32nd Annual Scientific Meeting

Limb Lengthening and Reconstruction Society:

ASAMI–North America

July 14 & 15, 2023

Everline Resort & Spa

Olympic Valley, CA

www.llrs.org

32nd Annual Scientific Meeting

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LLRS: ASAMI–North America

Future Meetings

Essentials of Lower Extremity Reconstruction (ELER)

January 26 & 27, 2024

Dallas, TX

AAOS Specialty Day

February 16, 2024

San Francisco, CA

33rd Annual Scientific Meeting

West Palm Beach, FL

Upcoming AAOS Meeting

2024 Annual Meeting

February 12–16, 2024

San Francisco, 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

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

Program Committee

L. Reid Nichols, MD

Stephen M. Quinnan, MD

Christopher A. Iobst, MD

Karen R. Syzdek, Executive Director

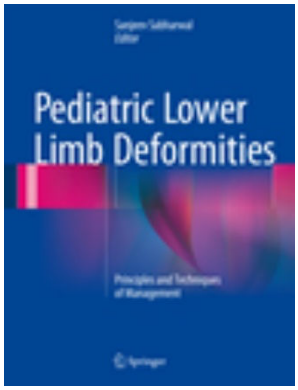
Pediatric Lower Limb Deformities

and

Limb Lengthening and Reconstruction Surgery Case Atlas Series

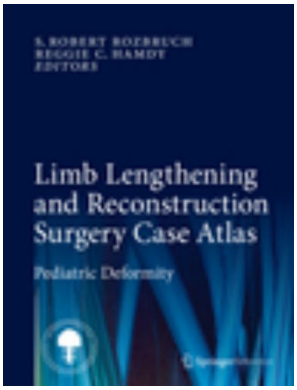
Pediatric Lower Limb Deformities

Sanjeev Sabharwal (Ed.)



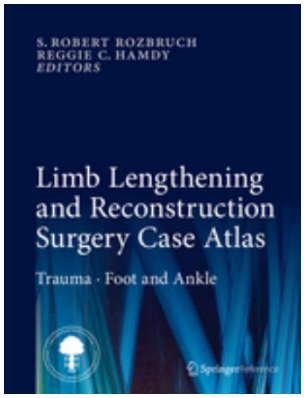
Pediatric Deformity

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



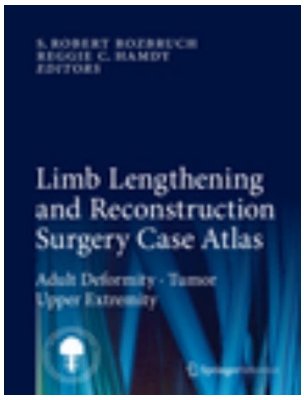
Trauma • Foot and Ankle

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

33rd Annual Scientific Meeting

West Palm Beach, FL

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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Traveling Fellowship Chair, Mentorship Program Chair
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Limb Lengthening and Reconstruction Society

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

32nd Annual Scientific Meeting

Objectives

Upon completion of LLRS's 32nd 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 32nd 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

NuVasive Inc.
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Smith & Nephew Inc.
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Thank you for the In–kind Donation

Baltimore Limb Deformity Course

Limb Lengthening and Reconstruction Society

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

Exhibitors

(listed in alphabetical order)

The LLRS thanks the following entities for their generous support.

LIFEBRIDGE HEALTH
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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/

BIOMARIN® BioMarin is a world leader in developing and commercializing innovative therapies for rare diseases driven by genetic causes. BioMarin remains steadfast to its original mission—to bring new treatments to market that will make a big impact on small patient populations. Visit www.biomarin.com to learn more.

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

DePuy Synthes 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.

Integrum Integrum's OPRA™ Implant System has been in use since 1998 and has transformed the lives of hundreds of amputees worldwide. It is the only FDA approved bone–anchored device for amputees. The innovative technology allows amputees to directly connect their prosthesis to their skeleton, allowing for greater range of motion, a more stable attachment, and improved sensory feedback.

NuVasive is a world leader in minimally invasive, procedurally–integrated solutions. From complex spinal deformity to limb lengthening and complex limb reconstruction solutions, Nuvasive is transforming surgery with innovative technologies designed to deliver reproducible surgical outcomes. The PRECICE® System uses a proprietary magnetic technology intended for limb lengthening, open and closed fracture fixation, pseudoarthrosis, mal–unions, non–unions, and bone transport of long bones. https://www.nuvasive.com/

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/

As the world seeks better solutions for bone healing, the Bonalive S53P4 bioactive glass technology represents a new standard in patient care. Evolving at the intersection of technology and human biology, TriMed Bonalive is transforming the future of healthcare focusing explicitly on complex surgery, with one of the most evidence–based technologies in the industry.

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 4, 2023**. *Your responses are needed for CME credit to be valid.*

https://www.surveymonkey.com/r/LLRSAM2023

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 9.75 AMA PRA Category 1 Credits™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Please join us next year!

33rd Annual Scientific Meeting

West Palm Beach, FL

Please complete the evaluation online at

https://www.surveymonkey.com/r/LLRSAM2023

on or before **August 4, 2023.**


33rd Annual
Baltimore Limb Deformity Course
August 24-26, 2023
Pre-Courses
Wednesday, August 23, 2023
• Cadaver Lab: Tibia and Foot
• Cadaver Lab: Complex Pediatric Hip/Pelvis/Femur Surgery
Post-Courses
Sunday, August 27, 2023
• Charcot Foot and Ankle
• Clubfoot Treatment: Ponseti and Beyond
LIFEBRIDGE HEALTH
Rubin Institute for Advanced Orthopedics
CARE BRAVELY
Endorsed By:
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Limb Lengthening and Reconstruction Society
DeformityCourse.com
Four Seasons Hotel, Baltimore, Maryland, USA
Save the Date: 34th Annual Baltimore Limb Deformity Course
August 21-25, 2024


ELER
Essentials of Lower Extremity Reconstruction
Scottish Rite for Children
Dallas, TX
January 26 & 27, 2024
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

Christopher August Iobst, MD, FAAOS (Columbus, OH)
Submitted on: 04/07/2023
Metalogix: Paid consultant
Nuvasive: Paid consultant
Orthofix, Inc.: Paid consultant
Smith & Nephew: Paid consultant
Wishbone, Medical: Paid consultant

Reid Boyce Nichols, MD, FAAOS (Wilmington, DE)
Submitted on: 05/12/2023
AAOS: Board or committee member
Journal of Children's Orthopedics: Editorial or governing board
Journal of Pediatric Orthopedics: Editorial or governing board
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid presenter or speaker
Orthopediatrics: Paid presenter or speaker
Pediatric Orthopaedic Society of North America: Board or committee member
Ruth Jackson Orthopaedic Society: Board or committee member
Smith & Nephew: Paid presenter or speaker

Stephen Matthew Quinnan, MD, FAAOS
Submitted on: 06/04/2023
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Bone Support: Paid consultant
DePuy, A Johnson & Johnson Company: Paid consultant
Globus Medical: IP royalties; Paid consultant
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Submitted on: 05/06/2023
AAOS: Board or committee member
Arthrex, Inc: Paid consultant; Research support
Smith & Nephew: Paid presenter or speaker
Stryker: Paid presenter or speaker

Munjed Al Muderis, FRACS, FRCS (Ortho), MBChB (Australia)
Submitted on: 06/08/2023
Aesculap/B.Braun: Unpaid consultant
Journal of Military and Veterans' Health: Editorial or governing board
Medacta International SA: IP royalties
Osseointegration International Pty Ltd: IP royalties; Paid consultant; Stock or stock Options
Specifica Pty Ltd: Paid consultant
World Journal of Orthopaedics: Editorial or governing board

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Anirejuoritse Bafor, FACS, MD
Submitted on: 05/30/2023
Bayer: Research support
Morison industries: Research support
WishBone Medical, Inc.: Paid consultant

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American Academy for Cerebral Palsy and Developmental Medicine: Board or committee member
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
Orthopediatrics: Paid presenter or speaker
Pediatric Orthopaedic Society of North America: Board or committee member
Raising Special Kids: Board or committee member
Springer: Publishing royalties, financial or material support

Mitchell Bernstein, MD, FAAOS (Canada)
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Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant
NXTSens MY01: Research support
Orthofix, Inc.: Paid consultant
Resolute Medical: Paid consultant
Restor3d: Paid consultant; Stock or stock Options
Smith & Nephew: Paid consultant
Synthes: Paid consultant

James Alan Blair, MD, FAAOS, FACS (Augusta, GA)
Submitted on: 04/12/2023
Integra: Paid consultant
Nuvasive: Paid consultant
Orthopaedic Trauma Association: Board or committee member
Smith & Nephew: Paid consultant; Research support
Stryker: Paid consultant

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Submitted on: 03/28/2023
Journal of Children's Orthopedics: Editorial or governing board
Orthofix, Inc.: IP royalties

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(This individual reported nothing to disclose); Submitted on: 05/05/2023

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Submitted on: 04/05/2023
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Canadian Paediatric Orthopaedic Group (CPOG): Board or committee member
Canadian Paediatric Orthopaedic Trauma Course: Board or committee member
European Paediatric Orthopaedic Society (EPOS): Board or committee member
Orthopediatrics: Paid consultant; Research support
Pediatric Orthopaedic Society of North America: Board or committee member

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Smith & Nephew: Paid consultant

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Orthopaedic Trauma Association: Board or committee member

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Sharon Eylon, MD
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Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant
Orthofix, Inc.: Paid consultant

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Submitted on: 04/07/2023
AAOS: Board or committee member
MDPI/IJERPH: Editorial or governing board
Pediatric Orthopaedic Society of North America: Board or committee member
Pediatric Research in Sports Medicine: Board or committee member
Ruth Jackson Orthopaedic Society: Board or committee member

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Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant; Paid presenter or speaker
Smith & Nephew: Paid consultant; Paid presenter or speaker
Synthes: Paid consultant; Paid presenter or speaker

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Limb Lengthening and Reconstruction Society: Board or committee member
Orthopediatrics: Paid consultant
Pediatric Orthopaedic Society of North America: Board or committee member

Marie Fridberg
Submitted on: 06/05/2023
DOS. Danish Orthopaedic Society: Board or committee member
EFORT: Board or committee member
IODA, International Orthopaedics Diversity Alliance: Board or committee member

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AAOS: Board or committee member
Conventus: IP royalties; Stock or stock Options
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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DePuy Synthes: Other financial or material support
Nuvasive: Other financial or material support; Paid consultant
Orthofix, Inc.: Other financial or material support
OrthoPediatrics: Other financial or material support; Paid consultant
Paragon 28: Other financial or material support
Pega Medical: Other financial or material support
Smith & Nephew: Other financial or material support; Paid consultant and royalties
Stryker: Other financial or material support
WishBone Medical: Other financial or material support

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Jaclyn Faye Hill, MD, FAAOS (Houston, TX)
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Nuvasive: Paid presenter or speaker
Orthopediatrics: Paid presenter or speaker
Pediatric Orthopaedic Society of North America: Board or committee member
Stryker: Paid consultant

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Mitsubishi Tanabi Pharmaceutical America: Research support

Joseph R Hsu, MD, FAAOS
Submitted on: 06/05/2023
Austin Medical: Paid consultant
Smith & Nephew: IP royalties; Paid consultant; Paid presenter or speaker
Stryker: IP royalties; Paid consultant; Paid presenter or speaker

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Submitted on: 05/01/2023
Orthofix, Inc.: Unpaid consultant

Aaron J Huser, DO (Jupiter, FL)
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Limb Lengthening and Reconstruction Society

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

Agenda

Grand Sierra Ballrooms A & B, Lobby Level

Friday, July 14, 2023

7:30 a.m.	Meeting Registration/Check–In Opens
7:30–8:30 a.m.	Continental Breakfast – Grand Sierra A **Visit Corporate Partners**
8:15–8:27 a.m.	Welcome/Introduction/Disclosure – Grand Sierra B *L. Reid Nichols, MD*
8:28–8:48 a.m.	**Session I: Nonunion** Moderator: Paul E. Matuszewski, MD
8:28–8:34 a.m.	Is Selectively Culturing Long Bone Nonunions Safe?: A Multicenter Study *Joseph R. Hsu, MD*
8:35–8:41 a.m.	Preoperative Prophylactic Antibiotics Decrease Culture Yield in Nonunion Repair Procedures – *Laura Bess, MD*
8:42–8:48 a.m.	Discussion
8:49–9:19 a.m.	**Session II: Trauma** Moderator: Stephen M. Quinnan, MD
8:49–8:55 a.m.	Clinical Outcomes of the Reverse Sural Flap Performed by Orthopaedic Trauma Surgeon – *James A. Blair, MD*
8:56–9:02 a.m.	Long–term Functional Outcomes Following Major Lower Limb Trauma Sustained in the Military – *Jessica C. Rivera, MD*
9:03–9:09 a.m.	Bromelain–Based Enzymatic Debridement in Muscle Tissue Trauma *Jessica C. Rivera, MD*
9:10–9:19 a.m.	Discussion
9:20–9:49 a.m.	**Section III: Bone Defects** Moderator: Austin T. Fragomen, MD
9:20–9:26 a.m.	A Technique for Tibial Bone Transport with a Single Set of Automated Hexapod Struts – *Shawn M. Hines, MD*
9:27–9:33 a.m.	Specific Indications for Segmental Bone Transport Techniques in Pediatric Bone Defect Reconstruction – *Mikhail Samchukov, MD*

9:34–9:40 a.m.	Distraction Osteogenesis Reconstruction Following Resection of Bone Sarcomas: Surgical, Functional and Oncologic Outcomes from a Prospective Trial Analysis – *Daniel E. Prince, MD, MPH*
9:41–9:49 a.m.	Discussion
9:50–10:44 a.m.	**Session IV: Osseointegration** Moderator: S. Robert Rozbruch, MD
9:50–9:56 a.m.	Medium–term Outcomes of Transfemoral Osseointegration in Association with Total Hip Replacement – *Munjed Al Muderis, MD*
9:57–10:03 a.m.	Medium–term Outcomes of Transtibial Osseointegration in Association with Total Knee Replacement – *Munjed Al Muderis, MD*
10:04–10:10 a.m.	Limb Reconstruction with Osseointegrated Transfemoral Prosthesis following Radical Amputation of Lower Extremity Sarcomas *Mohamed E. Awad, MD*
10:11–10:17 a.m.	The Use of Osseointegrated Titanium Implants to Treat Bilateral Amputees – *Munjed Al Muderis, MD*
10:18–10:24 a.m.	Defining the Minimal Clinically Important Difference of Health–Related Quality of Life Measures following Osseointegrated Transfemoral Prosthesis in Amputees – *Mohamed E. Awad, MD*
10:25–10:31 a.m.	Postoperative Osseointegration Rehabilitation Protocols: A Scoping Review with Recommendations for Progress – *Taylor Reif, MD*
10:32–10:44 a.m.	Discussion
10:45–11:05 a.m.	Refreshment Break – Grand Sierra A **Visit Corporate Partners**
11:06–11:51 a.m.	**Session V: Limb Deformity – Practice** Moderator: Jaclyn F. Hill, MD
11:06–11:12 a.m.	Prospective Multi–Center Comparison of Modified Scoliosis Instruments and PODCI in Pediatric Limb Deformity Patients – *Tyler J. Moon, MD*
11:13–11:19 a.m.	International Field Test of LIMB–Q Kids: A New Patient Reported Outcome Measure for Lower Limb Differences – *Anthony Cooper, MD*
11:20–11:26 a.m.	Limb Lengthening and Reconstruction Society AIM Index – Reliability in Assessing Disease Severity – *Gourav Jandial, MD*

11:27–11:33 a.m.	Length of Stay and Readmission Rates After Limb Lengthening Surgery *S. Robert Rozbruch, MD*
11:34–11:40 a.m.	Burnout in Limb Reconstruction Surgeons – *Christopher A. Iobst, MD*
11:41–11:51 a.m.	Discussion
11:52 a.m.–12:30 p.m.	**Session VI: Limb Deformity – Techniques** Moderator: Mitchell Bernstein, MD
11:52–11:58 a.m.	The Percutaneous Comminuted Closing Wedge Osteotomy "Perc Wedge": A Powerful Solution for Deformity Correction – *Stephen M. Quinnan, MD*
11:59 a.m.–12:05 p.m.	Comparative Fixation Devices for Preventing Migration of the Proximal Tibiofibular Joint During Tibial Lengthening: A Tether Versus Screw Fixation – *Jidapa Wongcharoenwatana, MD*
12:06–12:12 p.m.	Removal of Hardware after Orthopaedic Surgery: What are Patients Saying? – *Brian J. Page, MD*
12:13–12:19 p.m.	Modified Super Hip Procedure for Fibrous Dysplasia of the Proximal Femur – *Toshifumi Hikichi, MD*
12:20–12:30 p.m.	Discussion
12:30–1:35 p.m.	Lunch – Grand Sierra A **Visit Corporate Partners**
1:36–2:21 p.m.	**Session VII: Limb Deformity – Topics to Get You Thinking** Moderator: Raymond W. Liu, MD
1:36–1:42 p.m.	Comparison of Three Methods of Intraoperative Angulation Measurement for Malunion Surgery: Visual Estimation, Goniometer, and Inclinometer *Philip K. McClure, MD*
1:43–1:49 p.m.	Proximal TibioFibular Joint in Tibial Lengthening Osteotomy *Mina Gerges, MD, MSc*
1:50–1:56 p.m.	Mechanical Stimulation of Bone Regenerate via External Fixator Axial Dynamization – *Alexander Cherkashin, MD*
1:57–2:03 p.m.	Complications in Limb Reconstruction Surgery–Can We Report Them Reliably? – *Elizabeth Hubbard, MD*
2:04–2:10 p.m.	Comparing RVUs for Intramedullary Limb Lengthening Procedures to Common Pediatric Orthopaedic Surgeries to Determine Adequate Compensation – *Jill C. Flanagan, MD*
2:11–2:21 p.m.	Discussion

2:22–3:10 p.m.	Presidential Guest Lecture **Lizardry Lessons from Perthes Disease** *Jonathan Schoenecker MD, PhD* *Pediatric Orthopaedics* *Vanderbilt University Medical Center*
3:15–6:00 p.m.	Afternoon On Your Own – Members
3:15–7:00 p.m.	Afternoon On Your Own – Nonmembers
6:00–6:45 p.m.	Business Meeting – **Current LLRS Members only**
7:00–7:30 p.m.	Pearls of Wisdom – Sun & Spa Decks
7:30–9:30 p.m.	President's Reception – Sun & Spa Decks

Saturday, July 15, 2023

7:30 a.m.	Meeting Registration/Check–In Opens
7:30–8:30 a.m.	Continental Breakfast – Grand Sierra A **Visit Corporate Partners**
8:15–8:20 a.m.	Announcements – Grand Sierra B
8:21–8:36 a.m.	**Traveling Fellowship Presentation** Introduction by Jaclyn F. Hill, MD *Marco Domenicucci, MD* *Goeffrey Maracek, MD* *Henry Ndasi, MD* *Paa Kwesi Baidoo, MD* *Marie Fridberg, MD* *Amanda McCoy, MD*
8:37–9:22 a.m.	**Session VIII: Pediatrics** Moderator: Christopher A. Iobst, MD
8:37–8:43 a.m.	Physeal Bar Excision Using 3D Image Guidance: Technique and Results *Wendy Ramalingam, MD*
8:44–8:50 a.m.	Knee Joint Line Obliquity at Skeletal Maturity After Growth Modulation Treatment of Genu Varum and Genu Valgum – *David A. Podeszwa, MD*
8:51–8:57 a.m.	Not Just Your Average Anterolateral Bow (of the Tibia!) *Aaron J. Huser, DO*
8:58–9:04 a.m.	Patients with Significant Femoral Version Abnormalities Report Lower Quality of Life than Asymptomatic Controls – *Michael D. Greenstein, BS*
9:05–9:11 a.m.	Hibernation of Percutaneous Hemiepiphysiodesis Plates is Safe in Patients with Congenital Limb Deficiencies – *Claire Shannon, MD*
9:12–9:22 a.m.	Discussion
9:23–10:00 a.m.	**Session IX: Bone Problems** Moderator: Jill C. Flanagan, MD
9:23–9:29 a.m.	Intramedullary Rodding of Long Bones in Patients with Osteogenesis Imperfecta: To Supplement with a Plate or Not to Supplement with a Plate? – *Jeanne M. Franzone, MD*
9:30–9:36 a.m.	Limb Reconstruction in Patients with Paley 5A Tibial Hemimelia *Aaron J. Huser, DO*

9:37–9:43 a.m.	Preferences and Priorities for Decision Making in Congenital Femoral Deficiency (CFD): A Stated Preference Survey of Patients, Caregivers, and Clinicians – *Ilene Hollin, PhD*
9:44–9:50 a.m.	Metabolic Impacts on Surgical Outcomes after Hemiepiphysiodesis for Hypophosphatemic Rickets – *Oussama Abousamra, MD*
9:51–10:00 a.m.	Discussion
10:01–10:30 a.m.	Refreshment Break – Grand Sierra A **Visit Corporate Partners**
10:31–11:30 a.m.	Alessandro Codivilla Guest Speaker **The Spark!** *Ryan "Birdman" Parrott* *Former Navy SEAL Sniper* *Founder and CEO of American Extreme*
11:31–11:51 a.m.	**Session X: Internal Lengthening Nails** Moderator: Jessica C. Rivera, MD
11:31–11:37 a.m.	Qualitative and Quantitative Assessment of the Regenerate Bone Formed During Intramedullary Limb Lengthening Using a Caprine Tibia Model: A Pilot Study – *Christopher A. Iobst, MD*
11:38–11:44 a.m.	Does Percentage of Tibial Canal Reaming for Insertion of Intramedullary Nail to Correct Limb Length Discrepancy Influence Consolidation Time? *Philip K. McClure, MD*
11:45–11:51 a.m.	Discussion
11:52 a.m.–12:20 p.m.	**Session XI: Pain Management** Moderator: Mani D. Kahn, MD
11:52 a.m.–11:58 a.m.	Can Patients have a Regional Block if the Limb is or was Infected? *Joseph R. Hsu, MD*
11:59 a.m.–12:05 p.m.	Regional Neuromuscular Blocks and Pain Catheters for Perioperative Pain Control in the Setting of Osteogenesis Imperfecta Extremity Orthopaedic Procedures – *Jeanne M. Franzone, MD*
12:06–12:12 p.m.	The Effect of Ketorolac on Pediatric Bone Healing Rate Following Osteotomy in Patients with Deformity or Limb Length Discrepancy *Christopher A. Iobst, MD*
12:13–12:20 p.m.	Discussion
12:21–1:00 p.m.	President's Remarks and Introduction of 2023–2024 President *L. Reid Nichols, MD and Stephen M. Quinnan, MD*

Session I: Nonunion

Moderator: Paul E. Matuszewski, MD

Is Selectively Culturing Long Bone Nonunions Safe?: A Multicenter Study

Joseph R. Hsu, MD; Olivia Rice, MD
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What was the question?
The predictive ability for occult infection of preoperative inflammatory markers in fracture nonunion surgery have been a subject of debate for decades. Further, there is uncertainty around the practice of routine culture due to risk of spurious results in presumed aseptic versus missing a hidden pathogen. This study aimed to evaluate the strategy of selectively culturing during nonunion surgery (only when a marker is positive) compared to routine culture.

How did you answer the question?
We retrospectively reviewed patients (age > 16) treated for long bone nonunion between 2006–2021 in 12 large healthcare systems, involving multiple surgeons. Demographics, injury characteristics, labs, culture results, and postoperative outcomes were compared among all subgroups with and without intraoperative cultures obtained.

What are the results?
A total of 1227 nonunions were included, of which 78% had preoperative inflammatory labs (WBC, ESR, CRP). 457 (37%) nonunions were presumed aseptic (negative screening serum markers); 399 (33%) were presumed septic (positive screening markers). Only 689 (56%) received intraoperative cultures (74% of presumed septic; 45% of presumed aseptic; 51% of patients without markers). 141 (20%) of all cultures resulted positive (25% of presumed septic; 6% of presumed aseptic ("surprise positive"); 20% of patients without markers). Presumed aseptic with no cultures (n = 250) had similar outcomes to the negative marker/negative culture group (n = 180) with persistent nonunion rates of 15% and 16% respectively. These two groups had the best outcomes. "Surprise positive" patients (n=27) had similarly bad outcomes to septic nonunions (n=76) with persistent nonunion rates of 37% and 26% respectively. Presumed aseptic with no culture outperformed "surprise positive" patients (persistent nonunion 15% vs. 37%, p=0.012).

What are your conclusions?
We demonstrated significant variance in utilization of cultures with more than half of surgeons not obtaining cultures in presumed aseptic cases. These presumed aseptic patients without a culture performed as well as presumed aseptic with negative cultures. "Surprise positive" cultures continue to perplex. While this group was quite small (6% of cultures; 2% overall), their results were among the worst. It is difficult to determine if surprise positive cultures represent a group with higher susceptibility to complication, are the result of nontherapeutic antibiotic presence/pressure, or some other factors. Selective microbial culturing during nonunion surgery based on preoperative clinical suspicion seems to be reasonable, but the possibility of surprise positive cultures remains a concern.

Preoperative Prophylactic Antibiotics Decrease Culture Yield in Nonunion Repair Procedures

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What was the question?
Infection is a leading cause of fracture nonunion and nonunion repair failure. Cultures are frequently taken during nonunion repair surgery to guide postoperative treatment. However, there is no clear consensus regarding the administration of preoperative prophylactic antibiotics. Holding antibiotics at the time of nonunion repair might increase culture yield; however, this practice must be balanced with the risk of surgical site infection. In the arthroplasty literature there have been several randomized controlled trials demonstrating no difference in culture yield for periprosthetic joint infection with prophylactic antibiotic administration, but this has not yet been described for nonunion repair procedures. We hypothesized that preoperative prophylactic antibiotics given at the time of nonunion repair would not affect intraoperative culture yield.

How did you answer the question?
Retrospective review of a multicenter (13 sites) nonunion repair database. Included cases were patients age >18 with a long bone (humerus, tibia, femur) nonunion treated with nonunion repair >6 months after index operative treatment. Cultures were defined as negative, positive, or positive but believed to be contaminant. Odds ratios were calculated for giving or holding antibiotics based on elevated preoperative laboratory work–up (i.e., ESR, CRP, and WBC) and clinical evidence of infection. The association between giving or holding preoperative prophylactic antibiotics and culture yield was then assessed using Chi–square analysis.

What are the results?
877 eligible cases were identified. No cultures were taken in 305 cases. Of the remaining 572 cases preoperative prophylactic antibiotics were given in 436 cases and held in 136 cases. Odds ratios were nonsignificant ($p>0.05$) for both preoperative laboratory work–up and clinical evidence of infection, suggesting that these factors did not influence the “decision” to hold prophylaxis. A statistically significant association between the administration of preoperative prophylactic antibiotics and culture yield was found ($p=0.033$, Fragility Index=1). In cases where prophylaxis was held cultures were positive in 21.8% of cases (29/133, 95%CI 15.1–29.8%), whereas in cases where prophylaxis was administered 14.1% of cultures were positive (60/427, 95%CI 10.9–17.7%).

What are your conclusions?
Though common practice to administer preoperative prophylactic antibiotics at the time of nonunion repair, we found this practice may decrease culture yield, which could potentially lead to misdiagnosis of a nonunion as aseptic. Further research is needed understand the balance between culture yield and surgical site infection.

Table 1: Association between Preoperative Prophylactic Antibiotics and Culture Yield

Preoperative Prophylactic Antibiotics Given		Cultures			P -value*
	Total	Negative (N=471)	Positive (N=89)	Contaminant (N=12)	
Yes	436 (76.22%)	367 (84.17%)	60 (13.76%)	9 (2.06%)	0.0327
No = Held	136 (23.78%)	104 (76.47%)	29 (21.32%)	3 (2.21%)	

*Test negative vs positive by excluding contaminant

Session II: Trauma

Moderator: Stephen M. Quinnan, MD

Clinical Outcomes of the Reverse Sural Flap Performed by Orthopaedic Trauma Surgeons

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What was the question?
Open wounds to the distal leg not amenable to primary closure or skin grafting are often seen in orthopaedic trauma and infection. The reverse sural flap (RSF) has been described as a means of local tissue transfer for wound coverage over the distal leg and hindfoot, avoiding the need for free tissue transfer. While commonly performed by plastic or microvascular surgeons, limited outcome data exists regarding the RSF performed by non–microvascular trained orthopaedic trauma surgeons.

How did you answer the question?
A retrospective analysis was conducted on all patients who received a RSF at our institution between September 2020 and August 2022. All cases were performed by two fellowship–trained orthopaedic trauma surgeons who do not have formal microvascular training. Patients required follow–up to flap healing or failure for study inclusion. Case variables collected included patient demographics/comorbidities, indication for coverage, wound size, RSF viability, RSF healing time, and RSF cosmetic outcome. A cosmetic grade of excellent was assigned to flaps that healed without raised skin margins, while a grade of good or fair was assigned to flaps healing with slightly raised or raised skin margins, respectively.

What are the results?
17 patients underwent a RSF during the study period, 15 of which had sufficient clinical follow–up. Average patient age was 43.6 years (19–76 years), 14/15 (93.3%) were male, and an average follow–up of 31.8 weeks (5–111 weeks). Seven patients (46.7%) received a RSF for wound coverage due to acute traumatic wounds, while eight patients (53.3%) underwent a RSF secondary to surgical site infection (SSI) following open fracture. Average wound size was 29.8 cm2 (6–72 cm2). Flap viability was noted in 12/15 (80.0%) patients, with 3/15 (20.0%) patients experiencing RSF necrosis/failure. Two–thirds of flap failure cases presented with SSI following RSF. The remaining cases of flap failure resulted secondary to poor non–weightbearing compliance leading to flap shearing and coagulation. Diabetes was present in 2/3 of flap failure cases. Cosmetic outcomes among the surviving flaps were excellent or good in 11/12 (91.7%) patients, with an average soft tissue healing time of 57.4 days (23–116 days).

What are your conclusions?
The RSF is a powerful and reliable technique for soft tissue coverage of the distal leg and hindfoot that can be performed without microvascular training.

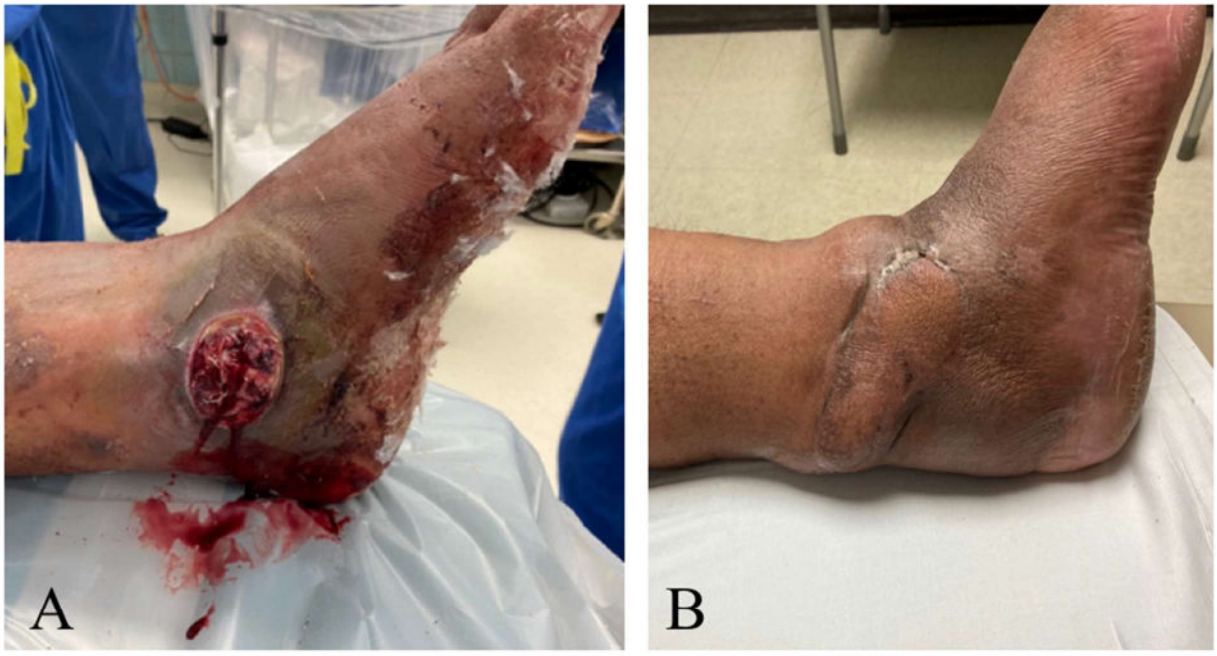

Figure 1. 45-year-old male presenting with a neglected ankle fracture/dislocation and medial ankle wound which underwent definitive coverage with a reverse sural flap (RSF). A, Medial ankle wound at time of patient presentation. B, Healed RSF.

Long–term Functional Outcomes Following Major Lower Limb Trauma Sustained in the Military

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What was the question?
Prior studies of service members sustaining severe lower extremity trauma between 2003 and 2007 found that approximately three years post–injury, individuals treated with early amputation had better functional outcomes than those treated with limb salvage. The present study follows this cohort nearly 10 years later to determine if outcomes improved and if there were differences over time and across treatment and age subgroups.

How did you answer the question?
Study participants (n=307) were contacted approximately 10 years after their first interview (T1) and completed an additional (T2) assessment, which included the Short Musculoskeletal Function Assessment (SMFA). Comparisons were made across treatment groups at T1 (unilateral or bilateral injury; salvage or amputation) and stratified by age at injury (< 25 and >=25). Linear and logistic mixed–effect models were used to measure the overall effects of time, age at injury, treatment at T1 and participant characteristics on the SMFA.

What are the results?
Overall, few differences are observed in SMFA outcomes at T2 (average 13.0 years post injury) compared to T1 for the 212/307 (69%) T2 respondents. Results indicate persistent moderate–to–high levels of disability. Stratifying by treatment group, differences in SMFA outcomes among salvages did not change, but worsened for amputees (SMFA mobility difference: 6.1 for amputees, –0.5 for salvages). Stratifying treatment groups by age, these differences were driven by age. After adjusting for covariates, participants < 25 undergoing amputation experienced significantly superior SMFA results (lower scores) to those whose limbs were salvaged (Coefficients and p–values: Dysfunction: –13.2 p= 25 at T1, there were no significant differences over time by amputation status.

What are your conclusions?
Thirteen years post–injury, study participants reported moderate to high dysfunction following major lower limb trauma. Results differed by age and treatment. Younger participants undergoing amputation at T1 initially fared better than salvage patients, but had significantly worse SMFA outcomes at T2, while outcomes for salvage patients did not change. Reasons for this decline in younger patients with limb amputation are unclear; however, additional efforts are needed to help maximize long term functioning in patient following severe trauma regardless of limb status.

Bromelain–Based Enzymatic Debridement in Muscle Tissue Trauma

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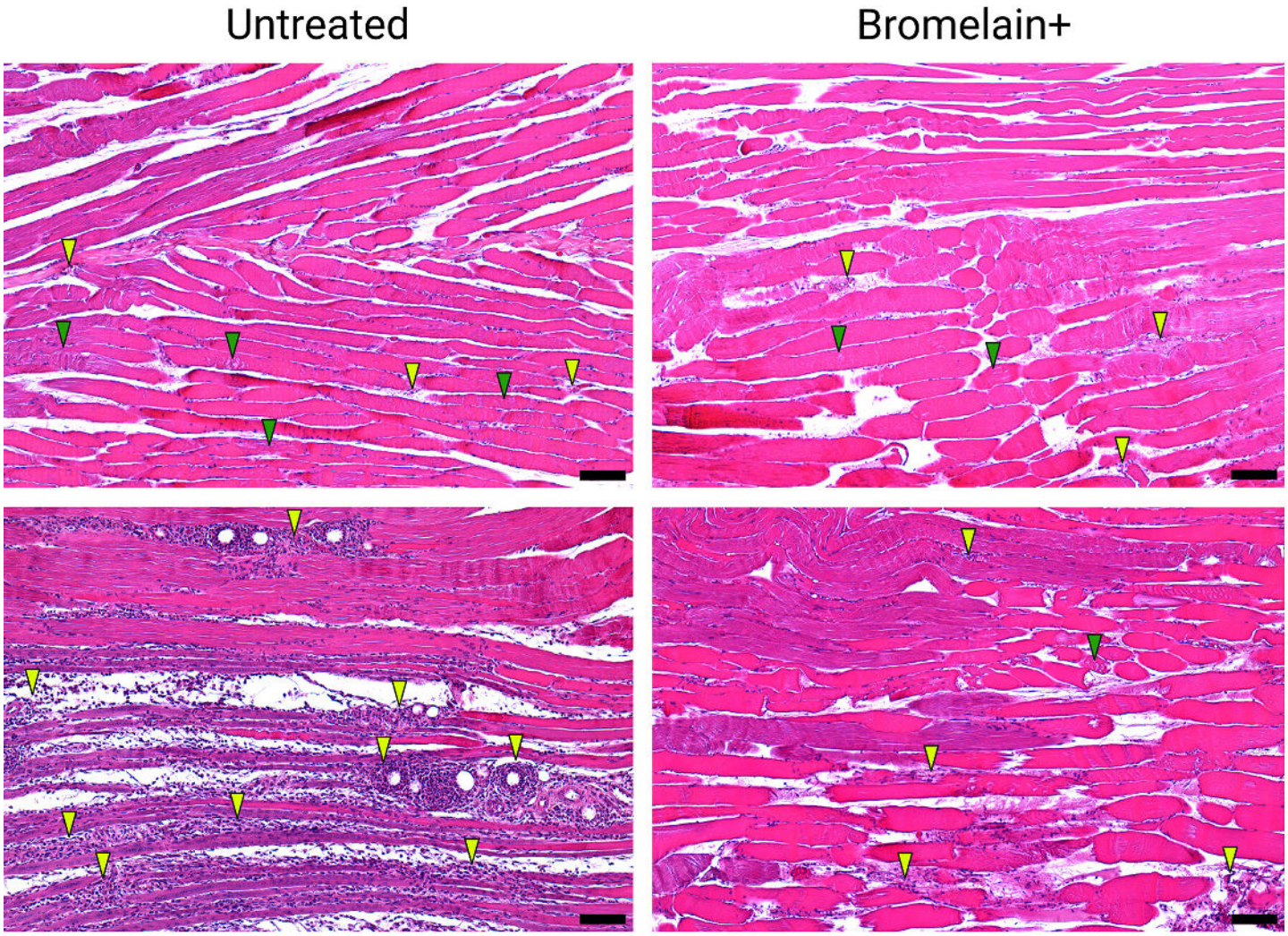
Tara Korbal, MA

What was the question?
Bromelain is a proteolytic enzyme found in the pineapple plant which has anti–inflammatory properties. Bromelain–based enzymatic debridement (BED) is used in burn wound debridement. BED may have other beneficial applications where debridement of devitalized tissue is necessary. Traumatic open wounds involving muscle require adequate debridement to remove devitalized tissue but the remaining muscle may be adversely affected by inflammation. The aim of this research is to establish if BED debrides damaged muscle while reducing inflammation in a murine model of extremity trauma.

How did you answer the question?
A freeze burn injury was created by applying a liquid nitrogen cooled rod against exposed tibialis anterior (TA) musculature in a common lab mouse (Mus musculus). Afterwards, the wounds either underwent saline irrigation or application of a bromelain–soaked gauze. After 30 minutes, time 0 animals were sacrificed, and the TA muscle harvested. Time 96–hour animals' wounds were closed with suture and were allowed activities ad lib until day 4 following the injury. At this time, the animals were sacrificed, and the TA muscle harvested. Harvest muscle was formalin fixed, decalcified, paraffin processed, embedded, and sectioned at 4µm onto positively charged slides and stained by hematoxylin and eosin (H&E).

What are the results?
Compared to the uninjured muscle on the left, these are representative examples on the right of the H&E stained muscle that sustained the freeze burn injury, and saline irrigation. The yellow arrowheads are indicating of enlarged, edematous expansion with inflammatory infiltrates of the endomysial space between myofibers. The green arrow heads are rhabdomyolysis. Alternatively, following traumatized muscle treated with bromelain soaked gauze, there appear to be fewer inflammatory infiltrated and less myonecrosis.

What are your conclusions?
By examining bromelain treated muscle injury, these results suggest the potential for BED in treating traumatized acute muscle injury by adequately debriding devitalized muscle and supporting control of inflammation. Ongoing study is underway on how damaged muscle may be recovered and how BED affects contaminated wound models.


Untreated
Bromelain+

Session III: Bone Defects

Moderator: Austin T. Fragomen, MD

A Technique for Tibial Bone Transport with a Single Set of Automated Hexapod Struts

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Michael J. Anderson, Michael T. Makowski, J. Spence Reid

What was the question?
To describe a relatively simple technique for tibial bone transport using three rings connected by four threaded rods with a single set of automated hexapod struts to mobilize the transport segment. This method takes advantage of the simplicity of classic tibial transport with the patient convenience and enhanced biology of automated segment movement 20x/day.

How did you answer the question?
Two patients with infection–related segmental defects were treated with this technique in the last year (Table 1). Both cases were distal–third defects and sequela of open tibia fractures. Prior to segmental resection, tibial osteotomy and frame placement, each patient had undergone multiple operative interventions. Patient 1 previously underwent intramedullary nail placement with distal fibula intramedullary screw fixation, hardware removal with debridement and external fixator placement, and two subsequent debridements requiring rotational flap advancement. Patient 2 previously underwent intramedullary nail placement, subsequent dynamization, followed by hardware removal and antibiotic nail placement.

Both frames were constructed of three 150 mm rings connected by four 8mm threaded rods in such a way that allowed placement of 6 hexapod struts between the proximal and middle rings. Corticotomy was via a Gigli saw and transport was antegrade. Transport rate was 0.75 mm/day in 20 increments (7AM to 10 PM) after a 10 day latency period. The hexapod software was setup such that the only nonzero deformity parameter manually entered was the length of transport. Both patients had a docking site procedure with autogenous proximal tibial bone graft from Gerdy's tubercle. Both patients underwent early conversion to a modified intramedullary nail (custom hole to hold transport segment) by suprapatellar approach. The first patient required a small translational correction (5mm) at the docking site prior to nailing which was managed by removing the automated struts and placing standard hexapod struts between the distal two rings and linear distractors between the proximal two rings for two weeks. Both patients were encouraged to be full weight bearing during frame treatment and after IM nail placement.

What are the results?
Both patients went on to successful bone transport, bone grafting/docking, as well as definitive tibial IMN placement. Regenerate quality was good despite continued smoking by patient 2. Most importantly, the patients made no frame adjustments during treatment, and no strut swaps were required for these segmental defects. Despite being highly constrained by the 4 threaded rods, there was no mechanical impingement of the transport ring.

A Technique for Tibial Bone Transport with a Single Set of Automated Hexapod Struts *continued*

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What are your conclusions?
Tibial bone transport with a single set of automated hexapod struts is a viable technique in the treatment of tibial segmental defects requiring bone transport. This eliminates the complexity and cost of "double stacking" of struts when threaded rods are not used to span the tibial frame. It is impossible to know in these cases if regenerate biology was enhanced by the 20x increments of the 0.75mm/day transport speed, or if the 9 hour pause during sleep is necessary. Nonetheless, all basic science studies support the concept of smaller more frequent frame movements to create better regenerate. Patient convenience was enhanced and this may be a driving factor in utilizing this automated technique in certain populations such as pediatrics, the elderly, the disabled, and noncompliant patients. Further studies are needed to determine the role for this technique in bone transport.

Table 1. Patient characteristics and treatment course

	Patient 1	Patient 2
Age	21	50
Gender	Female	Male
Injury	ATV accident	Steel plate on leg
Smoking status	Non-smoker	Current smoker
Size of defect	6.2 cm	4.3 cm
Cultures	*E. cloacae* & *Clostridium spp.*	*Streptococcus viridans*
Injury to frame	54 days	301 days
Frame to bone grafting	119 days*	95 days
Frame to IM nailing	119 days*	151 days

*Intramedullary nailing occurred in the same procedure as bone grafting

Specific Indications for Segmental Bone Transport Techniques in Pediatric Bone Defect Reconstruction

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Alex Cherkashin, MD; Marina Makarov, MD; David Podeszwa, MD; John Birch, MD

What was the question?
Reconstruction of bone defects in children following debridement of pseudoarthrosis, resection of tumors, as well as post–traumatic or post–infectious bone loss still poses a challenge for limb reconstruction surgeons. Several approaches have been described as treatment options, including acute shortening followed by limb lengthening, free vascularized fibula transfer, and segmental bone transport. Segmental bone transport combines gradual defect closure until docking with the residual target bone segment and formation of distraction bone regenerate between the transport and residual host bone segments. Gradual transportation of the transport bone segment through the bone defect area in cases with circular external fixation is typically achieved by either transverse wires or/and half pins, oblique olive wires, or stainless–steel cable. The purpose of this study was to review different segmental bone transport techniques used in our institution and define specific indications for each of those techniques.

How did you answer the question?
We retrospectively reviewed 20 patients treated with circular external fixation and segmental bone transport. The charts and radiographs of those patients were evaluated with respect to age at limb reconstruction, diagnosis, severity of bone and soft tissue loss, dimensions and structure of the transport and residual bone segments, technical aspects of limb stabilization via circular external fixator and details of transport segment fixation, gradual movement and compression at the docking site, as well as duration of treatment and clinical and radiographic outcomes.

What are the results?
The cohort of patients included 11 males and 9 females whose age at the time of limb reconstruction ranged from 4.0 to 18.0 years. The diagnoses included: open (typically grade IIIB) tibial fractures often associated with other fractures and soft tissue loss (10), post–traumatic infected non–union (2), chronic osteomyelitis (3), tumor (3), and congenital pseudarthrosis of the tibia (2). Defects were located either in the femur (4) or tibia (16), and ranged in length from 4.0 to 14.0 cm.

All patients underwent the application of circular external fixation for limb stabilization. Three transport segment stabilization modules were used for 22 segmental bone transports, including: 1) two transverse half pins attached to a transport intercalary ring (4), 2) two oblique olive wires connected to special transport rods (15), and 3) stainless steel cable running around the plastic pulleys or balance screw before attachment to transport rods or special transport units (3). For docking between the transport and target segments, all patients underwent staged debridement, bone grafting, BMP application, and placement of two transverse cross tensioned wires for adequate compression at the end of transport.

We found that for balanced cable transport the appropriate length of the target bone segment was critical to allow insertion of wires and half pins for stable fixation and proper balance screw placement. Besides, sufficient diameter of intramedullary canal of the transport and target segments is necessary to allow cable insertion into transport segment and balance screw positioning in addition to cable insertion into target segment.

Specific Indications for Segmental Bone Transport Techniques in Pediatric Bone Defect Reconstruction *continued*

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Alternatively, bone transport using two oblique wires was not limited by intramedullary canal diameter or length of the target segment but required appropriate length of the transport segment to allow placement of the wires at the proper angle avoiding their multiple re–orientations during transport. Similarly, bone transport with two transverse wires or half pins was found to be beneficial in cases with appropriate length of the transport segment considering enough bone below/above the ring for debridement and compression with the target segment at the docking site. In those cases, the diameter of transport half pins should be more than 4 mm to overcome resistance from distraction regenerate and surrounding soft tissues and to avoid their bending during the transport.

What are your conclusions?

Segmental bone transport is a versatile tool for the treatment of bone defects in children. In each case, special consideration should be given to the method of transport segment fixation including the length of the transport and target segments, diameter of the intramedullary canal, and presence of muscle flaps and skin grafts. The described general algorithm for selecting an appropriate bone transport technique was extremely helpful for the management of bone defect reconstruction in our practice.

Distraction Osteogenesis Reconstruction Following Resection of Bone Sarcomas: Surgical, Functional and Oncologic Outcomes from A Prospective Trial Analysis

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Anthony Bozzo

What was the question?
The objectives of this study are to determine the complete bone healing and full weight bearing from initiation of DO, the time to initial cortex formation, and the influence of chemotherapy on the bone regeneration process. Our secondary objective is to report the surgical procedures required to achieve complete bone healing, the complication rate, and functional outcomes scores in this complex cohort of patients.

How did you answer the question?
We report on a prospective study of 30 consecutive patients who underwent primary or secondary DO–based reconstruction following osseous resection at our tertiary care institution from 2018–2021. Standard patient demographics, surgical details, radiological studies, laboratory values and complications were collected prospectively in addition to several validated functional scores and patient–reported outcome data that were routinely collected at follow–up visits every 3 months during the first year, every 4 months during the second year, every 6 months during the third year, and annually thereafter. They include the Musculoskeletal Tumor Society (MSTS), Time to Get Up and Go (TTGUG), and Toronto Extremity Salvage Scores (TESS).

What are the results?
The average resection length was 13.6 cm (SD 5.3, range 4–22). A total of 59 bone segments were transported; 34 were concurrent with chemotherapy and 25 were transported without any concurrent chemotherapy. All patients achieved full independent weight bearing of their operated extremity and the median time to full weight bearing was 12 months (IQR 9–16). The bone healing index was 2.3 (SD 0.7) for segments transported with concurrent chemotherapy and nearly twice as fast at 1.2 (SD 0.4) for segments transported without concurrent chemotherapy ($p<0.0001$). The mean time from initiation of bone transport until the first spanning regenerate cortex could be visualized on xray was 10.9 months (SD 6.2) for segments concurrent with chemotherapy, and 4.6 months (SD 2.6) for segments without concurrent chemotherapy ($p=.0006$). Patients underwent an average of 6.1 procedures (median 6, range 1–14). Of the 184 surgical procedures performed in our cohort, 92 (50%) were planned repeat lengthening procedures while half were unplanned including 37 (20%) for infection and 29 (16%) to address a non–union or mal–union. Final MSTS scores were 24.1 ± 5.0 (80.3%) at 2 years post–operatively and continued to improve at the 3– and 4–year post–op visits. Final TESS scores were 81.5 ± 11.5.

What are your conclusions?
This prospective series of distraction osteogenesis reconstruction in oncological patients demonstrates the efficacy of this method in both the primary and secondary reconstruction settings. All 30 patients achieved full bone healing and independent weight bearing at a median time of 1 year postoperatively and continued to show functional improvement afterwards. Surgeons and patients can expect bone healing to be nearly twice as fast for segments transported after completion of systemic chemotherapy compared to segments transported concurrently with adjuvant chemotherapy.

Session IV: Osseointegration

Moderator: S. Robert Rozbruch, MD

Medium–term Outcomes of Transfemoral Osseointegration in Association with Total Hip Replacement

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What was the question?
Transfemoral osseointegration (TFOI) for amputees has substantial literature proving superior quality of life and mobility versus a socketed prosthesis. Some amputees have hip arthritis that would be relieved by a total hip replacement (THR). No other group has reported performing a THR in association with TFOI (THR+TFOI). We report the outcomes of eight patients who had THR+TFOI, followed for an average 5.2 years. 1) what is the rate of complication following primary procedure; 2) how does patient prosthesis wear time and mobility change; 3) how does the patient's perception of using a prosthesis change (based on the Questionnaire for Persons with a Transfemoral Amputation, QTFA)?

How did you answer the question?
Our osseointegration registry was retrospectively reviewed to identify all patients who had TFOI and also had THR, performed at least two years prior. Six patients had TFOI then THR, one simultaneous, one THR then TFOI. All constructs were in continuity from hip to prosthetic limb. Outcomes were: complications prompting surgical intervention, and changes in subjective hip pain, K–level, daily prosthesis wear hours, Questionnaire for Persons with a Transfemoral Amputation (QTFA), and Short Form 36 (SF36). All patients had clinical follow–up, but one patient did not have complete mobility and quality of life survey data at both time periods.

What are the results?
Four (50%) were male, average age 52.7±14.8 years. Three patients (38%) had amputation for trauma, three for osteosarcoma, one each (13%) infected total knee and persistent infection after deformity surgery. One patient died one year after THR+TOFA from subsequently diagnosed pancreatic cancer. One patient had superficial debridement for infection with implant retention after five years. No implants were removed, no fractures occurred. All patients reported severe hip pain preoperatively versus full relief of hip pain afterwards. K–level improved from 0/8=0% K>2 (six were wheelchair–bound) to 5/8=63% (p=.026). At least 8 hours of prosthesis wear was reported by 2/7=29% before TOFA vs 5/7=71% after (p=.286). The QTFA improved in all categories, but not significantly: Global (40.0±21.6 vs 60.0±10.9, p=.136), Problem (50.2±33.2 vs 15.4±8.4, p=.079), and Mobility (35.9±26.8 vs 58.3±30.7, p=.150). The SF36 also improved minimally and not significantly: Mental (53.6±12.0 vs 54.7±4.6, p=.849) and Physical (32.5±10.9 vs 36.3±11.2, p=.634).

What are your conclusions?
THR+TFOI is a successful reconstruction option for amputees who desire relief from severe pain related to hip joint degeneration, and also the opportunity for improved mobility and quality of life that TFOI typically confers. In our cohort, the procedure proved safe: no associated deaths, no removals, one soft tissue debridement. Mobility improved markedly. Quality of life improved, but not to significant thresholds as measured by the surveys. THR+TFOI appears safe and reasonable to offer to transfemoral amputees with painful hip joint degeneration.

Medium–term Outcomes of Transtibial Osseointegration in Association with Total Knee Replacement

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Jason Shih Hoellwarth

What was the question?
Transtibial osseointegration (TFOI) for amputees has limited but clear literature identifying superior quality of life and mobility versus a socketed prosthesis. Some amputees have knee arthritis that would be relieved by a total knee replacement (TKR). No other group has reported performing a TKR in association with TTOI (TKR+TTOI). We report the outcomes of nine patients who had TKR+TTOI, followed for an average 6.5 years. Study aimed to analyse the following: 1) what is the rate of complication following primary procedure; 2) how does patient prosthesis wear time and mobility change; 3) how does the patient's perception of using a prosthesis change (based on the Questionnaire for Persons with a Transfemoral Amputation, QTFA)?

How did you answer the question?
Our osseointegration registry was retrospectively reviewed to identify all patients who had TTOI and who also had TKR, performed at least two years prior. Four patients had TKR first the TTOI, four patients had simultaneous TKR+TTOI, and one patient had 1 OI first then TKR. All constructs were in continuity from hinged TKR to the prosthetic limb. Outcomes were: complications prompting surgical intervention, and changes in daily prosthesis wear hours, Questionnaire for Persons with a Transfemoral Amputation (QTFA), and Short Form 36 (SF36). All patients had clinical follow–up, but two patients did not have complete survey and mobility tests at both time periods.

What are the results?
Six (67%) were male, average age 51.2±14.7 years. All primary amputations were performed to manage traumatic injury or its sequelae. No patients died. Five patients (56%) developed infection leading to eventual transfemoral amputation 36.0±15.3 months later, and 1 patient had a single debridement six years after TTOI with no additional surgery in the subsequent two years. All patients who had transfemoral amputation elected for and received transfemoral osseointegration, and no infections occurred, although one patient sustained a periprosthetic fracture which was managed with internal fixation and implant retention and walks independently. The proportion of patients who wore their prosthesis at least 8 hours daily was 5/9=56%, versus 7/9=78% (p=.620). Even after proximal level amputation, the QTFA scores improved versus prior to TKR+TTOI, although not significantly: Global (45.2±20.3 vs 66.7±27.6, p=.179), Problem (39.8±19.8 vs 21.5±16.8, p=.205), Mobility (54.8±28.1 vs 67.7±25.0, p=.356). SF36 changes were also non–significant: Mental (58.6±7.0 vs 46.1±11.0, p=.068), Physical (34.3±6.1 vs 35.2±13.7, p=.904).

Medium–term Outcomes of Transtibial Osseointegration in Association with Total Knee Replacement *continued*

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What are your conclusions?
TKR+TTOI presents a high risk for eventual infection prompting subsequent transfemoral amputation. Although none of these patients died, in general, TKR infection can lead to patient mortality. Given the exceptional benefit to preserving the knee joint to preserve amputee mobility and quality of life, it would be devastating to flatly force transtibial amputees with severe degenerative knee joint pain and unable to use a socket prosthesis to choose between TTOI but a painful knee, or preemptive transfemoral amputation for transfemoral osseointegration. Therefore, TTOI for patients who also request TKR must be considered cautiously. Given that this frequency of infection does not occur in patients who have total hip replacement in association with transfemoral osseointegration, the underlying issue may not be that linked joint replacement with osseointegrated limb replacement is incompatible, but may require further consideration of biological barriers to ascending infection and/or significant changes to implant design, surgical technique, or other yet–uncertain factors.

Limb Reconstruction with Osseointegrated Transfemoral Prosthesis following Radical Amputation of Lower Extremity Sarcomas

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Hope Davis–Wilson, Cory Christiansen, Jason Stoneback, Brecca Gaffney, Danielle Melton

What was the question?
Osseointegrated Transfemoral Prosthesis (OTFP) result from a surgical approach that permits the direct attachment of an external prosthesis to the residual bone in patients with limb amputation who have failed to tolerate traditional socket prostheses. We present here a series of patients who underwent prosthesis osseointegration after radical resection of lower extremity tumors.

How did you answer the question?
This is prospective consecutive case series of 6 patients with transfemoral amputation prospectively followed for at least 12 months after undergoing limb reconstruction with OTFP after radical resection of extremity sarcomas. All patients had previously used a traditional socket prosthesis prior to osseointegration. Data collected included patient demographics, comorbidities, surgical outcomes, patient–reported outcomes, and functional abilities. Several patient–reported outcome and functional tests were used to assess the patient's mobility, disability, pain, prosthetic use, and quality of life. Functional outcomes included the Questionnaire for Persons with a Transfemoral Amputation (Q–TFA), Time–Up and Go (TUG) test, Activity–Balance Confidence (ABC) scale, Prosthetic Limb Users Survey of Mobility (PLUS–M), Short Form–36 item (SF–36), Patient–Reported Outcomes Measurement Information System (PROMIS)–Global Health, World Health Organization Disability Assessment Schedule 2.0 (WHODAS 2.0) and Modified Oswestry Disability Index (MODI). Cohen's d (d) effect size was used to determine the magnitude of effect size postoperatively.

What are the results?
This case series consisted of 3 females and 3 males with an average age of 51 ± 4.2 years (range: 44 to 56 years). The average body mass index was 24.8 ± 4.3 kg/m2. All participants had unilateral transfemoral amputation (4 left and 2 right lower limb). The mean residual bone length was 209.4 mm ± 68.6 (range: 91.2 to 291.2 mm). The primary tumors were osteosarcoma (3 patients), chondrosarcoma (1 patient), synovial cell sarcoma (1 patient), and reticulosarcoma (1 patient). After primary resection, the mean time between amputation and Stage 1 transfemoral osseointegration was 23.5 ± 11.4 years (range: 8 to 38.7 years). Four out of those 6 patients experienced no adverse events at 12 months postoperatively. One year following OTFP surgery, all 6 patients reported substantial improvement in the four components of Q–TFA: prosthetic use (MD= 24.7, d=0.67), mobility (MD= 19.42, d=1.07), problem (MD= –24.90, d=1.2), global score (MD= 47.22, d= 1.5). Additionally, substantial postoperative improvements were also noted in WHO–DAS score (MD= –5.8, d=1.26), PLUS–M score (MD= 11.35, d=1.91) as well as physical function (MD= 25.8, d=1.3), physical (MD= 50, d=0.8) and emotional (MD= 33.3, d=0.7) health components of 36–SF. The same improvements were reported in physical (MD= 7.66, d= 1.35) and mental (MD= 7.3, d=1.9) components of PROMIS–GH. Albeit, patients reported significant improvements in their daily life activities, balance, and confidence at their 1–year clinic visit as measured by mean and total ABC scores, (MD= 9.2, d=1.09) and (MD= 148.3, d=1.09), respectively. However, there were no statistically significant improvement in neither TUG (MD=–1.2, d=0.2), nor MODQ (MD= –9.2, d=0.47).

Limb Reconstruction with Osseointegrated Transfemoral Prosthesis following Radical Amputation of Lower Extremity Sarcomas *continued*

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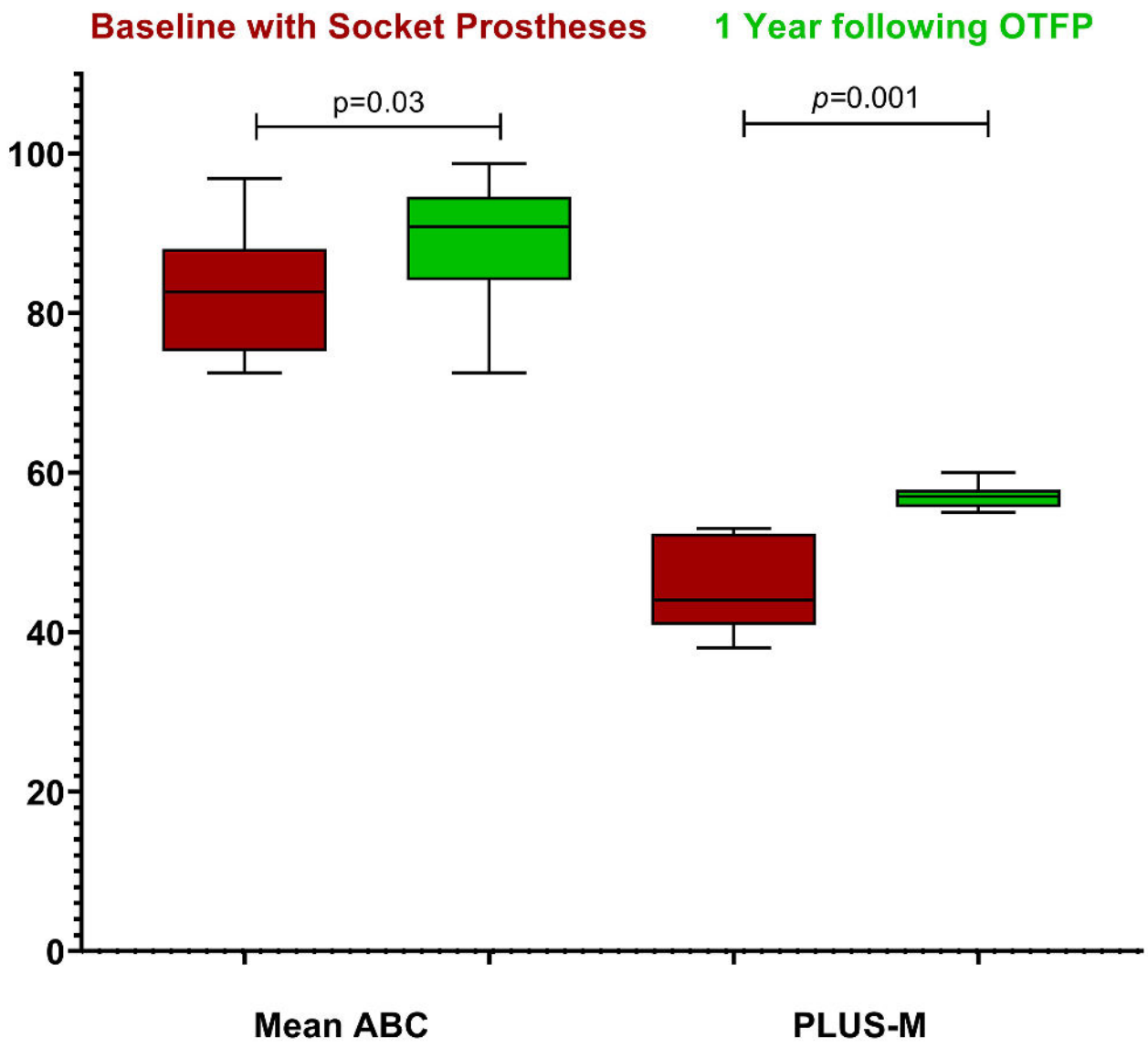
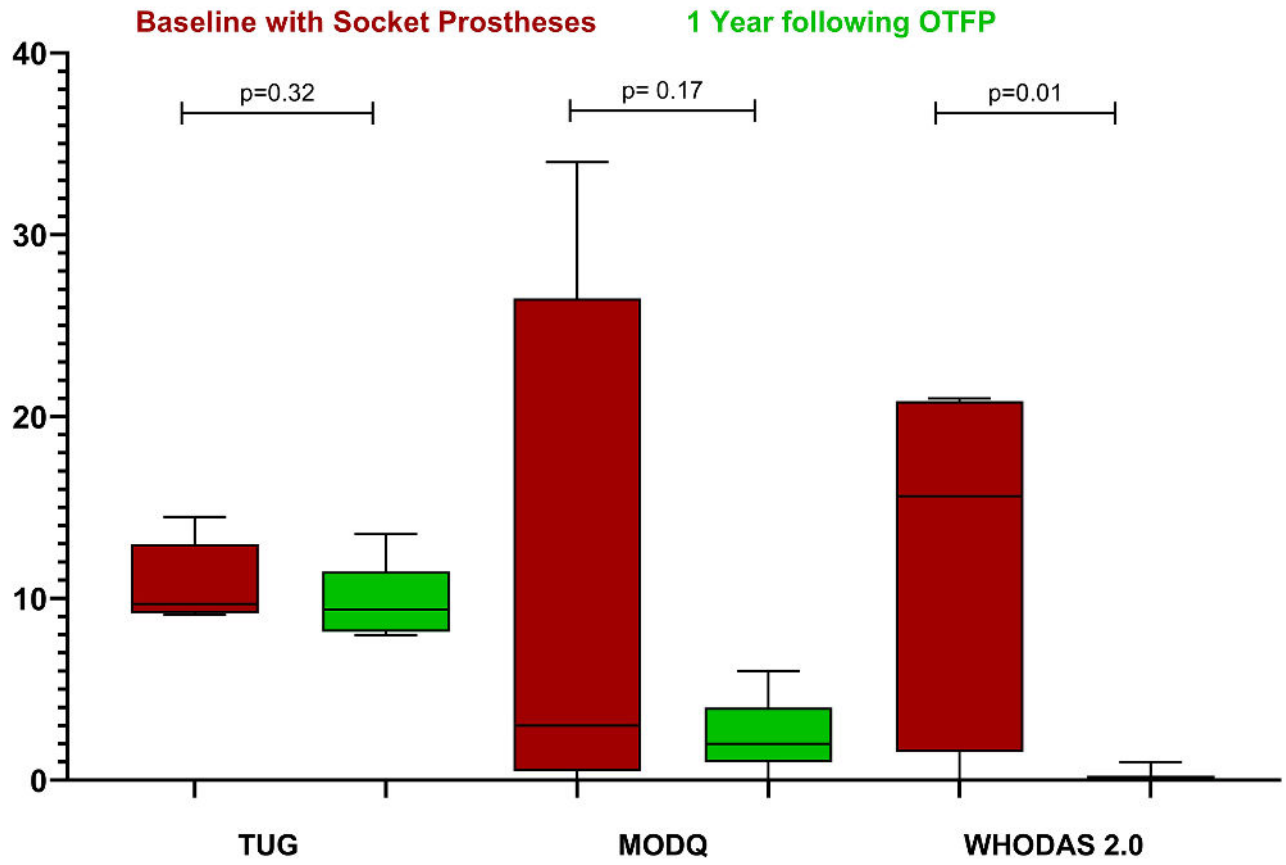
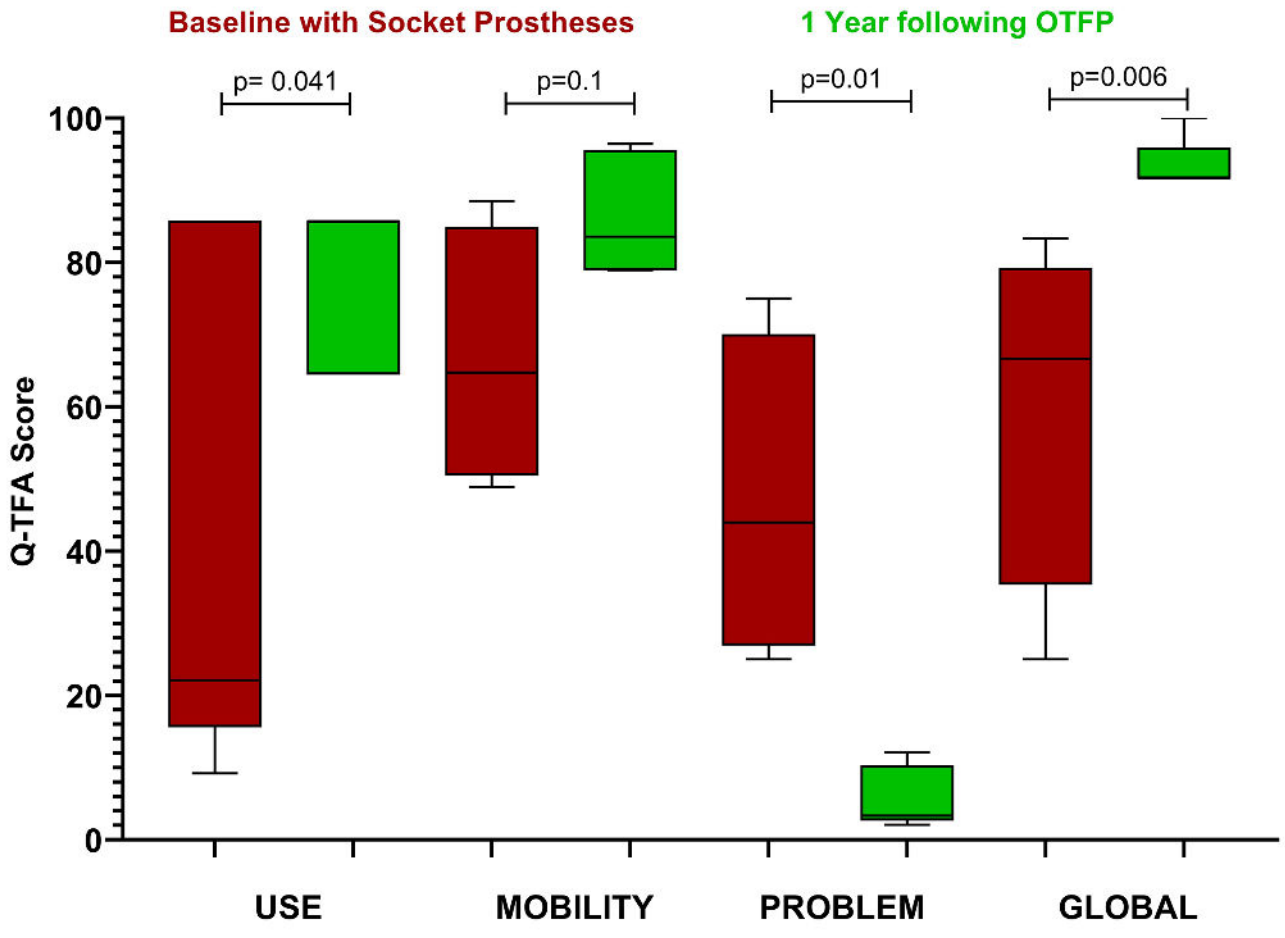
Hope Davis–Wilson, Cory Christiansen, Jason Stoneback, Brecca Gaffney, Danielle Melton

What are your conclusions?
OTFP following radical resection of lower extremity sarcomas offers an effective alternative to traditional socket prostheses. This procedure offered significant improvement compared to pre–resection use of a traditional socket–based prosthesis, in the limited cohort with a minimum follow up of 12 months.




Baseline with Socket Prostheses
1 Year following OTFP
40
30
20
10
0
p=0.32
p= 0.17
p=0.01
TUG
MODQ
WHODAS 2.0


Baseline with Socket Prostheses
1 Year following OTFP
Q-TFA Score
100
80
60
40
20
0
p= 0.041
p=0.1
p=0.01
p=0.006
USE
MOBILITY
PROBLEM
GLOBAL

The Use of Osseointegrated Titanium Implants to Treat Bilateral Amputees

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William Lu

What was the question?
Current socket prostheses remain problematic, resulting in more than 90% of patients with bilateral above–knee amputations being confined to a wheelchair due to the difficulty of mobilizing with prosthetics on both lower limbs. Osseointegration has been regarded as a novel approach to overcome persistent socket prosthetic issues, using a transcutaneous implant directly attached to the residual bone. A number of bilateral amputees have been treated with osseointegration in our centre since July 2012. Aim of this study is to report the early clinical outcomes in this particular group of patients, including the results of functional and quality of life assessments, and safety of the osseointegration procedure.

How did you answer the question?
Our osseointegration registry was retrospectively reviewed to identify 35 bilateral osseointegration patients, consisting of 30 males and 5 females, aged 22–66 (mean 36) years at surgery, with minimum two–year follow–up. Selection criteria were age over 18 years, bilateral amputees who had socket–related problems or were wheelchair–bound with short stumps and non–reconstructable limb pathology. Principle outcome measures included the Questionnaire for persons with a Trans–Femoral Amputation (Q–TFA), Short Form Health Survey 36 (SF–36), Six Minute Walk Test (6MWT), Timed Up and Go (TUG), and K–levels. Adverse events were recorded including infection, revision surgery, fractures, and implant failures.

What are the results?
Comparisons were made using differences between the mean pre–operative and mean post–operative values for each outcome measure. Significant improvements in all validated outcome measures were observed. The occurrence levels of adverse events, including the infection rate and revision rate, were similar to other established trans–femoral osseointegration studies.

What are your conclusions?
These preliminary results indicate that osseointegration surgery is a safe and effective alternative treatment for bilateral amputees experiencing socket–related discomfort. Compared to the suboptimal outcomes of socket prostheses, osseointegration currently provides one of the best chances for any bilateral amputee to walk again and regain the ability to perform daily activities.

Defining the Minimal Clinically Important Difference of Health–Related Quality of Life Measures following Osseointegrated Transfemoral Prosthesis in Amputees

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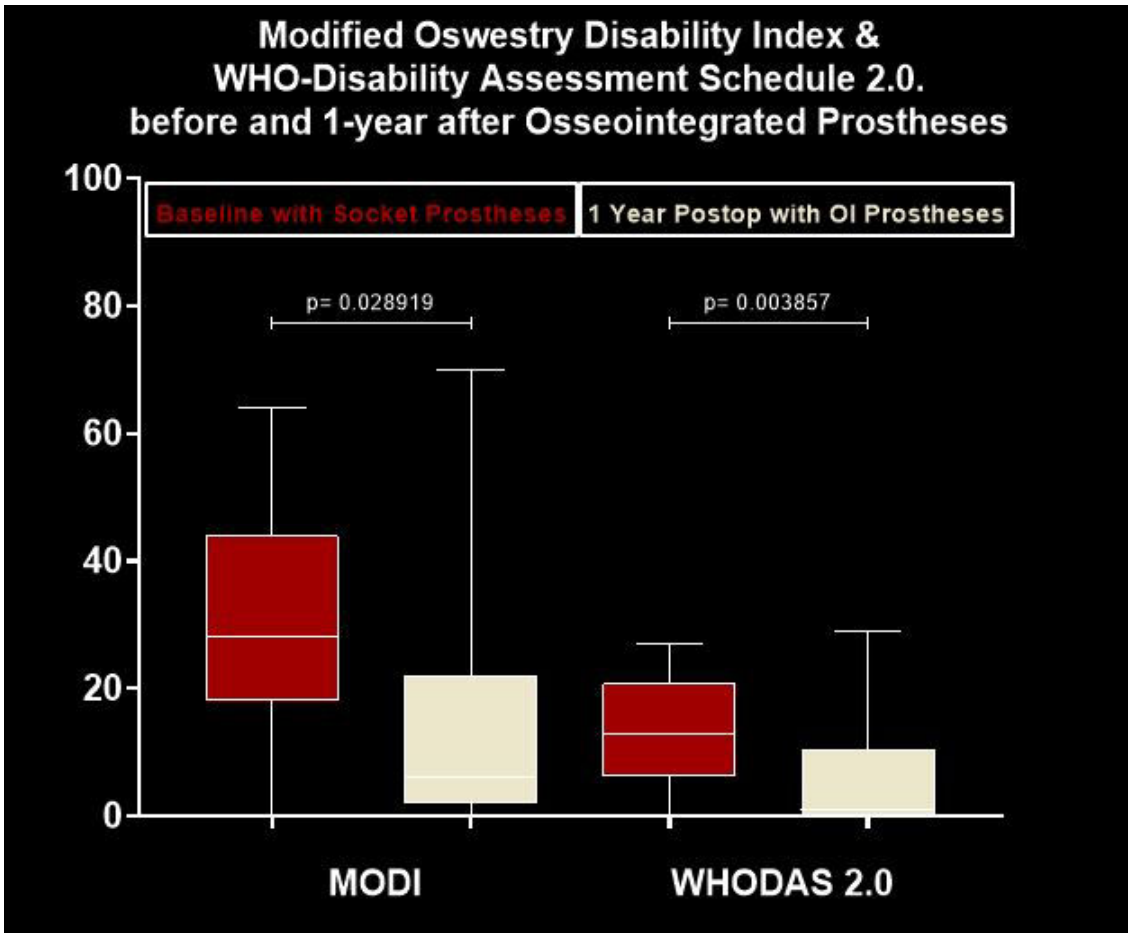
Brecca Gaffney, Cory Christiansen, Jason W. Stoneback, Danielle Melton

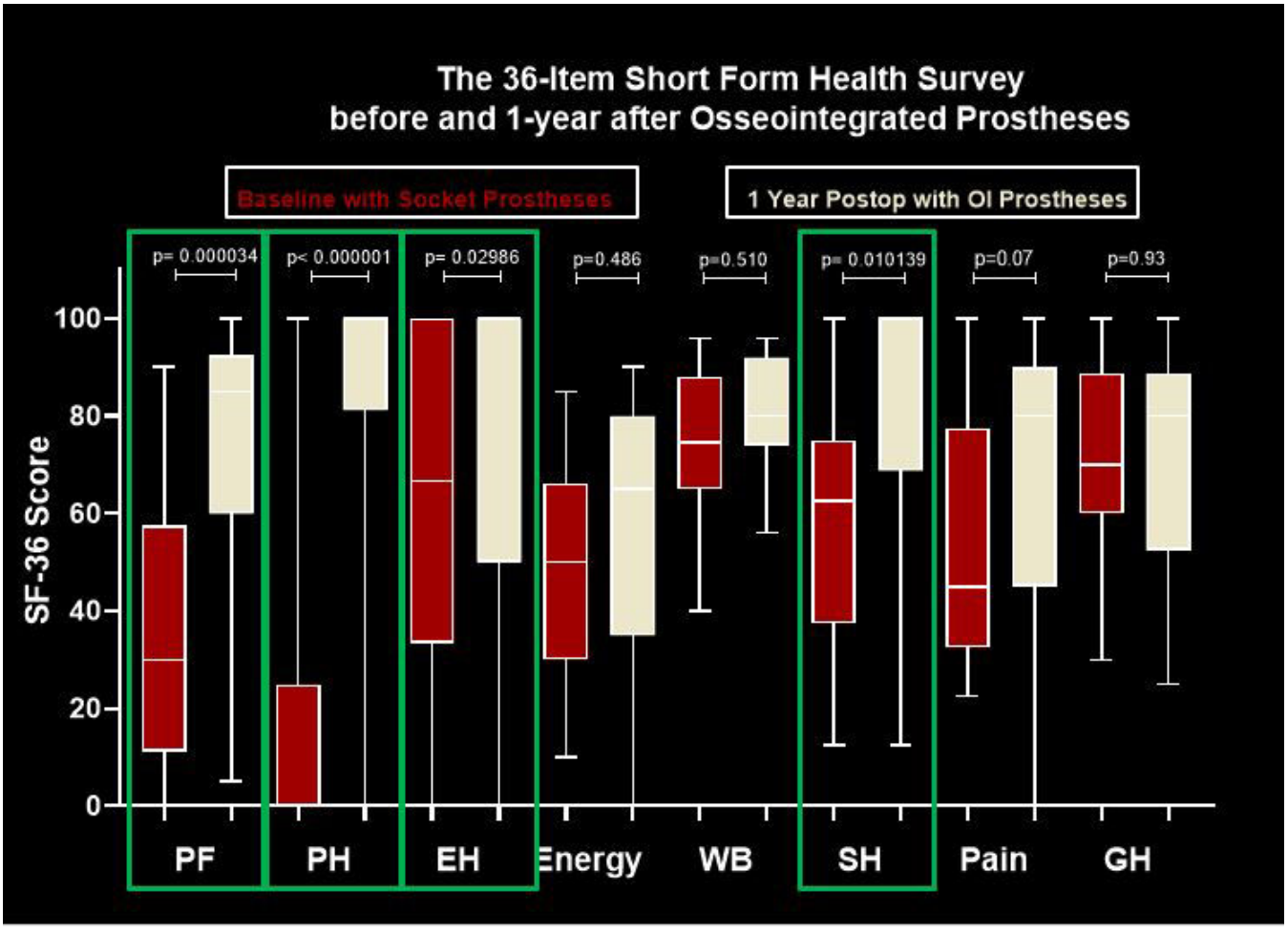
What was the question?
Osseointegrated Transfemoral Prosthesis (OTFP) is effective at improving the patient–reported health–related quality of Life (HRQoL). However, interpretation of HRQoL outcomes following OI transfemoral prosthesis implantation is hindered by the lack of established minimal clinically important differences (MCIDs). This study aimed to identify the MCID for HRQoL, measured using the Short Form–36 (SF–36), World Health Organization Disability Assessment Schedule 2.0 (WHODAS 2.0), Oswestry Disability Index (ODI), and PROMIS® (Patient–Reported Outcomes Measurement Information System®) Global Health instruments.

How did you answer the question?
Prospectively collected data from 33 patients who underwent two–stage OTFPI at a single institution were analyzed. (63.6% male, 51.9±10.5years). HRQoL assessment was performed preoperatively, and 1–year postoperatively using the SF–36, WHO–DAS 2.0, MODI, PROMIS measures. MCID was evaluated with a two–pronged methodology, using (1) six different distribution–based methods and (2) an anchor–based method using a anchor transition question (five–point scale). The transition items were collected at 1–year and MCID thresholds were established by receiver operating characteristic analysis, through mean change in patients somewhat better. Pooled MCIDs were computed as the arithmetic weighted mean.

What are the results?
At baseline, all HRQoL reported measures were completed by the 33 participants, except for the SF–36 (missing for 13 patients). The estimated pooled MCIDs established by distribution–based methods for SF–36 components were: 11.2 for physical function; 17.01 for physical health; 18.9 for emotional health; 9.2 for energy domain; 12.8 for social health; 7.5 for well–being; 10.2 for pain domain; and 8.8 for global health. Estimated pooled MCID was –3.15 for the WHO–DAS 2.0 and –7.6 for MODI. Estimated pooled MCIDs for PROMIS global health components were +1.44 for physical component and +1.1 for the mental component.

What are your conclusions?
The MCIDs identified in this study provide estimates to interpret patient–reported HRQoL questionnaires (SF–36, PROMIS Global Health, WHO–DAS, and MODI) following OTFPI. We have established a set of thresholds for these questionnaires to guide determination of patients who are most likely to achieve clinical improvement postoperatively, based on baseline status.


Modified Oswestry Disability Index &
WHO-Disability Assessment Schedule 2.0.
before and 1-year after Osseointegrated Prostheses
Baseline with Socket Prostheses
1 Year Postop with OI Prostheses
p= 0.028919
p= 0.003857
100
80
60
40
20
0
MODI
WHODAS 2.0


The 36-Item Short Form Health Survey
before and 1-year after Osseointegrated Prostheses
Baseline with Socket Prostheses
1 Year Postop with OI Prostheses
p= 0.000034
p< 0.000001
p= 0.02986
p=0.486
p=0.510
p= 0.010139
p=0.07
p=0.93
SF-36 Score
100
80
60
40
20
0
PF
PH
EH
Energy
WB
SH
Pain
GH

Postoperative Osseointegration Rehabilitation Protocols: A Scoping Review with Recommendations for Progress

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Matan Grunfeld, S. Robert Rozbruch, Jason Hoellwarth

What was the question?
Transcutaneous osseointegration consistently provides significant quality of life and mobility benefits versus socket prosthesis rehabilitation. However, investigation of the postoperative rehabilitation process has been neglected. The primary aim of this study was to understand the similarities and differences among lower extremity osseointegration rehabilitation protocols. The secondary aim was to identify shortcomings and suggest recommendations to improve rehabilitation.

How did you answer the question?
A scoping review of human osseointegration literature was performed, selecting studies which reported a protocol for rehabilitation following lower extremity osseointegration. Key commonalities and differences in regards to surgical stages, milestones of progress, timing expectations, and loading recommendations were organized. Then, critique of apparent controversy or shortcomings was performed and suggestions proposed to investigate and address those aspects.

What are the results?
683 articles were gathered from 4 electronic databases. 658 were excluded as duplicates or for lacking description of lower extremity osseointegration rehabilitation, yielding 24 articles included in this scoping review. All protocols shared the same linear progression of set goals: surgical stages, time until progressive loading, loading protocol, and rehabilitation with “conclusion” upon achieving independent ambulation (Figure 1). The most impactful difference among protocols was whether one or two surgical stages were used, often determined by surgeon adherence to implant manufacturer recommendations. An additional difference was the time patients were kept non–weight bearing following externalization of the abutment, between days to months. There were less impactful differences regarding the pace of weight progression and at what weight to attach a full leg prosthesis. There were notable consistent shortcomings among the literature. None cited basic science or data–based clinical experience supporting the rationale behind recommended timings. None described specific or consistent additional clinical goals once full weight bearing was achieved. None provided specific details regarding differences in rehabilitation of transtibial versus transfemoral amputations. Finally, none investigated the actual success of achieving recommended goals on schedule or how to address setbacks during rehabilitation.

Based on the literature assessment, the following recommendations were proposed. The most important and also most achievable recommendation is to specifically investigate the consistency of goal achievement through the rehabilitation process, including what setbacks occur and how they are addressed. The next recommendation is to expect better performance from osseointegrated patients: simply walking is too low an expectation and likely does not optimize performance for many patients; activity–specific or deficit–centric rehabilitation may consistently maximize performance beyond simple ambulation. Third, it is likely beneficial to consider technology that assists in the evaluation and assessment of patients in short– and long–term rehabilitation gains, such as wearable activity trackers, gait analyzers that work outside a laboratory, or ways to “gamify” activity.

Postoperative Osseointegration Rehabilitation Protocols: A Scoping Review with Recommendations for Progress *continued*

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What are your conclusions?

The study and advancement of rehabilitation techniques following lower extremity osseointegration is woefully neglected. Optimistically, despite this relative inattention, osseointegrated patients already generally do better than in a socket. Specifically improving the postoperative rehabilitation likely can further improve amputee performance. Explicitly focusing on the study of rehabilitation following osseointegration, perhaps guided by the proposed recommendations, may expedite the realization of such potential.

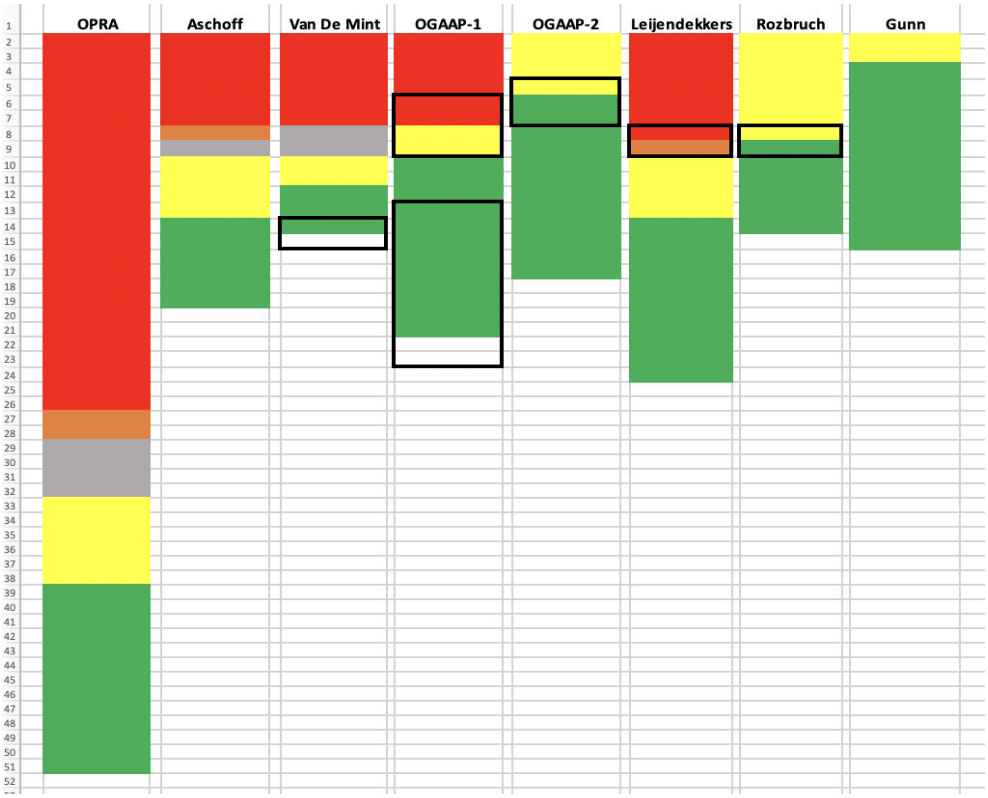

Figure 1: Graphical illustration of post-operative lower extremity osseointegration rehabilitation protocol timelines. The horizontal axis represents the different rehabilitation protocols (when named) or the representative surgeon. The vertical axis enumerates the number of weeks of each rehabilitation stage. All authors followed the same order of recovery as stated in the text. Colors indicate the different phases. When not mentioned in the protocol (or if less than one week in length), the phase (color) is omitted from this overview schematic. Red - waiting period between surgical stages. Orange - resting period. Gray - PT with no weight bearing. Yellow - training prosthetic period. Green - aided walking with a full length prosthetic. The black outlines represent the range during which transition to the next stage occurs, when specified by the author.

Session V: Limb Deformity – Practice

Moderator: Jaclyn F. Hill, MD

Prospective Multi–Center Comparison of Modified Scoliosis Instruments and PODCI in Pediatric Limb Deformity Patients

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Emily Canitia, Kouami Amakoutou, Naveen Jasty, Numera Sachwani, Jill C. Flanagan, Raymond W. Liu

What was the question?
Patient–reported outcome (PRO) instruments are important in modern research, but there are no validated PROs specific for pediatric limb deformity (LD) patients. At LLRS 2021 we previously presented preliminary data on limb deformity modifications of two commonly used scoliosis instruments, the Early Onset Scoliosis Questionnaire (LD–EOSQ, used for ages 0–10 years) and the Scoliosis Research Society Questionnaire (LD–SRS, used for ages 11–18 years), to the Pediatric Outcomes Data Collection Instrument (PODCI), which is well validated and widely utilized in general pediatric orthopaedics. This is a follow up study with a complete dataset, as well as content validity testing for the LD–EOSQ and LD–SRS instruments.

How did you answer the question?
Limb deformity modifications were created by substituting the word “leg” for “back” in the scoliosis questionnaires, creating the LD–EOSQ and LD–SRS instruments. We then queried the CHILD (Children’s Hospitals Investigating Limb Deformity) database, which is a prospective multi–center limb deformity database consisting of children 18 years and younger indicated for any surgery which alters bone shape. All children were preoperatively administered the appropriate limb deformity instruments as well as age–appropriate PODCI questionnaires, and similar domains of each instrument were compared. In addition, we compared scores for the different instruments with LLRS AIM scores. Content validity assessments for the LD–EOSQ and LD–SRS were also collected from a representative sample of participants.

What are the results?
For 36 children ages 10 years and younger (table 1), LD–EOSQ Quality of Life and PODCI Global function had comparable scores (3.9 versus 4.0, $p = 0.21$) and high correlation ($R2=0.82$). However, LD–EOSQ Family Impact was scored lower than PODCI Happiness (3.9 versus 4.4, $p = 0.03$) with moderate correlation ($R2=0.48$).

For 35 children ages 11–18 years (table 2), LD–SRS compared to PODCI demonstrated worse scores for Physical Function (3.8 verses 4.7, $p < 0.001$), better scores for Pain (4.1 versus 3.7, $p = 0.004$), and similar scores for LD–SRS Mental Health and PODCI Happiness (3.8 versus 4.1, $p = 0.15$). There were moderate to high correlations between comparable domains ranging from R2 values of 0.40 to 0.71. The correlations varied between instrument scores and LLRS AIM (Tables 1–2). While LD–EOSQ and PODCI correlated similarly with LLRS AIM score, LD–SRS had greater correlation with LLRS AIM score compared to PODCI for Physical Function ($R2 = 0.33$ versus 0.12) and Pain domains (0.27 and 0.09). Content validity assessments demonstrated that the LD–EOSQ took an average of 10.7 minutes to complete and achieved each validity criteria in 100% of patients while the LD–SRS took an average of 17.1 minutes to complete and achieved each validity criteria in greater than 80% of patients (table 3).

Prospective Multi–Center Comparison of Modified Scoliosis Instruments and PODCI in Pediatric Limb Deformity Patients *continued*

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Emily Canitia, Kouami Amakoutou, Naveen Jasty, Numera Sachwani, Jill C. Flanagan, Raymond W. Liu

What are your conclusions?
The limb deformity modified outcome instruments correlated well with PODCI questionnaires on most comparable domains, were quick to complete, and met validity criteria in a majority of patients. In adolescents, the LD–SRS had worse functional scores but better pain scores compared to PODCI, while the LD–EOSQ had worse family impact scores compared to PODCI. This fits well with the expectation that adolescents should be more physically affected by their limb deformity than younger children, while parental burden may be greater with younger pediatric limb deformity patients. Both findings suggest that the modified scoliosis systems might better capture limb deformity patient issues as compared to PODCI, while the content validity assessments suggested that these are acceptable tools from the patient perspective. Finally, increased correlation between LD–SRS Function/Activity and LD–SRS Pain with LLRS AIM further suggests that LD–SRS may better reflect limb deformity outcomes versus PODCI in adolescents.

Table 1. Comparison between LD-EOSQ and PODCI in comparable domains and with LLRS AIM score for children 10 years and under. Results considered significant if $P < 0.05$.

Children 10 Years and Under (N = 36, Mean Age 7.1 ± 2.6 years)				
PRO Domain	LD-EOSQ Quality of Life	PODCI Global Function	LD-EOSQ Family Impact	PODCI Happiness
Score	3.9 ± 0.7	4.0 ± 0.7	3.9 ± 0.8	4.4 ± 1.1
P-value	0.21		**0.03**	
Correlation between instruments (R^2)	0.82		0.48	
Correlation with LLRS AIM (R^2)	0.16	0.17	0.28	0.25

Table 2. Comparison between LD-SRS and PODCI in comparable domains and with LLRS AIM score for children 11-18 years old. Results considered significant if $P < 0.05$.

Children 11 – 18 years (N = 35, Mean Age 14.5 ± 2.6 years) – Self Reported						
PRO Domain	LD-SRS Function/ Activity	PODCI Mobility and Sports	LD-SRS Pain	PODCI Pain/ Comfort	LD-SRS Mental Health	PODCI Happiness
Score	3.8 ± 0.7	4.7 ± 0.7	4.1 ± 0.7	3.7 ± 0.6	3.8 ± 0.9	4.1 ± 1.1
P-value	**< 0.001**		**0.004**		0.15	
Correlation between instruments (R^2)	0.40		0.50		0.71	
Correlation with LLRS AIM (R^2)	0.33	0.12	0.27	0.09	0.02	0.14

Table 3. Results from post-survey validity questionnaire for both LD-EOSQ and LD-SRS.

	LD-EOSQ (N = 12)	LD-SRS (N = 22)
Does this questionnaire sufficiently address areas of life that are important to you?	100%	82%
Did you find the questionnaire easy to understand?	100%	91%
Did you find the length of this questionnaire acceptable?	100%	82%
Did you find the number of response choices appropriate?	100%	82%
Time to complete (minutes)	11 ± 7	17 ± 10

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

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Jan Duedal Rolfing, Bjoern Vogt, Mohan Belthur, Melissa Esparza, Alicia Kerrigan, Jonathan Wright, Ashish Ranade, Louise Johnson, David Podeszwa, Juergen Messner, Christopher Iobst, Sanjeev Sabharwal, Jussi Repo, Sharon Eylon

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.

Our research questions were:
• Are the items included in LIMB–Q Kids psychometrically valid?
• Do the items included in the LIMB–Q Kids scales follow the Rasch model?

How did you answer the question?
We conducted an international field test study where LIMB–Q Kids was completed by children with lower limb differences from several sites across the world. Clinical data was collected for all children who completed LIMB–Q Kids. The final field–test version consists of 11 scales (159 items) that measure appearance, physical function, symptoms (hip, knee, ankle, foot, and leg), leg–related distress, and school, social and psychological function. This version was rigorously translated into Danish and German. Translations that are in progress include Arabic, Finnish, Hindi, Hebrew, Portuguese and Spanish.

What are the results?
An international field–test study is underway in 15 countries (25 sites with a target recruitment of 150 participants per country). 310 completed LIMB–Q Kids have been received to date with the target of 500 before the final analysis. A preliminary analysis of the available data using Rasch Measurement Theory analysis provided evidence that the scales in the LIMB–Q Kids work as hypothesized.

What are your conclusions?
No internationally applicable PROM exists for children with LLDs. Data from the international field–test study will be used to reduce items and perform psychometric testing of LIMB–Q Kids. The rigorous TCA process provided versions of LIMB–Q Kids in different languages. Once completed, the LIMB–Q Kids will provide a common metric for outcome assessment for children with lower limb differences internationally.

Limb Lengthening and Reconstruction Society Aim Index – Reliability in Assessing Disease Severity

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Harpreet Chhina, Anthony Cooper

What was the question?
The Limb Lengthening and Reconstructive Society (LLRS) AIM Index has been shown to reliably classify the complexity of lower limb deformities in and between observers. Our study aimed to assess the correlation between the LLRS AIM index and the disease severity. We also aimed at identifying the strengths and limitations of this scoring system across multiple clinical conditions.

How did you answer the question?
We performed a retrospective study in which LLRS AIM Index was calculated for 50 patients (aged less than 16 years) based on their status before their first surgery from the senior author. Patients with prior surgeries were not included in this dataset. During the scoring, a descriptive analysis of the strengths and limitations of the scoring system was recorded for each patient. The calculated scores were compared with the severity, which was measured in the form of the total number of surgeries done at the time of the most recent follow–up and the associated complications.

What are the results?
The LLRS AIM scores of 50 patients ranged from 0 to 12 as per the index grading system with 11 patients having substantial complexity. Out of 50, 23 underwent single or multiple surgical interventions, 20 did not require any surgical intervention and 7 have been planned for surgery. We found that with each unit increase in LLRS AIM Score, the chance of needing surgery increased by 17% (Rate ratio = 1.17, 95% Cl = 1.09 to 1.24, p

What are your conclusions?
Based on our current analysis, it can be concluded that a higher LLRS score is associated with an increased need for surgical intervention and therefore an assumed increase in disease severity. The rate of surgery increases by 17%, for each unit increase in LLRS AIM index score. We have demonstrated that the LLRS scoring system is a useful tool for stratifying complexity across patients with different clinical conditions. However, the scores in pathologies like rotational malalignments and different tibial bowing conditions should be interpreted with caution and there may need to be modifiers to the scoring system to account for these variations. A study with a larger sample size is ongoing to confirm these findings.

Length of Stay and Readmission Rates After Limb Lengthening Surgery

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What was the question?
Limb lengthening techniques have evolved from the use of external fixation to widespread adoption of modern internal lengthening nails. As surgical techniques advance, it is anticipated that the length of stay (LOS) required and the readmission rates reported after these procedures will continue to improve into the future. We report on the LOS and readmission rates after limb lengthening procedures in a contemporary patient cohort.

How did you answer the question?
This was a retrospective cohort study analyzing all lower limb lengthening events in a single center between October 2016 and June 2022. There were 297 lengthening events, of which 130 were stature lengthening events, in 190 patients in total. All other lengthenings were for either congenital or acquired deformities. There were 11 external fixators used and the remaining 286 events were performed with internal lengthening nails. There were 101 patients with concurrent deformity correction at the time of lengthening. The primary outcomes of interest were LOS and readmission rates (defined as a hospital stay of >24 hours). Associated variables were analyzed and significant relationships were reported using appropriate statistical analysis.

What are the results?
The median LOS was 2 days (IQR2–3). Factors associated with an increased LOS included increasing age (p=0.0023), adult more than pediatric patients (mean 3.1 v 2.7 days) (p=0.048), ethnicity (Hispanic longest – mean 3.6 days, Asian shortest – mean 2.6 days) (p=0.0049) and the day of the week on which the procedure was performed (Tuesday and Friday – median 2 days, Monday, Wednesday, Thursday – median 3 days) (p=0.0205). There was a 10.1% (30/297) readmission rate for the whole cohort. Twenty–nine patients had 1 unplanned procedure, 8 patients had 2 procedures and 1 person had 3 procedures for complication management. The factors associated with a higher readmission rate included increasing age (p=0.0018), higher index LOS (p=0.0002) and longer total time spent lengthening (p=0.0002).

What are your conclusions?
We report on the LOS and readmission rates after limb lengthening procedures in a contemporary patient cohort. The only modifiable variable for LOS is the day of the week on which the procedure was performed. The only modifiable risk factors for readmission were increasing age, index LOS and the total time spent lengthening.

Burnout in Limb Reconstruction Surgeons

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Anirejuoritse Bafor, Kirsten Tulchin–Francis

What was the question?
Burnout in the medical profession is increasing, especially after the pandemic. Since limb reconstruction surgeons are routinely faced with complex patients that require complicated management strategies, there are strong risk factors for developing burnout. While burnout studies have been performed in other orthopedic surgical subspecialties, to our knowledge, this has never been investigated among limb reconstruction surgeons. The aim of this study was to evaluate the incidence and contributing factors to burnout among international limb reconstruction surgeons.

How did you answer the question?
An anonymous, IRB approved, secure REDCAP database survey was emailed to international limb reconstruction surgeons. The survey included demographic questions, 4 open ended questions and two validated measures: patient Health Questionnaire 4 (PHQ–4) to screen for symptoms of anxiety and depression and the Maslach Burnout Inventory–Human Services Survey for Medical Personnel (MBI), the gold standard tool for assessing burnout in health professionals. Statistical analysis was performed using the Kruskal–Wallis test and the Mann–Whitney test.

What are the results?
103 completed responses were submitted from surgeons representing at least 16 different countries. On average, the responding surgeons were 83% male and defined themselves as 20% early–career (1–10 years' experience), 47% mid–career (11–20 years' experience) or 33% senior (21 years or more experience). They averaged a 54–hour work week with 5 call nights a month and 12 limb construction cases per month.
The PHQ–4 results demonstrated normal total scores, as well as normal scores in each of the subgroups for anxiety and depression across all 103 respondents. There were no differences between the three career levels (early, mid, senior).

The MBI results demonstrated high emotional exhaustion in 19%, high depersonalization in 15% and low personal accomplishment in 24% of respondents. Overall, 38% displayed burnout symptoms and 16% exhibited severe burnout. Although not statistically significant, the mid–career group was the most affected.

When asked how the surgeon deals with complications or disappointing results that occur in his/her patients, 31% of the respondents described unhealthy, prolonged responses to dealing with complications involving rumination, self–blame, internalization, loss of sleep and having it affect their personal and professional lives.

52% reported having wellness counseling available in the workplace but only 6% use these services. 23% stated they have previously or currently been treated with counseling and/or medication to help with mood and/or anxiety.

56% of participants were comfortable with conflict situations. Response themes identified included trying to actively avoid these situations, feeling exhausted by them and having more difficulty dealing with colleague conflict than patient conflict.

Burnout in Limb Reconstruction Surgeons *continued*

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Anirejuoritse Bafor, Kirsten Tulchin–Francis

What are your conclusions?
We believe this is the first study to evaluate burnout in limb reconstruction surgeons. Given the international nature of the participants, the findings indicate that burnout is a global concern among limb reconstruction surgeons with 38% of the respondents exhibiting burnout symptoms and 16% at risk for severe burnout. The results of the study help to define the scope of the problem in limb reconstruction. Further initiatives to develop wellness programs for limb reconstruction surgeons that assist in identifying and mitigating burnout will be necessary.

Session VI: Limb Deformity – Techniques

Moderator: Mitchell Bernstein, MD

The Percutaneous Comminuted Closing Wedge Osteotomy "Perc Wedge": A Powerful Solution for Deformity Correction

Stephen M. Quinnan, MD

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Stephen Forro, DO; William Pavlis

What was the question?
Correction of diaphyseal and metaphyseal deformity and malunion with intramedullary fixation offers many advantages. However, correction of large angular deformities with a percutaneous opening wedge osteotomy can lead to large bone gaps with delayed healing or very poor regenerate formation if lengthening is performed. We used a novel osteotomy method that we have termed the “perc wedge”, in which a percutaneous comminuted closing wedge osteotomy is used to address these concerns. We aim to answer the question of whether the clinical results of perc wedge osteotomy reliably overcome these challenges?

How did you answer the question?
The reviewed 41 consecutive cases of a single surgeon who performed a perc wedge osteotomy for correction of malunion or deformity. We evaluated the magnitude of the deformity. The success of correction, and the union rates and healing times of the osteotomies/regenerate

What are the results?
A total of 41 perc wedge osteotomies in 34 patients were studied. Of the 41 osteotomies, 17(41.5%) were performed in conjunction with lengthening, using either precise or stryde lengthening nail. The average lengthening in this set of patients was 29.9mm. The remaining 24(58.5%) patients had osteotomies performed in a static fashion (ie. without lengthening). 26(63.4%) osteotomies in this study were used to treat deformity in 2 or more planes. Coronal plane deformities ranged from 26° varus to 17° valgus. Sagittal plane deformities ranged from 34° apex anterior to 22° apex posterior. Although our technique does not aim to focus on treatment of isolated rotational deformities, we were able to utilize it in both coronal and sagittal plane deformities with associated rotational components, which ranged between 15° internal to 38° external rotation deformity. Successful deformity correction was defined alignment within 5° of goal with radiographic healing of the osteotomy site. 39/41(95.1%) osteotomy sites achieved this, with 2 going on to union, but failing to correct within 5°. Both of these osteotomies were made in the proximal tibia for correction of significant apex anterior deformity, which proved to be the most difficult to correct and maintain. 100% osteotomy site union rate was achieved in both the static osteotomy group, as well as those that underwent lengthening in conjunction with corrective osteotomy. Average time to union was 220 days. 2 patients in our study went on to have complications in their post op course. The first occurred in a patient who underwent corrective osteotomy to his tibia, followed by ipsilateral femur 11 months later. Shortly after the second osteotomy, he developed pain in his total hip prosthesis on the same side. He later was diagnosed with prosthetic joint infection, and the implant was revised, which ultimately slowed the union rate of his femoral osteotomy site significantly. The other complication in the study occurred in a patient being treated with proximal tibial osteotomy and lengthening to correct her distal tibia fracture malunion and associated nonunion. On first postoperative visit after beginning lengthening, X Rays revealed she had begun lengthening at both her osteotomy site, as well as the nonunion site distally. While this is not a complication persay, it did force us to have her refrain from lengthening for longer than initially planned, and thus should be mentioned in our findings. Overall, 38/41 cases went on to union at osteotomy site complication free, with a complication rate of 7%. As stated previously, the 3 cases that make up that 7% also went on to osteotomy site union.

The Percutaneous Comminuted Closing Wedge Osteotomy "Perc Wedge": A Powerful Solution for Deformity Correction *continued*

Stephen M. Quinnan, MD

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Stephen Forro, DO; William Pavlis

What are your conclusions?
The perc wedge osteotomy offers an exciting new option for treatment of diaphyseal and metaphyseal deformities. The technique is optimal when combined with intramedullary nailing techniques for deformity correction including the use of the reverse planning method. The healing results from the technique when performed for static correction are excellent. The results with concomitant lengthening through the same site are also excellent even for very large deformities. In addition, it offers a significant advantage in avoiding surgical incisions and deep surgical dissection and stripping. We believe that this combination of advantages offers the most powerful alternative to date for correction of large deformities with concomitant bone loss.

Comparative Fixation Devices for Preventing Migration of the Proximal Tibiofibular Joint During Tibial Lengthening: A Tether Versus Screw Fixation

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S. Robert Rozbruch

What was the question?
When lengthening the tibia segment using motorized internal lengthening nails (MILN), undesired distal migration of the proximal fibula segment is prevented by tibiofibular stabilization, traditionally using a screw. A tightened cortical suspensory fixation rope (tether) is an alternative option, but its appropriateness has never been studied. To address this knowledge gap, for surgical benefit, the current study compares the use of a tether or a screw for proximal tibiofibular joint fixation during tibial lengthening with MILN. Using the radiographic measurement of proximal tibiofibular joint (fibular head) migration to determine the difference in the fixation stability. The primary outcome was the amount of radiographic proximal tibiofibular joint migration. The secondary outcome was the clinical impact of fibular migration, specifically knee motion, pain, and peroneal nerve deficit.

How did you answer the question?
A retrospective study was conducted on patients who underwent tibial lengthening with MILN between April 2016 and June 2022. Two cohorts were compared: 18 limbs with tether fixation versus 29 limbs with screw fixation. Data on the patient's age, sex, etiologies, and clinical outcomes were collected. Radiographic measurements included the lengthening distance and the amount of proximal fibular migration. The total proximal fibular migration distance was determined by the distance between the tip of tether or screw relative to the line drawn between the medial and lateral tibial plateau (Figure 1), the distal fibular migration distance was measured as the distance between the tip of screw relative to the line drawn parallel to ankle joint line (Figure 2). The difference of the distance in both parameters were evaluated at the end of lengthening versus the immediate postoperative radiograph, altogether with tibial and fibular lengthening distance (Figure 3). The migration ratio was calculated by dividing migration distance by the total lengthening achieved. The relationship between the magnitude of lengthening with the direction and magnitude of tibiofibular migration was assessed using Pearson correlation. Significance was set as $p<0.05$.

What are the results?
In total, 47 limbs from 41 patients, with average age 35.01 ± 13.72 years old. There were 28 males (68.29%) and 13 females (31.71%). The tether group demonstrated a statistically significant greater both migration distance and ratio than the screw group (both $p < 0.001$), with an average migration distance of 8.39 ± 5.09 mm and 2.59 ± 3.06 mm, respectively (Figure 4 and 5). Distal tibiofibular migration distances in both tether and screw groups were not significantly different ($p=0.41$), with averages of 1.8 ± 1.9 mm and 2.33 ± 1.37 mm, respectively. No correlation was found between the amount of tibial lengthening and the distance of proximal fibular migration in both the tether group ($p = 0.96$) and the screw group ($p = 0.32$). There was no significant difference in the change of knee extension between both groups ($p = 0.3$) (Figure 6), and no patients reported knee pain or tightness.

What are your conclusions?
Screw fixation of the proximal tibiofibular joint during MILN lengthening provides better resistance to fibular migration than a tether, but the two options provide equivalent clinical outcomes. Consequently, either option may be suitable based on the surgeon’s preference.

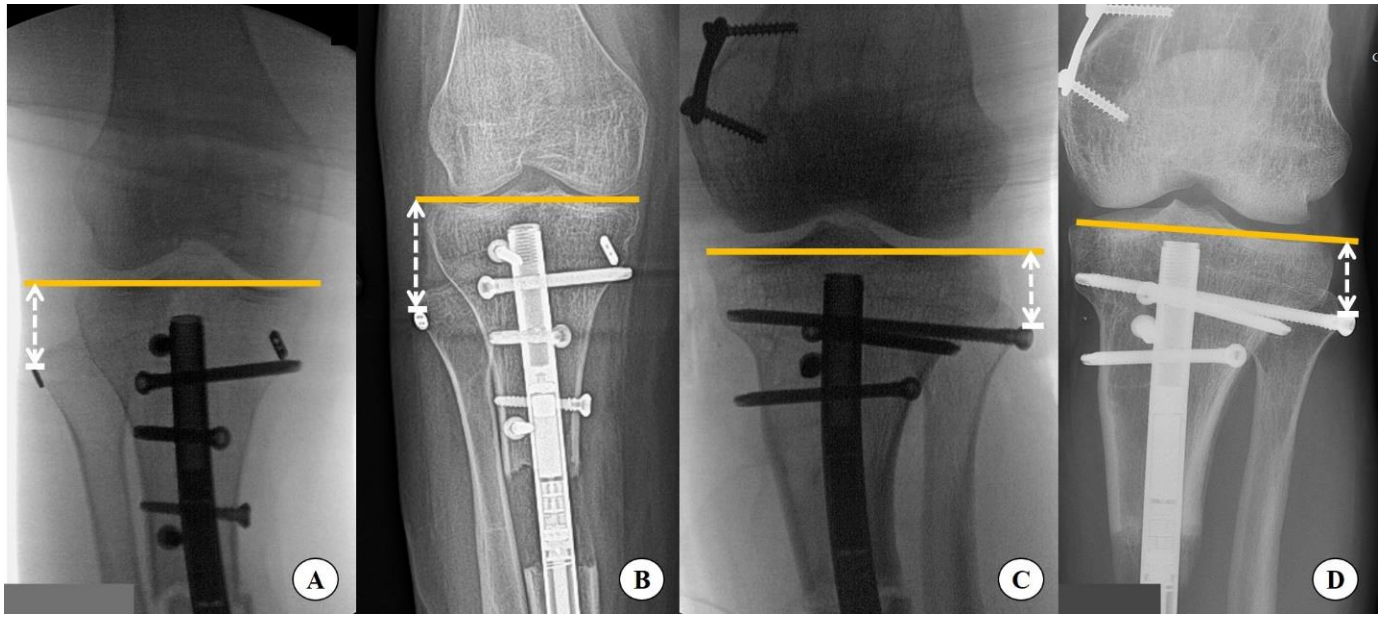

Figure 1. Radiographic measurements of the difference of proximal fibular migration distance from sample patients. In the tether group, the immediate postoperative distance was 26 mm (A) and 37 mm at the end of lengthening (B). In the screw group, the immediate postoperative distance was 22 mm (C) and 25 mm at the end of lengthening (D).

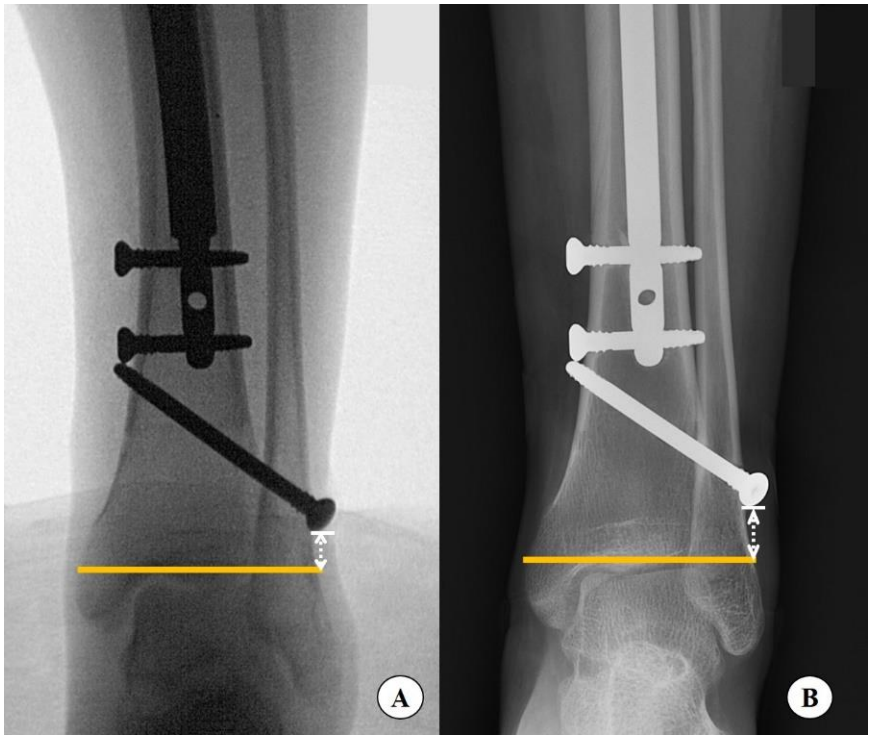

Figure 2. Radiographic measurements of the difference of distal fibular migration distance from sample patients. The immediate postoperative distance was 8 mm (A) and 11 mm at the end of lengthening (B).

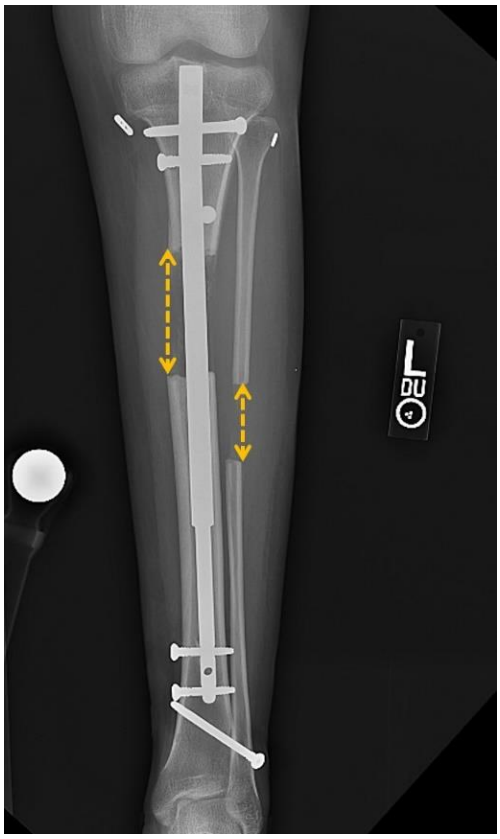

Figure 3. Radiographic measurements at the end of lengthening showed tibial was lengthened 50 mm and fibular was lengthened 32 mm. Fibular/tibial lengthening ratio was 64%.

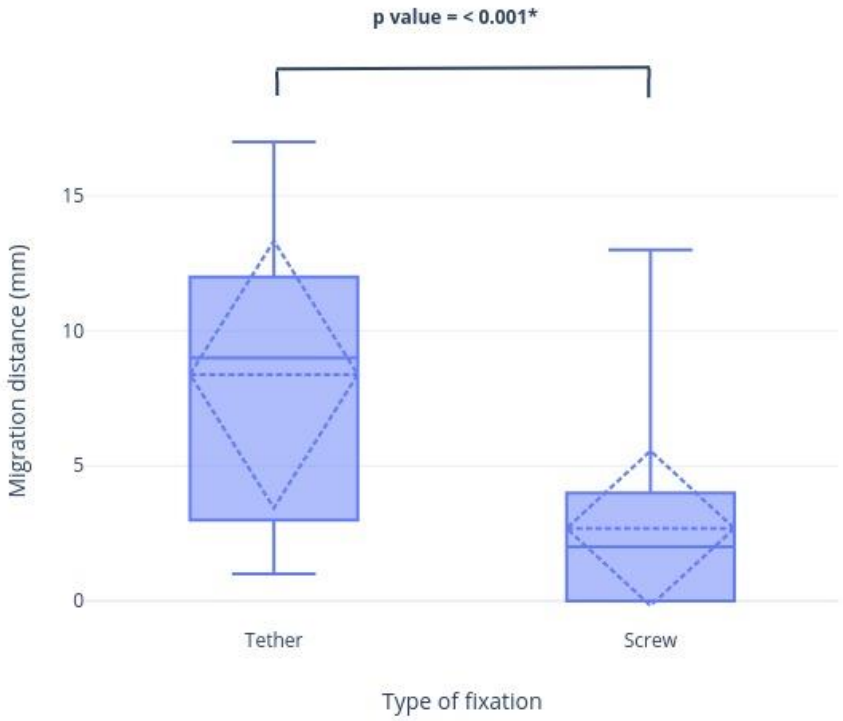

Figure 4. Box plot of proximal tibiofibular migration distance between tether and screw fixation groups with Mean and SD

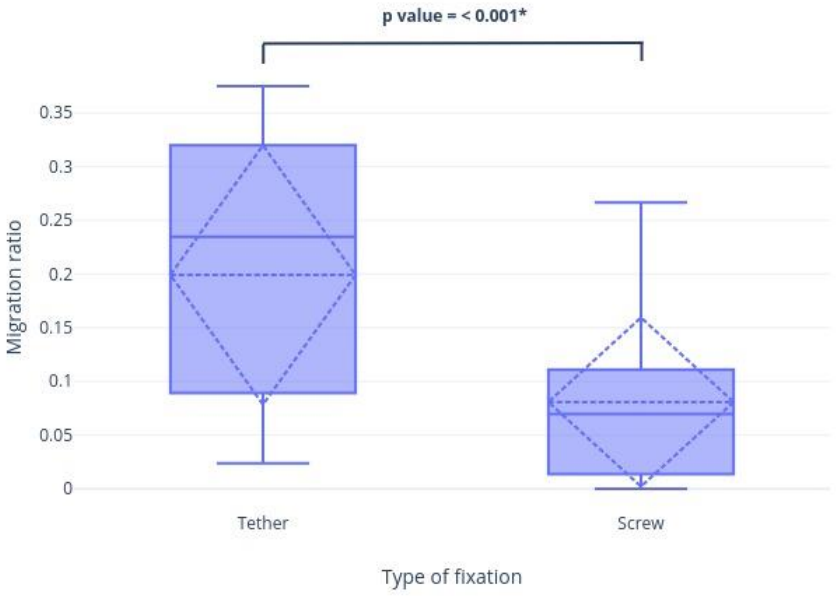

Figure 5. Box plot of proximal tibiofibular migration ratio between tether and screw fixation groups with Mean and SD

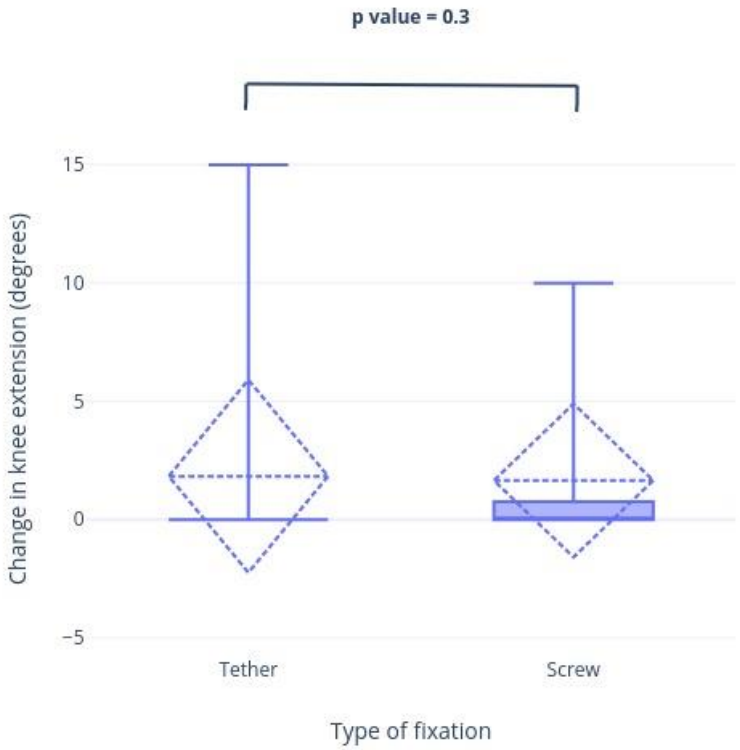

Figure 6. Box plot of change in knee extension after tibial lengthening between tether and screw fixation groups with Mean and SD

Removal of Hardware after Orthopaedic Surgery: What are Patients Saying?

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What was the question?
Removal of hardware (ROH) after orthopaedic surgery may improve patient outcomes, function, and decrease pain. Previous literature reports a complication rate of approximately 10% and suggest the associated risks of the procedure may outweigh the benefits. However, retained hardware may create future problems because bone will bond with titanium making late removal complicated, dangerous and/or impossible. Additionally, retained hardware may make future surgery considerable more complicated (e.g. total hip replacement post intramedullary nail). We surveyed our patients who underwent this procedure to ask their overall status, joint stiffness, pain, swelling, and mobility post–operatively. Secondarily, we analyzed the complication profile and rate.

How did you answer the question?
This was a retrospective chart review including all patients who underwent ROH in 2016–2022. One hundred seventy–three patients with 314 pieces of hardware met inclusion criteria. There was a total of 181 ROH surgeries. All patients were sent a brief 3–question survey which asked: (1) Why did you get your hardware removed?; (2) How did your overall status change after ROH?; (3) How did the ROH affect your stiffness, pain, swelling, and mobility? Patient demographics and complications were recorded. Seventy–six patients (43.9%) responded to our survey.

What are the results?
Patients reported a variety of reasons for ROH, which can be seen in Figure 1. The majority of patients (86.9%) of patients reported their overall status improved after ROH (Figure 2). The majority of patients reported that they improved in regards to stiffness (73.7%) , pain (73.6%%) , swelling (61.8%), and mobility (76.3%) (Figure 3). Similar results were seen among different implants removed (i.e. plates, nails, and screws).

There were a total of 11 complications (6.1%) which included: 5 infections, 2 patients with unresolved pain, 1 hematoma, 1 chronic regional pain syndrome exacerbation, and 1 recurrent deformity. All infections were treated with oral antibiotics and improved. All other complications resolved with treatment except for the patient who developed recurrent deformity.

What are your conclusions?
The overwhelming majority of patients who underwent ROH in this population were very satisfied with the procedure. They reported improvement in stiffness, pain, swelling and mobility; the greatest improvement was reported in mobility. The complication rate was low (6.1%); there were no major complications. ROH can be a meaningful operation to patients allowing them to improve their quality of life with a low complication rate.

Figure 1. Reason(s) Patients Chose to have Hardware Removed (% of entire cohort)

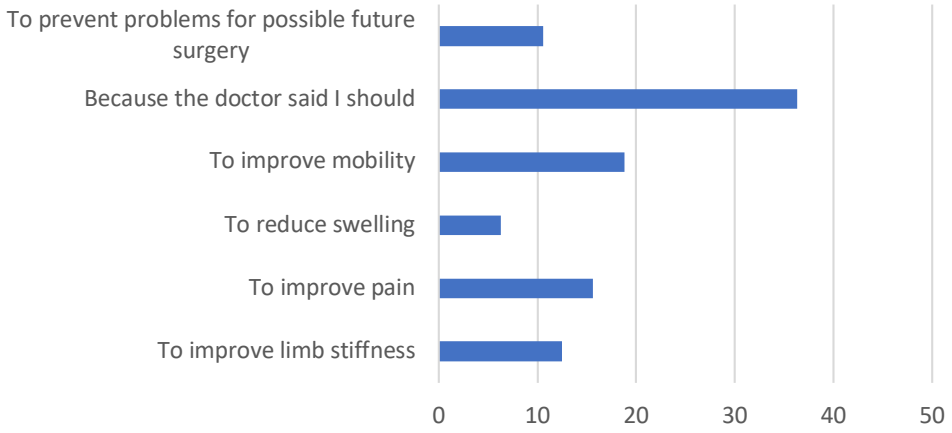


Figure 2. Overall Patient Status After Hardware Removal (% of entire cohort)

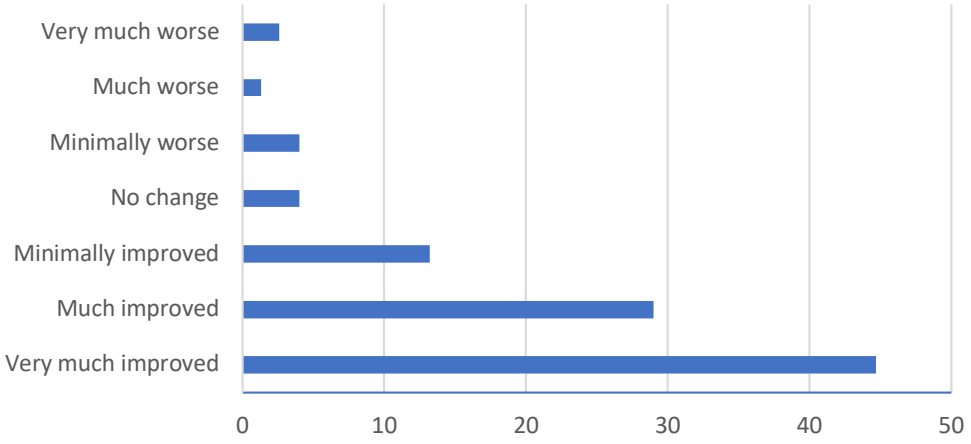
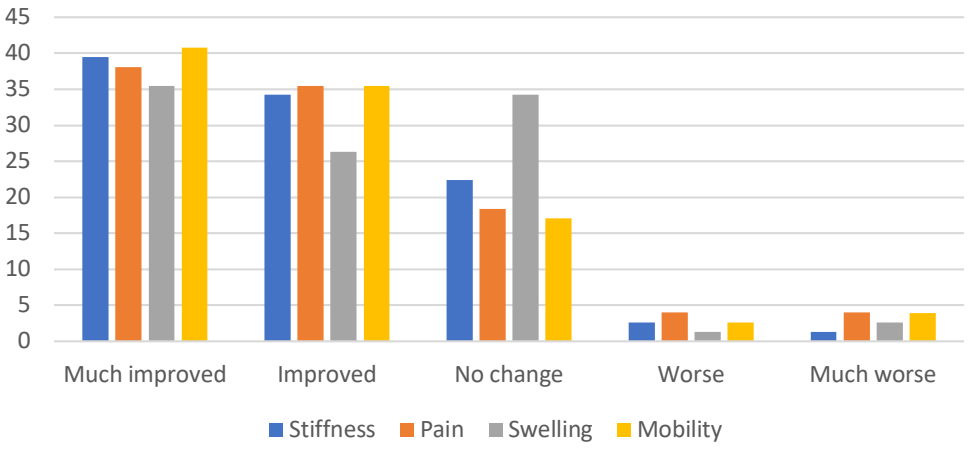


Figure 3. Hardware removal affect on symptoms.



Modified Super Hip Procedure for Fibrous Dysplasia of the Proximal Femur

Toshifumi Hikichi, MD

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Hidenori Matsubara, Tamon Kabata, Yoshitomo Kajino, Kanu Shimokawa,
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What was the question?
The fibrous dysplasia (FD) lesion of the proximal femur result in the most common complex deformities ("Shepherd's crook" coxa vara deformity). The possibility of pathological fractures is high due to mechanical factors, and the gradual progression of the deformity at multiple lesion due to the extensive presence of tumors makes it difficult to choose appropriate treat ment or implants. We utilized a modified version of the Systematic Utilitarian Procedure for Extremity Reconstruction (SUPER) hip technique developed by Paley for congenital femoral defects to address this complex and progressive deformity. Therefore, the question of this study is whether the modified SUPER hip technique for FD can achieve good alignment, maintain alignment, and prevent pathologic fractures.

How did you answer the question?
We retrospectively studied five patients who had undergone the modified SUPER hip procedure. Modified SUPER hip procedure was done as below.
Based on SUPER hip procedure, Valgus and rotational corrective osteotomy was performed as a reference CORA, locking plate was inserted to prevent progressive femoral neck coxa vara deformity. To prevent fracture other deformity sites such as distal femoral and tibia, we performed gradual lengthening and correction using a frame.
We examined mean age, gender, primary disease, location of the FD lesions, the presence of gradual correction in the tibia or distal femur. Primary outcome included the presence of postoperative pathological fractures. Secondary outcome included the preoperative and at last follow–up radiographic alignment, such as neck shaft angle, femoral anteversion, Hip knee angle (HKA), anatomical medial proximal femoral angle (aMPFA), lateral proximal femoral angle (LDFA,) anatomical/mechanical medial proximal tibial angle (aMPTA, mMPTA), anatomical/mechanical lateral proximal tibial angle (aLDTA, mLDTA), % mechanical axis (%MA), Limb length discrepancy (LLD), and the amount of change in neck shaft angle after the operation. The data expressed the mean value.

What are the results?
Five cases were recorded. Three males and two females. The mean age at surgery was 15.2 ± 5.0 years. All cases had FD/Mccune–Albright syndrome; FD sites were bilateral femur/tibia in two cases, and unilateral femur/tibia in three cases. Gradual correction was performed in three cases, one case at distal femur and two cases at tibia. Mean final follow–up was 6.5 ± 3.5 years. There were 0 cases (0%) with pathological fractures during the follow–up period. Preoperative alignment was as follow. Neck shaft angle 77.6 ± 15.1 degrees, femoral anteversion 4.8 ± 15.0 degrees, aMPFA 59.4 ± 18.1 degrees, LPFA 110.8 ± 18.5 degrees, aLDFA 78.4 ± 6.5degrees, mLDFA 88 ± 4.7 degrees, aMPTA 89.6 ± 1.9 degrees, mMPTA 92.8 ± 3.4 degrees, aLDTA 88.8 ± 2.4 degrees, mLDTA 85 ± 3.8 degrees, LLD 17.8 ± 14.0, and %MA 62.8 ± 26.0. At the final follow–up, the neck shaft angle was 125 ± 8.2 degrees, femoral anteversion 11.2 ± 2.5, aMPFA 81 ± 11.9 degrees, LPFA 91 ± 14.5 degrees, aLDFA 83 ± 3.4 degrees, mLDFA 90 ± 3.1 degrees, aMPTA 87.6 ± 2.8 degrees, mMPTA 90.3 ± 3.9 degrees, aLDTA 86 ± 4.5 degrees, mLDTA 86.4 ± 4.5degrees, LLD 20.4 ± 16.0, and %MA 48 ± 21.1. The amount of change the femoral neck shaft angle was 8.4 degrees, decreasing by 1 degree per year. Representative cases were provided.

Modified Super Hip Procedure for Fibrous Dysplasia of the Proximal Femur
continued

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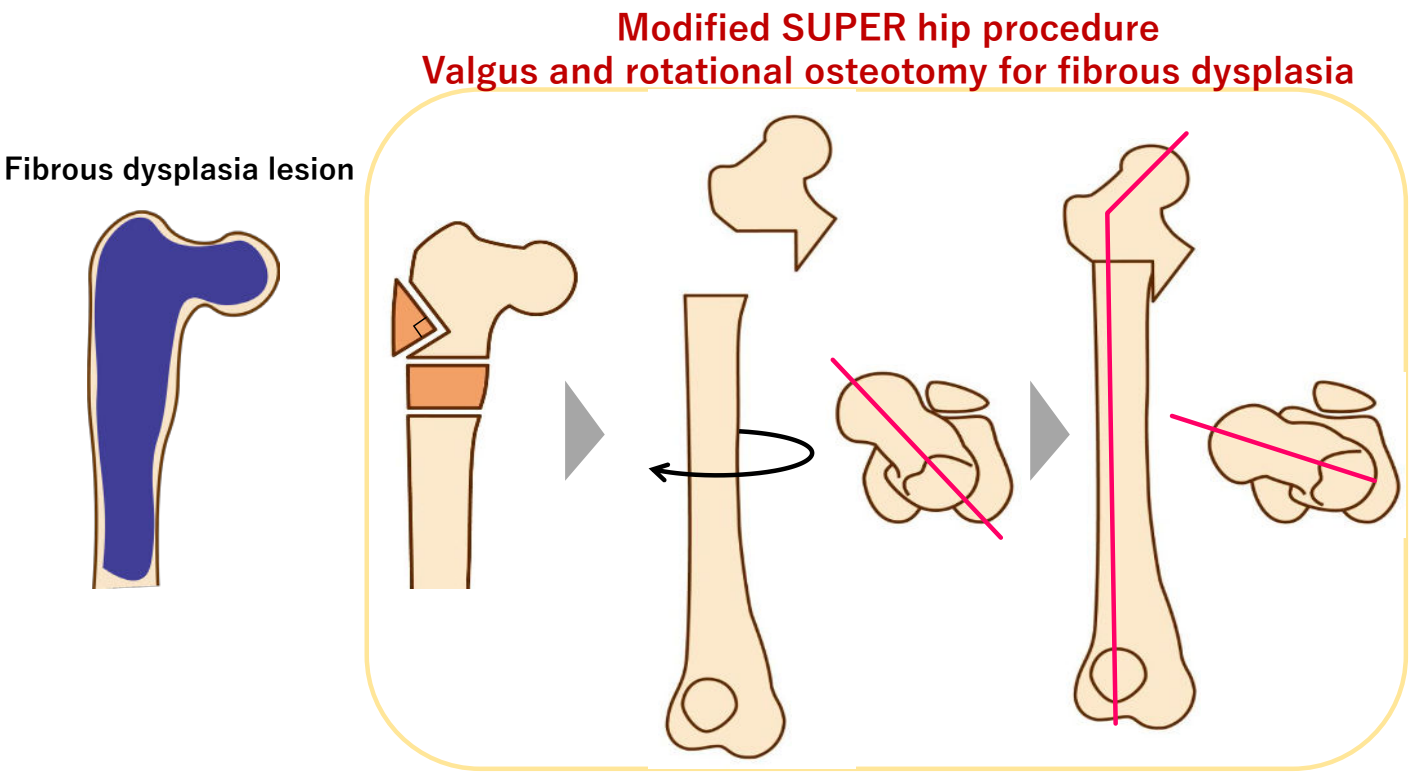
Hidenori Matsubara, Tamon Kabata, Yoshitomo Kajino, Kanu Shimokawa,
Hiroyuki Tsuchiya

What are your conclusions?
The Modified SUPER hip procedure for FD of the proximal femur was useful in preventing deformity, pathological fractures, and might be enabled the acquisition of good radiographic alignment.



Session VII: Limb Deformity – Topics to Get You Thinking

Moderator: Raymond W. Liu, MD

Comparison of Three Methods of Intraoperative Angulation Measurement for Malunion Surgery: Visual Estimation, Goniometer, and Inclinometer

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What was the question?
Is a more accurate measurement achieved using a measuring tool, such as a goniometer or an inclinometer, when compared to visual assessment?

How did you answer the question?
Testing was performed with the Sammons Preston Rolyan model (Patterson Medical, Warrenville, IL). Ball–in–tube inclinometers also allow for reproducible rotational measurements, such as the common Scoliometer (Orthopedic Systems Inc, Haywood, CA) or the Accuangle device (Innomed Inc, Savannah, GA) as was used for this investigation.
Ten left synthetic femora (Sawbones, Vashon Island, WA) were fitted with one proximal and one distal bicortical 6 mm external fixator half pins. Pins were placed laterally and in the axial plane but with random amounts of angulation up to 48°between the two pins. All responders were orthopedic residents or attendings, and each performed six total sets of measurements with each set of measurements done on separate days. Responders first performed two separate sets of visual estimation of the angles between the two half–pins. Responders then completed measurement sets with a standard goniometer and the Accuangle inclinometer, each performed twice, and in random order. The gold standard measurement was performed with a digital inclinometer (iGaging, San Clemente, CA) accurate to 0.2°. Averages of the absolute values of the errors were calculated for each technique and compared.

What are the results?
Seven orthopedic attendings and residents completed the quiz. The mean magnitudes of error were for visual estimation 6.4° [95% CI: 5.8–7.6°], for goniometer of 2.2° [95% CI: 2.1–2.3°], and for Accuangle of 1.9° [95% CI: 1.8–2.0°] was calculated. Intraobserver–weighted Cohen's Kappa values were 0.64, 0.81, 0.82 for visual estimation, goniometer, and Accuangle, respectively. When comparing the measurements obtained by different raters, intraclass correlation coefficients (ICC), of 0.75 [95% CI: 0.55–0.92], 0.95 [95% CI: 0.89–0.99], and 0.96 [95% CI: 0.90–0.99] were obtained with visual estimation, goniometer, and Accuangle measurements, respectively. However, when comparing the three different measuring tools, an ICC of 0.82 [95% CI: 0.75–0.88] was obtained.

What are your conclusions?
Visual estimation of angles is less accurate than either goniometer or ball–in–tube inclinometer measurements ($P < 0.05$), however, the magnitude of error was surprisingly small (6.4°). When performing osteotomies for orthopedic deformity correction, such as occurs commonly with malunion surgery, 6° is likely a clinically significant amount of error. An objective measurement tool should be used whenever possible to help minimize error. Goniometers and inclinometers are simple to use and readily sterilizable.

Proximal TibioFibular Joint in Tibial Lengthening Osteotomy

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Harpreet Chhina, Anthony Cooper

What was the question?
Is it necessary to temporarily fix the proximal tibiofibular joint (PTFJ) during tibial lengthening or is it sufficient to only fix the distal tibiofibular joint (DTFJ)?

How did you answer the question?
This was a retrospective case series spanning 3 years, examining patients who received tibial lengthening osteotomies. Demographics including age, sex, and underlying disease were obtained. Patient reported and clinical outcomes including, peroneal nerve palsy, knee pain or instability were assessed. Finally, radiographic measures were collected including PTFJ migration, DTFJ migration and tibial and fibular length gained post osteotomy.

What are the results?
We identified 51 patients (56 limbs) who had tibial lengthening osteotomy. 16 patients were excluded due to refusal to participate in research and/or lack of sufficient radiographic data. Remaining 35 patients (38 limbs), 26 males, 9 females, had etiologies as shown in table 1.
0/38 limbs had PTFJ fixation. 37/38 limbs had DTFJ fixation. 1/38 had syndesmotic tight rope, 1/38 had wire fixation, 9/38 had cannulated screws and 26/38 had cortical screws, 1/38 had no distal fixation. Duration of follow up after frame removal was 16.5 months (1.8–53).
No incidents of peroneal nerve palsy. No post–operative knee pain or instability. We found that DTFJ fixation did not prevent migration at the PTFJ joint (Table 2), however this was not found to be clinically relevant in this cohort and did not result in any complication at the PTFJ (e.g. peroneal nerve palsy, knee instability or pain); this is consistent with existing literature.2,4 Work by Shaym et al 2009 shows that fixing the PTFJ does not guarantee prevention of distraction at the joint.2 The same literature also mentions that lengthening tibia by > 25% increases distraction of the PTFJ.2 Our mean was 19.9%, with 10 patients who had tibial lengthening between 25–40%, none of them had any complications.
Other complications not related to PTFJ included 2 patients had failure of cannulated distal tibio–fibular screw, 2 regenerate fractures.

What are your conclusions?
Although there was migration at the PTFJ, there were no clinically significant complications associated with this. Fixation of the PTFJ may not be necessary for tibial lengthening

Fibular hemimelia	9
Blounts	5
Hemi-hypertrophy	5
Idiopathic	3
Post traumatic	2
Tibial postero-medial bowing	2
XY chromosomal Mosaicism	1
Compartment syndrome	1
Meningococcal septicmemia	1
Anterior horn cell disease	1
Ollier's disease	1
Leri-Weill Dyschondrosteoisis	1
Spondyloepiphyseal dysplasia	1
Post infectious physeal injury	1
Congenital Tibial Pseudoarthrosis	1

Table 1: etiology breakdown of sample size

	Mean (mm)	Range (mm)
Proximal fibular migration	13.58	0.8-25.8
Distal fibular migration	-0.5	-13.8-10.6
Tibial length gained	56.1	4.0-103.0
Tibial lengthen gained %	19.9%	1.03%-44.4%
Fibular length gained	38.9	1.1-87.0
Fibular length gained %	13.8%	2.8%-39.2%

Table 2: radiographic measures of PTFJ, DTFJ and length gained.

Mechanical Stimulation of Bone Regenerate via External Fixator Axial Dynamization

Alexander Cherkashin, MD

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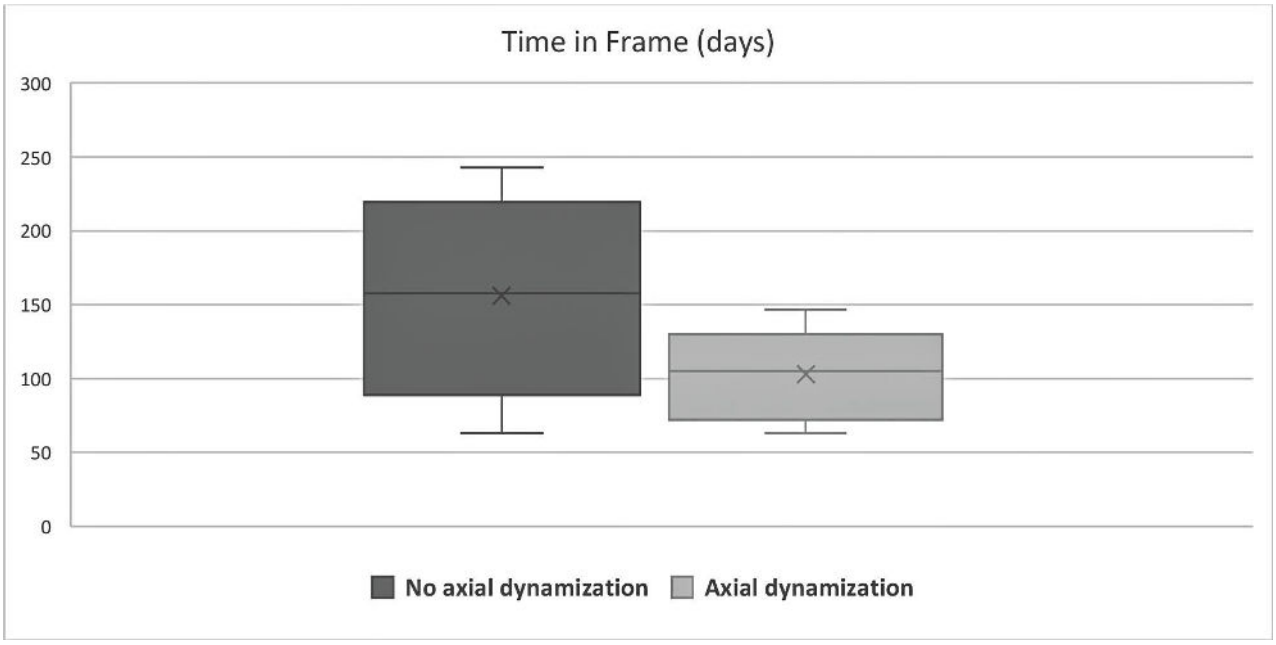
Mikhail Samchukov, Kelly Jeans, Meghan Wassell, David Podeszwa

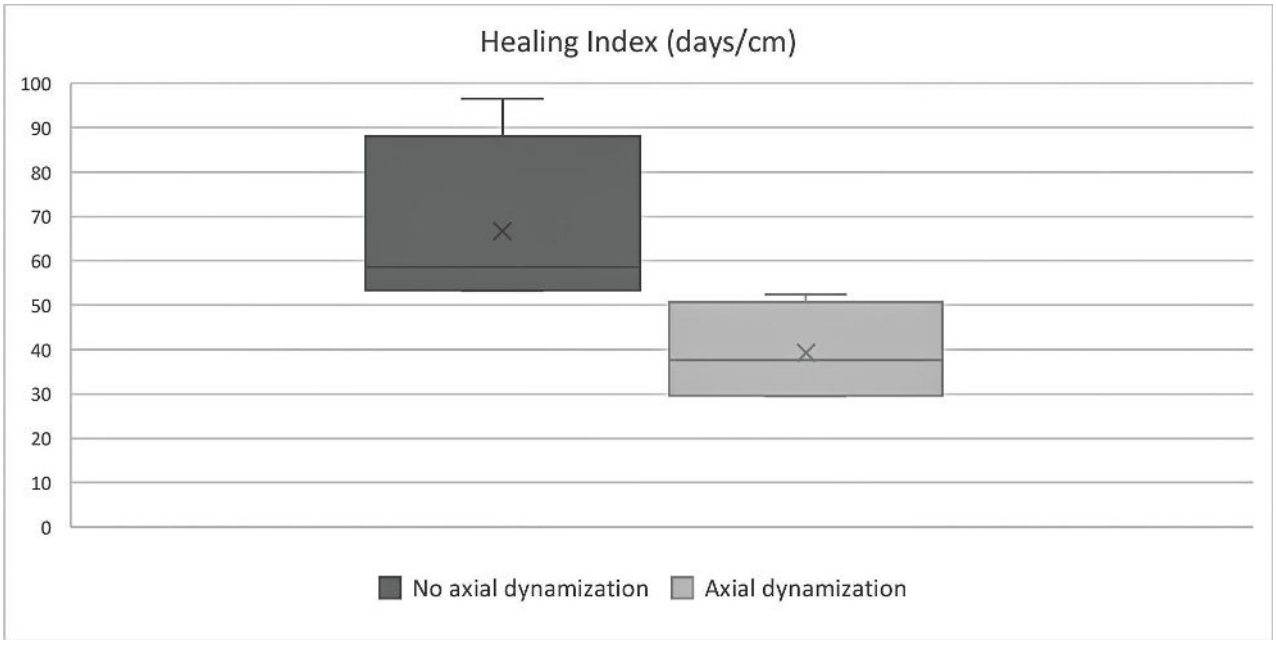
What was the question?
Extended treatment in external fixators increases risk of complications and patient frustration. Different modalities of mechanical stimulation of the distraction regenerate may reduce time in an external fixator. Reducing frame stability to stimulate the regenerate may impact patients' weightbearing and comfort. Axial frame dynamization only allows axial loading while preventing sharing and bending forces. For over 5 years we are now routinely fit patients with a dynamization device 3–4 weeks after acute correction or fracture reduction, and after finishing gradual correction and/or lengthening. Does application of axial dynamization devices affects patient ability to bear weight in the external fixator? Is treatment time in the external fixator reduced when the frame is dynamized?

How did you answer the question?
Gait analysis was performed on five patients undergoing treatment in external fixators for congenital pseudarthrosis of the tibia (2 patients), tibial deformity correction (2 patients) and open tibial fracture (1 patient). Analysis was performed on the day of frame dynamization using spring–loaded adjustable dynamization devices. The analysis was run first with the devices completely locked (no frame dynamization) and repeated with the unlocked devices providing up to 3 mm of axial motion. We also compared time in external fixator for 12 recent patients with axial dynamization against 12 matched historical controls (similar etiology, diagnosis, age, gender, and amount of lengthening) without axial dynamization. Healing index (days in frame per 1 cm of lengthening) was calculated for the patients undergoing limb deformity correction and lengthening (between 3 to 6 cm) in both groups.

What are the results?
All patients fitted with the dynamization devices reported immediate feeling the frame weight decrease and improved ability to walk. Gait analysis in five patients with axially dynamized fixators (unlocked dynamization devices) did not show any significant difference in the gait pattern compared to that with locked devices. Average time in frame was significantly shorter in the dynamization group compared to the non–dynamized patients (145 days in non–dynamized group vs. 103 days in axial dynamization group). Healing index in the patients with min 3 cm of lengthening was 66.7 in non–dynamized group vs. 39.3 in axial dynamization patients.

What are your conclusions?
Controlled axial frame destabilization does not affect patient gait and weightbearing. Patients fitted with the dynamization devices reported improved ability to bear weight. Overall time in frame and healing index were significantly shorter in the group with axial dynamization. A larger cohort is needed, but this study suggests that axial dynamization may significantly shorten the time a patient is in an external fixator.


Time in Frame (days)
300
250
200
150
100
50
0
No axial dynamization
Axial dynamization


Healing Index (days/cm)
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No axial dynamization
Axial dynamization

Complications in Limb Reconstruction Surgery– Can We Report Them Reliably?

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David Podeszwa, MD; Alexander Cherkashin, MD; Mikhail Samchukov, MD

What was the question?
Limb reconstruction surgery carries high risks for complications, but there is no uniform way in which complications are being reported. In general surgery and orthopedic literature, the Clavien–Dindo classification scheme has been evaluated and found to be a reliable classification scheme for rating perioperative complications.(1–4) We sought to evaluate the reliability of this classification scheme for patients undergoing limb reconstructive surgery and compare its reliability to two other classification schemes.

How did you answer the question?
We developed a series of 45 clinical vignettes describing scenarios involving pediatric and adult patients undergoing limb reconstructive procedures. Four attending level orthopaedic providers who specialize in limb reconstruction as well as four orthopaedic fellowship trainees were asked to review each case vignette and classify the case according to the Clavien–Dindo, Paley(5), and Cherkashin(6) classification systems (Figure 1A – 1C). Results were analyzed and percent agreement as well as intra–rater correlation coefficient was calculated for each classification system.

What are the results?
The greatest overall agreement was seen with the Clavien–Dindo classification scheme, with reviewers agreeing on the exact complication severity for 60% of the scenarios, versus 46% agreement with the Cherkashin classification and 33% agreement with the Paley classification. The Clavien–Dindo classification system had significantly greater inter–rater reliability (ICC 0.889) than both the Cherkashin (ICC 0.822; p

What are your conclusions?
When comparing 3 classification systems for grading complication severity in cases of deformity correction, surgeons agreed on the exact complication severity in about 3/5 of cases. The Clavien–Dindo classification system had the greatest inter–rater agreement and reliability compared to both the Paley and the Cherkashin classification schemes. This data suggests that utilizing the Clavien–Dindo system would allow for more uniform reporting and rating of surgical complications for surgeons perform limb lengthening and reconstruction surgeries. However, this pilot study will need to be extended to a broader group of surgeons to better determine the intra–rater and inter–rater reliability of these systems.

System	Overall Agreement	Intraclass Correlation Coefficient (ICC)
Clavien-Dindo	60%	0.889
Paley	33%	0.708
Cherkashin	46%	0.822

Table 1

Figure 1A: The Clavien-Dindo classification system

Grade	Definition	Examples
1	A complication that does not change routine care or follow-up for the patient	Patient presents to a scheduled wound care visit with mild superficial dehiscence of a surgical incision that requires local wound care but no antibitoics or other changes in management.
2	A deviation from the normal postoperative course which requires outpatient treatment and/or outpatient monitoring of the condition	Patient with an external fixator develops progressive pain, erythema, swelling and drainage from a pin site requiring oral antibiotic.
3	A complication which requires surgical treatment and/or an unplanned hospital readmission	Patient has persistent erythema, swelling and drainage around a pin site despite antibiotic therapy and x-rays demonstrate lucency around the pin. Ultimately the patient is taken to the OR for revision of the external fixator and debridement of the pin site after pin removal.
4	A complication that is life- or limb-threatening, an ICU admission, with potential for permanent disability	Patient is admitted for necrotizing fasciitis of the operative limb and admitted for extensive surgical debridement, prolonged IV antibiotics and requires treatment in the SICU. OR While undergoing a femoral lengthening, the patient's hip dislocates. After attempted open reduction to stabilize the hip, the patient develops avascular necrosis with persistent hip pain and loss of motion.
5	Death	One week after surgery, the patient presents to the ER with severe chest pain, shortness of breath and hypoxemia. The patient goes into cardiac arrest and is unable to be resuscitated. Post-mortem demonstrates that the patient had a large pulmonary embolus.

Figure 1B: The Paley classification system

Category	Definition	Examples
Problem	An expected difficulty that arises during the distraction of the fixation period that is fully resolved by the end of treatment through NONOPERATIVE means.	Patient undergoing a lengthening develops a knee flexion contracture managed through physical therapy and dynamic bracing. The patient completes the lengthening and has full knee range of motion.
Obstacle	An expected difficulty that arises during the distraction of the fixation period that is fully resolved by the end of treatment through OPERATIVE means.	Patient undergoing deformity correction and lengthening develops premature consolidation. Revision surgery is needed to create a new osteoplasty site to continue lengthening.
Complication	Any local or systemic intraoperative or perioperative complication or difficulty during distraction or fixation that remains unresolved by the end of the treatment period and any early or late posttreatment difficulty	While undergoing a lengthening, a patient dislocates their knee. Despite attempted intervention the joint cannot be reduce and the patient has persistent stiffness and pain.

Figure 1C: The Cherkashin classification system

Category	Definition	Examples
I	Treatment plan deviation was corrected within the existing treatment plan. Treatment goals were achieved with minor adjustments	A patient undergoing deformity correction with an external fixator develops a pin tract infection treated with oral antibiotics
II	A new treatment plan needs to be established to correct the deviation and achieve the treatment goals	Patient undergoing lengthening with an intramedullary rod falls and the implant breaks. Patient requires a return to the OR for nail exchange and continues lengthening.
IIIA	Complication led to the failure to achieve treatment goals, but the patient condition IS NOT WORSE than it was prior to the treatment.	Patient undergoing a lengthening with an intramedullary rod fails to perform regular at home lengthenings and develop premature consolidation prior to achieving planned correction.
IIIB	Complication led to the development of a new pathologic process. Therefore, the patient condition after treatment IS WORSE than it was prior to treatment	Patient undergoing lengthening sustains a hip dislocation that requires both acute femoral shortening and an open reduction and capsulorraphy to reduce.

Comparing RVUs for Intramedullary Limb Lengthening Procedures to Common Pediatric Orthopaedic Surgeries to Determine Adequate Compensation

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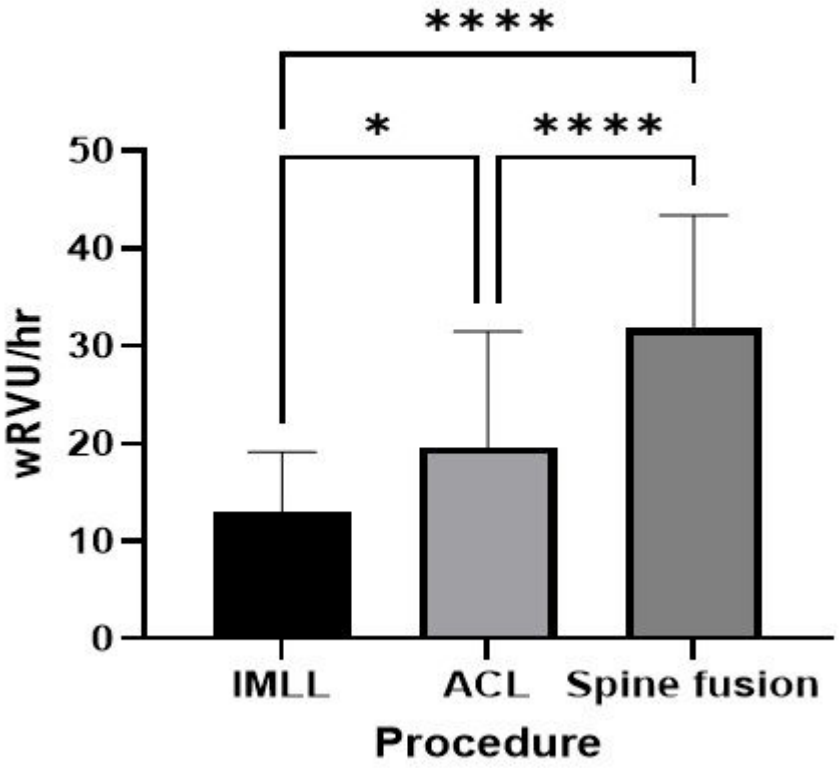
Christopher Iobst, Anirejuoritse Bafor, Sonia Gilani

What was the question?
Reimbursement for services rendered by physicians is determined by a computation of the relative value unit (RVU) associated with CPT codes. It is based on the amount of work required to provide a service, the resources available, and the level of expertise involved. Because limb reconstruction surgeons often are among the lowest RVU generators in their practice group, we wanted to evaluate whether the RVU values were comparable across different orthopedic subspecialties. Consequently, this study compares the documented RVU totals of three common pediatric orthopedic surgeries, arthroscopic ACL reconstruction, spinal fusion for adolescent idiopathic scoliosis and antegrade femoral intramedullary limb–lengthening (IMLL).

How did you answer the question?
This was an IRB–approved, multicenter, retrospective chart review. Charts of subjects who had ACL reconstructions, including meniscal repairs; spinal fusion surgeries for adolescent idiopathic scoliosis (7–12 levels), including Ponte osteotomies; and femoral antegrade internal limb lengthening procedures, each completed by fellowship–trained pediatric orthopedic surgeons were reviewed. Comparisons were carried out between several parameters, including the mean duration of each procedure, the number of CPT codes associated with each procedure, the number of post–operative visits in the 90–day global period, and the computed wRVU for each procedure.

What are the results?
50 charts (25 from each center) for each procedure were reviewed. The results are summarized in the table and figure below. The RVU per hour was significantly lowest in the antegrade femur lengthening group ($p < 0.0001$). The number of post–op visits in the 90 day global post–surgery period were significantly higher in the antegrade femur lengthening group ($p < 0.0001$).

What are your conclusions?
RVUs per time are statistically significantly lowest in the limb lengthening group and highest in the scoliosis group. The limb lengthening patient also requires significantly more visits and time in the post–operative period compared to the other groups. These extra visits during the global period don't add any RVU value to the lengthening surgeon and occupy clinic spots that could be filled with new patients. Based on this data, a review of the RVU values assigned to the limb lengthening codes may be necessary.



	IMLL	ACL	Spine Fusion	p value
Age	15.34 ± 4.614	15.54 ± 2.111	14.68 ± 2.714	0.0540
BMI	21.46 ± 3.790	22.89 ± 4.294	22.68 ± 4.547	0.1606
Anesthesia duration	183.5 ± 50.13	107.9 ± 43.65	334.6 ± 57.99	<0.0001
Surgery duration	120.8 ± 48.16	80.72 ± 46.64	237.1 ± 44.12	<0.0001
Post op visit	7.320 ± 2.272	2.060 ± 0.7398	2.00 ± 0.9897	<0.0001
CPT codes used	1.94 ± 0.68	2.0 ± 0.948	5.42 ± 1.416	<0.0001
wRVU	22.91 ± 5.871	18.81 ± 4.185	130.5 ± 63.22	<0.0001
wRVU/hr	13.06 ± 6.06	19.61 ± 11.88	31.89 ± 11.49	<0.0001

Presidential Guest Lecture

Lizardry Lessons from Perthes Disease

Jonathan Schoenecker, MD, PhD
Pediatric Orthopaedics
Vanderbilt University Medical Center

Traveling Fellowship Presentation

Introduction by Jaclyn F. Hill, MD

2022 Adult Fellows
Marco Domenicucci, MD
Goeffrey Marecek, MD
Henry Ndasi, MD

2023 Pediatric Fellows
Paa Kwesi Baidoo, MD
Marie Fridberg, MD
Amanda McCoy, MD

Session VIII: Pediatrics

Moderator: Christopher A. Iobst, MD

Physeal Bar Excision Using 3D Image Guidance: Technique and Results

Wendy Ramalingam, MD

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Neil Johnson, MD

What was the question?
Can intraoperative 3D imaging be utilized to successfully excise physeal bars in pediatric patients with deformity resulting from partial physeal arrest?

How did you answer the question?
The study identified and analyzed five pediatric patients with partial physeal arrest and resulting deformity who underwent physeal bar excision in a hybrid operating room in conjunction with musculoskeletal interventional radiology. Intraoperative 3D imaging via the XperCT system was used to target and excise each physeal bar using cylindrical Corb trephine drills and curettes through minimally invasive surgical approaches. Subsequently, intraoperative 3D imaging was used to ensure complete excision of the bar and then Cranioplast bone cement was utilized for interposition. Patient demographics, injury and deformity characteristics, and postoperative complications were recorded. Preoperative and postoperative imaging were evaluated to quantify initial deformity and correction.

What are the results?
Four of the five patients developed partial physeal arrest following fractures of the lower extremity, while one patient developed leg length discrepancy due to physeal bar of the proximal tibia as a sequela of neonatal osteomyelitis. Patient demographics, injury and deformity characteristics, and results are shown in Table 1. All patients had preoperative 3D imaging for surgical planning and underwent physeal bar excision using 3D image guidance with cranioplast interposition as shown in Figure 1.
All patients in this series had clinical and radiographic improvement in their angular deformities following their procedures with an average of 7.5ą4.5 degrees of angular correction at most recent follow up (11.8ą6.5 months). Angular deformity correction occurred at a rate of 0.8ą0.2 degrees per month. Figure 2 shows one example of improved sagittal alignment over time. The patient with leg length discrepancy without angular deformity due to a proximal tibia central physeal bar had resumption of growth of the affected leg with decrease in overall leg length discrepancy by 2.15 cm over a 21–month period (Figure 3). There were no postoperative complications or secondary procedures during the study period.

What are your conclusions?
Physeal bar excision utilizing intraoperative 3D image guidance resulted in improved radiographic angular deformities and leg length discrepancy for all patients without any apparent complications in this small case series. The utilization of intraoperative 3D imaging may improve surgical outcomes and reduce the risk of complications in pediatric patients with partial physeal arrest. Long term follow up is needed to ensure resolution of deformities over time.

Patient No.	Gender	Age at Injury	Mechanism of injury	Fracture Type and Location	Location of Physeal Bar	Preoperative Deformity	Preoperative deformity	Preoperative 3D Imaging	Physeal Bar Size as Percentage of Physis	Age at Surgery (years)	Follow-up (months)	Postoperative Deformity	Correction	Postoperative Complications
1	F	7.8	Trampoline	SH II Proximal tibia	Central Anterior Proximal Tibia	Genu recurvatum	15.7 degrees	MRI, CT	7.7	9.0	5.6	11.7 degrees	4 degrees	none
2	M	7.2	Ped vs MVC	SH II Distal femur	Central Posterior Distal Femur	Genu procurvatum	7 degrees	MRI, CT	2.6	7.9	5.8	3.2 degrees	3.8 degrees	none
3	M	12.0	Scooter	SHIV Proximal tibia	Central Posterior Proximal Tibia	Genu procurvatum	21 degrees	CT	12.1	13.5	13.0	7.9 degrees	13.1 degrees	none
4	M	6.5	Trampoline	SH II Distal tibia	Central Distal Tibia	Ankle Valgus	11.3 degrees	MRI	6	7.8	13.4	2.2 degrees	9.1 degrees	none
5	M	0.0	Neonatal Osteomyelitis	N/A	Central Proximal Tibia	Leg Length Discrepancy	3.55 cm	MRI	4.9	3.4	21.4	1.4 cm	2.15 cm	none

Table 1: Patient Demographics and Results

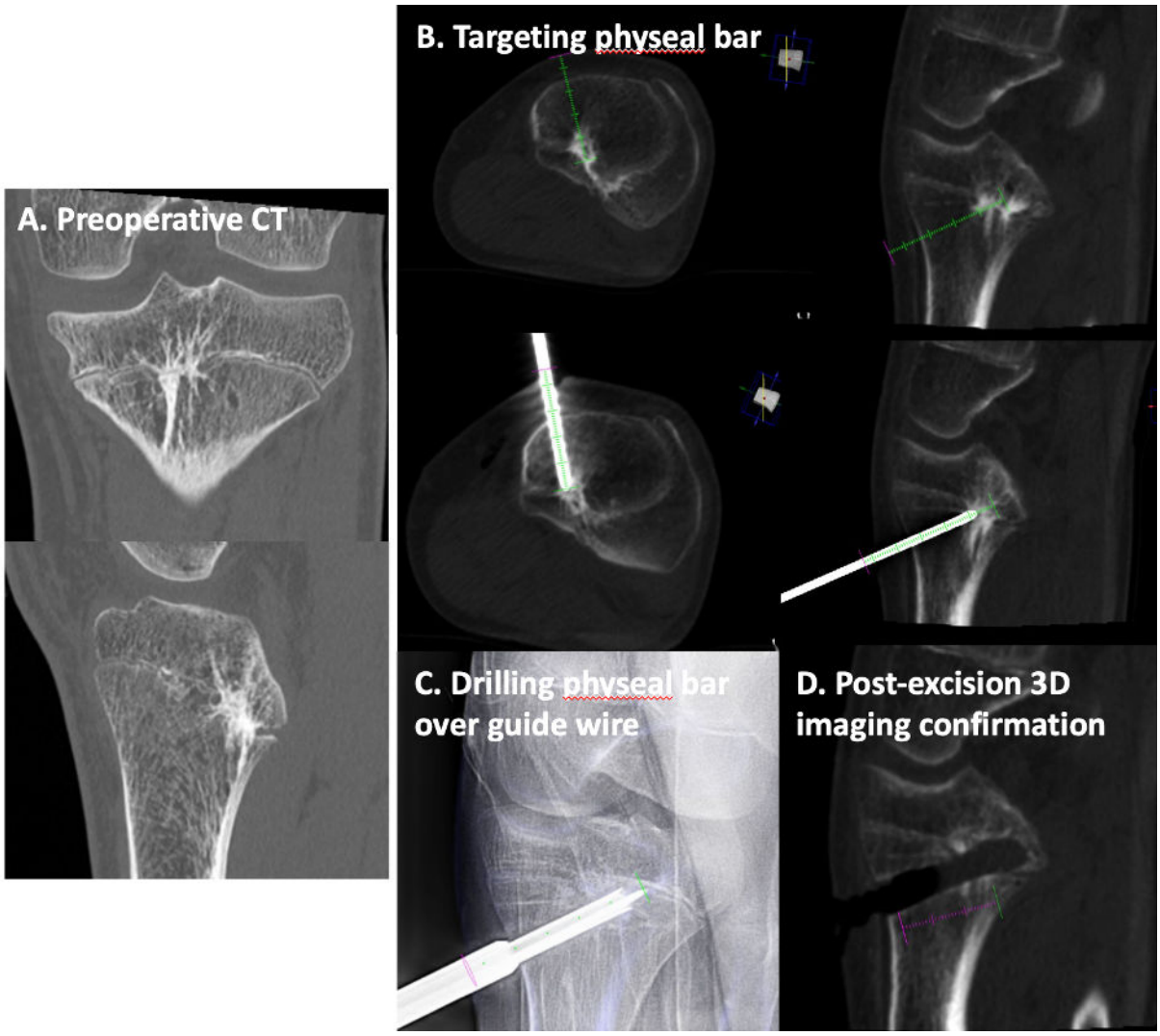

Figure 1: Preoperative Planning and Execution of Physeal Bar Excision Using the XperCT Image Guidance System.

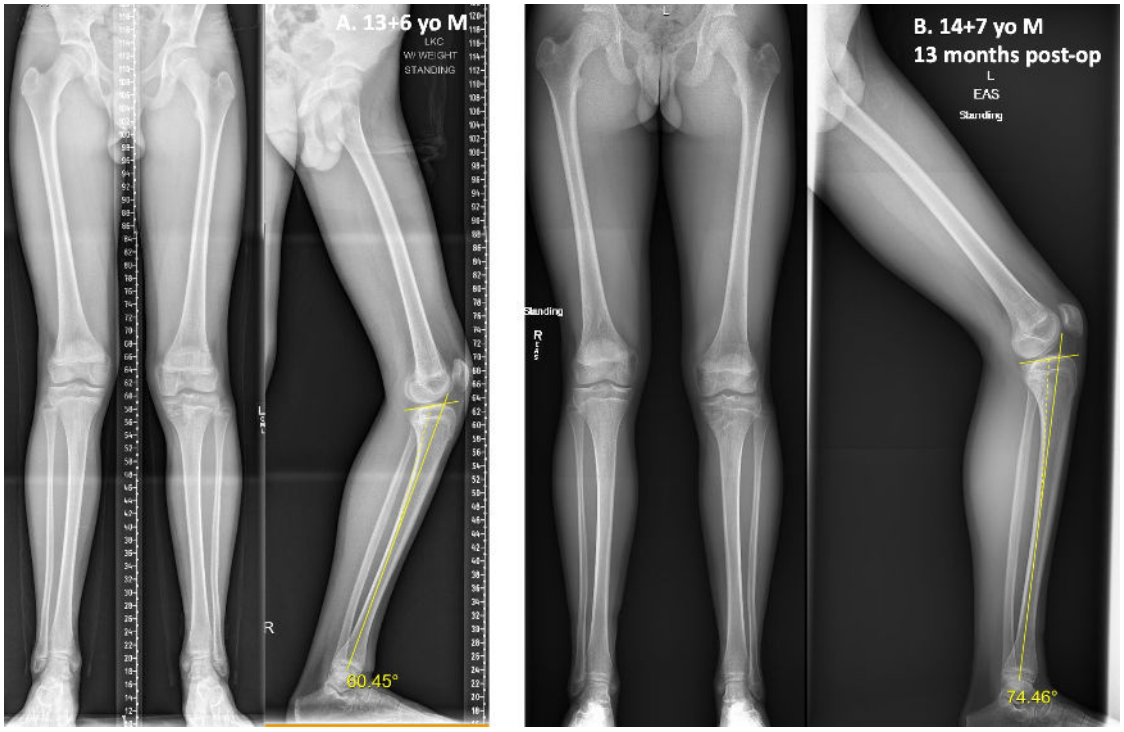

Figure 2: 13 year old male with SHIV proximal tibia fracture that went on to develop genu procurvatum deformity (A) and knee pain. Post-operative x-rays (B) show improvement in pPTA 13 months following treatment.

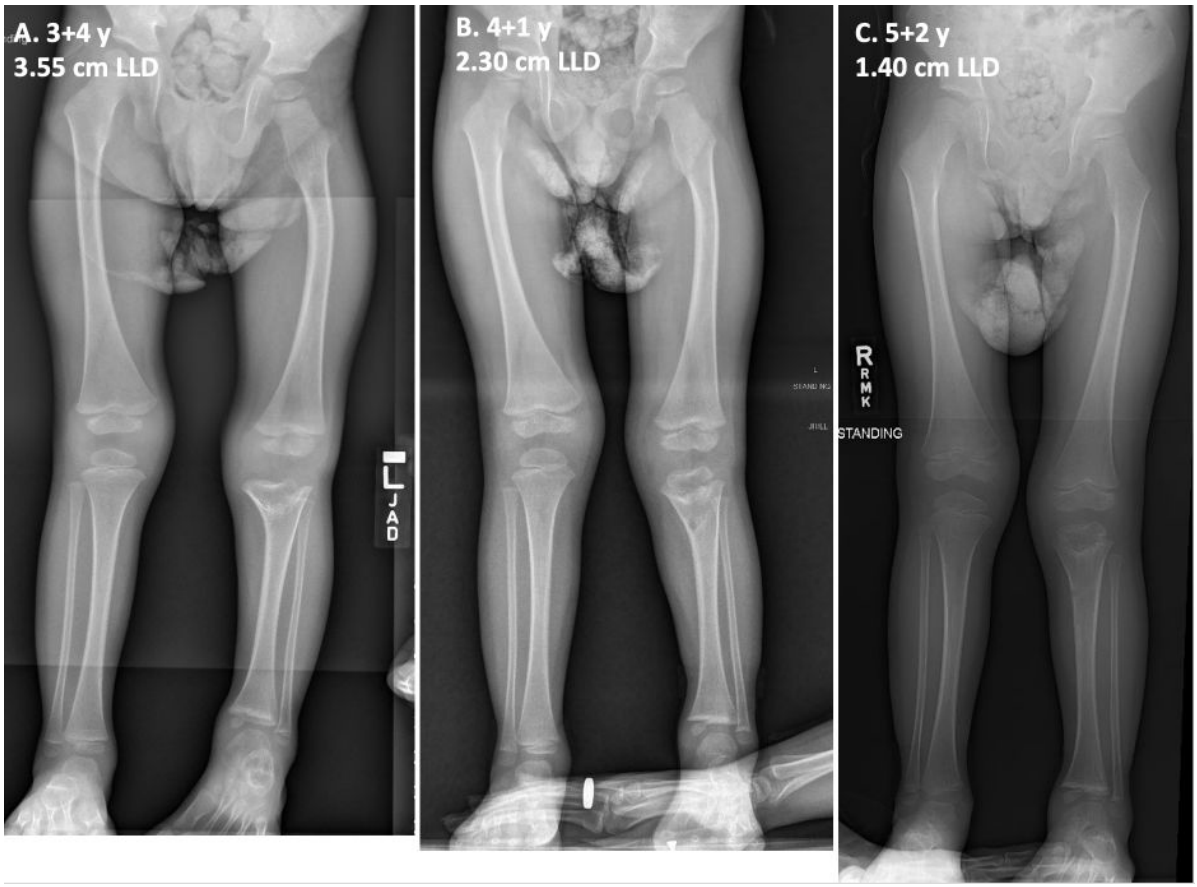

Figure 3: 3 yo M with neonatal osteomyelitis sequela of proximal tibial central physeal arrest with resulting 3.55 cm leg length discrepancy (A). Following physeal bar excision, the proximal tibia resumed normal growth, exhibiting improved morphology and decreasing leg length difference over time (B, C).

Knee Joint Line Obliquity at Skeletal Maturity After Growth Modulation Treatment of Genu Varum and Genu Valgum

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Taylor Zak, MD; Elizabeth Hubbard, MD; Anthony Minopoli, BS; Claire Shivers, BS

What was the question?
Knee joint line obliquity, particularly medially directed obliquity, increases the stress on the cartilage of the knee which can lead to cartilage injury and early onset of osteoarthritic changes. Growth modulation is a reliable technique for the restoration of the mechanical axis in patients with genu varum and genu valgum. However, the incidence joint line obliquity after growth modulation is unclear. This study asked the following question: What is the incidence of knee joint line obliquity in the skeletally mature patient after growth modulation of the distal femur and/or the proximal tibia for genu valgum or genu varum?

How did you answer the question?
We retrospectively analyzed all patients who underwent growth modulation of the distal femur and/or the proximal tibia for genu valgum or genu varum and were followed to skeletal maturity. Inclusion criteria included all patients with standing anteroposterior (AP) radiographs of the bilateral lower extremities pre–operatively and at skeletal maturity. Patients undergoing an osteotomy of the affected lower extremity at any time after the initiation of growth modulation and prior to maturity were excluded from the study. The patient's demographic and surgical data were recorded. The radiographic parameters analyzed pre– and post–operatively included the mechanical axis deviation (MAD), the mechanical lateral distal femoral angle (mLDFA), the mechanical medial proximal tibial angle (mMPTA), the lateral distal tibia angle (LDTA), the joint line convergence angle (JLCA), and the joint line obliquity angle (JLOA). A JLOA $\geq 4°$ was considered abnormal. For comparisons of pre–post data, we used a paired t–test or Wilcoxon's signed rank test as appropriate.

What are the results?
204 limbs (71 varus, 131 valgus) in 129 patients (76 bilateral) were included in the study. Location of growth modulation was distal femur (95), proximal tibia (70), and distal femur with proximal tibia (39). The majority of patients underwent single hole (8–plate or O–plate) tension band plating (160, 78%) while multi–hole tension band plates (I–plate or H–plate) was used in 33 (16%) patients, and percutaneous screws used in 11 (6%).
Overall, 130 limbs (64%) had knee joint line obliquity pre–operatively. 66 (32%) limbs still had joint line obliquity at skeletal maturity. Of those with joint line obliquity, 13 had obliquity that was worse, 8 overcorrected to the opposite joint obliquity, and 6 patients started with normal obliquity but ended with significant joint line obliquity.
For patients with varus and valgus, the MAD was significantly improved at skeletal maturity (p

What are your conclusions?
Joint line obliquity must be considered in the treatment of genu varum and genu valgum. 64% of patients in this cohort demonstrated knee joint line obliquity pre–operatively. Growth modulation for the treatment of these conditions does not fully correct joint line obliquity and can make it worse. Further analysis in needed to identify those most at risk for under–/over–correction so alternative and/or additional treatments can be considered.

Not Just Your Average Anterolateral Bow (of the Tibia!)

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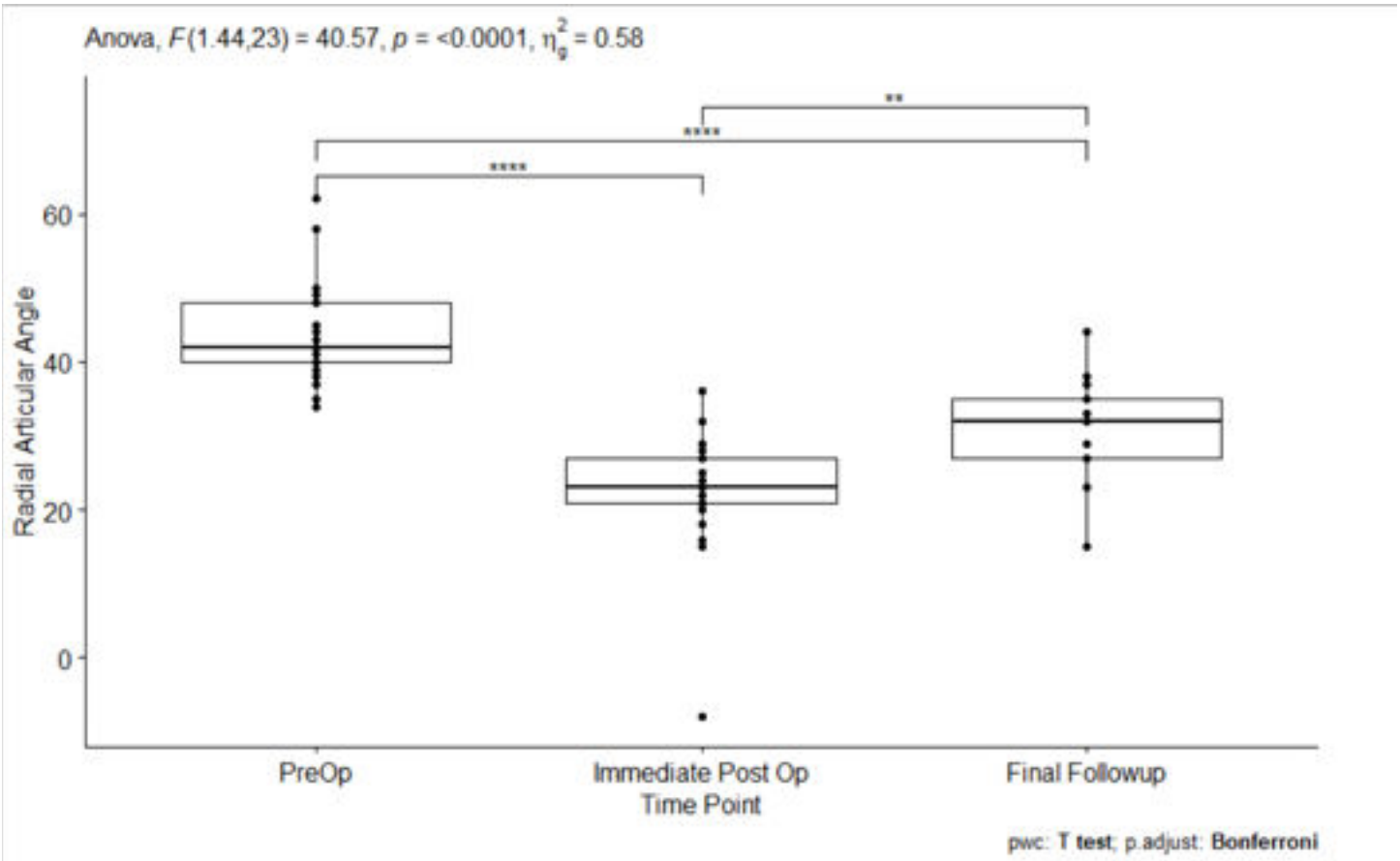
David S. Feldman, Craig Robbins, Dror Paley, Claire Shannon, Katherine Miller

What was the question?
What is congenital anterolateral bowing of the tibia with polydactyly (CABTP)?

How did you answer the question?
We retrospectively reviewed the charts and radiographs of patients who were diagnosed with CABTP, anterolateral bowing of the tibia (ALB) and Paley type 1 tibial hemimelia (TH) (examples of each can be found in Figure 1). Radiographic measurements were performed on coronal views of the bilateral lower extremities and of the tibia/fibula. Measurements included length of the ipsilateral fibula and tibia, length of the contralateral fibula and tibia, diaphyseal deformity of the tibia, limb length discrepancy, presence/absence of polydactyly and presence/absence of fibular deformity. Paired t–test was performed to compare the fibula:tibia ratios of ipsilateral and contralateral limbs. One–way ANOVA was performed to compare fibula:tibia ratios of the ipsilateral limbs and initial limb length discrepancy in each diagnostic group followed by Tukey's honestly significant difference procedure. Fisher's Exact test was used to compare the presence/absence of fibular deformity between the groups. Significance was set at $p < 0.05$.

What are the results?
Six patients were identified in each group. There was one patient with bilateral congenital anterolateral bowing of the tibia with polydactyly. The mean age in the ALB group was 2.4 years, in the TH group 8.7 years and 4.1 years in the CABTP group. The mean ipsilateral fibula:tibia ratio in the ALB group was 1.01 (±0.002), in the TH group 1.05 (±0.02) and 1.09 (±0.06) in the CABTP group. When compared to their contralateral/uninvolved limb: there was no difference in the ALB group ($p = .2722$) but there was significance differences for the TH group ($p = .0046$) and the CABTP group ($p = .0384$). Comparison of the ipsilateral limb ratios demonstrated a significant difference between the ALB group and the CABTP group ($p = .0078$). The diaphyseal deformity of ALB was similar to CABTP ($p = .9609$) and both ALB and CABTP had greater diaphyseal deformity than TH ($p = .0033$, $p = .0058$, respectively). The mean limb length discrepancy in the ALB group was 2.5mm (±6.7mm), in the TH group was 40.2mm (±8.4mm) and 52.8mm (±37.9mm). Comparison of the limb length discrepancies demonstrated a difference between the ALB and TH group ($p = .0190$) and between the ALB and CABTP group ($p = .0033$); however no difference was found between the TH and CABTP group ($p = .6291$). Fibular deformity was present more in the ALB group compared to the CABTP group ($p = .0291$). However, it was not significantly more present in the ALB group compared to the TH group ($p = .0801$) or the TH group compared to the CABTP group ($p = .8224$). There were no cases of polydactyly in the TH or ALB group. All patients had polydactyly in the CABTP.

What are your conclusions?
CABTP is a distinct entity from ALB and is part of the spectrum of TH. Although ALB and CABTP both have bowing, they were significantly different in every other measurement. There were no statistical differences between CABTP and TH when it came to fibula:tibia ratio, limb length discrepancy and fibular deformity. Although there were no patients in the TH group with polydactyly, it is well–known that polydactyly is part of TH as well. Consideration should be given to adding CABTP into the classifications for tibial hemimelia.


Anova, F(1.44,23) = 40.57, p = <0.0001, η²g = 0.58
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Radial Articular Angle
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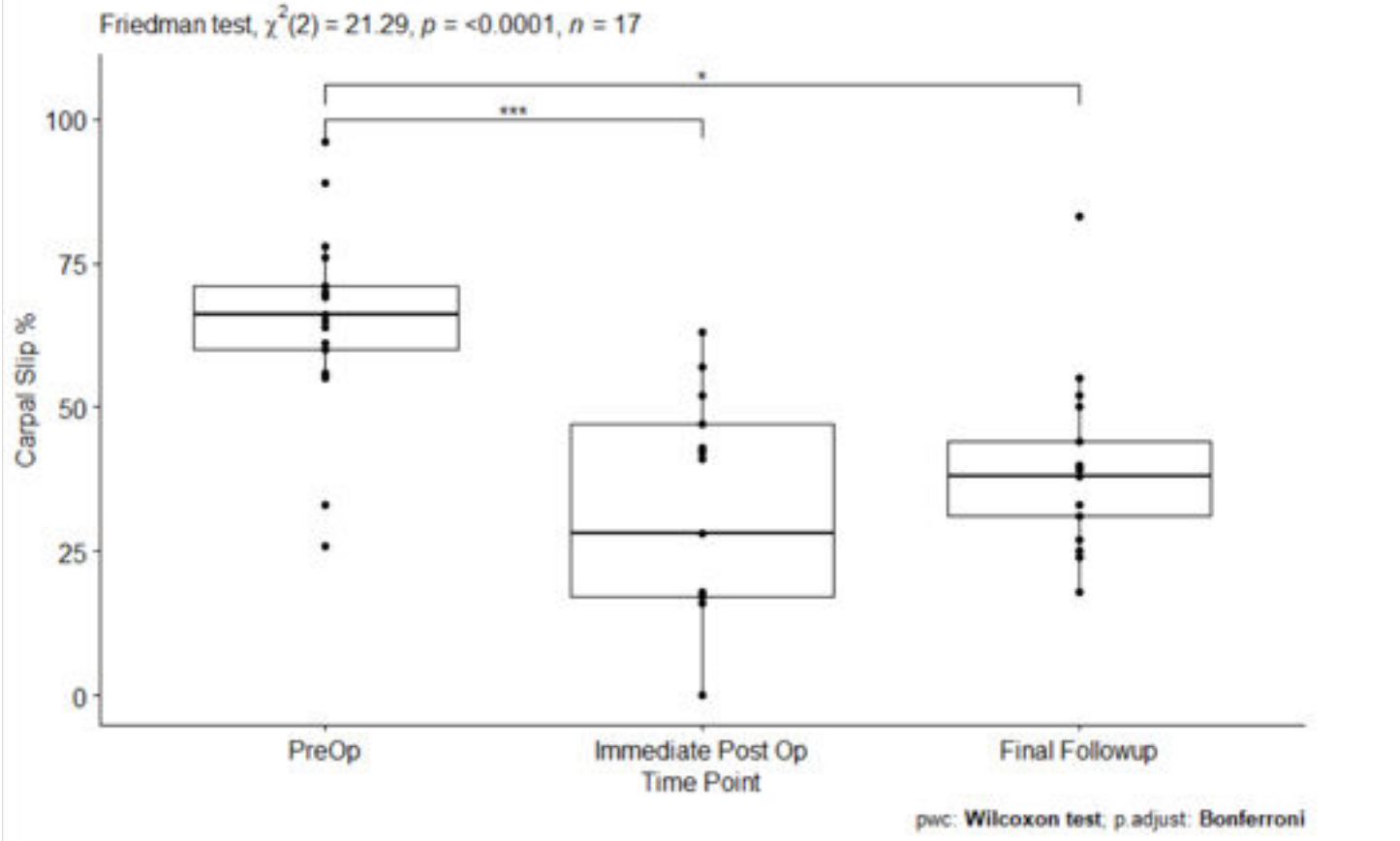
pwc: T test, p.adjust: Bonferroni


Friedman test, χ²(2) = 21.29, p = <0.0001, n = 17
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Carpal Slip %
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PreOp
Immediate Post Op
Final Followup
Time Point
pwc: Wilcoxon test, p.adjust: Bonferroni

Patients with Significant Femoral Version Abnormalities Report Lower Quality of Life than Asymptomatic Controls

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Bridget K Ellsworth, Gerard A Sheridan, S Robert Rozbruch, Austin T Fragomen,

What was the question?
Symptomatic femoral malrotation can significantly affect one's quality of life enough to seek surgical correction. Currently, there is no established baseline quality of life for such patients. The primary aim of this study was to establish the quality of life deficit using the Limb Deformity Scoliosis Research Society (LD–SRS) and Patient–Reported Outcomes Measurement Information System (PROMIS) for patients with symptomatic femoral rotation abnormality versus patients with no symptomatic lower extremity complaints.

How did you answer the question?
Our practice's operative log was queried to include all patients at least 18 years old who were scheduled for unilateral or bilateral femoral derotation osteotomy with intramedullary nail fixation or external frame fixation between December 2018 and August 2022. Patients were indicated for rotational correction based on history, physical examination, and computerized tomography (CT) study. Because this study examines exclusively preoperative quality of life, patients need not have had surgery and no follow–up is necessary. Patients were excluded if they were under 18 years old, they did not complete the LD–SRS and PROMIS surveys, or rotational correction was not a primary patient complaint. Patients were included if lengthening or deformity correction occurred concurrent with rotational correction. This yielded 33 patients.
A control cohort was created by using LD–SRS and PROMIS scores from 30 volunteers with no history of lower extremity surgery, previously surveyed through convenience sampling. Survey scores were compared by Student's t–test (p

What are the results?
Demographic comparisons between the rotational group vs. controls identified cohort matching for age (p=0.399) and sex (p=0.696). There was a significantly higher number of individuals self–identifying as Asian/Pacific Islander in the control group and a significantly higher number of patients self–identifying as White in the rotational group (p=0.025).
Patients with femoral malrotation reported significantly worse scores than control subjects on all survey domains, both for LD–SRS [Total (3.5±0.62 vs. 4.58±0.37, p

What are your conclusions?
Patients with symptomatic femoral malrotation experience significantly worse quality of life as determined by all LD–SRS and PROMIS domains, versus healthy controls. The use of these surveys can assist with confirming whether patients are likely to benefit from operative intervention for symptomatic femoral rotation abnormality. They may also help patients understand in what ways they may derive improved quality of life following surgery.

Hibernation of Percutaneous Hemiepiphysiodesis Plates is Safe in Patients with Congenital Limb Deficiencies

Claire Shannon, MD

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Dror Paley, Corey Fuller

What was the question?
What is the risk of recurrent genu valgum and unintended overcorrection due to hibernation of a percutaneously inserted hemiepiphysiodesis plate in patients with congenital limb deficiencies?

How did you answer the question?
A retrospective radiographic and chart review was performed using ICD–10 codes for limb reduction deficits and deformities of hips/knees/feet between 2009 and 2018. All patients with Fibular Hemimelia(FH) and Congenital Femoral Deficiency(CFD) who underwent percutaneous hemiepiphysiodesis of the distal femur or proximal tibia for genu valgum were included. Patients with subsequent hibernation of the hemiepiphysiodesis plate with a minimum of 2–year follow–up were noted for subgroup analysis. Medical charts and radiographs were reviewed for reactivation episodes, rebound deformity, and unintended overcorrection.

What are the results?
Thirty–seven cases of percutaneous hemiepiphysiodesis for genu valgum were identified in patients with FH (15) and CFD (22) between 2009 and 2018. The average age at plate insertion was 5.8 years. The mean Mechanical Axis Deviation (MAD) was 16.9mm, and the mean femoral–tibial angle (FTA) was 9.5 degrees at the time of plate insertion. The average time to correction was 8.9 months, and 100% of patients achieved full correction of genu valgum. Nineteen patients (51%) underwent hibernation of the hemiepiphysiodesis plate. Sixteen patients (37%) developed recurrent valgus, and 13/16 underwent reactivation of the previously hibernated plate. Three patients required insertion of a new plate due to valgus in another bone. No patient had unintended overcorrection of the mechanical axis.

What are your conclusions?
Hibernation of percutaneously inserted hemiepiphysiodesis plates is safe in patients with congenital limb deficiencies and does not result in unintended overcorrection of the mechanical axis.

Session IX: Bone Problems

Moderator: Jill C. Flanagan, MD

Intramedullary Rodding of Long Bones in Patients with Osteogenesis Imperfecta: To Supplement with a Plate or Not to Supplement with a Plate?

Jeanne M. Franzone, MD; Amelia M. Lindgren

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Kenneth J. Rogers

What was the question?
To compare the outcome of intramedullary rodding of long bone segments with and without supplementary plate and screws.

How did you answer the question?
A retrospective review identified patients with OI who underwent intramedullary rodding of long bone segments from 2014–2021. Inclusion criteria included a minimum of one year follow–up and sufficient fracture data. Medical records and radiographs were reviewed for demographics, instrumentation details, refracture rate and location.

What are the results?
225 bone segments in 56 patients were included (25 females, 31 males); 93 femurs, 86 tibias, 28 humeri, 18 forearms. OI Types were: 29 type 3, 20 type 4, 6 type I, 1 type 8, 1 Bruck Syndrome. The average age at surgery was 8.4 years (1.7–23.9); 94.6% were on bisphosphonates. Mean follow–up was 4.2 years (1–8.5). A supplementary plate was used for 63 (28%) of the segments. 67 of 162 (41.3%) segments without a plate were revisions; 48 of 63 (76.2%) segments with a plate were revisions ($p<.05$). The mean plate size was 2.5mm (2.0–3.5mm), mean number of screws was 6.0 (3–10), 79.7% bicortical, primarily locking screws. 11 plates were used at nonunions, 1 buttress, 2 supporting allograft and 50 for rotation/length control. One plate broke, 1 became loose. Twelve plates were removed with one fracture at a prior screw hole. The re–fracture rate per year of segments without a rod was 0.18 and with a rod was 0.12 ($p=0.44$). Of the re–fractures with a plate, 19 were adjacent to the plate; 15 were elsewhere. Two nonunions of fractures adjacent to plates required revision. Three segments with plates (4.5%) had a fracture adjacent to the plate with deformity requiring urgent revision. Five segments without plates (3.1%) had a fracture with acute bend of the rod requiring urgent revision.

What are your conclusions?
This is the first study to document outcomes of intramedullary rods with supplementary plate and screw constructs in OI patients with a comparison group of patients. Supplementary fixation with a small plate and screw construct with an intramedullary device for OI patients may provide additional stability at an osteotomy, fracture or nonunion site without incurring an increased fracture rate. A subset of re–fractures adjacent to a plate caused bending to require urgent revision and may support routine plate removal after healing although the same reason for revision occurs without a plate.

Limb Reconstruction in Patients with Paley 5A Tibial Hemimelia

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David S. Feldman, Craig Robbins, Dror Paley, Claire Shannon, Katherine Miller

What was the question?
What are the clinical results of limb reconstruction in patients with Paley 5A tibial hemimelia at a minimum follow–up of 5 years?

How did you answer the question?
A retrospective radiographic and chart review was performed using ICD–10 codes for limb reduction defects and deformities of the hips/knees/feet. 151 patients were identified with 203 limbs that met diagnostic criteria for tibial hemimelia. Inclusions criteria included a diagnosis of Paley 5A tibial hemimelia (absent tibia, patella present), history of patelloplasty reconstruction and a minimum follow–up of 5 years. Sixteen patients with sixteen limbs met the criteria. Demographic data, surgical history and medical history were reviewed. Clinical data was collected and included pre/post–operative: knee range of motion, ankle range of motion, ambulatory status and orthotic use. Surgical charts were reviewed and complications were recorded.

What are the results?
The mean age of the patients at their first surgery was 3.4 years (±2.9 years). Nine patients had bilateral tibial hemimelia. Four patients had associated comorbidities which included: two with Gollop–Wolfgang syndrome, one with congenital femoral deficiency, and one with a single kidney. Data for preoperative knee flexion deformity was available for 10 limbs and the mean was 42 degrees (±29 degrees). Active extension was reported in ten of the initial consultations and all 16 limbs had patellas. Equinus deformities were recorded for 6/16 patients and the mean deformity was 51 degrees (±22 degrees). All 16 patients had a preoperative clubfoot presentation. The mean preoperative limb length discrepancy was 47mm (±44mm).
The mean follow–up for the cohort 8.3 years (±2.1 years). The mean total number of surgeries was 6.9(±2.0). The mean number of complications per patient 5.8(±3.3) and mean number of complications requiring a return trip to the operating room (OR) was 2.1 (±1.2).
At the most recent follow–up visit, all 16 patients were ambulating. Ten patients had a mobile knee joint. The mean knee range of motion was 52 degrees (±39 degrees). The mean flexion deformity was 8 degrees (±12 degrees). Five patients were able to achieve complete knee extension. Eight patients had active extension, one did not and one patient's ability to extend their knee was not documented. Five patients had knee fusions with the mean position of fusion in 10 degrees (±6 degrees) of flexion. One patient underwent a through–knee amputation. All ankles were fused with the mean position of fusion was 4 degrees (±8 degrees) of equinus. Four patients did not wear an orthosis for ambulation, two wore AFOs, five wore KAFOs and one wore a prosthesis. There were four limbs with no documentation of an orthosis or prosthesis. Three patients who had knee motion did not require a brace for ambulation. The mean limb length discrepancy at final follow–up was 57.4mm (±41.5mm).

Limb Reconstruction in Patients with Paley 5A Tibial Hemimelia *continued*

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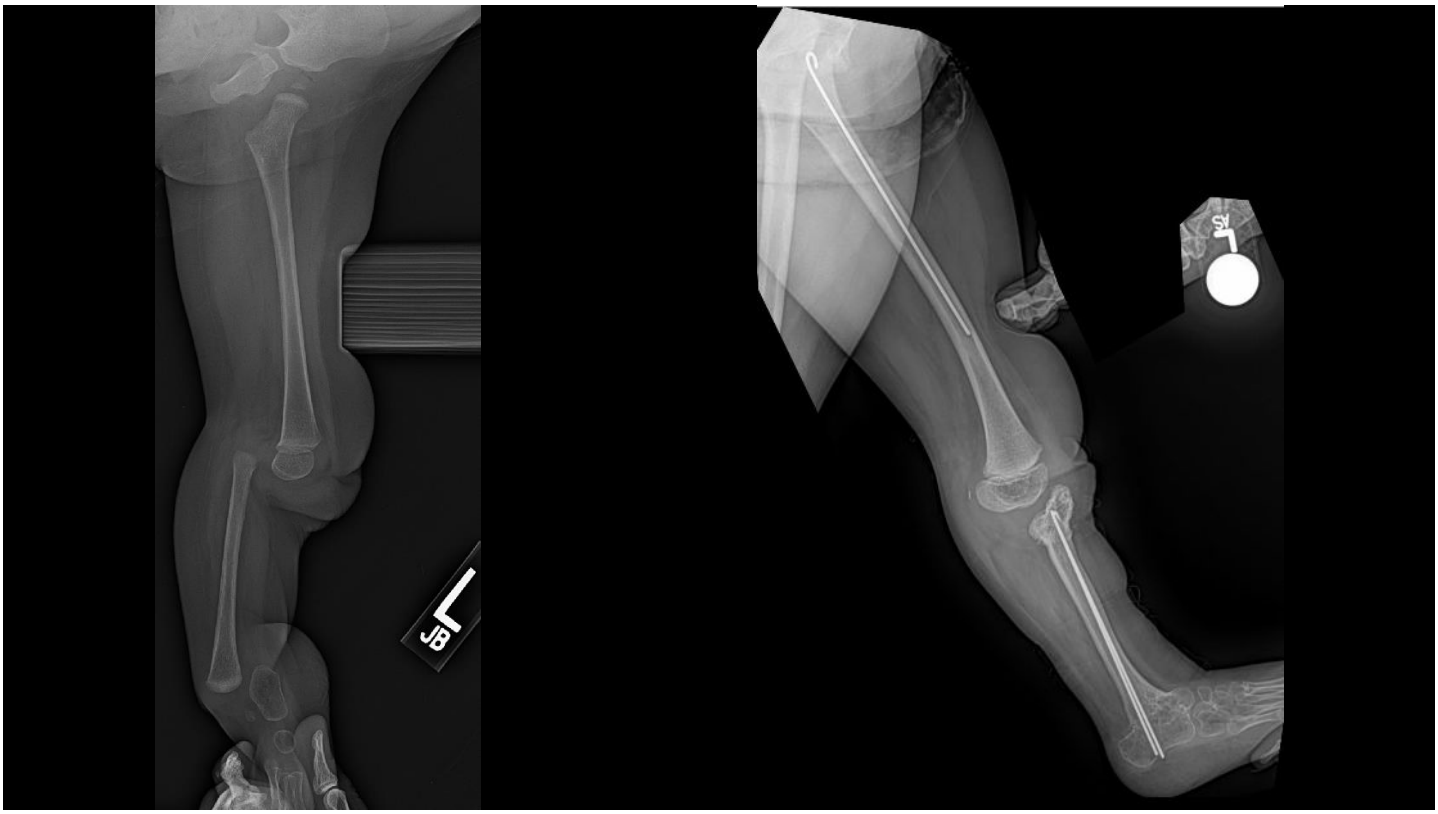
David S. Feldman, Craig Robbins, Dror Paley, Claire Shannon, Katherine Miller

What are your conclusions?
Reconstruction of Paley 5A tibial hemimelia with a patelloplasty maintained a mobile knee joint in 62% of the patients treated at a mean of 8 years (Figure 1 demonstrates preoperative and latest follow–up sagittal radiographs of a patient who underwent patelloplasty reconstruction). 15/16 patients maintained the limb without ablation. All patients were able to ambulate independently regardless of reconstructive path. Creation of a mobile knee joint in patients with Paley 5A tibial hemimelia is possible, but patients are likely to experience complications during the process. Additionally, the remaining limb length discrepancy and the steps necessary to achieve equalization may put this joint at risk. If reconstruction is unsuccessful, there is an option for knee fusion (to maintain the limb) or through knee amputation if adequate prosthetic care is available and ablation is culturally acceptable. It is important that patient expectations are appropriately set prior to undergoing reconstruction.



Preferences and Priorities for Decision Making in Congenital Femoral Deficiency (CFD): A Stated Preference Survey of Patients, Caregivers, and Clinicians

Ilene Hollin, PhD

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Henrike Schmalfuss, Corinna Franklin, Sarah Nossov

What was the question?
To better understand patient and family preferences for treatment decision making in CFD and to better understand sources of decisional conflict, we asked two questions:
1) What is the importance of various treatment feature when making a treatment decision?
2) What are the most/least difficult aspects of making a treatment decision?

How did you answer the question?
We surveyed patients (n=52), parents (n=121) and clinicians (n=47). Patients and parents were identified using an administrative database from a multicenter, pediatric orthopedic hospital system. The database was queried for patients with diagnosis codes related to having a short femur (i.e., proximal femoral focal deficiency, congenital femoral deficiency and congenital short femur). Patients at least 14 years of age, and parents of children of any age were recruited via mail, email, telephone, and in–person clinic visits. Clinicians were identified using the study investigators' professional networks, including Shriners Children's and the Limb Lengthening and Reconstruction Society. Surveys were administered online via Qualtrics and included a discrete choice experiment (DCE) to measure treatment features that influence decision making and a best worst scaling (BWS) experiment to measure the greatest sources of decisional conflict. To analyze the DCE we calculated the weight of feature importance, which is a measure of influence for a particular feature (higher scores indicate greater weight). To analyze the BWS we calculated preference shares, which is a measure of importance (higher scores indicate greater importance). We also assessed risk tolerance, role preferences for shared decision making, clinical characteristics and demographic information.

What are the results?
Results indicated that children and parents ordered the importance of treatment features similarly (Figure 1). The treatment feature that carried the most weight in treatment decision making was the treatment's mobility outcome. The three next features were weighted similarly and included avoiding amputation, number of surgeries, and chance of serious complication. The least weighted treatment feature was number of follow–up appointments, however parents weighted this more heavily than children (11.3% vs. 4.8%). Clinicians also placed the greatest weight on mobility outcomes, but placed much greater weight on mobility relative to other treatment features; the weight for mobility (47.2%) was more than double the weight of the next most important treatment feature (chance of serious complications; 19.3%). For clinicians, less weight was assigned to avoiding amputation (10.2%) than for children (23.3%) and parents (21.7%).
The preference share for the sources of decisional conflict varied across groups (Figure 2). For children, lack of information about conditions and treatments was the most difficult aspect of decision making, whereas, for parents it was permanency of the decision. For children, the least difficult aspect of decision making was worry that their parent would disagree with their choice, while parents worried least about the timing of the decision. Clinicians believed that the most difficult aspect of decision making for their patients and families would be weighing the pros and cons of treatment options and the least difficult aspect of decision making for their patients and families would be the lack of information about conditions and treatments.

Preferences and Priorities for Decision Making in Congenital Femoral Deficiency (CFD): A Stated Preference Survey of Patients, Caregivers, and Clinicians *continued*

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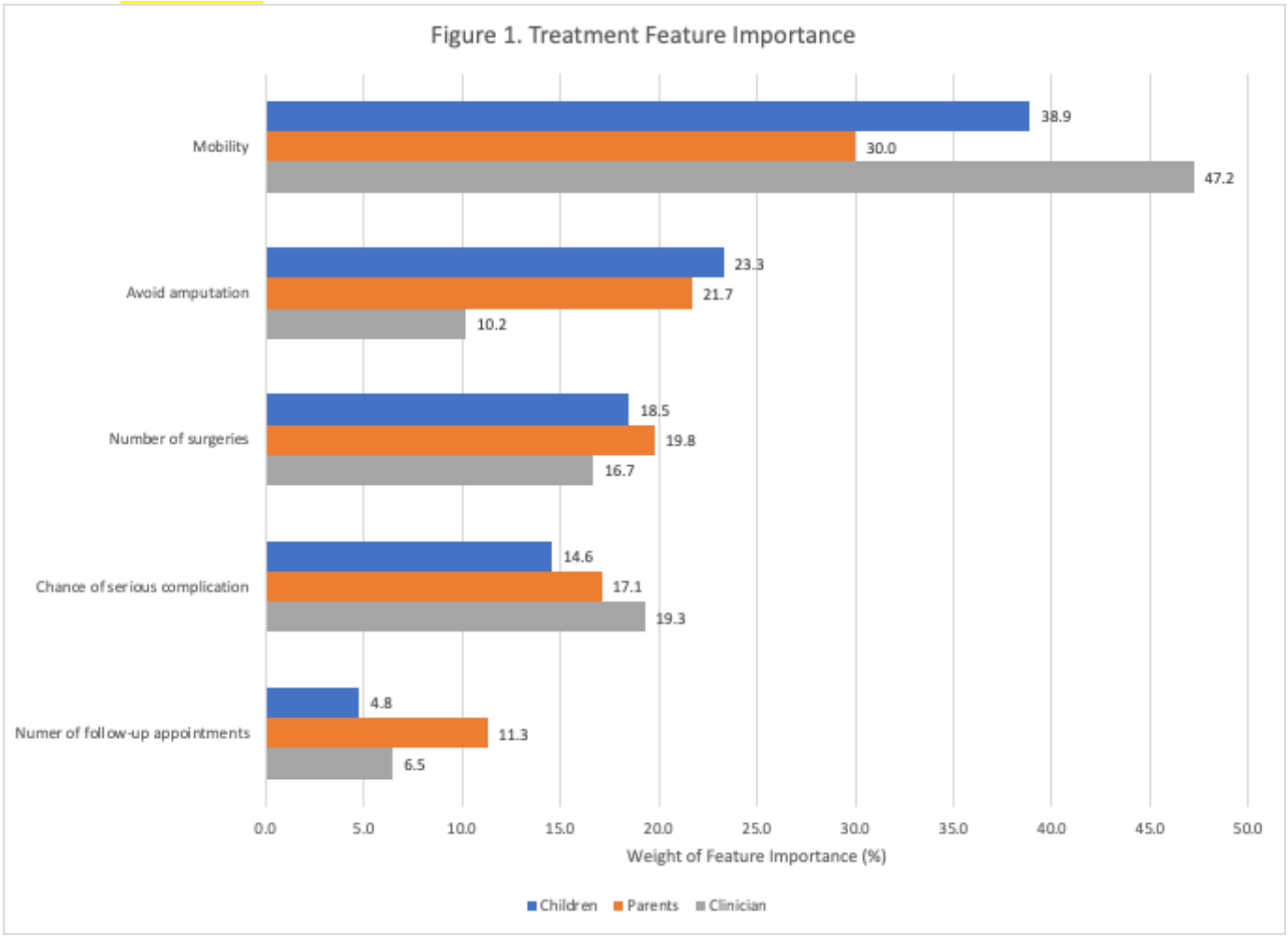
What are your conclusions?

The results of this study improve our understanding of the priorities and preferences of decision makers, as well as these sources of decisional conflict, which is foundational to developing decision tools such as patient decision aids that can help patients and caregivers choose treatment strategies that are concordant with their values, and in turn reduce decisional conflict and decisional regret. Furthermore, differences between patient and family priorities and clinician perception of patient and family priorities highlights the need for a patient–centered approach to shared decision–making.



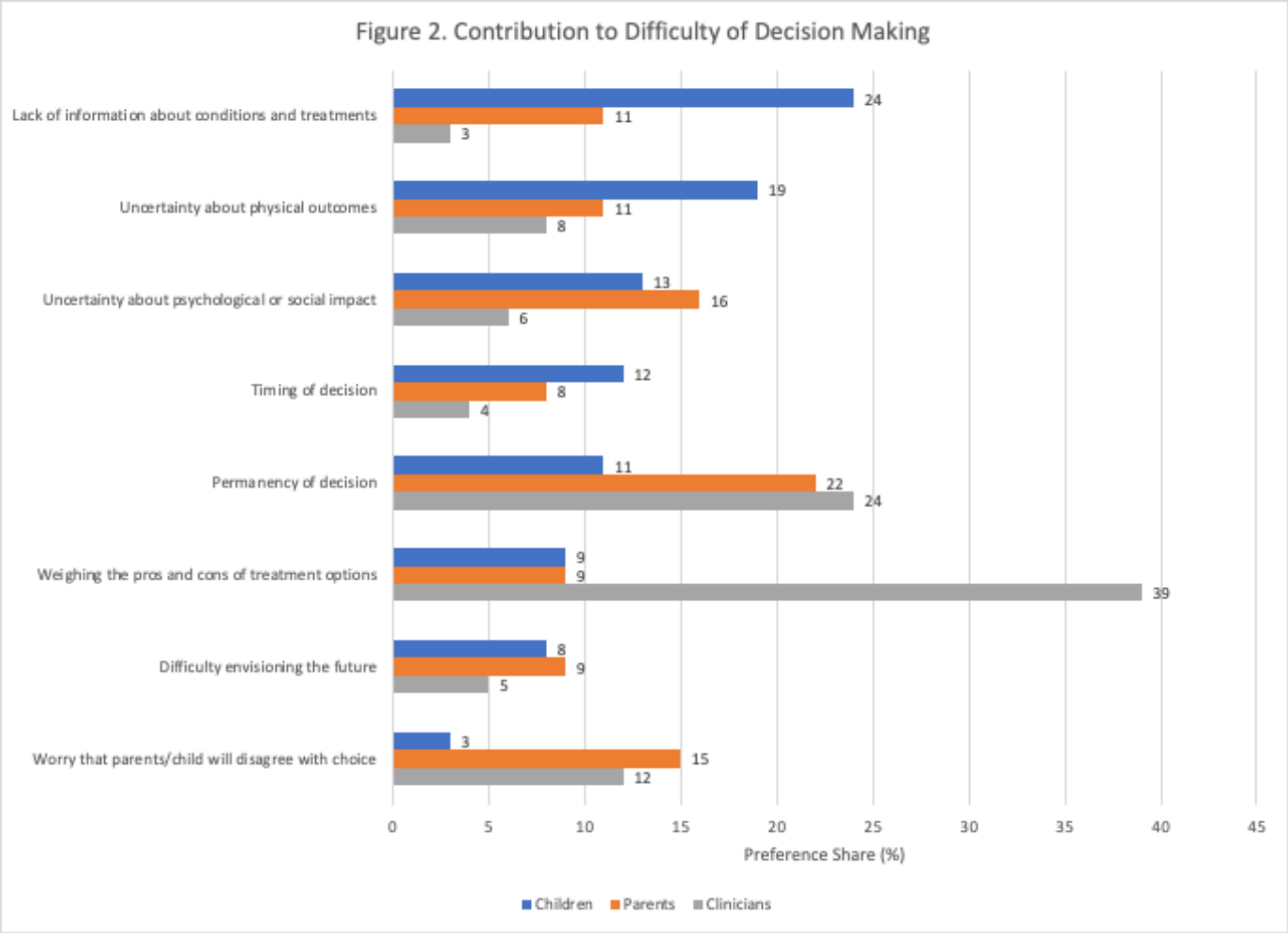


Figure 2. Contribution to Difficulty of Decision Making
Lack of information about conditions and treatments
24
11
3
Uncertainty about physical outcomes
19
11
8
Uncertainty about psychological or social impact
13
16
6
Timing of decision
12
8
4
Permanency of decision
11
22
24
Weighing the pros and cons of treatment options
9
9
39
Difficulty envisioning the future
8
9
5
Worry that parents/child will disagree with choice
3
15
12
0
5
10
15
20
25
30
35
40
45
Preference Share (%)
Children
Parents
Clinicians

Metabolic Impacts on Surgical Outcomes after Hemiepiphysiodesis for Hypophosphatemic Rickets

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Ian Marpuri, Irene Chen, Chelsey Grimbly, Anna Ryabets–Lienhard

What was the question?
Does metabolic control affect the rate of correction after hemiepiphysiodesis in hypophosphatemic rickets?

How did you answer the question?
Multicenter retrospective study. Records and radiographs of children with genetic forms of hypophosphatemic rickets who underwent hemiepiphysiodesis, were reviewed. The study period was 12 months pre– to 24 months postoperative. Serum alkaline phosphatase activity (ALP) was used to assess metabolic control as a percentage above the upper limit of normal (%ALP ULN) due to different reference ranges for age and sex. Mechanical axis deviation (MAD) was measured to assess surgical correction.

What are the results?
Twenty–four children (71% female) with hypophosphatemic rickets (22/24 X–linked hypophosphatemic rickets, 2/24 Fanconi syndrome) underwent hemiepiphysiodesis (mean age at surgery 9.3 +/– 3.6 years, 92% bilateral deformities). Correction to neutral (MAD ≤0mm) was achieved in 45% limbs by 12 months and in 76% by 24 months. Correction occurred in all valgus deformities but only 56% of varus deformities. Preoperatively, limbs that corrected had lower preoperative MAD (mean 38.3 vs 56.0 mm, p=0.008) but no significant difference in %ALP ULN (corrected 98% vs uncorrected 57%, p=0.06). %ALP ULN and MAD correlated positively at 12 months postop (r=0.8, p=0.005), while %ALP ULN at 12 months postop correlated negatively with both MAD rate of change (r=–0.72, p=0.02) and overall percentage MAD change (r=–0.75, p=0.02).

What are your conclusions?
Postoperative metabolic control of rickets as assessed by ALP appears to influence the rate of angular deformity correction regardless of preoperative values. Optimization of metabolic control and follow up are prudent for these patients to improve surgical outcomes. Larger studies are needed to further assess predictive factors for success after hemiepiphysiodesis.

Alessandro Codivilla Guest Speaker

The Spark!

Ryan "Birdman" Parrott
Former Navy SEAL Sniper
Founder and CEO of American Extreme

Session X: Internal Lengthening Nails

Moderator: Jessica C. Rivera, MD

Qualitative and Quantitative Assessment of the Regenerate Bone Formed During Intramedullary Limb Lengthening Using a Caprine Tibia Model: A Pilot Study

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Anirejuoritse Bafor, Sara McBride–Gagyi, Aidan Isler

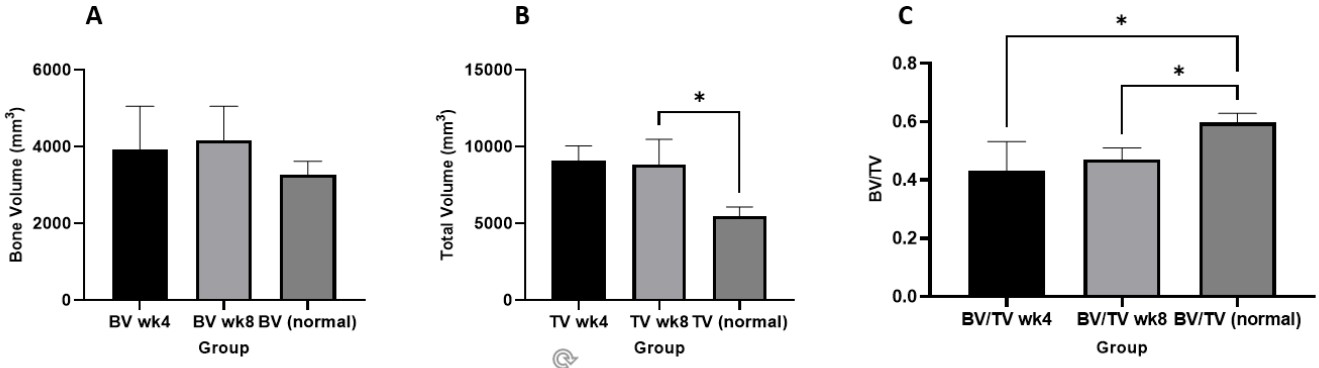
What was the question?
With increasing experience in limb lengthening using internal lengthening nails, it has become apparent that the regenerate bone that forms appears radiographically different than regenerate bone from external fixators. The visual differences are most likely related to the fact that the endosteal blood supply is damaged by reaming with internal lengthening nails as well as the fact that the nails are very stiff in the axial plane. While the regenerate bone formation from external fixation has been thoroughly examined with multiple animal models, we are not aware of any such studies involving internal lengthening nails.
Consequently, this study aimed to characterize the qualitative and quantitative properties of the regenerate bone formed during intramedullary limb lengthening in a goat tibia model.

How did you answer the question?
This was an IACUC–approved study using nine neutered male mature Spanish Cross goats. All animals had surgery performed on the left tibia. Under general anesthesia, a magnetically driven intramedullary lengthening nail was inserted in an antegrade fashion into the left tibiae. Following a latency period of 6 – 9 days, 2 cm of lengthening was carried out at a rate of 0.75 mm per day in increments of 0.25 mm three times a day. Plain x–rays were carried out weekly during lengthening and every 2 weeks during the consolidation phase of treatment, and a final x–ray at necropsy. Tibiae were harvested after 4 weeks and 8 weeks of consolidation for different animal groups. MicroCT analysis and histologic assessments were carried out on the harvested tibiae.

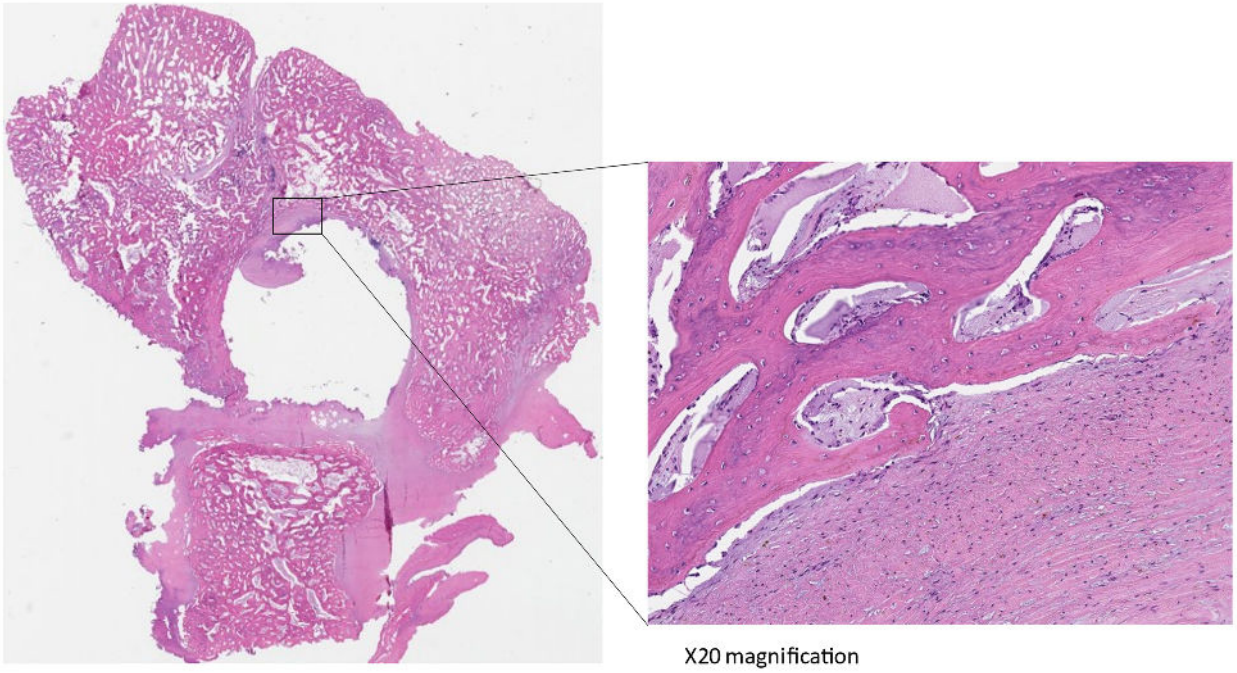
What are the results?
Two goats had low–energy osteotomies at the junction of the proximal tibial metaphysis and the diaphysis. These goats had a latency period of 6 days. They were distracted for 4 weeks and had 8 weeks of consolidation. Seven goats had high–energy diaphyseal osteotomies. All had a latency period of 9 days and 4 weeks of distraction. Three of these goats had a consolidation period of 4 weeks, while 4 had a consolidation period of 8 weeks.
Plain x–ray analysis – regenerate was visible in the distraction gap by the 3rd and 4th weeks in the low and high energy groups, respectively. It appeared more robust in the low–energy group compared to the high–energy osteotomy group. The low–energy group demonstrated faster consolidation of the regenerate compared to the high–energy osteotomy group.
MicroCT analysis – Low–energy metaphyseal osteotomy had higher bone volume (BV), total volume (TV), and bone volume fraction (BV/TV) measurements compared to the high–energy diaphyseal osteotomy group. An increase in TV preceded an increase in BV as mineralization occurred during regenerate bone consolidation.

What are your conclusions?
This is the first study to develop a model to describe a method for intramedullary lengthening using a large animal tibia. This study describes the qualitative and quantitative features of intramedullary lengthening regenerate over time. This pilot study provides the foundation for future studies regarding the biology of internal lengthening bone formation.

Comparison – 4 weeks vs 8 weeks of consolidation



Comparison of 4 weeks vs 8 weeks of consolidation for diaphyseal osteotomy vs normal. A. Bone volume (BV), B. Total volume (TV), C. Bone volume fraction (BV/TV)



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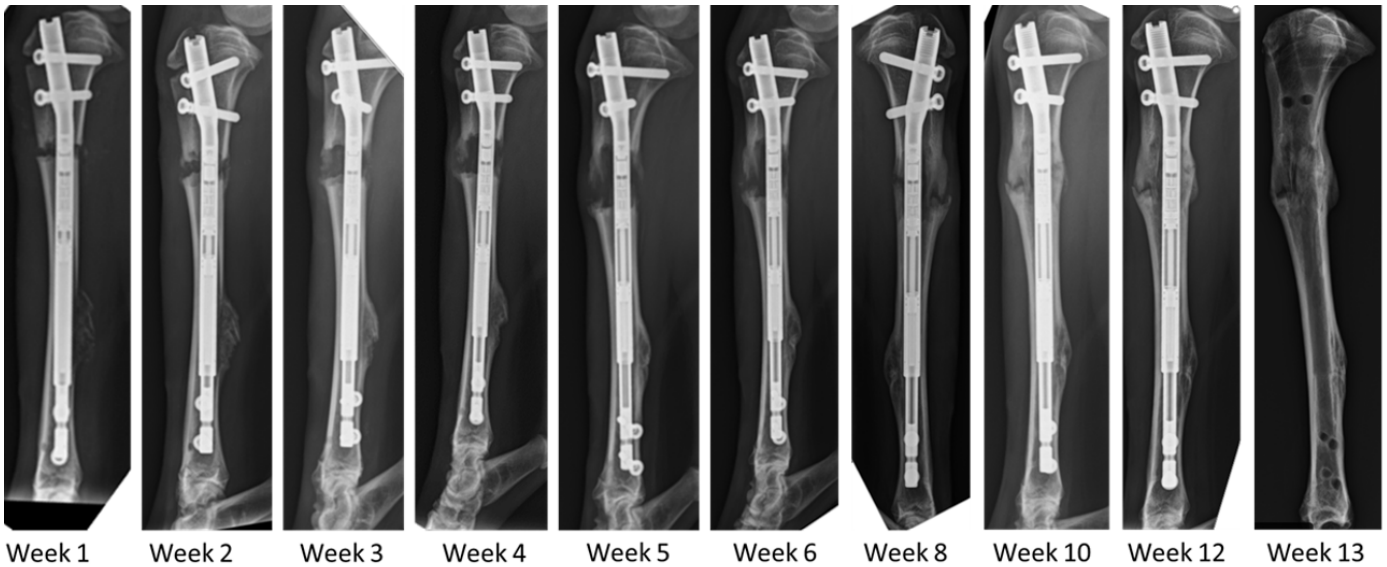

Does Percentage of Tibial Canal Reaming for Insertion of Intramedullary Nail to Correct Limb Length Discrepancy Influence Consolidation Time?

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What was the question?
As the diameter of tibial medullary canal varies significantly and is conventionally reamed approximately 1.5–2 centimeters (cm) larger than the intended diameter, complications with bone healing may arise. Delayed consolidation, as it relates to the percentage of the tibial canal reamed, has not been assessed in the setting of limb length discrepancy (LLD). Hence, we sought to investigate whether the percentage of canal reamed has an effect on developing delayed consolidation.

How did you answer the question?
We retrospectively reviewed clinical records of 55 patients (85 tibias) who underwent tibial lengthening for LLD from 2014 to 2021. Patients with follow–ups of

What are the results?
Eighty–five tibias (40 female; 45 male) with a mean age of 21 years and mean BMI of 23.8 were analyzed. Three tibias were excluded due to the absence of reamer size. The mean percentage of canal reamed among all three groups was 94%, with a mean consolidation index of 57.3. Forty–seven tibias (55%) developed delayed consolidation (>6 months), 7% of which required additional surgery. Neither percentage of the canal reamed, age, BMI, or sex showed any statistical significance on consolidation time.

What are your conclusions?
Our findings demonstrated no statistically significant result when assessing delayed consolidation and the degree of reaming prior to intramedullary nail insertion. This data presents an interesting finding which should be further corroborated with a larger sample size.

Table 1: Demographics, Etiology and Lengthening Achieved

Reamer Percentage	**<80%**	**80-120%**	**>120%**
Mean Age	21.1	19.8	22.1
Sex (M/F)	6 F; 12 M	26 F; 30 M	8 F; 3 M
Mean BMI	22.9	24.1	24.53
Lengthening			
Mean Distraction Index (mm/day)	0.60	0.68	0.63
Mean Consolidation Index (days/cm)	77.2	46.3	48.4
Final Length Achieved (cm)	3.6	4.5	4.9

Table 2: Consolidation Index Based on % of Canal Reamed

% of Canal reamed	N	Mean CI	SD	SE	95% Confidence Interval (lower bound)	5% Confidence Interval (upper bound)	*P* value
<80%	18	77.2	74.5	12.3	16	92	0.056
80-120%	56	46.3	20.1	2.89	26	66	0.958
>120%	11	48.4	23.6	15.9	3	52	0.635
Total	85	57.3	39.4	10.3			

Table 3: Other Variables Influencing Consolidation Index

Parameter	SE	Exp (B)	95% Confidence Interval (lower bound)	5% Confidence Interval (upper bound)	*P* value
Age	0.31	0.94	0.89	1.01	0.083
Sex	0.55	1.58	0.54	4.66	0.397
BMI	0.07	0.86	0.86	1.13	0.842
Etiology	0.01	0.97	0.97	1.02	0.626
Osteotomy Level	0.88	0.88	0.77	1.22	0.321

Session XI: Pain Management

Moderator: Mani D. Kahn, MD

Can Patients Have a Regional Block if the Limb is or was Infected?

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Meghan K. Wally, PhD; Amber Stanley, Rachel Seymour, Priyanka Kamath, Susan Odum, Melody Herman, Jenny Dhingra, Lindsay Lewis

What was the question?
Is administration of regional anesthesia safe in patients with a history of infection or active infection at the time of the block?

How did you answer the question?
We prospectively completed primary and revision complex orthopedic trauma surgeries at a Hospital Based Outpatient Department within one large healthcare system. All index surgeries occurred between November 2016 and June 2020. Use of regional anesthesia was based on surgeon and anesthesiologist preference. We then retrospectively reviewed patient charts and included patients with a history of infection who were treated by a single surgeon and the same anesthesia team. Patients were followed for at least one year postop. We collected data on anesthesia types, block location, upper or lower extremity, infection history, injury type and complications. Our primary outcome was postoperative infection at the block site.

What are the results?
One hundred and sixty–six patients underwent orthopaedic procedures at the hospital–based outpatient facility during the study period. We identified 44 patients who met the inclusion criteria. Thirty–one patients received lower extremity blocks, five patients received upper extremity blocks and eight patients underwent general anesthesia without regional anesthesia. None of our patients experienced the primary outcome, postoperative block site infection. Of the patients who underwent regional anesthesia, 4 (11%) experienced an infection requiring return to the OR for operative management within a year of the index procedure. None of these subsequent infections involved the block site. Three (75%) of these patients received lower extremity blocks and only 1 (25%) received an upper extremity block. All four patients returned to the OR several times for operative management of infection related complications away from the block site.

What are your conclusions?
Consistent with current literature, the occurrence of block site infection in patients with a history of infection was rare in our cohort. We believe that the benefits of regional anesthesia in orthopaedic limb deformity and trauma patients outweigh the risks. Our study provides support for use of regional anesthesia in patients with a history of infection at the time of the block. Finally, it is imperative that an anesthesiologist trained in regional anesthesia techniques is a part of the patient care team.

Regional Neuromuscular Blocks and Pain Catheters for Perioperative Pain Control in the Setting of Osteogenesis Imperfecta Extremity Orthopaedic Procedures

Jeanne M. Franzone, MD

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Kenneth J Rogers

What was the question?
Perioperative pain control for osteogenesis imperfecta (OI) patients undergoing reconstructive upper and lower extremity procedures is an important aspect of care. Adjunctive options to general anesthesia (GA) may provide perioperative pain control. Neuraxial regional anesthesia has been reported in the setting of OI. A paucity of data is available regarding regional neuromuscular blockade. Our objective is to report a series of regional nerve blocks for OI patients undergoing reconstructive extremity procedures.

How did you answer the question?
This is a retrospective review of patients with OI undergoing extremity orthopedic procedures with a nerve block. Procedures with epidural or caudal catheters were excluded. Chart review was completed for demographics, OI type, procedures, type of block, opioid use and pain score (intraoperatively, 24 hours, 24–48 hours).

What are the results?
The study sample includes 51 surgical encounters in 36 pts (19 male, 53%) with an average age of 11.9 years (3–26). Average weight at the time of surgery was 26.6kg (SD 11.9kg). OI types included Type 1 (1), Type 3 (25), Type 4 (21), Type 8 (1) and Type 11 (3). The surgical procedures included 38 procedures on 1 segment and 12 procedures on 2 segments. 36 (70.5%) of the procedures were revisions. Procedures included bone segments: 27 femur, 22 tibia, 11 humerus and 2 forearms. The number of anesthesia procedures per operative event was 1 (72.5%), 2 (17.5%) and 3 (10%). 92.5% included an indwelling catheter. Block types included lumbar plexus (25), adductor canal (8), femoral (8), sciatic (15), quadratus lumborum (1), popliteal (1), interscalene (5), supraclavicular (9). Intraoperative average fentanyl (mcg/kg) and morphine (mg/kg) were 3.76 (0–10.2) and 0.028 (0–0.32). PACU average Morphine (mg/kg) was 0.016 (0–0.10). PACU average pain score was 0.71 (Scale 0–5) (0–3.6). Morphine, Dilaudid and Oxycodone use in the first 24 hours was 0.034, 0.0017, and 0.168 respectively. Average pain score in the PACU and at 24 hours were 0.7 (SD = 1.2, 0–5) and 1.7 (SD = 1.6, 0–5) respectively. No adverse events related to the regional blocks were noted.

What are your conclusions?
The use of regional nerve blocks with indwelling catheters was safe and effective in this series of OI patients undergoing extremity procedures as demonstrated by low pain scores and minimal perioperative use of opioids. Future work is underway to compare pain medication requirements to a control group of patients.

The Effect of Ketorolac on Pediatric Bone Healing Rate Following Osteotomy in Patients with Deformity or Limb Length Discrepancy

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Anirejuoritse Bafor, Danielle Hatfield

What was the question?
The use of non–steroidal anti–inflammatory drugs (NSAIDs) as an alternative to opioids for analgesia following osteotomies for deformity correction and limb lengthening surgery has become more popular due to the risk of addiction to opioid medication. However, concerns about delayed healing in patients who have undergone osteotomies remain with the use of NSAIDs. This study assesses the effect of ketorolac on the rate of bone healing following osteoplasty in patients who have had either deformity correction or limb lengthening surgery.

How did you answer the question?
This was an IRB–approved, retrospective chart review. Charts of patients who had an osteotomy for deformity correction or limb lengthening were reviewed. The total amount of opioids used, calculated as the morphine milligram equivalent (MME), as well as the total amount of ketorolac used in the perioperative period, was determined for each patient. Comparisons were carried out between the MME requirements, the total amount of ketorolac used, and the time to healing for each group. We also carried out a subgroup comparison based on the use of a peripheral nerve catheter.

What are the results?
The charts of 123 patients (136 limbs) were evaluated in this study. This was made up of a total of 82 limbs in 70 patients who had deformity correction surgery (average age 16) and 54 limbs in 53 patients who had limb lengthening surgery (average age 14). We found no correlation between the total dose of ketorolac used and the duration of healing ($p = 0.220$ and $p = 0.860$ for the deformity correction group and the limb lengthening group, respectively). Deformity correction surgery was associated with statistically higher use of opioids but not ketorolac compared to limb lengthening surgery, even with the use of a peripheral nerve catheter. The use of peripheral nerve catheters in both groups of patients was associated with lower opioid use but higher ketorolac use. (See attached chart)

What are your conclusions?
The use of ketorolac was not significantly related to an increased time to healing in patients who had osteoplasty for deformity correction or limb lengthening.

	Deformity correction surgery	Limb lengthening surgery	p value
Total MME	134.4 ± 172.6	68.61 ± 51.82	0. 0012**
- No PNC	290.5 ± 269.2	98.57 ± 66.06	0.0066**
- PNC	102.3 ± 125.8	57.09 ± 40.59	0.0009***
Total Toradol (mg)	80.81 ± 78.12	79.67 ± 45.2	0.6514
- No PNC	62.57 ± 57.74	70.4 ± 56.85	0.7035
- PNC	84.56 ± 81.52	83.23 ± 40.15	0.6506