful limb salvage, there is limited understanding regarding the need for additional surgeries or eventual amputation. We investigated a single institutions limb salvage efforts to better understand the need for additional procedures.

How did you answer the question?
All patients that underwent LE limb salvage were retrospectively reviewed from 2014–2022 at a single level–1 Trauma center. Our primary clinical outcome was the incidence and indication of secondary surgeries following FTT.

What are the results?
92 LE free flaps were performed during the study period. The mean age was 45 and majority were male. 72% of flaps were fasciocutaneous while 28% were muscle flaps. 72% of patients required a secondary surgery following FTT, with a mean of 7 total surgeries per salvage attempt. 10% of patients proceeded to amputation (Table 1). BMI >30, higher frailty scores, flap type, and bone defects treated with masquelet technique were significantly associated with subsequent amputation (Table 2), p= 0.017, p=.024, p=0.005, p=0.04 respectively.

What are your conclusions?
FTT is an important component of limb salvage. Patients undergoing limb salvage should be counseled on the need for secondary surgeries, as the process is often not complete following FTT. Furthermore, risk factors identified in this study may increase the likelihood of subsequent amputation. Thorough preoperative counseling is necessary to optimize the post–operative course and expectations in this population.

Table 1. Amputation Characteristics following Attempted Limb Salvage

Patient #	Indication	Days following free flap	Additional Surgeries Prior to Amputation
1	Preference	14	2
2	Foot ischemia	7	1
3	Osteomyelitis	98	0
4	Painful non-union	598	3
5	Prior free flap failure	52	2
6	Infection	47	1
7	Prior free flap failure	22	3
8	Infection	46	2
9	Infection	125	2

Table 2: Risk Factors for Flap Loss and Subsequent Amputation

Risk Factors	Flap loss	Subsequent Amputation
Age	0.95	0.21
Gender	0.55	0.51
BMI >30	0.07	0.017 **
Flap Type	0.236	0.005 **
Masquelet Technique	0.35	0.04 **
Modified Frailty Index	0.107	0.024 **
Total Secondary Surgeries	0.051 **	0.376

** Indicates $p<0.05$

Gradual Reconstruction Algorithm for Distressed Soft Tissues: The GRADIST Method

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Walter Cerrutti, Roberto C. Hernandez–Irizarry, MD

What was the question?
Are soft tissue injury classification methods useful at the time of defining proper coverage care in skeletal trauma? Soft tissue lesions in the context of skeletal trauma often determine the outcome of fracture care. These lesions have a broad range of variability as they evolve from the critical initial phases of the injury. Most of the existing classification methods focalize only on an itemized description of the injury rather than on the prospective dynamics of the reconstructive process.

How did you answer the question?
We have designed a treatment algorithm to encompass the dynamic aspects of acute soft tissue trauma care. Our method is complementary to other descriptive classifications of both bone and soft tissues. Our objective is to share our experience with the use of the Gradual Reconstructive Algorithm for Distressed Soft Tissues (GRADIST) method. By using this classification and treatment algorithm we were able to better organize and navigate all the variables that encompass soft tissue injury treatment in acute and chronic skeletal trauma care. Once the lesion is initially addressed and stabilized, we classify the injury into 5 colors according to the depth of soft tissue damage and to the layer that needs to be repaired. Blue (Intact) Green [Epidermal deficit]; Yellow [Subepidermal deficit]; Red [Muscular deficit]; Black [Bone deficit]. Our algorithm of care focalizes first on the deepest area of deficit (black) and works it up on the color scale stage to stage towards definitive coverage (blue) . Each color encompasses the utilization of a variety of surgical interventions towards definitive soft tissue coverage. Green: Dermal substitutes or skin grafts. Yellow: Green + Granulation promoting techniques. . Red: Yellow + micro vascularized muscle flaps, Black: Red + Bone reconstruction techniques. Furthermore, each color is assigned into a surgical debridement schedule. Black is debrided every 48 hs, red every 72 hs, yellow every 4 days and green every 6 days. Each patient evolution through the algorithm is recorded allowing us to make comparisons between groups and to better design the resources needed for each given stage of treatment.

What are the results?
163 patients with below the knee skeletal trauma and Tschherne's III soft tissue injuries were included in this protocol from 2010–2022. They were initially classified as 35 green: 22 yellow, 31 red, and 75 as black at the time of their initial injury. The nature of the soft tissue reconstructive method was also assigned by stage: Black injuries were treated by osseous fixation and or reconstructive techniques followed by micro vascularized flap coverage. Red injuries were treated by local rotational flaps, soft tissue promoting membranes, and / or vac sponges. Yellow injuries were treated by granulation promotors and vac sponges, and green injuries were treated with different artificial skin options and definitive split thickness skin grafts. Every case was treated along with infectious diseases and plastic surgery departments. Patients' transition time from one stage to the other was recorded being on average 7 days for black, 10 days for red, 7 days for yellow and 6 days for green stages respectively. Division into stages allowed us to identify dynamic transition patterns. While a dynamic progression was the most common pathway, a static progression in the scale was highly predictive for long term osteomyelitis and or amputation. 5 patients in our series required below the knee amputation.

Gradual Reconstruction Algorithm for Distressed Soft Tissues: The GRADIST Method *continued*

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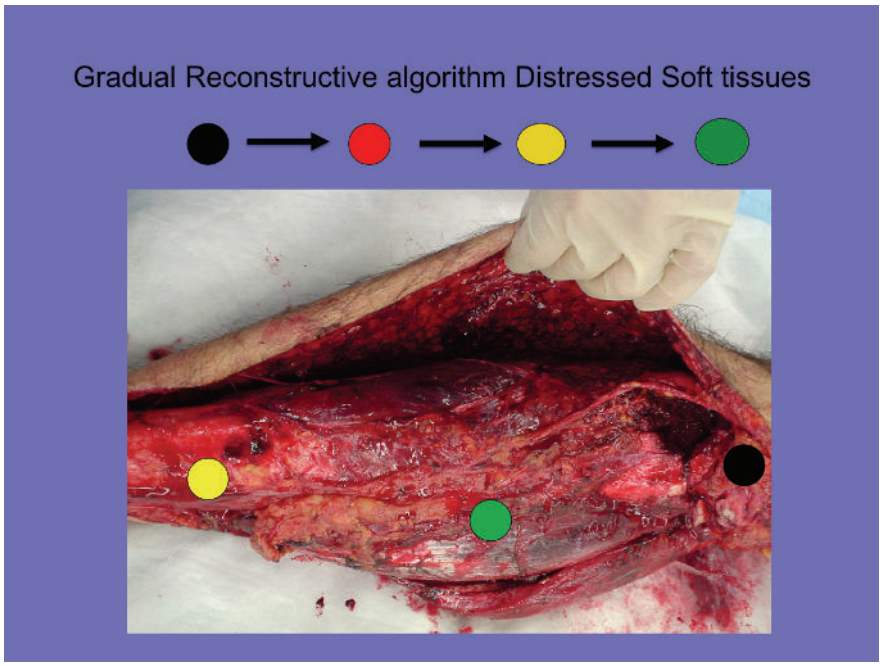
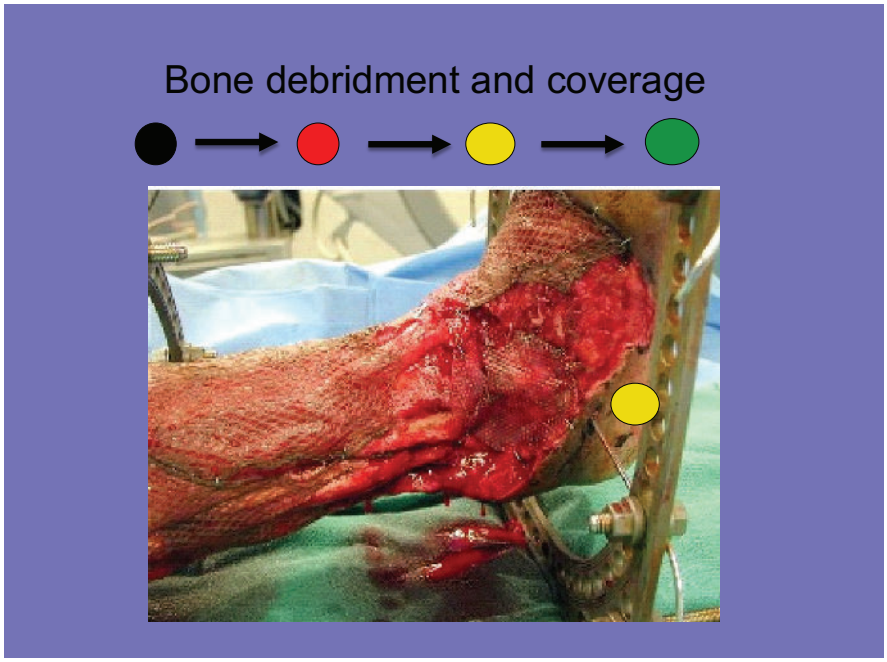
What are your conclusions?
We believe that every soft tissue injury undergoes a dynamic pathway through the treatment process that is difficult to assess and document by using the traditional classification methods. Rather than to replace any classification we believe that our method is complementary to any existing treatment algorithms. It allows for a better organization of the treatment plan, fasting times for anesthesia purposes, IV nutrition management, surgical scheduling, and for an optimal administration of surgical resources towards a successful definitive care.





Evaluating Embolic Load Differences: Medullary Versus Extramedullary Fixation Techniques in Tibia Fracture Surgery

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Roberto C. Hernandez–Irizarry, MD

What was the question?
Embolic marrow emboli generated during surgical fixation of long bone fractures has been associated with serious sequelae. This study aimed to compare embolic load during fixation with intramedullary nailing (IMN) versus open reduction and internal fixation (ORIF) of tibial fractures.

How did you answer the question?
We prospectively enrolled 25 patients with tibia fractures treated surgically at our level–I trauma center: 14 underwent tibial IMN and 11 underwent ORIF. All patients underwent continuous intraoperative TEE. The embolic load was measured based on the proportion of right ventricle volume occupied with emboli and categorized as none, minimal or significant based on the percentage of emboli seen in the echo field. The embolic load was evaluated during 3 distinct stages (ORIF: reduction, provisional, and definitive fixation; IMN: ball tip insertion, reaming, and nail insertion, and at 2 and 5 minutes after final fixation for both groups). Chart review was performed for demographic and perioperative data, and 30–day postoperative complications. The association between embolic load and fixation method was evaluated using chi–squared and regression analyses.

What are the results?
There was no significant difference among patients treated with intra– or extramedullary fixation with regard to basic demographics including age, gender, and perioperative vital signs ($p>0.05$). Significant embolic loads were more frequently detected with intramedullary fixation (64% vs. 9%; $p=0.005$). Patients who underwent ORIF were 94% less likely to record significant intraoperative embolic loads on TEE (OR:0.056, CI:0.005–0.570). Embolic load during TEE was not significantly associated with 30–day postoperative complications (n=2).

What are your conclusions?
Our findings demonstrate increased embolic load with intramedullary fixation of tibia fractures compared to extramedullary fixation methods. No significant clinical manifestations were observed in this investigation and postoperative complications after medullary fixation were infrequent. More research is needed to further characterize the clinical sequelae of embolic load.

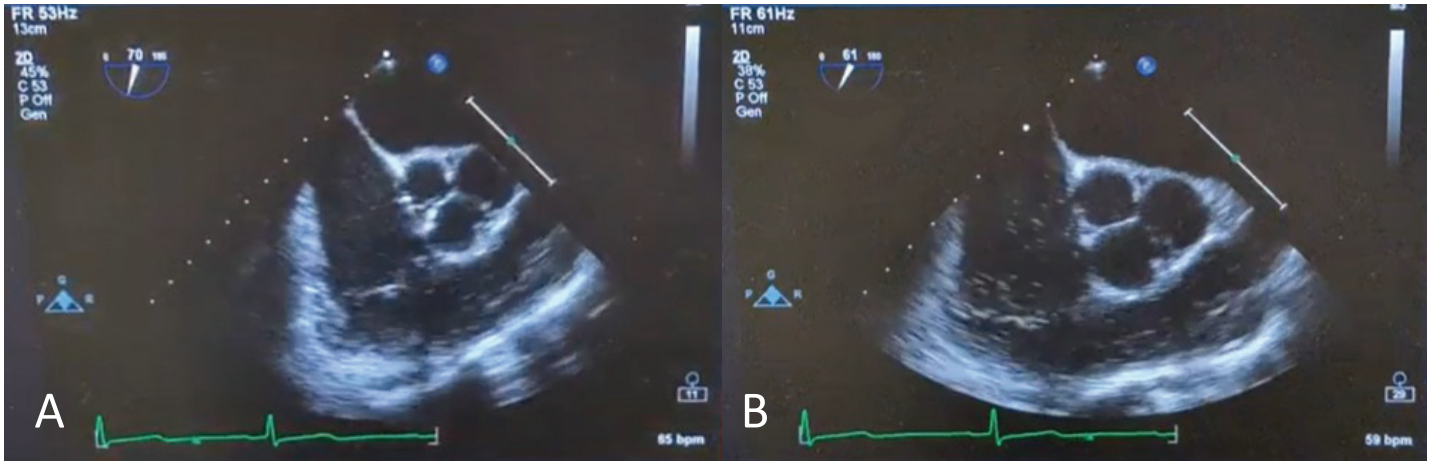

Figure 1: A, TEE mid-eosphageal RV Inflow Outflow Baseline showing no emboli. B, TEE mid-esophageal RV Inflow Outflow showing significant emboli.

Baseline (I)	Reduction (II)	Provisional Fixation (III)	Definitive Fixation (VI)	2 min Post- Fixation (V)	5 min Post- Fixation (VI)
None	None	None	None	None	None
None	None	None	None	Minimal	Minimal
None	Minimal	Minimal	Minimal	Minimal	Minimal
None	None	None	None	None	None
Minimal	N/A	N/A	Minimal	Minimal	Significant
None	None	None	Minimal	None	None
None	Minimal	Minimal	None	None	None
None	None	None	None	None	None
None	Minimal	Minimal	None	Minimal	Minimal
None	None	None	Minimal	Minimal	Minimal
None	None	None	None	None	None

Table 1B: ORIF Embolic Load Data

Baseline (I)	Ball Tip (II)	Reaming (III)	IMN Insertion (VI)	2min post IMN (V)	5 min post IMN (VI)
None	None	None	Minimal	Minimal	Minimal
None	None	Minimal	Significant	Minimal	Minimal
None	Minimal	Minimal	Minimal	None	None
None	Minimal	Significant	Significant	Minimal	None
Minimal	Minimal	Significant	None	None	None
None	Minimal	None	None	None	None
Minimal	Minimal	Significant	Significant	Minimal	Minimal
None	Minimal	Minimal	Significant	Minimal	Minimal
None	None	None	None	None	None
Minimal	Minimal	Minimal	Significant	Minimal	Minimal
None	Minimal	Minimal	Minimal	Signifcant	Minimal
Minimal	Minimal	Significant	Significant	Minimal	Minimal
None	None	None	None	None	None
Minimal	Minimal	Minimal	Minimal	Significant	Minimal

Table 1A: IMN Embolic Load Data

	IMN (N=14)	ORIF (N=11)	Overall (N=25)
Age, yrs, median [range]	35 [18-91]	32 [21-73]	34 [18-91]
Male, n (%)	8 (57.1%)	4 (36.4%)	12 (48%)
CHF, n (%)	1 (7%)	2 (18%)	3 (12%)
COPD, n (%)	0 (0%)	1 (9%)	1 (4%)
Hospital LOS, days, median [range]	3.5 [1-30]	2 [1-5]	3 [1-30]
Other orthopedic injuries, n (%)	2 (14%)	4 (36%)	6 (24%)

Table 2: Patient Demographics

	Medullary Fixation (14)	Extramedullary Fixation (11)	p-value
Age	35 (26-57)	32 (27-61)	0.8
Female	6 (43%)	7 (63)	0.4
End tidal CO2 pre	35 (32-38)	36 (34-38)	0.5
End Tidal CO2 Post	34 (33-34)	38 (33-42)	0.1
Peak Airway Pressure pre	18 (15-21)	20 (15-26)	0.4
Peak Airway Pressure Post	18 (15-20)	20 (16-22)	0.2
Any Embolic Event Detected	12 (86%)	7 (64%)	0.2
Significant Embolic Event Detected	9 (64%)	1 (9%)	0.005

Table 3

Alessandro Codivilla Guest Lecture

"Greeting Comfortable, Being Uncomfortable"

Rakesh Patel, MD, MBA
University of Michigan Health System

Session X: Pediatrics Part 2

Moderator: L. Reid Nichols, MD

Comparing Two Abbreviated Bone Age Assessment Methods to Greulich and Pyle and the Modified Fels Wrist System Using Serial Radiographs

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Neelufar Raja, Raymond W. Liu, MD

What was the question?
Accurate radiographic assessment of bone age is crucial in pediatric orthopaedic surgery. Two abbreviated methods of bone age assessment, the Shorthand Bone Age (SBA) Assessment and SickKids/Columbia (SKC) methods, were recently developed to serve as simpler and more efficient alternatives to the Greulich and Pyle Atlas. The SKC and SBA methods utilize a single radiographic criterion to assign ages. These methods have previously demonstrated substantial agreement with Greulich and Pyle but have not been compared on a serial radiographic collection where performance can be more carefully assessed. To clarify their performance, we compared the two shorthand systems to Greulich and Pyle, as well as the recent modified Fels wrist system, using a serial radiographic collection where heights were known for each subject to judge skeletal maturity.

How did you answer the question?
Three hundred and fifty–four de–identified left hand–wrist radiographs of 42 females (7 to 15 years) and 38 males (9 to 16 years) from the Bolton–Brush Collection were assigned bone ages by two medical students using both abbreviated bone age methods. Inter–rater reliability and intra–rater reliability were evaluated in a collection of 20 radiographs and compared to a faculty member through Spearman's rank correlation coefficient analysis, prior to measuring the full dataset. The inter–rater reliability coefficients ranged from 0.90 – 0.92 for the SBA method and 0.89 – 0.98 for the SKC method. The intra–rater reliability coefficients ranged from 0.87 – 0.92 for the SBA method and 0.854 – 0.92 for the SKC method (p

What are the results?
In both raters, the SBA abbreviated bone age assessment method resulted in a strong, positive correlation with 90% final height (p-value <0.01) using Spearman's rank correlation coefficient analysis and was comparable to Greulich and Pyle and modified Fels wrist, while the SKC shorthand system had lower performance (Tables 1-4).

What are your conclusions?
The Shorthand Bone Age (SBA) Assessment method had high correlation with the 90% Final Height skeletal maturity standard and performed comparably to Greulich and Pyle and modified Fels wrist, while the SickKids/Columbia (SKC) method did not. The relative ease of the SBA shorthand system, in addition to its relative performance, suggests potential utility. Further analysis and follow up clinical study is necessary to delineate the roles of these different systems.

TABLE I: SBA Males Compared to 90% Final Height

	Rater 1 SBA	Rater 2 SBA	mFels Wrist	Greulich and Pyle
r value	0.957	0.960	0.976	0.956
p-value	**	**	**	**

**. Correlation is significant at the 0.01 level (2-tailed).
mFels Wrist = modified Fels wrist system

TABLE II: SBA Females Compared to 90% Final Height

	Rater 1 SBA	Rater 2 SBA	mFels Wrist	Greulich and Pyle
r value	0.919	0.981	0.954	0.985
p-value	**	**	**	**

**. Correlation is significant at the 0.01 level (2-tailed).
mFels Wrist = modified Fels wrist system

TABLE III: SKC Males Compared to 90% Final Height

	Rater 1 SKC	Rater 2 SKC	mFels Wrist	Greulich and Pyle
r value	0.778	0.687	0.979	0.889
p-value	**	**	**	**

**. Correlation is significant at the 0.01 level (2-tailed).
mFels Wrist = modified Fels wrist system

TABLE IV: SKC Females Compared to 90% Final Height

	Rater 1 SKC	Rater 2 SKC	mFels Wrist	Greulich and Pyle
r value	0.856	0.817	0.975	0.944
p-value	**	**	**	**

**. Correlation is significant at the 0.01 level (2-tailed).
mFels Wrist = modified Fels wrist system

Post–Operative Outcomes of the Patellofemoral 360° Procedure for Complex Patellofemoral Instability

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Isabel Herzog, Andrew LoPolito

What was the question?
What are the radiographic, functional, and patient–reported outcomes of the Patellofemoral 360 procedure for complex patellofemoral instability?

How did you answer the question?
This was an IRB–approved retrospective level IV study. Patients who underwent the Patellofemoral 360° (PF360°) procedure — concurrent distal femoral realignment osteotomy (DFO), MPFL reconstruction, tibial tubercle transfer (TTT) osteotomy, and surgical lengthening of the iliotibial band (IT band) — at a single institution performed by two primary surgeons from January 2017 to December 2022 were recorded.
Demographic variables, such as age, sex, body mass index (BMI), comorbidities, and etiology were recorded. Mechanical axis deviation (MAD), lateral distal femoral angle (LDFA), medial proximal tibial angle (MPTA), tibial–tuberosity to trochlear groove distance (TT–TG), femur anteversion, femur valgus, and external tibial torsion were recorded for each limb. Patient recorded outcomes measures (PROMs), consisting of the Limb Deformity Scoliosis Research Society (LD SRS) score, PROMIS, EuroQol, Global Physical Health, and Global Mental Health, were recorded for each patient with both limbs assessed together; values were analyzed using t tests with statistical significance set at $p < 0.05$. The date of final follow–up, date of hardware removal, time to union, subsequent dislocation/subluxation events, final alignment and patellar metrics on x–ray, and final knee range of motion (ROM) were recorded for each limb. Complications including DVT, wound dehiscence, infection, delayed healing, nonunion, patellar dislocation, blood loss requiring transfusion, and nerve injury were recorded.

What are the results?
A total of 28 patients with 44 total limbs met inclusion criteria. 20 (71.4%) patients were female and 8 (28.6%) patients were male. The mean age at the time of surgery was 24.9 years and 12 (42.9%) patients had a history of prior knee surgery. 22 (78.6%) and 6 (21.4%) of patients had a history of patellar dislocation and patellar subluxation, respectively. The most common etiology was congenital (96.4%), followed by syndromic Ehlers–Danlos (3.6%). Among patients with bilateral surgery, the mean length of time between operations was 31.1 weeks. The mean length of time from the operation to hardware removal was 51.0 weeks. The mean time to full weight–bearing was 14.5 weeks.
The mean procedure time was 3.5 hours. The mean valgus deformity was 5.1° and the mean valgus correction was 5.05°. The mean anteversion was 16.7° and the mean internal and external rotational femur corrections were 16.2° and 20.25°, respectively. The mean TT–TG was 17.0. The mean final knee flexion and extension were 118.2° and –0.5°, respectively. The mean preoperative and postoperative LDFA were 85.9° and 90.1°, respectively (mean change = 4.2°). The mean preoperative and postoperative MAD were 16.0 mm lateral and 3.6 mm medial, respectively (mean change = 12.4 mm). Table 1 depicts the mean preoperative and postoperative scores for each PROM, along with the mean change. There were significant improvements in LD–SRS Pain ($p = 0.022$), LD–SRS Self Image/Appearance ($p < 0.001$), LD–SRS Total ($p = 0.007$), PROMIS – Pain Interference ($p = 0.047$), PROMIS – Physical Function ($p = 0.018$), PROMIS – Pain Intensity ($p = 0.002$), Global Physical Health ($p = 0.017$), and Global Mental

Post–Operative Outcomes of the Patellofemoral 360° Procedure for Complex Patellofemoral Instability *continued*

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What are the results? *continued*

Health (p = 0.036). Complications included one case of wound dehiscence and one patient requiring blood transfusion. According to normal postoperative follow–up (60.7% in 2024), there were no recurrences of patellar dislocation following the procedure.

What are your conclusions?
Recurrent patellar instability can be related to various anatomic features, such as valgus alignment, femoral anteversion, increased TT–TG distance, and attrition of the MPFL. In patients who possess several anatomic risk factors, concurrent correction of each pathology may reduce anesthesia time, length of hospital stays, and failure rates compared to separate procedures. External tibial torsion can be corrected through a supramalleolar osteotomy, but this may not directly impact patellofemoral tracking. The PF360° treats these combined issues by addressing them in a 360° arc within a single operation. This retrospective study in a single surgical setting with postoperative clinical follow–up demonstrates reduction in pain and resolution of patellar instability in patients undergoing this procedure.

	LD-SRS Function/ Activity	LD-SRS Pain	LD-SRS Self Image/ Appearance	LD-SRS Mental Health	LD-SRS Total	PROMIS - Pain Interference	PROMIS - Physical Function	PROMIS - Pain Intensity	EuroQol	Global Physical Health	Global Mental Health
Mean Pre-Op Score	3.49	3.66	3.44	3.66	3.56	54.39	41.93	45.56	0.66	43.85	47.04
Mean Post-Op Score	3.77	4.14	4.13	3.64	3.99	49.89	45.69	39.20	0.70	49.95	51.22
Mean Change in Scores	+0.28	+0.48	+0.69	-0.02	+0.43	-4.50	+3.76	-6.36	+0.04	+6.10	+4.18
P-value	0.083	**0.022**	**< 0.001**	0.46	**0.007**	**0.047**	**0.018**	**0.002**	0.11	**0.017**	**0.036**

Analysis of Serial Foot Radiographs to Determine Foot Height Multipliers

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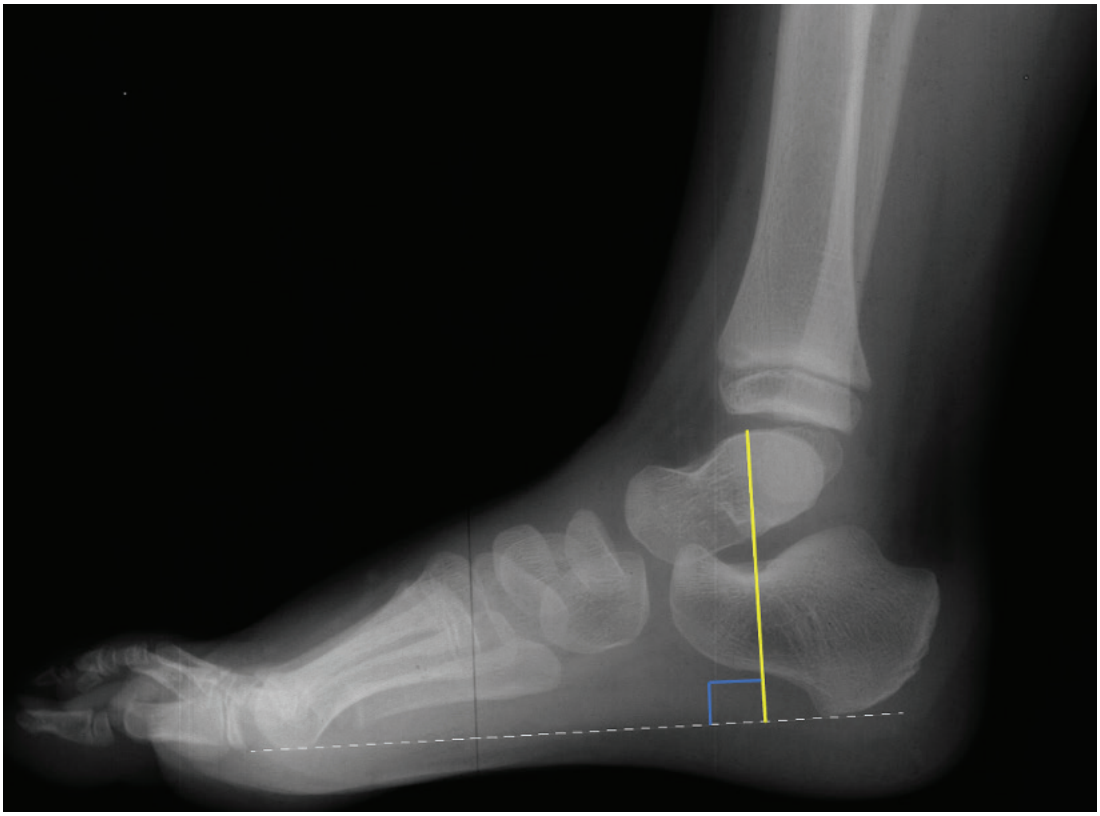
What was the question?
The Multiplier Method is a simple arithmetic calculation that can estimate the amount of growth remaining until skeletal maturity. When predicting lower limb length discrepancy (LLD), differences in foot height are typically added to the femur and tibia discrepancy. Foot height Multipliers have not yet been calculated using radiographic measurements, so it is unclear whether foot height develops at the same pace as the femur and tibia. This study used serial images to calculate foot height Multipliers and compared them to published lower limb and foot length Multipliers.

How did you answer the question?
The Bolton Brush radiograph collection was used to measure foot height on the lateral foot view. Radiographs were excluded if the image quality was poor or if important bony landmarks for foot height measurement, such as the head of the first metatarsal, inferior calcaneus, or superior talus, could not be easily visualized. Foot height was determined by drawing a straight line between the inferior head of the first metatarsal and the inferior calcaneus, and then measuring a line heading perpendicular from the first line to the superior aspect of the talus (Figure 1). Multipliers were calculated for ages where there were at least 10 serial radiographs. 212 patients with 2195 radiographs were included in the study, with 102 female patients (1131 radiographs) and 110 male patients (1064 radiographs). Foot height Multipliers were calculated for ages 0 to 17 years (females) and 0 to 18 years (males).

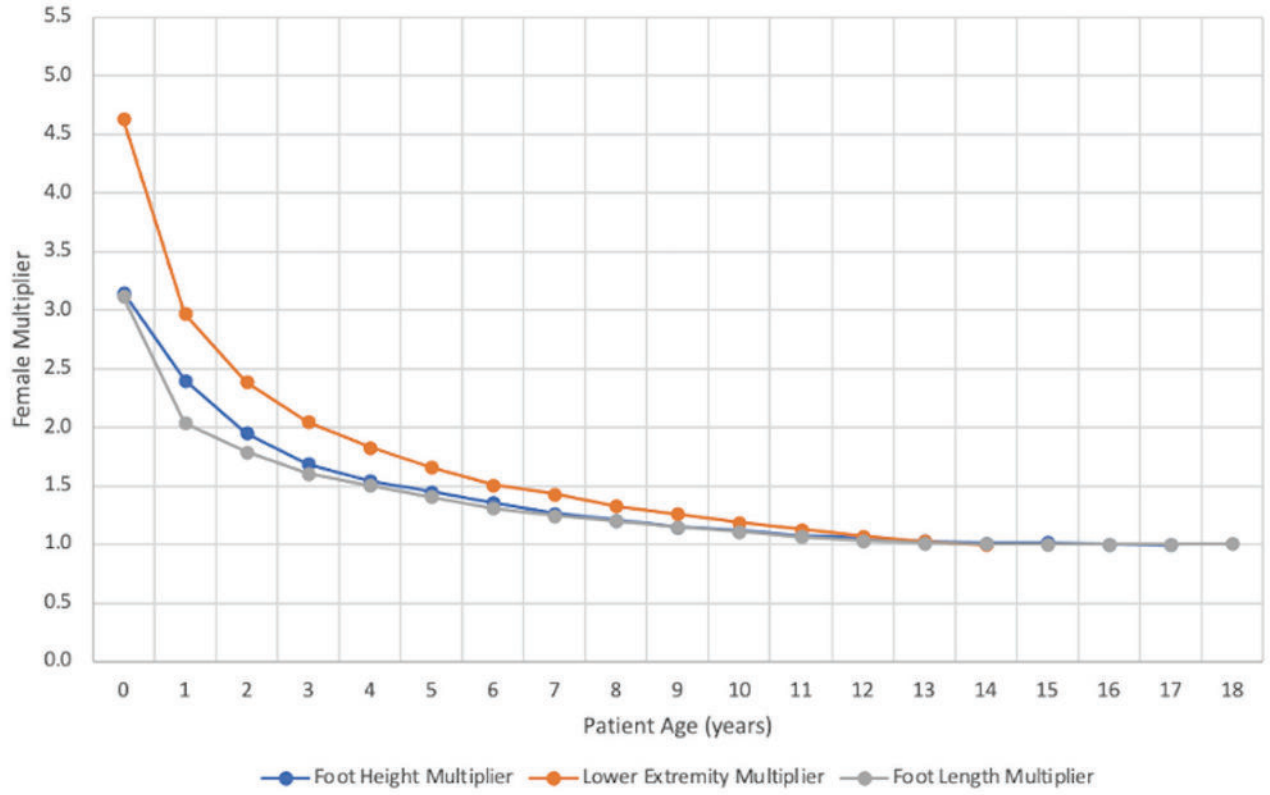
What are the results?
The Multipliers decreased with age in males and females, but qualitatively seem to plateau at age 13 in females and age 15 in males (Table 1). For females and males, lower extremity Multipliers have a more dramatic growth curve, indicating comparatively greater lower extremity growth after birth (Figure 2). However, when comparing a limb length discrepancy calculation using the lower extremity Multiplier versus the foot height Multiplier in a child with congenital femoral deficiency and fibula hemimelia with a total predicted LLD of 145 mm, the difference was 4.5 mm when using the foot height Multiplier.

What are your conclusions?
This paper provides a database of foot height Multipliers. Foot height does seem to grow on a different trajectory than other lower limb components, confirming that one should consider separate Multiplier values. Given the negligible difference created by the foot height Multiplier versus lower extremity Multiplier, separate use of the foot height Multiplier is likely only necessary in young children with large foot height discrepancies.

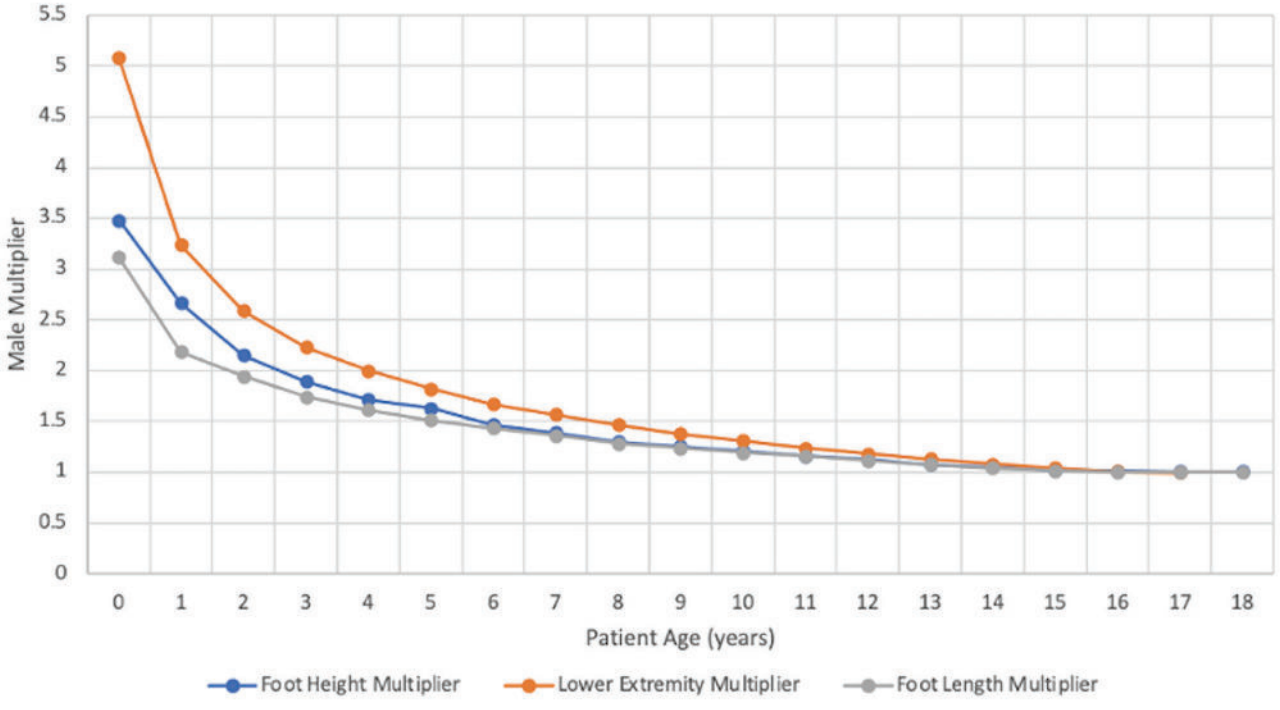


Patient Age (years)	Female Foot Height Multiplier	Male Foot Height Multiplier
0	3.150	3.484
1	2.403	2.669
2	1.951	2.151
3	1.687	1.893
4	1.543	1.716
5	1.450	1.634
6	1.357	1.468
7	1.265	1.388
8	1.208	1.302
9	1.149	1.254
10	1.122	1.210
11	1.075	1.161
12	1.060	1.128
13	1.028	1.078
14	1.016	1.053
15	1.019	1.020
16	1.003	1.013
17	1.000	1.011
18	-	1.007

A)


Female Multiplier
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Patient Age (years)
Foot Height Multiplier
Lower Extremity Multiplier
Foot Length Multiplier

B)


Male Multiplier
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Patient Age (years)
Foot Height Multiplier
Lower Extremity Multiplier
Foot Length Multiplier

Limb Length Discrepancy and Osteogenesis Imperfecta: Preventable or Inevitable?

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Bethany Graulich

What was the question?
Osteogenesis imperfecta (OI), commonly known as brittle bone disease, is a connective tissue disorder characterized by low bone mineral density, various degrees of spine and limb deformities, as well as other manifestations outside of the skeleton. Surgical management is typically reserved for progressive long bone deformities that are impairing function and/or leading to recurrent fractures. The preferred method for fixation is intramedullary rodding. Realigning the long bone deformities typically entails shortening the bone of various amounts, which could result in a limb length discrepancy (LLD). While LLD is commonly reported in individuals with OI, the prevalence and etiology of this discrepancy has not been widely investigated. Given the potential for LLD to worsen functional outcomes, we sought to determine the overall prevalence of LLD in children with OI. In addition, we wanted to understand if LLD changed over time once it was discovered. Lastly, we aimed to ascertain if there were risk factors that influenced LLD in patients with OI.

How did you answer the question?
We studied 78 children with osteogenesis imperfecta who were treated at a large metropolitan children's hospital. Thirty children were managed non–operatively while forty–eight underwent intramedullary rodding of at least one lower extremity long bone. LLD was tracked longitudinally in all patients with use of bilateral patella forward anterior–posterior lower extremity radiographs – all standing in the non–operative, and most were standing post–operatively in the surgical group. Measurements of LLD were standardized to measure the lengths of the femur and tibia only – using horizontal plumb lines from the top of the femoral head, the lateral femoral condyle, and the center of the tibia plafond as landmarks. Patients included had a minimum of two years of longitudinal growth data in the non–operative group, while the surgical group also had a minimum of two years of longitudinal growth data, and a minimum of 18 months follow–up in the post–operative period. LLD was defined as a difference in limb lengths (femur + tibia) of > 5 millimeters.

What are the results?
LLD was present in 90% of individuals from the non–operative group and in 96% of individuals in the operative group. There was no association between LLD in either group with bisphosphonates, ambulation status, or OI type. In the surgical group, there was no association with LLD and the number of rods inserted. In both surgical and non–operative groups, there was no specific growth patterns identified. Some patients' LLD stayed the same, in some the LLD changed where the opposite limb became longer over time, some progressively worsened, and some improved. (Figures 1–2)

What are your conclusions?
Overall, the prevalence of LLD in OI is > 90% in all severities. The change of LLD over time in OI does not follow any typical growth pattern as classically described by Shapiro. The change of LLD over time is likely dependent on a large number of variables – such as macro or micro fractures, rod bending, changes in bone quality, etc – which investigation of these variables are outside the scope of this study. Lastly, the study does demonstrate that LLD in children with OI is not always iatrogenic from surgery, and that they have the potential to self–correct over time.

Figure 1: LLD trend over time per patient in the non-op group

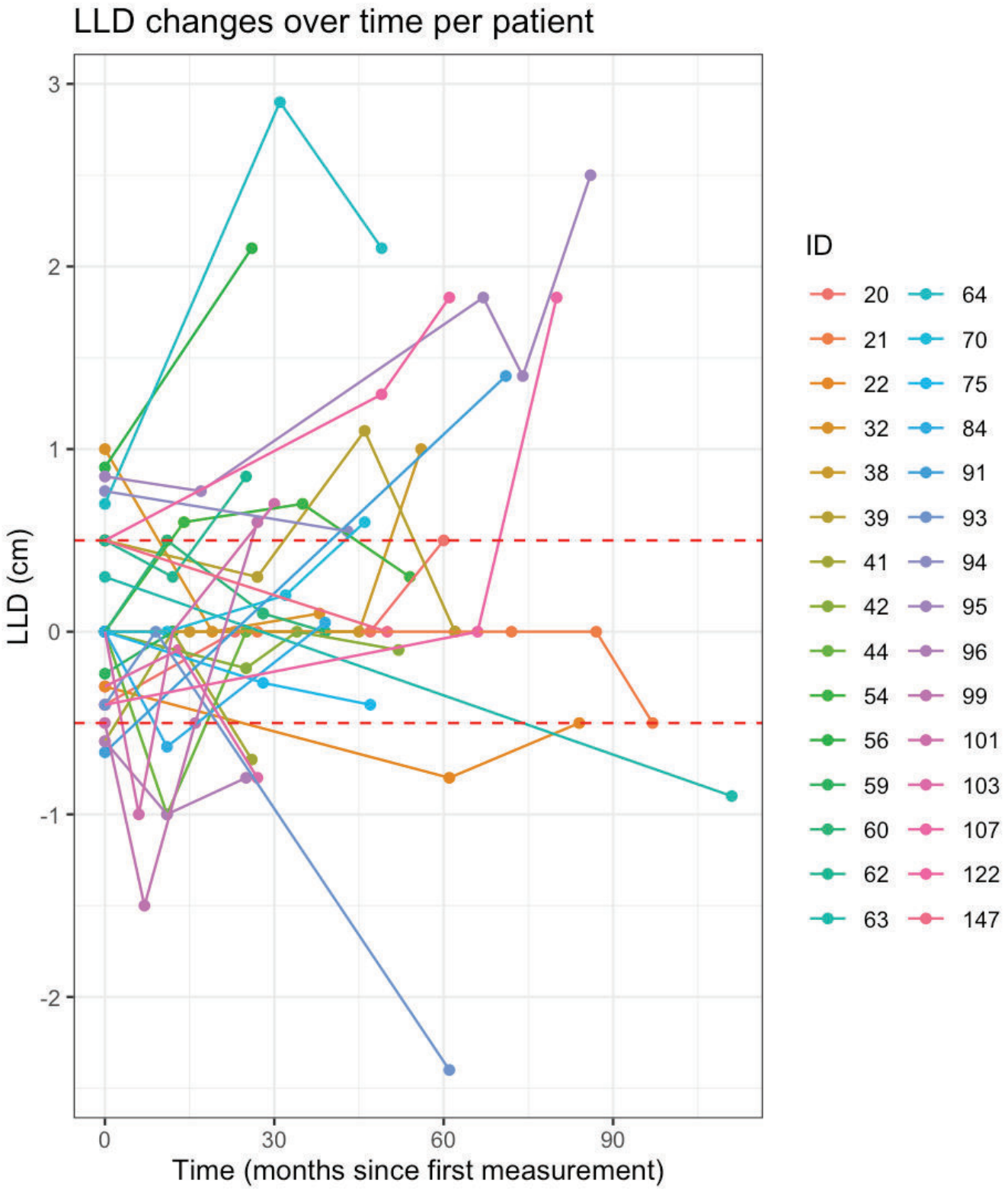


Figure 2A: LLD trend over time per patient in the surgical group

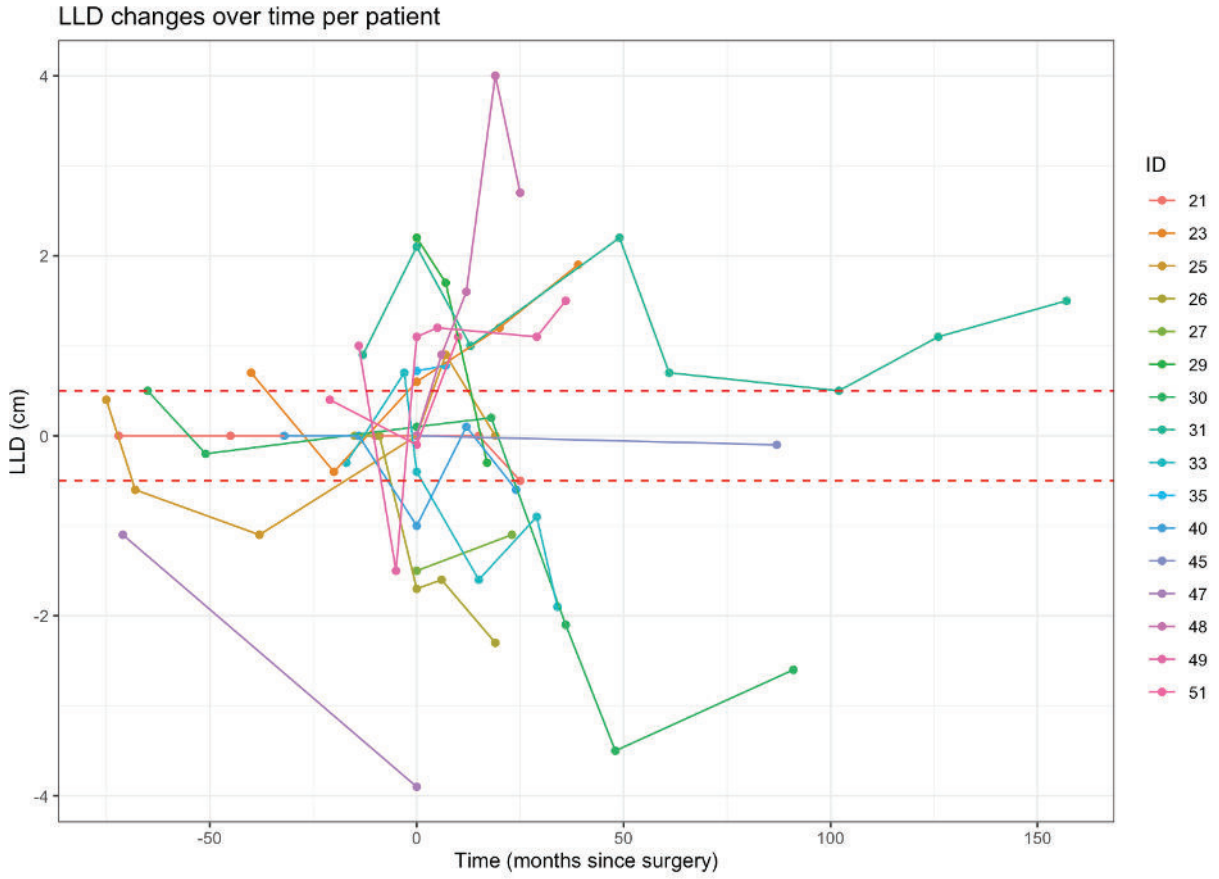


Figure 2B: LLD trend over time per patient in the surgical group

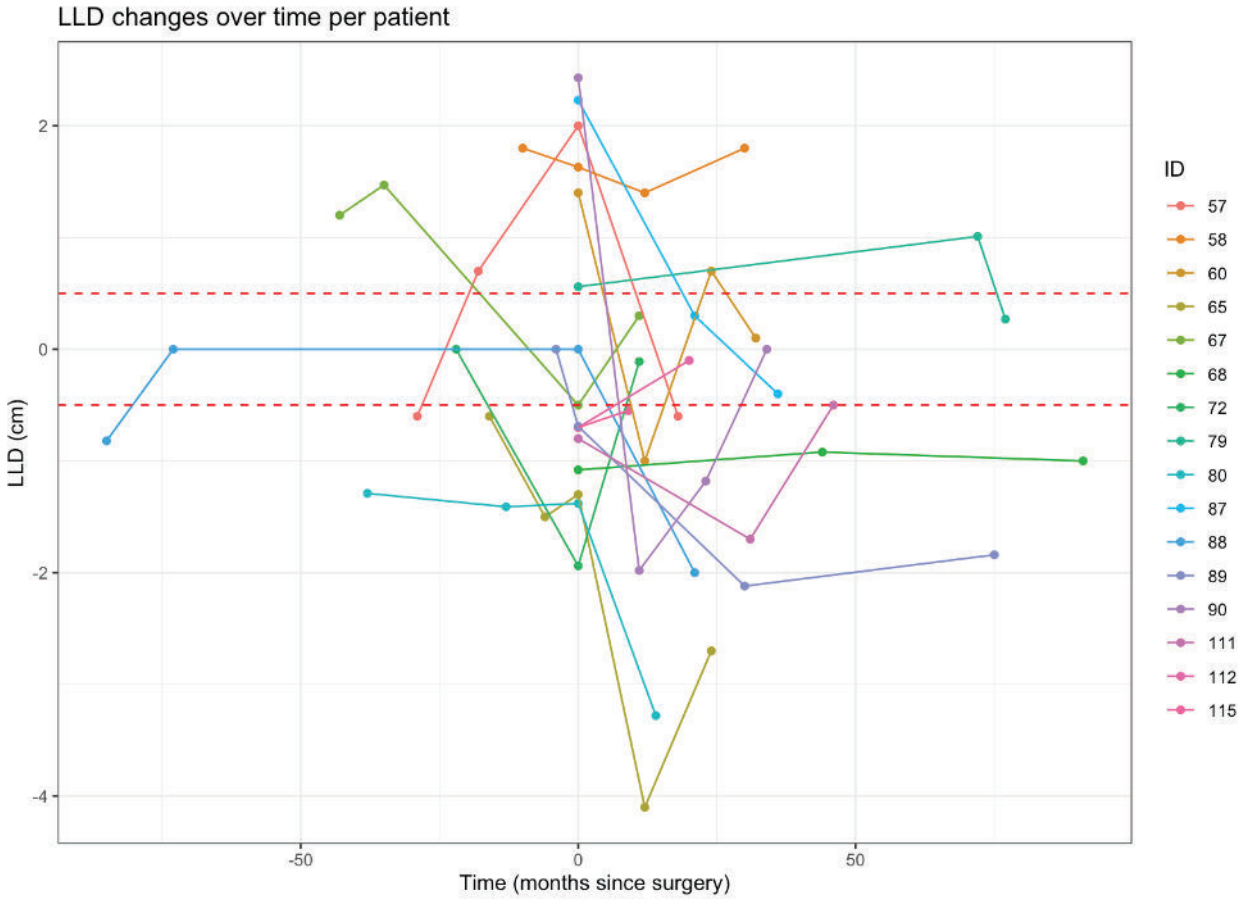
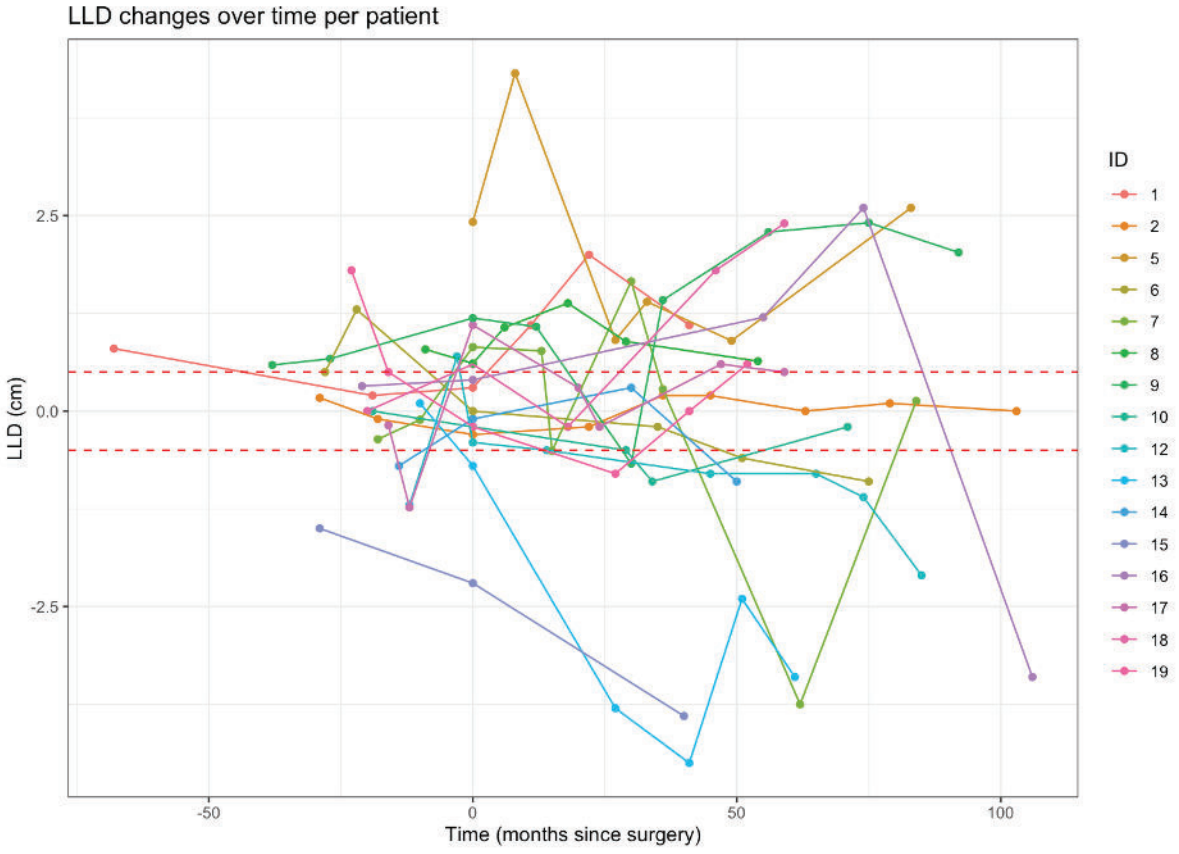


Figure 2C: LLD trend over time per patient in the surgical group



Session XI: Osseointegration Part 2

Moderator: Jason Stoneback, MD

Periprosthetic Fracture Management in Patients with Transfemoral Osseointegration

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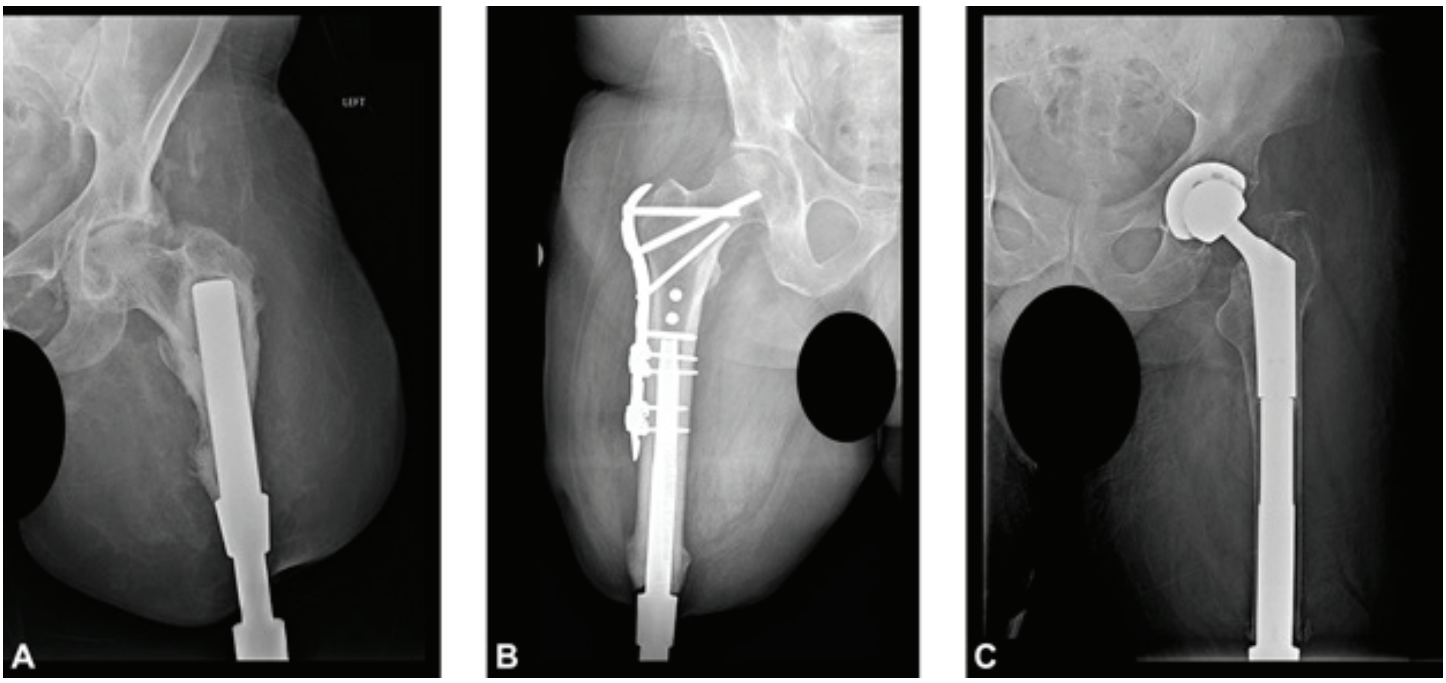
What was the question?
Transcutaneous osseointegration for amputees (TOFA) substantially improves both subjective and objective measures of quality of life (QOL) and mobility. However, one potential adverse event is periprosthetic femur fracture (PPFF). Existing literature exclusively reports open reduction internal fixation (ORIF) management for PPFF. What is the incidence of fracture? What is the utility of ORIF and two other previously unreported techniques: non–operative restricted weight bearing and coupled total hip arthroplasty?

How did you answer the question?
A retrospective review identified 126 press–fit osseointegration procedures (71 femur and 55 tibia) with at least six months of follow–up, of which seven patients sustained PPFF. No other limb segments (e.g. tibia) had periprosthetic fracture. Chart reviews identified the mechanism of injury, fracture management strategies, and time to full weight bearing ambulation. Factors such as age, sex, body mass index, laterality, amputation etiology, time from amputation to osseointegration, and implant dimensions were evaluated for their potential influence on periprosthetic fracture risks.

What are the results?
Seven patients (aged 25 to 58 years) sustained eight fractures (6.3% of all osseointegration procedures), exclusively in the femur (11.3% of femur–level implants: three in the femoral neck, one intertrochanteric, and four subtrochanteric). One patient sustained two fractures, two years apart. All index fractures occurred within the first year post–osseointegration, with six resulting from ground–level falls and two from other low–energy impacts; none were unprovoked. All fractures were located within 3.5 cm of the proximal tip of the osseointegration implant. Two of the fractures were managed nonoperatively with 6–9 weeks of non–weight–bearing followed by progressive loading. Five underwent open reduction and internal fixation using a reconstruction plate: these patients achieved full weight–bearing ambulation 12–16 weeks post–injury. One of the femoral neck fractures, initially managed with cannulated screws, was subsequently converted to a custom coupled total hip arthroplasty due to nonunion. None of the osseointegration implants were loose or were removed. Regression analysis did not reveal a significant association between the aforementioned potential risk factors and PPFF.

What are your conclusions?
Periprosthetic TOFA fractures only occurred in femur amputees, at a rate of 11.3%, only upon a specific injury mechanism. No implants loosened or were removed. Both restricted weight bearing and ORIF achieved resumption of full weight bearing in a reasonable time. Coupled arthroplasty appears appropriate when necessary. Indications for the optimal management strategy remain unclear and require additional focused investigation. No risk factors are recognized as significantly predictive of PPFF.


A
B
C

Transfemoral Osseointegration for patients with Amputation to manage Infected Total Knee Arthroplasty

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LaYow C. Yu, S. Robert Rozbruch, MD; Taylor J. Reif, MD;
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What was the question?
Press–fit osseointegration (PFOI) with a solid core implant is a rehabilitation alternative to socket prostheses for amputees. One of the most concerning adverse events is infection. For patients who have had transfemoral amputation to manage infected total knee arthroplasty (iTKA), there may be concern related to inserting a new metal implant into a limb with a history of infection. To investigate that concern, this study evaluated the occurrence of PFOI–related adverse events and their subsequent treatment in a cohort with patients with prior amputation due to iTKA.

How did you answer the question?
All patients who had osseointegration were evaluated for study inclusion if they had an amputation due to an iTKA as documented in history, or upon phone call inquiry. Patients were assessed for adverse PFOI–related events. Mobility data (k–levels) was also reported.

What are the results?
A total of 9 patients were evaluated. After TFOI, 2 patients experienced suspected infections, both of which were successfully treated with a 10–day course of oral doxycycline. No surgical interventions were performed, no implants were removed, no systemic complications occurred, no patients died. The average follow–up time after PFOI was 1.9±4.5 years (0.5–6.4 years).

What are your conclusions?
Previous PJI in an amputated limb does not present an apparent imminent threat of adverse events to PFOI. Presumptively, a limb that has been contaminated by prosthetic joint infection may have some increased risk of future infection. However, that risk has yet to prove meaningfully consequential. Patients with prior iTKA–related amputation likely should be counseled that they may have some increased risk of adverse events, but it currently seems reasonable to consider PFOI for them if they are struggling to achieve satisfactory mobility.

Transcutaneous Osseointegration in Patients with Diabetes Mellitus and/or Peripheral Vascular Disease: A Case Series of 5 Patients with Minimum 3–Year Follow–Up

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What was the question?
Press–fit osseointegration (PFOI) for amputees has demonstrated substantial evidence of improving mobility and quality of life for patients dissatisfied with socket prosthesis rehabilitation. Traditionally, patients with diabetes mellitus (DM) and/or peripheral vascular disease (PVD) have been considered unsafe for PFOI, given the potential risk for infection in potentially frail hosts. The primary aim of this investigation was to challenge that assumption by evaluating the safety of PFOI for patients with DM and/or PVD.

How did you answer the question?
Retrospective chart review was performed of our prospectively maintained osseointegration registry. Patients were included if they underwent PFOI of any lower limb segment, had a diagnosis of DM (any type) and/or PVD, and were at least three years post–PFOI. The primary outcome was adverse events prompting surgery. Secondary outcomes included changes in mobility (K–level, walking aids) and quality of life surveys (PROMIS Physical and Mental Health, LD–SRS Composite Score).

What are the results?
Five patients (4 men and 1 woman, aged 56.8± 6.8 years) were evaluated with follow–up time of 4.1±0.3 (3.6–4.3) years. One patient had non–insulin–dependent DM (NIDDM), three patients had PVD, and one patient had both NIDDM and PVD.

Regarding the primary aim of postoperative complications. No patients experienced implant loosening, periprosthetic fracture, procedure–related systemic complications, or died. Following PFOI, three patients received additional surgical intervention. One patient had osteomyelitis prompting debridement at 9 months post–PFOI. Two patients had refashioning to reduce redundant skin around the portal site at 4 years post–PFOI.

Before PFOI, the five patient K–levels were 0, 1, 2, 2, 3. All patients advanced their K–levels by at least one, to 1, 4, 3, 3, 4, respectively. Of the four patients who ambulated prior to PFOI, 3 used a walking aid; following PFOI, all patients ambulated and 1 used a walking aid.

4 patients had both pre–and post–operative surveys. All improved from baseline: PROMIS Global Physical Health (33.34 ± 2.94 vs 47.58 ± 7.60, p= 0.037) , PROMIS Global Mental Health (37.12 ± 6.48 vs 48.97 ± 5.08, p = 0.012), and LD–SRS Composite Scores from (2.48 ± 0.2 to 3.52 ± 0.56 (p = 0.022) at the most recent follow–up.

What are your conclusions?
PFOI appears safe to consider for patients with NIDDM and/or PVD. Only one patient had an adverse event (infection) prompting debridement. The two refashionings were not infected, and may have been avoidable with more aggressive tissue reduction at index surgery. No deaths or systemic complications occurred. Mobility improved dramatically, and quality of life measures improved significantly. Thus, it seems reasonable to consider PFOI for appropriately selected patients with NIDDM and/or PVD.

MRI is Safe for Amputees with Titanium Press–Fit Osseointegration

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What was the question?
Titanium press–fit osseointegration implants (PFOI) are a rehabilitation alternative to socket prostheses. Some patients may need magnetic resonance imaging (MRI) to evaluate local or distant anatomy for related or unrelated health concerns. Some clinicians and technicians may have concerns regarding the safety of these implants in an MRI suite. This seminal investigation of the safety of PFOI MRI evaluated whether any adverse events occurred for patients (pain, heating sensation, implant loosening, delay of care) or for the MRI machine (device damage).

How did you answer the question?
Patients who had PFOI surgery underwent retrospective chart review and were also contacted inquiring whether they had subsequent MRI to any body part. 34 patients had 51 total MRIs: 24 of the osseointegrated limb and 27 of other anatomy. All were asked if any adverse experiences such as pain, heating sensation, or implant loosening occurred. All original MRI imaging and reports were sought to evaluate for evidence of adverse patient or machine events.

What are the results?
No patients had any recognizable adverse event associated with MRI, including specifically pain, heating sensation, or implant loosening. No evidence of adverse machine interaction could be identified.

What are your conclusions?
MRI is safe for patients with titanium press–fit osseointegration implants. To optimally ensure safety, osseointegrated patients seeking MRI should confirm with their implant company that no non–titanium components might be part of their total prosthesis construct, and confirm they have no after–market modifications that may be ferromagnetic, such as screws or clamps.

Session XII: Adult Limb Deformity Part 2

Moderator: Kevin Tetsworth, MD

Frontal Plane Knee Motion Following Surgical Correction of Genu Valgum

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What was the question?
What are the differences in gait kinematics, kinetics and radiographic alignment in individuals with bilateral genu valgum following surgical correction with distal femoral osteotomy?

How did you answer the question?
This is a prospective IRB approved study of 6 individuals (5F, 170cm, 82kg, 23-41 y/o) with a diagnosis of painful bilateral knee valgus who underwent surgical correction with internal fixation. Subjects underwent gait analysis while walking barefoot at a self-selected speed over level ground pre- and post-op. The average follow-up period was 480 days. A 3D lower extremity model was built and knee frontal plane kinematics and external kinetics during the stance phase of gait were calculated (Orthotrak) for a minimum of 5 trials. 11 limbs were included in the analysis and changes in gait patterns were assessed using peak Knee Valgus Angle (KValA), 1st peak Knee Varus Moment (KVarM), 2nd peak KVarM, and KVarM impulse during stance. To standardize the point in the gait cycle, the 1st and 2nd Peak KVarM in both pre- and post-op curves were assessed at the % of stance that KVarM occurred on the post-op curve. Radiographic analysis included the assessment of Mechanical Axis Deviation (MAD) and Lateral Distal Femoral Angle (LDFA). Pre-post variables were compared using paired t-test. The post-op KVarM was compared to a matched set of previously collected control values (n=11individuals) using one-dimensional Statistical Parametric Mapping (SPM) [4]. Statistical significance was set at p

What are the results?
All biomechanical and radiographic outcomes significantly improved (Table 1). Preoperatively, KVarM differed from control for >98% of stance, compared to postoperatively where KVarM was within control values for 90% of stance (Figure 1).

What are your conclusions?
The distal femoral osteotomy surgery was successful in re-aligning the knee as shown by the improved radiographic measures and reduced knee valgus in walking. While an increase in varus moment was observed, this correction resulted in moments that were within the range of healthy controls as shown with SPM. The surgical correction successfully eliminated the pre-op negative moments and impulses, which would have negatively impacted the lateral compartment of the knee. This data shows the relationship between structure and function as surgically improved bone structure improved gait.

Table 1: Knee frontal plane kinematics and kinetics during stance and radiographic measures.

	Peak KValA (deg)	1st Peak KVarM (Nm/kg)	2nd Peak KVarM (Nm/kg)	KVarM Impulse (Nm·s/kg)	MAD* (mm)	LDFA (deg)
Pre-op	11.5 ± 4.5	0.01 ±0.09	-0.03 ± 0.13	-2.2 ± 4.6	-29.5 ± 13.7	81.3 ±4.3
Post-op	1.9 ± 2.8	0.32 ± 0.07	0.32 ± 0.10	13.2 ± 3.4	-0.2 ± 6.4	89.7 ±1.8
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

*negative values represent a lateral deviation

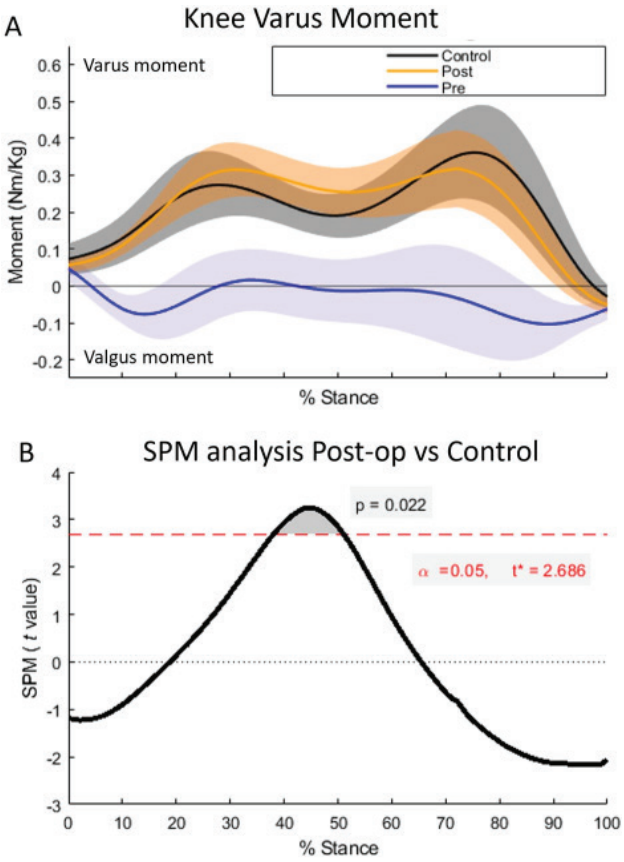

Figure 1. A. External knee varus moment for pre- op(blue), post-op(orange), and controls(black). **B**. SPM analysis comparing post-op to control values. The shaded area represents the stance phase during which the difference occurred.

Chatbots in Limb Lengthening and Reconstruction Surgery. How Accurate are the Responses?

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What was the question?
In the last decade, internet search engines and online platforms have been a resource for patients, providing answers to questions relating to healthcare. In pediatric orthopedics, studies have shown that a significant percentage of parents use online search engines to find out more about the health condition of their children. The recent introduction of Chatbots has provided an interactive medium to answer patient questions. The accuracy of responses with these programs in limb lengthening and reconstruction surgery has not previously been determined. Therefore, the purpose of this study was to assess the accuracy of answers from 3 free AI chatbot platforms to 23 common questions regarding treatment for limb lengthening and reconstruction.

How did you answer the question?
We generated a list of 23 common questions asked by parents before their child's limb lengthening and reconstruction surgery. Each question was posed to three different AI chatbots (ChatGPT 3.5 [OpenAI], Google Bard, and Microsoft Copilot [Bing!]) by three different answer retrievers on separate computers between November 17 and November 18, 2023. Responses were only asked one time to each chatbot by each answer retriever. Nine answers (3 answer retrievers x 3 chatbots) were randomized and platform-blinded prior to rating by three orthopedic surgeons. The 4-point rating system reported by Mika et al. was used to grade all responses.

What are the results?
ChatGPT had the best response accuracy score (RAS) with a mean score of 1.73 ± 0.88 across all three raters (range of means for all three raters – 1.62 – 1.81) and a median score of 2. The mean response accuracy scores for Google Bard and Microsoft Copilot were 2.32 ± 0.97 and 3.14 ± 0.82, respectively. This ranged from 2.10 – 2.48 and 2.86 – 3.54 for Google Bard and Microsoft Copilot, respectively. The differences between the mean RAS scores were statistically significant ($p < 0.0001$). The median scores for Google Bard and Microsoft Copilot were 2 and 3, respectively.

What are your conclusions?
Using the Response Accuracy Score, the responses from ChatGPT were determined to be satisfactory, requiring minimal clarification, while the responses from Microsoft Copilot were either satisfactory, requiring moderate clarification, or unsatisfactory, requiring substantial clarification.

Acute Pelvic Support Osteotomy in Patients Over 70 Years of Age in Failed Hip Arthroplasties

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What was the question?
Currently there are multiple patients over 70 years of age who have undergone several joint replacements, in a percentage greater than 25% with revisions and final treatment failure, with multiple causes. revisions were identified and it was determined that the number one cause of failure was aseptic loosening (40%), followed by instability (32%) and infection (28%). Obesity also has a significant percentage of patients. The question is what to do when a hip replacement revision can no longer be performed due to repeated infection, lack of bone stock or a very obese patient NOT a candidate for surgery, over 70 years of age, some not candidates for external fixation? The purpose of this study is to show the pelvic support technique as a possible option in the treatment of failed Arthroplasties, with some variations to the technique due to elderly patients, with comorbidities such as obesity and some not candidates for the application of external tutors.

How did you answer the question?
16 patients over 70 years of age (70 to 89 years), average age 78 years, with failed THR, not candidates for a new revision, were included in the study. A percentage of 75% with failed replacement and associated infection. They undergo surgery for total control of the infection, debridement and bone stabilization either with a temporary external fixation system for 4 months or immediate stability with premolded LCP (Locking Compression Plate) systems to provide valguization of the proximal segment of the femur and alignment. of the mechanical axis with a distal compensatory osteotomy, immediately improving the mechanical load on the hip and distributing the reactive force of the support throughout the pelvis, allowing a functional gait, without pain and with sufficient stability to carry out your activities of daily living, significantly improving their quality of life and independence. 40% of patients receive immediate pelvic support, with LCP plates, without bone lengthening due to their general condition, with a residual discrepancy between 4 to 7cm in length, solving this with a lift in the shoe to allow safe movement with walker A monolateral bone lengthening system is applied to 60%, for an average of 4 months where bone lengthening is performed by distraction osteogenesis in the distal osteotomy and compression in the proximal valgus osteotomy, at the end of the distraction period in an average lengthening of 55mm, we wait a month for the inflammatory period of the tissues to decrease and an early replacement to the LCP system is performed. Allowing early removal of the external fixator. The result of the procedure is validated based on the analog pain scale, on the ability to move in its normal environment, assisted movement with a walker, on the perception of independence for normal activities, on the simple perception of improved quality of life. before and after the procedure.

What are the results?
Positive cultures were obtained in 45% of the patients; they were treated with the comprehensive intramedullary bone infection protocol.
86% abandoned the use of a wheelchair or bed rest prior to treatment. 60% move with a walker for safety, 30% use a cane as an element of stability and safety and 10% can walk at home without external help. The improvement in pain was one of the most significant findings of the treatment with a positive improvement in 96% of the patients, with an initial average pain perception of 7 out of 10 to an average improvement of 3 out of 10, 25%. They report no pain, just some occasional discomfort. The parameter in improvement of quality of life with a 100% positive variation, based on personal and family perception.

Acute Pelvic Support Osteotomy in Patients Over 70 Years of Age in Failed Hip Arthroplasties *continued*

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What are your conclusions?

Pelvic support osteotomy is a surgery that can change the final outcomes in patients with failed hip joint replacements, it significantly changes the quality of life, functional independence and mobility in patients over 70 years of age, allowing these patients to return to their daily life with some limitations but making the end of your life easier.

It is a demanding technique, requiring training in surgical tactics to achieve a biomechanical and stability result that truly allows safe support, a distribution of the load throughout the pelvis and thus allows the movement of patients. There are some important variations to the traditional technique as in many cases there is no functional greater trochanter or gluteal muscles that can be recovered, this is why it is important to use a proximal anchoring suture that avoids inappropriate movements, while scarring and fibrosis contain the proximal segment. Additionally, the longer the proximal valgus segment, the greater the load distribution area, which will allow greater comfort and safety with the patient's weight support. The tactic of early replacement of external tutor to plates is used to avoid skin complications or failure of the external fixation system or infection due to the age of the patients.

This surgery may be a better option for patients NOT candidates for revision of failed joint replacements, better than a Girleston or an amputation secondary to untreated chronic infections in failed and infected THR. It is suggested to teach and implement this technique in extremity reconstructive surgery centers, to have a greater number of patients that will allow the indications and results obtained in this study to be validated. Every day the challenges in patients with hip surgeries are greater, life expectancy increases in advanced countries and it will be a successful alternative to the extent that a detailed technique is applied that adheres to all the principles of surgical tactics.

Evaluation of How to Determine if a Lateral Ankle View is Acceptable Using Rotated X-rays Generated from CT Scan 3D Models

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Beatriz Feijo, Raymond W. Liu, MD

What was the question?
Proper positioning of X-rays is important when analyzing limb deformity. It can be challenging to judge the quality of a lateral view of the ankle, and while various parameters for this have been published it is difficult to know how to interpret them clinically. We therefore asked how does rotational positioning of the ankle affects the quality of lateral ankle radiographs, and which parameters best demonstrate the degree of rotation.

How did you answer the question?
We performed a retrospective study using normal CT scans from our PACS system to create 3D simulated X-ray images. We started by aligning the 3D reconstruction into the "perfect" lateral position, based on the overlap of the talar dome, and then simulated an x-ray in this position. We measured the tibial width (TW), fibular width (FW), anterior tibiofibular interval (ATFI), and posterior tibiofibular interval (PTFI), and calculated ratios between these. We then rotated the 3D reconstruction in 5-degree intervals up to 15 degrees of both internal and external rotation, created simulated x-rays in these different positions, and measured the above parameters at each rotation interval (Figure 1). We defined ranges for each ratio based on half the mean difference between 5-degree rotational positions to assess how effectively different parameter ratios functioned for assessing a lateral view. This allowed us to determine the percent concentration of values that fit within each range, which represents how often one would be able to determine an image's rotational position within 5 degrees. We then repeated this analysis with 10 and 15 degrees.

What are the results?
A total of 57 patient CT scans were evaluated and 399 simulated x-rays were included in the analysis. PTFI:TW and ATFI:TW ratios were found to be the most sensitive to rotational changes (both r=.97). We calculated what percentage of radiographs fell within each rotational interval when dividing the results into 5, 10, and 15-degree intervals, and found PTFI:TW to have the highest concentration of values (Table 1). When the intervals were at 15 degrees PTFI:TW had 79-86% of patients within each range.

What are your conclusions?
PTFI:TW and ATFI:TW ratios are sensitive to rotational changes and can be used to assess whether lateral ankle radiographs are in proper rotational alignment. Using this approach, one can confidently say that an image is within 15 degrees of a perfect lateral if it falls within the normative range.

Figure and Table:

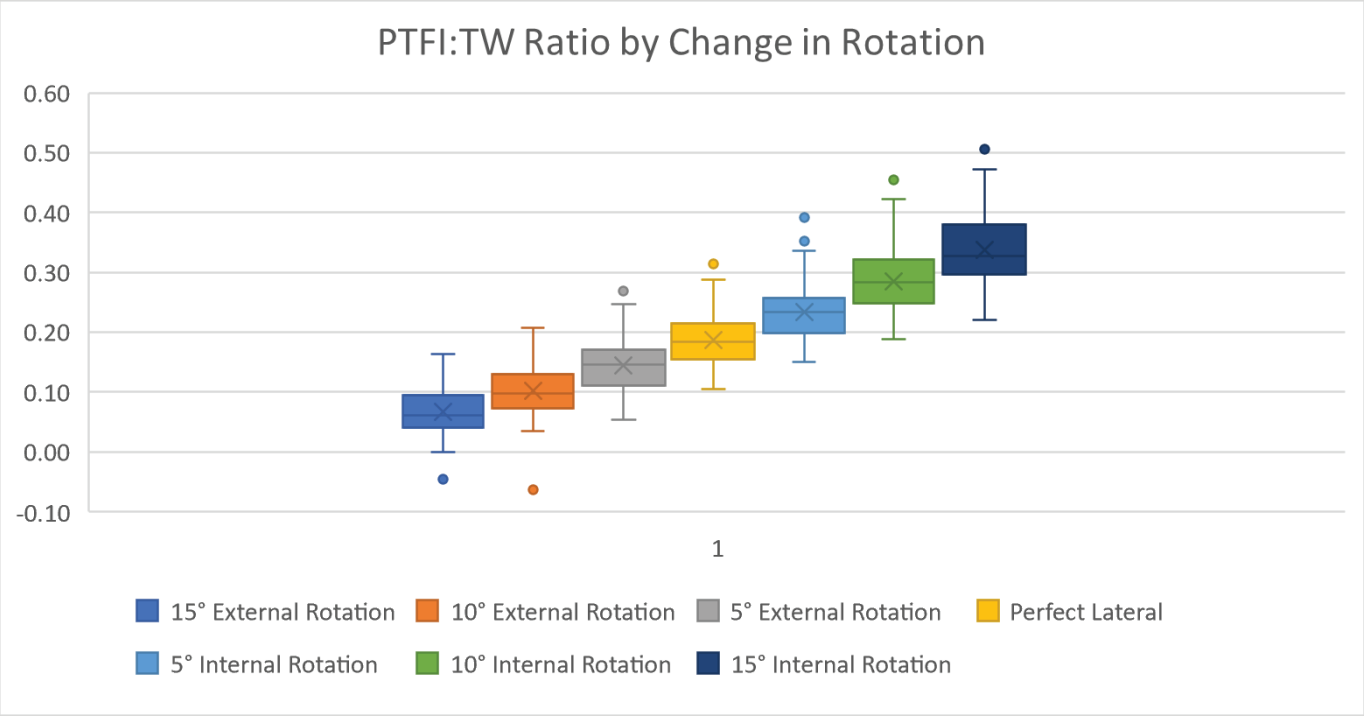

Figure 1. PTFI:FW ratios of perfect lateral, 5, 10, and 15 internal and external rotations of CT-based simulated X-rays. Ratios increase linearly from the most external to the most internal rotation.

Table 1: Percentage of radiographs within each rotational interval.

	5 Degree Rotation Range								10 Degree Rotation Range								15 Degree Rotation Range							
	ATFI:TW		PTFI:TW		PTFI:(PTFI+FW)		ATFI:(ATFI+FW)		ATFI:TW		PTFI:TW		PTFI:(PTFI+FW)		ATFI:(ATFI+FW)		ATFI:TW		PTFI:TW		PTFI:(PTFI+FW)		ATFI:(ATFI+FW)	
Rotation	Range of Values	Percent in Range	Range of Values	Percent in Range	Range of Values	Percent in Range	Range of Values	Percent in Range	Range of Values	Percent in Range	Range of Values	Percent in Range	Range of Values	Percent in Range	Range of Values	Percent in Range	Range of Values	Percent in Range	Range of Values	Percent in Range	Range of Values	Percent in Range	Range of Values	Percent in Range
15° Internal Rotation	(.18-.219)	23	(.315-.365)	30	(.395-.445)	33	(.27-.309)	14									(.13-.269)	74	(.265-.415)	86	(.35-.49)	81	(.23-.349)	53
10° Internal Rotation	(.22-.2649)	26	(.26-.3149)	35	(.35-.3949)	23	(.31-.349)	18	(.19-.289)	60	(.24-.34)	68	(.325-.415)	56	(.29-.369)	40								
5° Internal Rotation	(.265-.3149)	28	(.21-.259)	40	(.305-.349)	25	(.35-.389)	18																
Perfect Lateral	(.315-.359)	32	(.17-.209)	35	(.255-.3049)	25	(.39-.429)	18	(.29-.3849)	58	(.15-.239)	65	(.23-.3249)	58	(.37-.4449)	42	(.27-.4149)	77	(.13-.2649)	79	(.205-.349)	68	(.35-.4649)	67
5° External Rotation	(.36-.4049)	35	(.13-.169)	33	(.205-.2549)	32	(.43-.4649)	25																
10° External Rotation	(.405-.459)	37	(.09-.129)	38	(.155-.2049)	27	(.465-.499)	21	(.385-.475)	54	(.07-.149)	64	(.13-.229)	50	(.445-.515)	46								
15° External Rotation	(.46-.52)	42	(.05-.089)	32	(.105-.1549)	21	(.5-.54)	33									(.415-.565)	75	(.01-.129)	86	(.055-.2049)	72	(.465-.575)	74