LLRS
Limb Lengthening and
Reconstruction Society
ASAMI NORTH AMERICA

31st Annual Scientific Meeting

Limb Lengthening and Reconstruction Society:
ASAMI–North America

July 15 & 16, 2022
Hilton Portland Downtown
Portland, OR

www.llrs.org

LLRS
Limb Lengthening and Reconstruction Society
ASAMI NORTH AMERICA

LLRS: ASAMI–North America

Future Meetings

Essentials of Lower Extremity Reconstruction (ELER)
January 27 & 28, 2023
Dallas, TX

AAOS Specialty Day
Tuesday, March 7, 2023
Las Vegas, NV

32nd Annual Scientific Meeting
July 14 & 15, 2023
Lake Tahoe, CA

Upcoming AAOS Meeting

2023 Annual Meeting
March 6–11, 2023
Las Vegas, NV

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

Limb Lengthening and Reconstruction Society

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

First Vice President and Program Chair

L. Reid Boyce Nichols, MD, FAOA, FAAOS
Assistant Professor of Orthopaedic Surgery, Thomas Jefferson University
Nemours Children's Health, Delaware
reid.nichols@nemours.org

Program Committee

Raymond W. Liu, MD

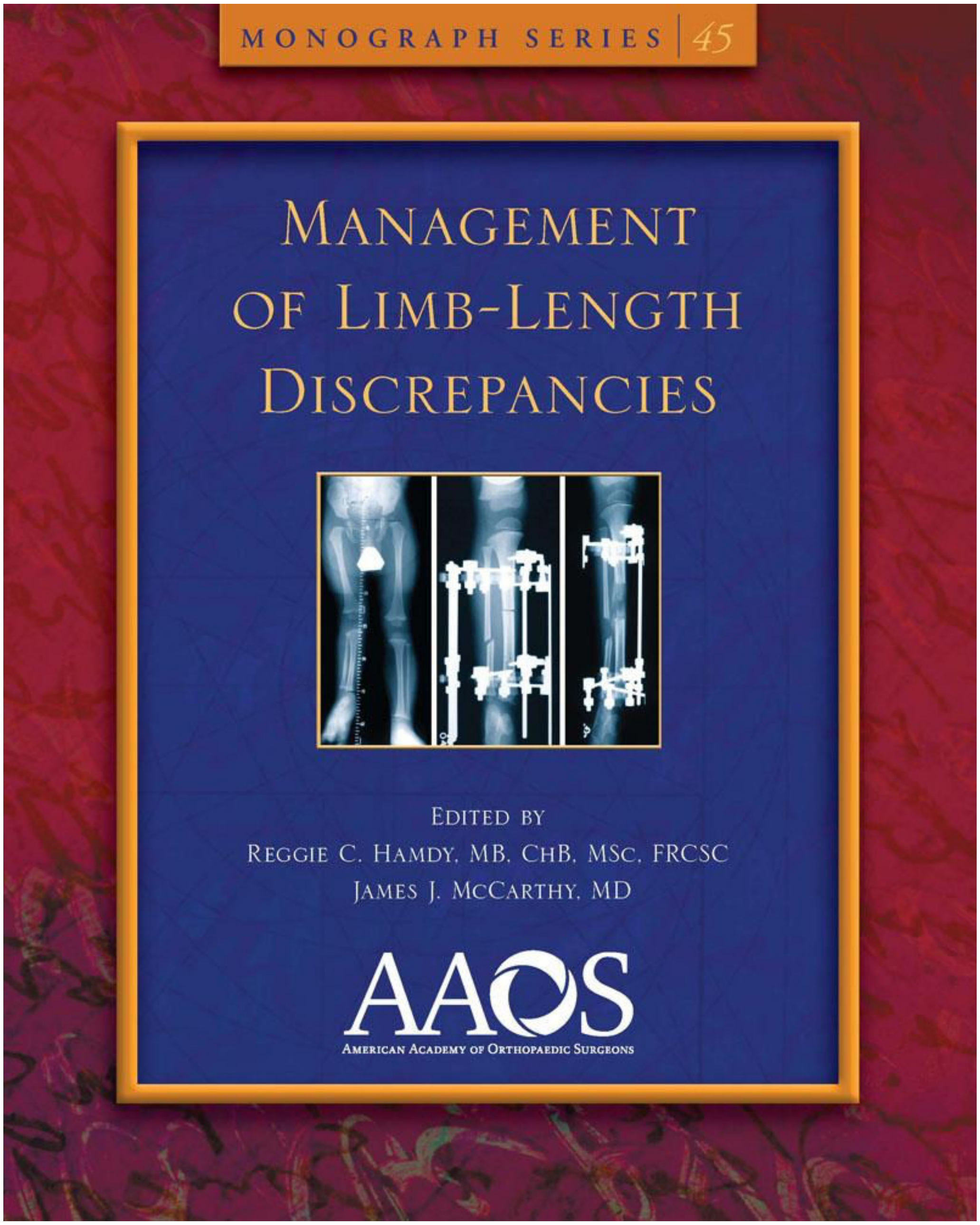
L. Reid Nichols, MD

Stephen M. Quinnan, MD

Karen R. Syzdek, Executive Director

Management of Limb–Length Discrepancies

Reggie Hamdy and Jim McCarthy (Eds.)



To review and order online visit

https://www.amazon.com/Management-Limb-Length-Discrepancies-Monograph-Reggie/dp/0892037466

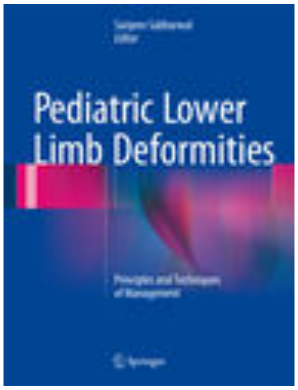
Pediatric Lower Limb Deformities

and

Limb Lengthening and Reconstruction Surgery Case Atlas Series

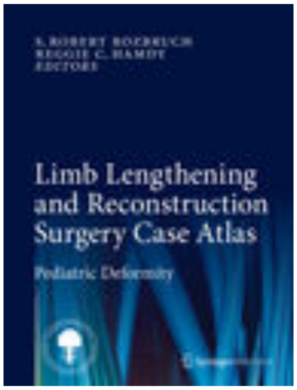
Pediatric Lower Limb Deformities

Sanjeev Sabharwal (Ed.)



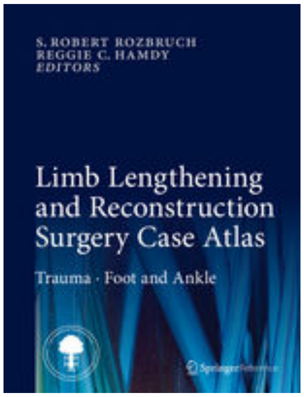
Pediatric Deformity

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



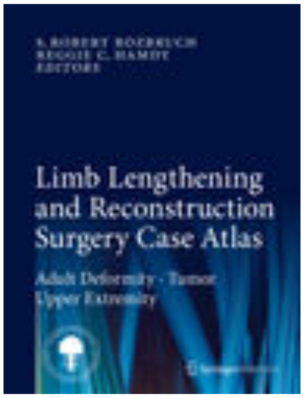
Trauma • Foot and Ankle

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
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Reconstruction Society
ASAMI NORTH AMERICA

32nd Annual Scientific Meeting
July 14 & 15, 2023
Resort at Squaw Creek
Lake Tahoe, CA

Visit www.llrs.org for more information.

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

2021–2022 Officers and Executive Board

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Raymond W. Liu, MD

First Vice President and Program Chair
L. Reid Nichols, MD

Second Vice President
Stephen M. Quinnan, MD

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Mitchell Bernstein, MD

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Research Chair
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Austin T. Fragomen, MD

Board of Specialty Societies (BOS) Representative
Mani Kahn, MD

Traveling Fellowship Chair, Mentorship Program Chair
Jaclyn F. Hill, MD

Limb Lengthening and Reconstruction Society

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

31st Annual Scientific Meeting

Objectives

Upon completion of LLRS's 31st 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 31st 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

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Thank you for the generous grant

Orthofix Inc.
Thank you for the generous grant

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Thank you for the generous grant

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Exhibitors

Biocomposites Inc.
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Thank you for the In–kind Donation

Baltimore Limb Deformity Course
ILLRS 2022 Cancun

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
Rubin Institute for
Advanced Orthopedics

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

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

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

The 5th Combined Congress of ASAMI–BR and the ILLRS Societies will be held in Cancun, Mexico, October 12–15, 2022. Please contact asamimexico@gmail.com for more information. Click here for the Congress website.

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.

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

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/

Orthofix Medical Inc. is a global medical device company with a spine and orthopedics focus. The Company's mission is to deliver innovative, quality–driven solutions as we partner with health care professionals to improve patient mobility. With a comprehensive portfolio of limb reconstruction products, Orthofix Orthopedics solves the most challenging orthopedic conditions of adult and pediatric patients worldwide. Focused on delivering solutions at the forefront of limb reconstruction, including post–traumatic, deformity correction, and limb lengthening, the company's approach combines innovative products, digital services and industry–leading medical education programs to fully address the needs of today's patients, surgeons and care team. www.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 36 surgical systems that serve three of the largest categories within the pediatric orthopedic market. This offering span 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 45 countries outside the United States. For more information, please visit www.orthopediatrics.com

OSSIO® strives to become THE gold standard in orthopedic fixation by encouraging natural bone healing that will ultimately eliminate hardware removal procedures, minimize implant–related complications, alleviate pain, and dramatically improve the healthcare economics of orthopedics. https://ossio.io/

Based in Durham, North Carolina, restor3d is a leading medical device company focused on enabling surgeons to improve the reconstruction and repair of the human body through 3D printed implants with enhanced anatomical fit and superior integrative properties. restor3d seeks to improve medical device solutions by leveraging expertise in 3D printing of advanced biomedical materials, anatomic and kinematic modeling, and AI based planning and design tools. https://www.restor3d.com/

For the surgeons treating complex deformities and acute fractures, Smith+Nephew delivers the industry’s most comprehensive portfolio of external fixation solutions. The TAYLOR SPATIAL FRAME is the most advanced and versatile circular fixation system on the market, allowing for uncompromised stability with infinite adjustability to achieve precise anatomic alignment. https://smith–nephew.com/, https://www.spatialframe.com/

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. https://trimedortho.com/

Limb Lengthening and Reconstruction Society

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

Meeting Evaluation

The meeting evaluation is online. Please go to the following link and complete the evaluation by **Friday, August 5, 2022**. *Your responses are needed for CME credit to be valid.*

https://www.surveymonkey.com/r/LLRSAM2022

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 8 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!

32nd Annual Scientific Meeting

July 14 & 15, 2023

Resort at Squaw Creek

Lake Tahoe, CA

Please complete the evaluation online at

https://www.surveymonkey.com/r/LLRSAM2022

on or before **August 5, 2022.**

Limb Lengthening and Reconstruction Society

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

Disclosures

Program Committee

Raymond W Liu, MD, FAAOS (Cleveland, OH)
Submitted on: 03/15/2022
AAOS: Board or committee member
Journal of Pediatric Orthopedics: Editorial or governing board; Publishing royalties, financial or material support
Limb Lengthening and Reconstruction Society (LLRS): Board or committee member
Orthopediatrics – Royalties paid to my university: IP royalties
Pediatric Orthopaedic Society of North America: Board or committee member

Reid Boyce Nichols, MD, FAAOS (Wilmington, DE)
Submitted on: 04/20/2022
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
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: 02/03/2022
Biocomposites: Paid consultant
Bone Support: Paid consultant
DePuy, A Johnson & Johnson Company: Paid consultant
Globus Medical: IP royalties; Paid consultant
Limb Lengthening and Reconstruction Society: Board or committee member
Microbion: Paid consultant
Nuvasive: Paid consultant
Smith & Nephew: Paid consultant
Stryker: Paid consultant

Karen R Syzdek, Staff (Austin, TX)
(This individual reported nothing to disclose); Submitted on: 01/17/2022

Faculty

Jeffrey D Ackman, MD, FAAOS (Chicago, IL)
(This individual reported nothing to disclose); Submitted on: 06/13/2022

Komi Eddie Afetse, BA, BS
(This individual reported nothing to disclose); Submitted on: 02/08/2022

Animesh Agarwal, MD, FAAOS (San Antonio, TX)
Submitted on: 04/22/2022
3M: Paid consultant; Paid presenter or speaker
AAOS: Board or committee member
AO North America: Paid presenter or speaker
Bone Solutions: Paid consultant; Paid presenter or speaker
Bone Support: Paid consultant; Paid presenter or speaker; Research support
Clinical Orthopaedic Society: Board or committee member
EO2 Concepts: Paid consultant; Paid presenter or speaker
Journal of Orthopaedic Trauma: Editorial or governing board
Orthopaedic Research Society: Board or committee member
Orthopaedic Trauma Association: Board or committee member
Smith & Nephew: Paid consultant; Paid presenter or speaker
Springer: Publishing royalties, financial or material support

Julie Agel, ATC (Seattle, WA)
Submitted on: 04/11/2022
American Orthopaedic Society for Sports Medicine: Board or committee member
Orthopaedic Trauma Association: Board or committee member

SHAKIB Al–Jawazneh
(This individual reported nothing to disclose); Submitted on: 06/14/2022

Munjed Al Muderis, FRACS, FRCS (Ortho), MBChB (Australia)
Submitted on: 03/14/2022
Aesculap/B.Braun: Unpaid consultant
Journal of Military and Veterans' Health: Editorial or governing board
Medacta International SA: IP royalties
Mobius Medical: Paid consultant
NeuRA Neuroscience Research Australia: Board or committee member
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

Shafaf Hasin Alam Jr, MD
(This individual reported nothing to disclose); Submitted on: 04/17/2022

Fikret Berkan Anarat, MD (Turkey)
(This individual reported nothing to disclose); Submitted on: 06/16/2022

Yohei Asano, MD (Japan)
(This individual reported nothing to disclose); Submitted on: 05/10/2022

Benjamin Averkamp, MD (Charlotte, NC)
(This individual reported nothing to disclose); Submitted on: 02/02/2022

Dr. Anirejuoritse Bafor
Submitted on: 06/13/2022
Bayer: Research support
Morison industries: Research support
WishBone Medical, Inc.: Paid consultant

Ali Bas, MD (Turkey)
(This individual reported nothing to disclose); Submitted on: 07/01/2022

Douglas N Beaman, MD, FAAOS
Submitted on: 03/12/2022
Limb Lengthening and Reconstruction Society: Board or committee member

Mitchell Bernstein, MD, FAAOS (Canada)
Submitted on: 02/02/2022
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant
Orthofix, Inc.: Paid consultant
Smith & Nephew: Paid consultant

Christian Blough, MD, BS
(This individual reported nothing to disclose); Submitted on: 04/07/2022

Christina Bourantas, BA
(This individual reported nothing to disclose); Submitted on: 04/04/2022

Joshua Rory Buksbaum, BA, BS
(This individual reported nothing to disclose); Submitted on: 04/02/2022

Stephanie Butler, DPT (Wilmington, DE)
(This individual reported nothing to disclose); Submitted on: 03/28/2022

Anuj Sharad Chavan
(This individual reported nothing to disclose); Submitted on: 04/17/2022

Andrew Chen, MD, MPH (Chapel Hill, NC)
(This individual reported nothing to disclose); Submitted on: 01/29/2022

Daniel B Chen
(This individual reported nothing to disclose); Submitted on: 06/03/2022

Harpreet Chhina, PhD (Canada)
(This individual reported nothing to disclose); Submitted on: 04/11/2022

Chris Church, PT (Wilmington, DE)
(This individual reported nothing to disclose); Submitted on: 03/28/2022

Anthony Cooper, FRCS (Ortho) (Canada)
Submitted on: 03/24/2022
Canadian Orthopaedic Association: Board or committee member
Canadian Paediatric Orthopaedic Group (CPOG): Board or committee member
Canadian Paediatric Orthopaedic Trauma Course: Board or committee member
Cerapedics: Paid consultant
European Paediatric Orthopaedic Society (EPOS): Board or committee member
IPSEN: Paid consultant
Orthopediatrics: Paid consultant; Research support
Pediatric Orthopaedic Society of North America: Board or committee member
Vilex, Inc.: Paid consultant

Daniel Roy Cooperman, MD, FAAOS (New Haven, CT)
(This individual reported nothing to disclose); Submitted on: 06/14/2022

Michael Do (CLEVELAND, OH)
(This individual reported nothing to disclose); Submitted on: 06/12/2022

Maureen Donohoe, DPT, PT (Wilmington, DE)
(This individual reported nothing to disclose); Submitted on: 03/29/2022

Emilie–Ann Downey, MD (Canada)
(This individual reported nothing to disclose); Submitted on: 03/15/2022

David Dueber, PhD
(This individual reported nothing to disclose); Submitted on: 06/13/2022

David S Feldman, MD, FAAOS (West Palm Beach, FL)
Submitted on: 04/14/2022
orthopediatrics: IP royalties; Paid consultant

Austin Thomas Fragomen, MD, FAAOS (New York, NY)
Submitted on: 04/07/2022
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

David Fralinger, MD (Chicago, IL)
(This individual reported nothing to disclose); Submitted on: 01/19/2022

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Submitted on: 06/13/2022
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

Jeanne M Franzone, MD, FAAOS
Submitted on: 06/13/2022
American Orthopaedic Association: Board or committee member
Limb Lengthening and Reconstruction Society: Board or committee member
Orthopediatrics: Paid consultant
Pediatric Orthopaedic Society of North America: Board or committee member

Ryan Furdock, MD (Cleveland, OH)
(This individual reported nothing to disclose); Submitted on: 01/15/2022

Marianne Gagnon, MSc (Canada)
(This individual reported nothing to disclose); Submitted on: 03/30/2022

Adam Daniel Geffner, BA
(This individual reported nothing to disclose); Submitted on: 04/01/2022

Erik John Geiger, MD (New York, NY)
(This individual reported nothing to disclose); Submitted on: 06/13/2022

Michael Freeman Githens, MD, FAAOS (Seattle, WA)
Submitted on: 06/13/2022
DePuy, A Johnson & Johnson Company: Paid consultant
Osteocentric Technologies: IP royalties; Paid consultant
Synthes: Paid presenter or speaker
Techniques in Orthopaedics: Editorial or governing board
Western Orthopaedic Association: Board or committee member
Wolters Kluwer Health – Lippincott Williams & Wilkins: Publishing royalties, financial or material support

Vaida Glatt, PhD (San Antonio, TX)
Submitted on: 06/12/2022
Orthopaedic Research Society: Board or committee member

Rosalind Groenewoud (Canada)
(This individual reported nothing to disclose); Submitted on: 06/13/2022

Amanullah Haidary
(This individual reported nothing to disclose); Submitted on: 04/17/2022

Amber A Hamilton, BA (New York, NY)
(This individual reported nothing to disclose); Submitted on: 04/17/2022

Ahmed Ismail Hammouda, MD
(This individual reported nothing to disclose); Submitted on: 06/13/2022

Noah James Harrison, MSc
(This individual reported nothing to disclose); Submitted on: 05/09/2022

Katsuhiro Hayashi, MD (Japan)
(This individual reported nothing to disclose); Submitted on: 05/23/2022

John D. Henley, PhD
Submitted on 5/14/2022
Board member/committee appointments for a society: Commission for Motion Laboratory Accreditation

Roberto C Hernandez–Irizarry, MD (Guaynabo, PR)
(This individual reported nothing to disclose); Submitted on: 02/08/2022

Dedi Ho, BS
(This individual reported nothing to disclose); Submitted on: 04/07/2022

Jason Shih Hoellwarth, MD
(This individual reported nothing to disclose); Submitted on: 03/14/2022

Joseph R Hsu, MD, FAAOS
Submitted on: 01/31/2022
Orthopaedic Trauma Association: Board or committee member
Smith & Nephew: IP royalties; Paid consultant
Stryker: IP royalties; Paid consultant; Paid presenter or speaker

Aaron Huser, DO
Submitted on: 04/17/2022
Biomarin: Paid presenter or speaker

Alexander Hysong, MD (Charlotte, NC)
(This individual reported nothing to disclose); Submitted on: 02/02/2022

Kentaro Igarashi, MD, PhD (Japan)
(This individual reported nothing to disclose); Submitted on: 05/29/2022

Christopher August Iobst, MD, FAAOS (Columbus, OH)
Submitted on: 03/30/2022
Nuvasive: Paid consultant
Smith & Nephew: Paid consultant
Wishbone, Medical: Paid consultant

Kayla M Jaime
(This individual reported nothing to disclose); Submitted on: 03/15/2022

Chan–Hee Jo, PhD (Dallas, TX)
(This individual reported nothing to disclose); Submitted on: 06/01/2022

Yassine Kanaan, MD (Dallas, TX)
(This individual reported nothing to disclose); Submitted on: 04/13/2022

Nathan Khabyeh–Hasbani
(This individual reported nothing to disclose); Submitted on: 06/12/2022

Dylan Kluck, MD
(This individual reported nothing to disclose); Submitted on: 04/15/2022

Tara Korbal
(This individual reported nothing to disclose); Submitted on: 06/13/2022

Nathaniel T. Koutlas, MD (Chapel Hill, NC)
(This individual reported nothing to disclose); Submitted on: 01/28/2022

Denver Burton Kraft, MD (Washington, DC)
(This individual reported nothing to disclose); Submitted on: 06/12/2022

Richard W Kruse, DO, FAAOS (Wilmington, DE)
Submitted on: 06/14/2022
AAOS: Board or committee member
Clinical education Medical Advisory Board: Board or committee member
Orthopaediatrics: Paid consultant
Osteogenesis Imperfecta fFoundation: Board or committee member
Pediatric Orthopaedic Society of North America: Board or committee member

Steven Kurapaty, MD (Chicago, IL)
(This individual reported nothing to disclose); Submitted on: 05/22/2022

Anderson Lee, BS (Yorba Linda, CA)
(This individual reported nothing to disclose); Submitted on: 06/04/2022

Joel A Lerman, MD, FAAOS (Sacramento, CA)
(This individual reported nothing to disclose); Submitted on: 06/13/2022

Ashley Levack, MD
Submitted on: 02/01/2022
Orthopaedic Trauma Association: Board or committee member

Raymond W Liu, MD, FAAOS (Cleveland, OH)
Submitted on: 03/15/2022
AAOS: Board or committee member
Journal of Pediatric Orthopedics: Editorial or governing board; Publishing royalties, financial or material support
Limb Lengthening and Reconstruction Society (LLRS): Board or committee member
Orthopediatrics – Royalties paid to my university: IP royalties
Pediatric Orthopaedic Society of North America: Board or committee member

Conor Flynn McCarthy, MD
(This individual reported nothing to disclose); Submitted on: 05/24/2022

Philip Kraus McClure, MD, FAAOS
Submitted on: 06/13/2022
Biocomposites: Other financial or material support
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Limb Lengthening and Reconstruction Society

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

Agenda

Friday, July 15, 2022

7:00 a.m.	Registration Opens
7:15–8:00 a.m.	Continental Breakfast – Ballroom 1 **Visit Corporate Partners**
8:00–8:04 a.m.	Welcome/Introduction/Disclosure* – Ballroom 2
8:05–8:32 a.m.	**Session I: Nonunion** Moderator: Jessica C. Rivera, MD, PhD
8:05–8:11 a.m.	Staged Treatment is Superior to Single Stage Treatment for Infected Humeral Nonunions – *Rachel B. Seymour, PhD*
8:12–8:18 a.m.	Malnutrition is Predictive of Complications after Non–Union Fracture Repair of the Lower Extremity – *Anna Meyer*
8:19–8:25 a.m.	Femoral Nonunion Exchange Nailing: Are we Getting Better Results Now? *Meghan Wally, PhD*
8:26–8:32 a.m.	Discussion
8:33–9:08 a.m.	**Session II: Basic Science** Moderator: Christopher A. Iobst, MD
8:33–8:39 a.m.	An Anatomic Study of the Proximal Tibial Epiphysis with Relevance to Percutaneous Epiphysiodesis using Transphyseal Screws (PETS) *Raymond W. Liu, MD*
8:40–8:46 a.m.	Triphasic Model for Human Growth – *Dror Paley, MD*
8:47–8:53 a.m.	The Systematic Isolation of Key Parameters for Estimating Skeletal Maturity on Lateral Elbow Radiographs – *Margaret A. Sinkler, MD*
8:54–9:00 a.m.	Biomimetic Hematoma: Novel Carrier Delivers Extremely Low Dose rhBMP–2 for Highly Effective Healing of Large Bone Defects in Goats *Vaida Glatt, PhD*
9:01–9:08 a.m.	Discussion

9:09–9:54 a.m.	**Session III: Osteotomy** Moderator: Raymond W. Liu, MD
9:09–9:15 a.m.	A Novel Osteotomy for Medial Osteoarthritis of the Knee Joint – Distal Tibial Tuberosity Focal Dome Osteotomy combined with Intra–Articular Condylar Osteotomy (Focal Dome Condylar Osteotomy): Technique and Preliminary Result – *Kentaro Igarashi*
9:16–9:22 a.m.	Derotational Osteotomy of the Femur and/or Tibia for Youth with Anterior Knee Pain – *Marianne Gagnon, MSc*
9:23–9:29 a.m.	Distal Femoral Osteotomy for the Correction of Valgus Deformity Using the Modified Reverse Planning Method *Christopher A. Iobst, MD*
9:30–9:36 a.m.	Tibial Osteotomy Surgery Safety Profile – *S. Robert Rozbruch, MD*
9:37–9:43 a.m.	Bilateral Distal Femoral Osteotomy in Patients with Valgus Deformity Results in Improved Outcome Scores – *S. Robert Rozbruch, MD*
9:44–9:54 a.m.	Discussion
9:55–10:15 a.m.	Refreshment Break – Ballroom 1 **Visit Corporate Partner**
10:16–11:01 a.m.	**Session IV: Practice Management** Moderator: Harold J.P. van Bosse, MD
10:16–10:22 a.m.	Early Experience with Robotic Autostrut–Controlled Hexapod External Fixators – *Jason Shih Hoellwarth, MD*
10:23–10:29 a.m.	Fully Automated Analysis of the Anatomical and Mechanical Axes from Pediatric Standing Lower Limb Radiographs using Convolutional Neural Networks – *Yousif Murad*
10:30–10:36 a.m.	Outpatient Orthopaedic Trauma and Limb Deformity Surgery: Is it Safe? *Rachel B. Seymour, PhD*
10:37–10:43 a.m.	Inter and Intra–Rater Reliability of the Checketts Grading System for Pin Site Infections across All Skin Colours – *Rosalind Groenewoud*
10:44–10:50 a.m.	Current Procedural Terminology (CPT) Coding in Pediatric Limb Reconstruction Surgery – *Christopher A. Iobst, MD*
10:51–11:01 a.m.	Discussion

11:02–11:47 p.m.	**Session V: Internal Lengthening Nails** Moderator: David Frumberg, MD
11:02–11:08 a.m.	Radiographic Changes without Symptoms Predominate Following Limb Lengthening with a Weight Bearing Lengthening Nail *Taylor J. Reif, MD*
11:09–11:15 a.m.	Treatment of Angular Deformity and Limb Length Discrepancy with a Retrograde Femur Magnetic Intramedullary Nail: Fixator–Assisted, Blocking Screw Technique – *Erik J. Geiger, MD*
11:16–11:22 a.m.	Performance and Complications of a Titanium Internal Lengthening Nail: A Retrospective Review of 286 Bone Lengthening Events *Taylor J. Reif, MD*
11:23–11:30 a.m.	Use of the Antegrade Femoral Nail in Pediatric Patients *Adam D. Geffner*
11:31–11:36 a.m.	Early Weight–Bearing Accelerates Regenerate Bone Mineralization: A Pilot Study Comparing Two Postoperative Weight–Bearing Protocols following Intramedullary Limb Lengthening using the Pixel Value Ratio – *Christopher A. Iobst, MD*
11:37–11:47 a.m.	Discussion
11:48 a.m.–12:40 p.m.	Lunch – Ballroom 1 **Visit Corporate Partners**
12:41–1:15 p.m.	**Session VI: Pediatrics** Moderator: L. Reid Nichols, MD
12:41–12:46 p.m.	The Effectiveness of Serial Casting in the Treatment of Recurrent Equinovarus in Children with Arthrogryposis – *L. Reid Nichols, MD*
12:47–12:53 p.m.	The Fate of Bent Telescopic Rods in Children with Osteogenesis Imperfecta: Do All Bent Rods Need to be Revised? *Jeanne Franzone, MD*
12:54–1:00 p.m.	How Does Femoral Varus Deformity Respond to Guided Growth in Blount Disease? – *Janet L. Walker, MD*
1:01–1:06 p.m.	Achondroplasia: The Ruse of Rhizomelia – *Aaron J. Huser, DO*
1:07–1:15 p.m.	Discussion
1:16–2:00 p.m.	<u>Presidential Guest Lecture</u>* **Change** *John Gerard Birch, MD*

2:01–2:20 p.m.	Refreshment Break – Ballroom 1 **Visit Corporate Partners**
2:21–2:55 p.m.	**Session VII: Osteointegration** Moderator: Stephen M. Quinnan, MD
2:21–2:26 p.m.	Removal of Press–Fit Transtibial Osseointegration Implants: A Discussion of Risk Factors and Outcomes – *Jason Shih Hoellwarth, MD*
2:27–2:33 p.m.	Transcutaneous Osseointegration for Amputees with Short Residual Bone: Is there Increased Risk for Complications? *Jason Shih Hoellwarth, MD*
2:34–2:40 p.m.	Transfemoral Osseointegration for Amputees with Diabetes Mellitus *Amanullah Haidary*
2:41–2:46 p.m.	Developing an Infection Criteria for Osseointegration *Amanullah Haidary*
2:47–2:55 p.m.	Discussion
2:56–3:05 p.m.	**Traveling Fellowship Presentation*** Introduction by Jaclyn F. Hill, MD *Ahmed Hammouda, MD* *Dr. Carlito C. Valera, Jr.*
3:06–3:45 p.m.	Business Meeting – **LLRS Members only**
4:15 p.m.	Buses depart for President's Reception Board bus at the corner of SW 6th Avenue and SW Salmon Street Across 6th Avenue from hotel
5:00 p.m.	**President's Reception**
9:00 p.m.	Buses depart to return to hotel

Saturday, July 16, 2022

7:15 a.m.	Registration Opens
7:15–8:00 a.m.	Continental Breakfast – Ballroom 1 **Visit Corporate Partners**
8:00–8:05 a.m.	Announcements* – Ballroom 2
8:06–8:42 a.m.	**Session VIII: Pediatric Growth** Moderator: Jaclyn F. Hill, MD
8:06–8:12 a.m.	The Modified Fels Knee Skeletal Maturity System in Prediction of Leg–Length Discrepancy – *Dylan Kluck, MD*

8:13–8:19 a.m.	Comparison of “Human” and Artificial Intelligence Hand–and–Wrist Skeletal Age Estimation in an Epiphysiodesis Cohort *Marina R. Makarov, MD*
8:20–8:26 a.m.	Does the Technique of Lengthening Effect Physeal Growth in Patients with Achondroplasia? A Comparison of the Simultaneous and Consecutive Surgery – *Dr. Ali Bas*
8:27–8:33 a.m.	Can Zometa Lines be Used to Study Growth in Patients with Congenital Pseudarthrosis of the Tibia? – *Katherine Miller, MD*
8:34–8:42 a.m.	Discussion
8:43–9:05 a.m.	The History of ASAMI–North America and ASAMI International* *Dror Paley, MD*
9:06–9:19 a.m.	Discussion
9:20–9:30 a.m.	Memorial of James C. Binski, MD* – *John D. Wyrick, MD*
9:30–10:00 a.m.	Refreshment Break – Ballroom 1 **Visit Corporate Partners**
10:01–10:20 a.m.	Poster Session* – please visit each poster
10:21–10:57 a.m.	**Session IX: Trauma and Foot/Ankle** Moderator: J. Spence Reid, MD
10:21–10:27 a.m.	Validation of a Novel Bone Defect Classification *Geoffrey Marecek, MD*
10:28–10:34 a.m.	Fibular Displacement Predicts Tibial Malrotation in Simulated Tibia–Fibula Fractures – *Geoffrey Marecek, MD*
10:35–10:41 a.m.	A Clinical Comparison of Complex Ankle Arthrodesis using 2 Fixation Techniques: Ilizarov External Fixation versus Intramedullary Arthrodesis Nail – *Austin T. Fragomen, MD*
10:42–10:48 a.m.	Increased Posterior Tibial Slope Increases Difficulty for Suprapatellar Nailing – *Anna Meyer*
10:49–10:57 a.m.	Discussion
10:58–11:34 a.m.	**Session X: Miscellaneous** Moderator: Mitchell Bernstein, MD
10:58–11:04 a.m.	Correlation Between Femoral Neck Version, Sagittal Femoral Bowing Angle, and Sagittal Offset of the Femoral Head from the Distal Femur Axis in an Osteological Collection – *Dedi Ho*

11:05–11:11 a.m.	Survey of Adult Function after Blount Disease in Childhood: An Exercise in Futility? – *John Gerard Birch, MD*
11:12–11:18 a.m.	Publications Rates of Abstracts Presented at LLRS Annual Meetings *Tara Korbal, BA*
11:19–11:25 a.m.	Ipsilateral Healthy Segment Response to Leg Length Discrepancy *John Gerard Birch, MD*
11:26–11:34 a.m.	Discussion
11:35 a.m.–12:00 p.m.	President's Remarks and Introduction of 2022–2023 President* *Raymond W. Liu, MD* and *L. Reid Nichols, MD*

*indicates non-CME session

Session I: Nonunion

Moderator: Jessica C. Rivera, MD, PhD

Staged Treatment is Superior to Single Stage Treatment for Infected Humeral Nonunions

Rachel B. Seymour, PhD; Andrew Chen, MD; Patrick Pallitto; Nathaniel Koutlas; Noah Harrison; William Obremskey, MD; Alexander Hysong; Samuel L. Posey; Joseph R. Hsu, MD;

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What was the question?

Humeral nonunions are challenging to treat. Even after successful revision surgery, full functional recovery is limited. The surgical treatment of aseptic humeral nonunions is well documented, but the literature is limited regarding the treatment of infected humeral nonunions. Although thorough debridement, irrigation, and systemic antibiotics remain the cornerstone in the treatment of an infected nonunion, it is unclear what the overall union rate is after surgical treatment.

How did you answer the question?

We performed a retrospective analysis of a database of 2,012 long bone nonunions. Within the database are 271 humeral nonunions gathered from 9 level I trauma centers. We searched these humeral nonunions to identify those that were infected prior to the nonunion procedure. A nonunion was considered septic in the presence of a draining sinus or positive intraoperative cultures. Standard patient demographics, fracture characteristics, fixation techniques, bone grafting, intraoperative culture results, and complications were collected. The primary outcome was overall union rate. Secondary outcomes included post–operative complications.

What are the results?

A total of 33 patients with an infected humeral nonunion after initial surgical fixation that met inclusion criteria were identified with adequate follow–up. The mean follow–up time for a confirmed infected nonunion was 17.3 months. The median age at the time of index injury was 50, and although it trended towards younger (36) in those that ultimately united, this was not statistically significant (p=0.13). Of the initial injuries, 43.5% were open. The initial fixation construct in the majority of patients were plate and screws (81%). 94.1% of patients with a positive culture grew a single organism. The definitive nonunion procedure for infected humerus nonunion was successful only 51% (n=17) of the time. Pre–planned staged treatment was associated with successful union (76.5% vs 37.5%, p=0.024). Postoperative complications were seen in 53.1% of patients and significantly more common in the persistent nonunion group (68.8% vs 25.0%, p=0.013). Tobacco use, diabetes, BMI, and bone grafting did not appear to impact union.

What are your conclusions?

This study supports our hypothesis that infected humeral nonunions are challenging to treat and are at high risk for persistent nonunion (48.5%). These findings suggest that further research into the best treatment strategies for infected humeral nonunions is needed, and staged treatment is a promising strategy.

Malnutrition is Predictive of Complications after Non–Union Fracture Repair of the Lower Extremity

Anna Meyer; Jesse Seilern; Roberto Hernandez–Irizarry, MD

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What was the question?

Is malnutrition, frailty, or both predictive of postoperative complications in lower extremity nonunion repair?

How did you answer the question?

In this population–based analysis, the ACS–NSQIP database was queried from 2015–2020 for patients undergoing aseptic femoral and tibial NFR. Patients were divided into cohorts: malnourished (serum albumin 3.5g/dL), frail (mFI–5 ≥2), malnourished and frail, and healthy (non–malnourished and non–frail). Primary and secondary outcome variables were 30–day complications (incl. cardiovascular and pulmonary complications, surgical site– urinary tract–, and systemic infections) and hospital resource utilization (length of stay (LOS), unplanned readmission and reoperation, adverse hospital discharge), respectively. Chi–squared and multivariable logistic regression analyses were performed to evaluate for associations between malnutrition/frailty, and outcome variables. Odds ratios (OR) were reported with 95% confidence intervals (CIs).

What are the results?

Of 827 patients, 508 (61.4%) were healthy, 133 (16.1%) were malnourished, 133 (16.1%) frail, and 53 (6.4%) were malnourished and frail. Malnourished and frail patients had the highest incidence of postoperative complications (28%), followed by malnourished (27%) and frail patients (24.8%). Malnourished, frail, and malnourished and frail patients had significantly higher resource utilization (LOS, readmission, reoperation, adverse hospital discharge). However, when controlled for age, gender, ASA classification, procedure duration, and location (femur/tibia), only malnourished patients revealed significantly higher odds of developing ≥1 complications (OR:2.3, CI:1.38–3.83), and adverse hospital discharge (OR:3.13, CI:1.81–5.41) compared to healthy patients.

What are your conclusions?

Findings indicate that malnutrition is an independent risk factor for postoperative complications and increased hospital utilization in patients undergoing lower extremity NFR. This data highlights potential utility of nutritional intervention in this unique subset of orthopaedic patients.

Femoral Nonunion Exchange Nailing: Are We Getting Better Results Now?

Megan Wally, PhD; Benjamin Averkamp; Tamar Roomian; Ziqing Yu; Andrew Chen, MD; Roman Natoli; Hassan Mir; Jessica C. Rivera, MD, PHD; Rachel Seymour, PhD; Joseph R. Hsu, MD; Paul Matuszewski, MD

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What was the question?

While ~90% of femur fractures treated with intramedullary nail heal, 5–10% of patients fail initial treatment and progress to nonunion. One approach for treating femoral nonunions is through exchange nailing with reported union rates between 53–100%. These studies are based on small cohorts of patients with older implants, instruments, and techniques. The goal of our study was to evaluate rates of osseous healing and outcomes in femoral nonunions with contemporary exchange nailing.

How did you answer the question?

We retrospectively reviewed patients (age ³ 18) from five academic Level 1 trauma centers who sustained femur fractures (AO/OTA 31, 32, 33) initially treated with intramedullary fixation that developed nonunion and were treated with exchange nailing for the index nonunion surgery. The primary outcome measure was osseous union. We further analyzed union rate by AO/OTA classification, nonunion type, implants used, time from initial procedure, and infection status at time of indexed nonunion procedure. Standard demographic data was also obtained.

What are the results?

From a database of 1,959 long bone nonunions, we identified ninety–nine femurs in ninety–nine patients which met inclusion criteria. 68 of 99 femurs (69%) achieved union following initial exchange nail procedure. Rates of osseous union were similar by AO/OTA classification (p=0.36), nonunion type (hypertrophic, oligotrophic, atrophic) (p=0.58), implant/biologic used (p=0.15), and time from initial procedure until exchange nail procedure (p=0.18). Fifty–nine patients had inflammatory labs (CRP, ESR) and cultures obtained at time of first non–union surgery with no significant differences in union (p=0.57) based on lab and culture results. A considerable number of complications were encountered. 29 patients underwent subsequent re–operation (most secondary to continued nonunion), 20 were readmitted, 20 had persistent nonunion, 11 experienced hardware failure and 4 had a new infection.

What are your conclusions?

This large, multicenter study with modern implants, instruments, and techniques for exchange nailing femoral nonunions demonstrates disappointing rates of osseous healing (31% failure) consistent with the lower end of reported data in previous literature.

Session II: Basic Science

Moderator: Christopher A. Iobst, MD

An Anatomic Study of the Proximal Tibial Epiphysis with Relevance to Percutaneous Epiphysiodesis using Transphyseal Screws (PETS)

Raymond W. Liu, MD; Michael Do; Conor McCarthy; Daniel Cooperman

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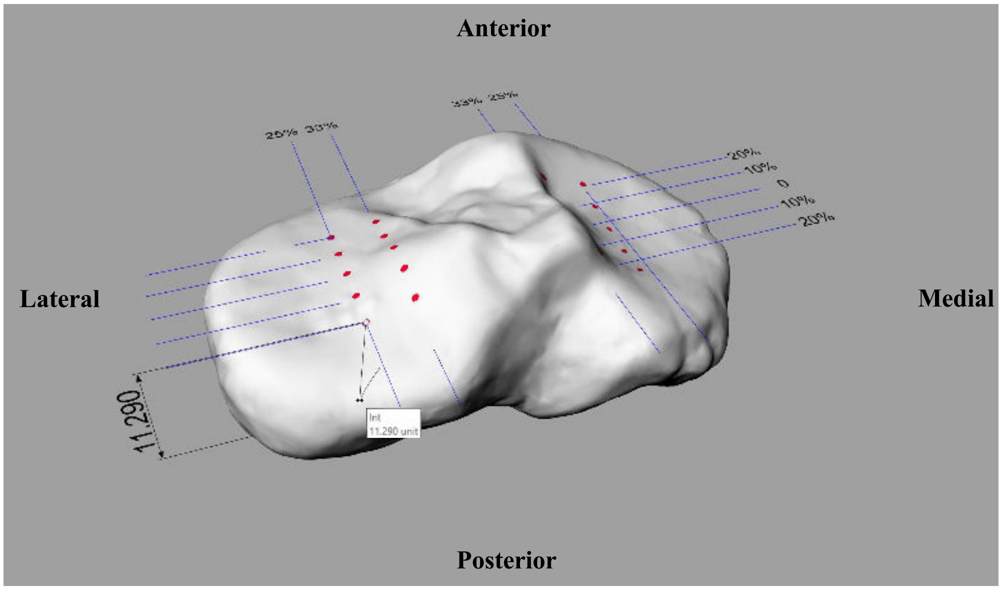
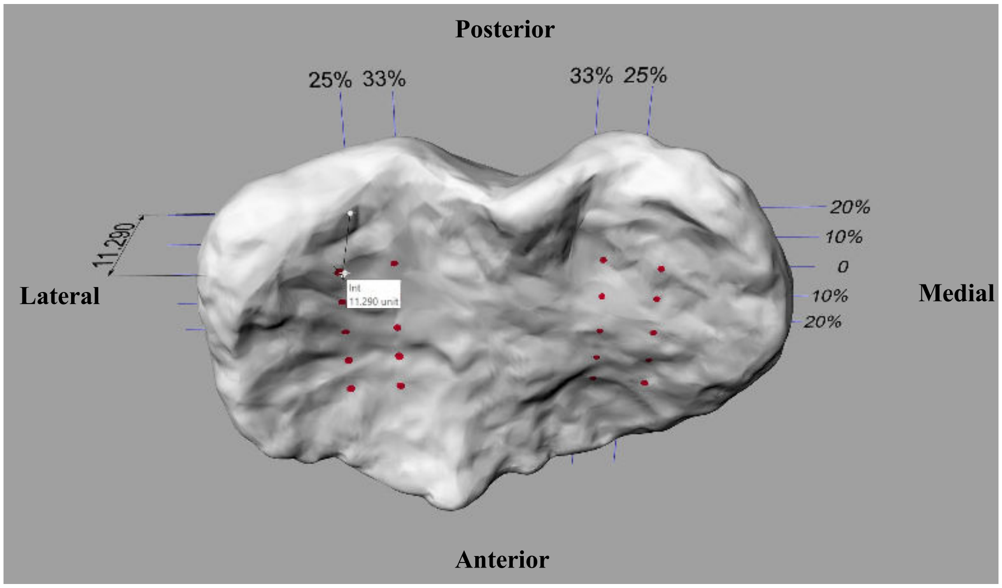
What was the question?
A potential complication of PETS is development of tibial valgus deformity, which may occur secondary to decreased screw purchase in the thinner medial proximal tibial epiphysis. The thickness of the proximal tibial epiphysis has not yet been well quantified.

How did you answer the question?
Three–dimensional surface scans of 32 cadaveric proximal tibial epiphyses in specimens aged 3 to 17 years old were obtained and computer modeling software was utilized to measure the thickness of the proximal tibial epiphysis at 20 standardized potential screw insertion points according to a generated 5x4 map. In the sagittal plane, 5 markers were set at 0 (midline), 10%, and 20% of the total physeal length away from midline in the anterior and posterior directions, and in the coronal plane, 4 markers total were set at 25% and 33% of the total physeal width away from the medial and lateral edges (Figure 1).

What are the results?
When normalized to the total width of the proximal tibial epiphysis, the lateral side is thicker compared to the medial side (Figure 2). The positions with the greatest thickness are located at the midline in the sagittal plane and 33% of the total physeal width away from the medial and lateral edges in the coronal plane (0.265 and 0.261 normalized thickness respectively). The proximal tibial epiphysis is particularly thin 25% from the medial edge (normalized thickness range: 0.196–0.221). Multiple regression analysis revealed a significant relationship between increasing age and female sex with thinner normalized medial and lateral heights.

What are your conclusions?
During PETS, screws should be positioned centrally in the sagittal plane and 33% of the total width away from the medial and lateral edges of the proximal tibial epiphysis in the coronal plane to obtain greater screw purchase. Caution should be taken when inserting screws in the medial 25% of the proximal tibial epiphysis as it is thinner relative to the lateral edge, particularly in females.





Proximal Tibial Epiphysis Thickness Normalized by Total Physeal Width		Posterior					
		25%	33%	50% (midline)	33%	25%	Lateral
Medial	20%	🟥 **0.196**	🟨 **0.241**	-	🟧 **0.230**	🟥 **0.209**	
	10%	🟥 **0.207**	🟩 **0.254**	-	🟩 **0.253**	🟧 **0.223**	
	0 (midline)	🟥 **0.218**	🟩 **0.265**	-	🟩 **0.261**	🟨 **0.231**	
	10%	🟧 **0.221**	🟩 **0.262**	-	🟨 **0.249**	🟧 **0.228**	
	20%	🟥 **0.219**	🟨 **0.250**	-	🟨 **0.233**	🟧 **0.221**	
	Anterior						

🟩 1st Quartile 🟨 2nd Quartile 🟧 3rd Quartile 🟥 4th Quartile

Triphasic Model for Human Growth

Dror Paley, MD; Alexis Pietak

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What was the question?

Can a physics–based mathematical model be derived to accurately describe human growth including both length and velocity of the femur, tibia, and height?

How did you answer the question?

If we consider height or bone length as a function of time (L(t)), then the growth velocity and existing height can be related by some constant value, ψ, such that: (dL(t))/dt=ψL(t). The form of ψ(t) for human growth is unknown. Using the CDC height growth data from ages 0–18 and the Anderson and Green femur and tibia growth data from ages 1–18, we found the simplest and most accurate mathematical description of ψ(t) for human growth includes three phases:

1) Phase A – an exponentially decreasing function prominent in the infant–toddler age group (0 to 4 years)
(2) Phase B – a Gaussian function prominent in the juvenile age group (4 to 10 years)
(3) Phase C – a Gaussian function prominent in the adolescent age group (10 to 18 years)

We found these three components add together to form an excellent description of the growth rate functions indicated by real data, and taken together, constitute the three phases of the TGM. Mathematically we write these three components of the TGM's growth rate function as: ψ(t) = Aexp(–αt) + Bexp(t–t'/β)exp2 +Cexp(t–t"/γ)exp2

Phase A Phase B Phase C

Where A represents the initial value of the exponential component, α describes the rate of decline of the exponential component, B and C describe the amplitude of the first and second Gaussian curves, β and γ are related to the widths of the first and second Gaussian curves, and t' and t" describe the ages of the peak center for the first and second Gaussian curves.

What are the results?

We found the TGM provides an excellent fit to growth curves (length and velocity,RMSE calculated) and gives insight into the dynamics of human growth. Best fits of other published models including Logistic, Gompertz, and Preece–Baines models to growth data show large discrepancies, especially with regards to growth velocity (RMSE calculated). We also quantitated the contribution of each of the three phases of the TGM to total growth. The majority of height (61% to 68% of total growth) is acquired in phase A (infant–toddler growth) of the TGM, with the remaining growth accumulation split between the juvenile and adolescent growth phases. Growth data for a population is partitioned into percentile curves. By normalizing individual growth curves by their value at maturity we generated similar curves for all percentiles within a gender. In addition to the similarity of growth curves when they are scaled by the mature length, multiplying the timescale of a growth curve by a constant factor (λ), generated similar curves for all percentiles within gender and can map all percentiles for both genders to one curve. In other words, dilating (i.e. stretching or contracting) time scales of individual growth curves by (λ) coalesced growth curves of different percentiles and genders into a single growth curve. Values of λ required to map each percentile to the 50th percentile curve for individual genders, and to map the 50th percentile curve of females to the 50th

Triphasic Model for Human Growth *continued*

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What are the results? *continued*

percentile curve of males, show a significant reduction in RMSE between the two curves being mapped after timescale dilation. Within gender groups, for both males and females, the 3rd percentile curve is indicated to have a relative time scale 3% expanded relative to the 50th percentile, while the 97th percentile time scale is approximately 3% contracted compared to the 50th percentile. Females of all percentiles are indicated to develop on a time scale that is 20% contracted compared to males of the respective percentile.

What are your conclusions?

The TGM was found to very accurately describe height growth curves and velocities from pooled population growth data (e.g. CDC height growth curves), individual longitudinal height growth curves (e.g. Berkley Growth Study data), and long bone growth data for femur and tibia lengths (e.g Anderson and Green femur and tibia length data). Importantly, as a physics–based model, the TGM has parameters that can readily be associated with the growth curve features (e.g. adolescent growth peak centre) and to biological phenomena regulating growth (e.g. an exponential decay of growth potential may correspond to decreasing cell proliferation with telomere shortening, whereas a Gaussian growth potential may correspond to a period of enhanced human growth factors(endocrine) production, thereby providing deeper insights into the human growth processes. The TGM may help us predict long bone length and height at skeletal maturity and identify deviations from expected growth in patients who will mature early or late.

Figure:

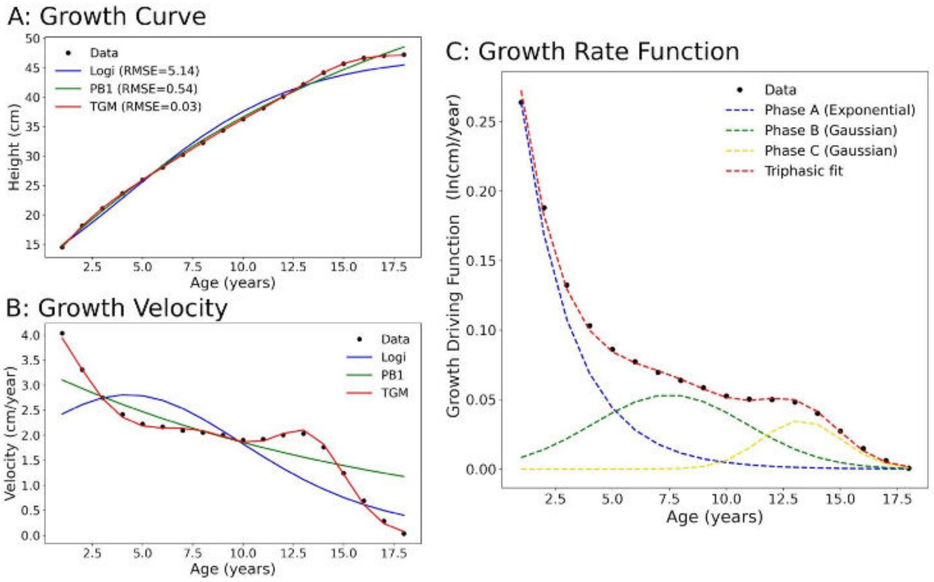

Figure Caption:

Modeling human growth dynamics using the TGM. Fits of the Logistic, Preece-Baines, and TGM models to the mean male femur data (Anderson-Green, 1964) are shown fit to the growth curve in (A) and to the growth velocity in (B). The TGM is based upon a growth rate function that is calculated as the rate of change of the natural logarithm of the growth curve, and is shown for the mean male femur data in (C). The three independent growth regimes, corresponding to the three growth phases of the TGM, are resolved in (C).

The Systematic Isolation of Key Parameters for Estimating Skeletal Maturity on Lateral Elbow Radiographs

Margaret A. Sinkler, MD; Ryan J. Furdock, MD; Daniel Chen; Raymond W. Liu, MD

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What was the question?

Skeletal maturity estimation has a central role in the management of scoliosis and lower limb deformity. While methods of estimating skeletal maturity on an elbow radiograph exist, they have not been optimized by the addition of demographics and use of modern computing. Therefore, we sought to find if we can create a more reliable, rapid, and accurate method for measuring skeletal maturity on an elbow radiograph compared to prior methods.

How did you answer the question?

Four parameters from the modified Sauvegrain method and seven novel parameters were screened for correlation to skeletal maturity and for reliability. Ten of these parameters were evaluated on serial peripubertal elbow radiographs, with Greulich and Pyle (GP) skeletal age from corresponding hand radiographs as a comparison. Stepwise linear regression and generalized estimating equations were used to identify significant radiographic and demographic parameters for estimating skeletal maturity based on 90% of final height. The accuracy of the elbow system was compared to: 1) GP only; 2) olecranon apophysis only; 3) age, sex, and GP; 4) age, sex, and olecranon apophysis; 5) age, sex, and elbow system with AP and lateral parameters, 6) age, sex, and elbow system with only AP parameters, and 7) age, sex, and elbow system with only lateral parameters.

What are the results?

377 radiographs from 77 patients (40 girls and 37 boys) were included. Following stepwise linear regression, four radiographic parameters were included in the elbow AP and lateral system; three were included in the elbow AP system, and four were included in the elbow lateral system. The elbow AP and lateral system and the elbow lateral system predicted skeletal maturity with a mean discrepancy of 0.39 years for each, making more accurate predictions than the other five systems ($p<0.01$ for all). The elbow lateral system had the lowest percent of outlier predictions one year or more discrepant from the skeletal maturity reference (4.9%), although it was only statistically better than the GP only (28.3%) and olecranon apophysis only (20.7%) groups ($P<001$ for both).

What are your conclusions?

We systematically identified four parameters on a lateral elbow radiograph that outperform Greulich and Pyle and the olecranon apophysis systems in skeletal maturity estimation. The addition of parameters from the AP elbow view did not enhance performance, simplifying clinical use. Future clinical validation will be necessary to understand the utility of this system.

	GP Only	Modified Sauvegrain (OA Only)	Age + Sex + GP	Age + Sex + Modified Sauvegrain (OA Only)	Elbow System (AP + Lateral)	Elbow System (AP Only)	Elbow System (Lateral Only)
Mean prediction discrepancy ± SD, *yrs*	0.57 ± 0.53	0.66 ± 0.50	0.43 ± 0.30	0.43 ± 0.36	0.39 ± 0.34	0.42 ± 0.34	0.39 ± 0.33
Mean prediction discrepancy (p-value)	**<.001**	**<.001**	**0.009**	**0.001**	0.782	**0.008**	--
% of Outlier Predictions (>1 year off)	28.3%	20.7%	5.4%	6.3%	5.2%	5.4%	4.9%
Outlier predictions (p-value)	**<.001**	**<0.001**	0.774	0.182	1	0.727	--
R^2	0.797	0.762	0.908	0.892	0.907	0.904	0.907
Bold = P <0.05 GP = Greulich and Pyle; OA = olecranon apophysis. Note that the GP Only and OA Only columns are the only systems currently widely used.							

Biomimetic Hematoma: Novel Carrier Delivers Extremely Low Dose rhBMP–2 for Highly Effective Healing of Large Bone Defects in Goats

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What was the question?

The management of patients with large bone defects remains one of the most challenging clinical problems faced by clinicians today. Many techniques have been employed for the treatment of skeletal defects, however, all of these existing treatment options have high complication rates, significant risk of treatment failure, and often require multiple surgeries. One of the most promising treatments is the use of recombinant human bone morphogenetic protein 2 (rhBMP–2) delivered on an absorbable collagen sponge (ACS). However, it uses extremely high doses of BMPs, and has been associated with severe side effects such as the inability of the collagen sponge to contain the rhBMP–2, allowing it to leach out into surrounding tissues. The fracture hematoma naturally serves as a scaffold that activates a cascade of biological events to initiate bone repair. Studies have shown that the removal of a hematoma delays fracture healing, and that the structural properties of it, such as the porosity and thickness of fibrin fibers, influences bone repair. Our previous rat study demonstrated an ex vivo–created “Biomimetic Hematoma” (BH) that mimics the intrinsic structural properties of normal fracture hematoma, consistently and efficiently enhanced the healing of large bone defects at extremely low doses of rhBMP–2 (0.33 µg). The aim of this study was to test

How did you answer the question?

Goat 2.5 cm tibial defects were stabilized with circular fixators, and divided into groups (n=2–3): 2.1 mg rhBMP 2 delivered on an ACS; 52.5 µg rhBMP–2 delivered within the BH; and empty group. The BH was created using autologous blood with a mixture of calcium and thrombin at specific concentrations. Healing was monitored with X–rays. After 8 weeks, femurs were assessed using microCT. Histology is in progress.

What are the results?

Using 2.1 mg on ACS was sufficient to heal 2.5 cm bone defects. Empty defects resulted in a nonunion after 8 weeks. Radiographic evaluation showed earlier and more robust callus formation with 97.5 % (52.5 µg) less of rhBMP–2 delivered within the BH, and all tibias were fully bridged at 3 weeks. The bone mineral density was significantly higher in defects treated with BH than with ACS. Defects in the BH group had smaller amounts of intramedullary and cortical trabeculation compared to the ACS group, indicating advanced remodeling.

What are your conclusions?

Consistent with our study in rats, the results confirm that the ex vivo BH is able to mimic the function of innate fracture hematoma, which is the natural reservoir for rhBMP–2 and many other growth factors essential for bone healing, while also more efficiently regulating their release into the defect. The delivery of rhBMP–2 within the BH was much more efficient than on an ACS. Not only did the large bone defects heal consistently with a 40x lower dose of rhBMP–2, but the quality of the healing was also superior in the BH group based on the callus size and the bone morphometric parameters at 8 weeks. These findings should significantly influence how rhBMP–2 is delivered clinically to maximize the regenerative capacity of bone healing while minimizing the dose required. This treatment would significantly reduce the risk of adverse effects associated with BMPs, the treatment costs, and the non–union rate.

Session III: Osteotomy

Moderator: Raymond W. Liu, MD

A Novel Osteotomy for Medial Osteoarthritis of the Knee Joint – Distal Tibial Tuberosity Focal Dome Osteotomy combined with Intra–Articular Condylar Osteotomy (Focal Dome Condylar Osteotomy): Technique and Preliminary Result

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What was the question?

Focal Dome Condylar Osteotomy (FDCO) is a novel surgical technique for medial compartment osteoarthritis of the knee joint with varus deformity. We combined distal tibial tuberosity focal dome osteotomy centered on the center of rotation and angulation (CORA) with the longitudinal condylar intra–articular osteotomy. The present study provides surgical technique, early clinical and radiological outcomes of FDCO for osteoarthritis of the knee joint.

How did you answer the question?

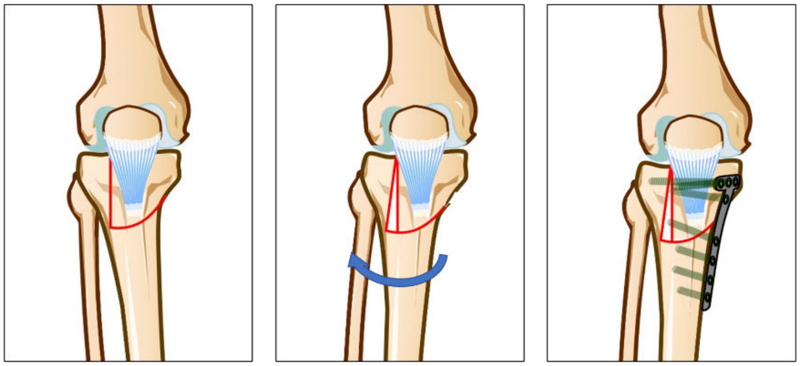
The clinical data of 19 patients (20 knees) with medial compartment osteoarthritis who were treated with FDCO between November 2018 and April 2021 was retrospectively analyzed. There were 3 males (3 knees) and 16 females (17 knees) with a mean age of 64.9 ± 10.0 years at the time of surgery. Mean body mass index was 26.2 ± 3.4 kg/m2. We compared the pre and postoperative radiographic and clinical variables including % mechanical axis deviation (%MA), femorotibial angles (FTA), hip–knee–ankle (HKA) angles, medial proximal tibial angles (MPTA), modified Insall–Salvati Index (mISI), modified Caton–Deschamps Index (mCDI), and modified Blackburne–Peel Index (mBPI), and mechanical axis–lateral tibia plafond angle (MA–LTP) on radiographs, knee range of motion (ROM), Osteoarthritis Outcome Score (KOOS) and the time to union. Mean follow–up of the patients was 15.1 months.

What are the results?

The %MA, FTA, HKA, and MPTA significantly changed from 16.0 ± 11.5% to 62.7 ± 7.7%, from 180.5 ± 3.4° to 171.7 ± 3.9°, from –7.1 ± 2.9° to 3.5 ± 2.6°from 84.4 ± 1.3° to 92.4 ± 2.3° respectively. For the patella high index, mISI, mCDI, and mBPI showed no statistically significant postoperative changes. MA–LTP significantly changed from 97.2 ± 2.8° to 90. 3± 1.9°. ROM showed no statistically significant postoperative change from –3.3 ± 4.1° to –2.3 ± 3.0°for extension, from 127.2 ± 9.5°to 128.0 ± 8.8°for flexion. All subscales of KOOS improved significantly after surgery. The KOOS symptoms improved from 64.4 ± 18.1 to 80.9 ± 9.5 (P <.0005), pain from 62.4 ± 8.8 to 85.8 ± 7.1 (P <.0001), activities of daily living from 69.5 ± 7.7 to 89.6 ± 6.7 (P <.0001), sport from 39.0 ± 13.0 to 60.5 ± 22.9 (P <.0001), and quality of life from 39.3 ± 10.9 to 69.1 ± 14.9 (P <.0001) at final follow–up.

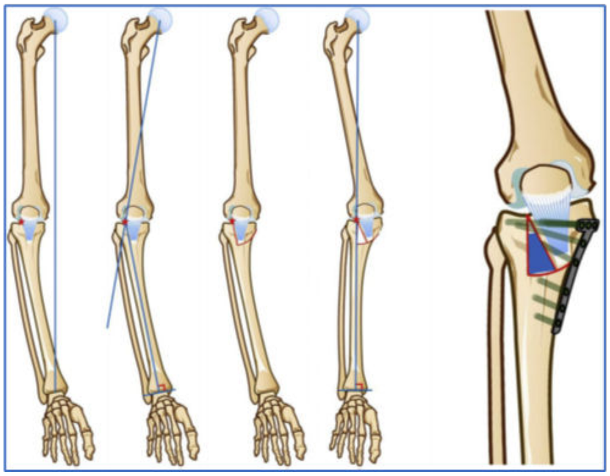
What are your conclusions?

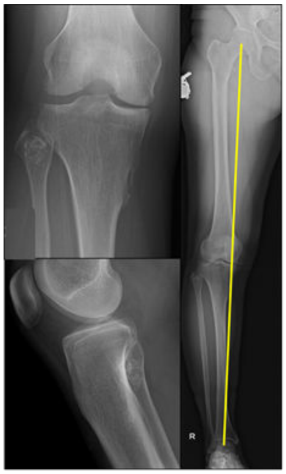
In the present study, we combined the distal tibial tuberosity focal dome osteotomy centered on the CORA with the longitudinal condylar osteotomy (Focal Dome Condylar Osteotomy: FDCO) for knee OA. The advantages of this procedure are as follows: physiological orientation of adjacent joint is achieved; limb length is maintained; joint stabilization in the coronal plane is achieved; patella infra is prevented; sufficient bone contact between the medial and posterior cortex is achieved; early weight–bearing walking is possible; fibular osteotomy is not required. This study shows FDCO leads to significant improvement of patient reported outcomes and function after intervention and demonstrates reliable mechanical axis correction with subsequent shift of weight–bearing without patella infra.

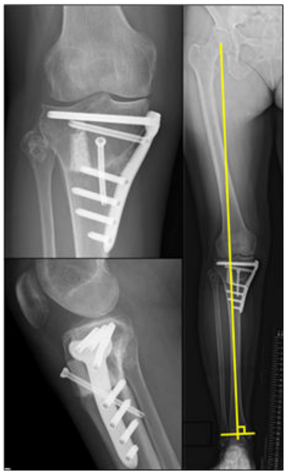


Distal tibial tuberosity focal dome osteotomy combined with intra-articular condylar osteotomy

Focal Dome Condylar Osteotomy: FDCO







Derotational Osteotomy of the Femur and/or Tibia for Youth with Anterior Knee Pain

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What was the question?

What is the effect of lower extremity torsional abnormalities on mobility, function, pain and gait pattern? What is the effect of derotational osteotomy of the femur and/or tibia on these outcomes?

How did you answer the question?

Participants aged 14 to 21 years with a combination of femoral and tibial torsion and candidates for surgery were recruited at a tertiary health–care center. Pre–operative clinical and radiological examination were obtained including, rotational profile by a computed tomography scan (CT scan) before surgery. Before and one year after surgery, participants had a clinical examination (range of motion and manual muscle strength), a quantitative gait analysis (QGA) and they completed the "Pediatric Outcomes Data Collection Instrument (PODCI)", a patient reported outcomes questionnaire measuring the level of mobility, function, pain and happiness. The Wilcoxon Signed Rank test was used to assess whether pre–post–surgery changes were statistically significant. The results are reported as: median (95% confidence interval [CI]).

What are the results?

To date, eight female participants aged 16.6 years (95% CI: 14.9 years, 20.9 years) have completed the study. Baseline CT scan results demonstrate increased femoral anteversion (31°; 95% CI: 15°, 46°) and increased external tibial torsion (47°; 95% CI: 35°, 72°). Derotational osteotomy was performed in 14 femurs (25° external; 95% CI: 18°, 30°) and in 11 tibias (20° internal; 95% CI: 13°, 25°). Participants were reassessed at 13.4 months (95% CI: 12.2 months, 15.8 months) post–surgery. The pre–and post–surgery clinical outcomes can be found in Table 1 and PODCI outcomes in Figure 1. For the QGA, a significant change of 14° for the mean hip rotation during stance (95% CI: –13°, –15°; $p < 0.001$) and a change of 12.3° (95% CI: 11.9°, 12.6°; $p < 0.001$) for the mean knee rotation during stance were observed.

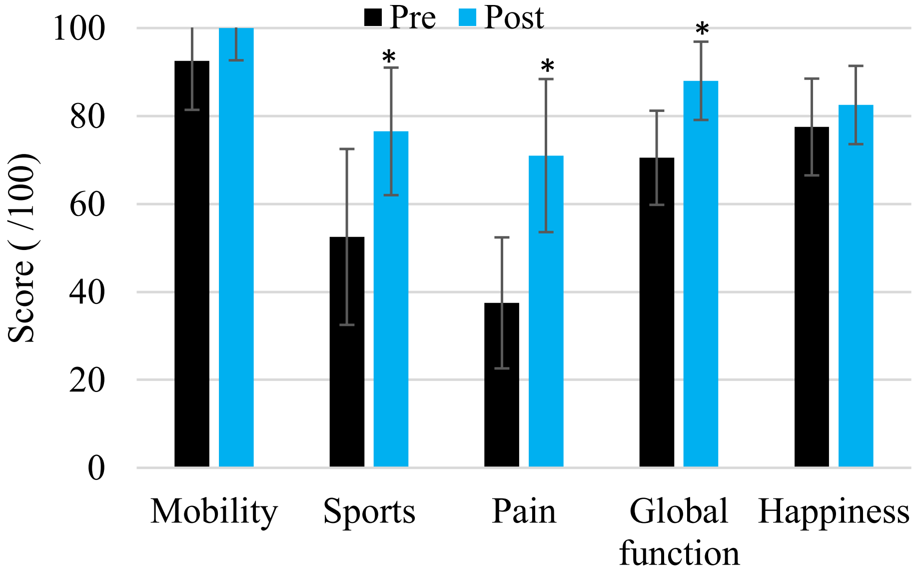
What are your conclusions?

Preliminary results suggest that in appropriately selected patients, who are evaluated with clinical, radiological and gait analysis parameters benefit from derotational osteotomies. Clinical and gait analysis parameters improved post operatively. We anticipate two–year outcomes will continue to improve; however, it needs to be examined as well.

Table 1. Pre-and post-clinical outcomes; * $p < 0.05$

	Measurements	**Pre-surgery**	**Post-surgery**
Range of motion	Hip internal rotation	70° (55°; 80°)	50° (45°; 59°)*
	Hip external rotation	25° (20°; 35°)	45.5° (40°; 57°)*
	Bimalleolar axis	30° (24°; 40°)	21° (10°; 28°)*

Figure 1. Pre-and post-surgery PODCI results.
*$p < 0.05$



Tibial Osteotomy Surgery Safety Profile

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What was the question?

For tibial osteotomy surgery, what are the rates of compartment syndrome, vascular injury, neurologic injury, venous thromboembolism, and additional surgery to manage hardware or infection complications? What is the safety profile of this surgery so commonly employed in the limb lengthening and reconstruction surgery area of orthopedic surgery?

How did you answer the question?

A retrospective chart review of our patient registry was performed for all index tibial osteotomies performed by our surgical team in the years of 2019, 2020, and 2021. Independent variables included: surgical indication, tibial osteotomy location, fixation method, whether a fasciotomy was performed, whether the fibula was osteotomized, whether tranexamic acid was used, and postoperative anticoagulation medication. Dependent variables included the outcomes listed in the Question section.

What are the results?

132 index tibial osteotomies were performed between January 2019 and August 2021. These comprised 30 high tibial osteotomies for coronal plane deformity, 1 supramalleolar osteotomy for coronal plane deformity, 15 other coronal plane deformity corrections, 10 rotational deformity corrections, 24 malunion or nonunion corrections, 12 primary lengthenings, 2 sagittal plane deformity corrections, 5 bone transport procedures, 21 biplanar deformity corrections, and 12 multiplanar (3 or more anatomical planes) deformity corrections. The fibula was osteotomized in 72 surgeries, prophylactic fasciotomy was performed for 36 anterior compartments and 16 lateral compartments. All but two patients received intraoperative tranexamic acid. Postoperative pharmacologic anticoagulation was aspirin for 110, rivaroxaban for 9, multiagent for 9, and none for 4. No instances of compartment syndrome, nerve palsy, or pulmonary embolism occurred. There were two episodes (1.7%) of deep vein thrombosis. 24 patients (25 tibias, 18.9%) had unplanned surgeries: three hardware adjustments, three syndesmosis stabilizations, four soft tissue releases for equinus contracture, three fractures, six debridements for infection, one amputation for inability to eradicate pre–existing infection, and 11 for nonunion.

What are your conclusions?

Elective tibia osteotomies can be performed in a variety of locations and for a variety of indications without incurring the most feared complications of compartment syndrome, vascular injury, or neurologic injury. Vascular thrombotic events are consistently preventable with aspirin for routine situations, or other anticoagulants when required. Complications such as delayed or nonunion can occur but are manageable non–emergently. Most local complications noted in this series were not directly related to the tibial osteotomy but rather the broader goal of transport or lengthening.

Bilateral Distal Femoral Osteotomy in Patients with Valgus Deformity Results in Improved Outcome Scores

S. Robert Rozbruch, MD; Amber A. Hamilton; Stephen J. Wallace, MD; Adam Geffner

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What was the question?

The lateral opening wedge distal femoral osteotomy (DFO) is an effective treatment to improve mechanical alignment and function related to pain and joint stability in patients with valgus deformity of the lower extremities. The aim of this study is to assess if patient reported outcomes at least one year after bilateral DFO reflect an improvement in hip and knee outcome measures as well as subjective perception of body image.

How did you answer the question?

A total of 39 patients that underwent bilateral distal femoral osteotomy at the study institution for valgus deformity correction were identified. Patients at least 12 months out from surgery were included in this study. There were 32 female and 7 male patients. Pre–operative responses to the Limb Deformity–Modified Scoliosis Research Society (LD–SRS), Knee injury and Osteoarthritis Outcome Score Jr. (KOOS Jr.), and the International Hip Outcome Score (iHOT 12) surveys were assessed retrospectively. The same surveys were administered post–operatively. A paired t–test analysis was used to assess changes in pre–operative and post–operative outcome scores.

What are the results?

The mean time to follow up was 35.7 months. The improvement in mean LDSRS scores before surgery (3.1ą 0.6) and one year after surgery (4.2ą 0.4) was statistically significant (p=0.02).

What are your conclusions?

Bilateral DFO in patients with valgus deformity improves limb deformity related quality of life and overall hip and knee health at least one year after surgery.

Session IV: Practice Management

Moderator: Harold J.P. van Bosse, MD

Early Experience with Robotic Autostrut–Controlled Hexapod External Fixators

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What was the question?
Autostrut is a technology which features computer–controlled motors mated to hexapod frame struts. The expected benefits of these programmed gradual frame adjustments (up to 20 sessions daily) without user interaction include reduced pain and improved regeneration of distraction osteogenesis and histogenesis tissue. The surgical implants and technique remain unchanged from traditional manually adjusted hardware. This observational study investigated the problems associated with this robotic technology and their solutions.

How did you answer the question?
A retrospective review was performed of all patients who had Autostrut motors placed on their hexapod frame. Charts were reviewed for patient demographics, anatomic site for frame application, indication for treatment, any issues directly related to motors and the solution to those issues, and also any setbacks, problems, or complications that occurred beyond those directly related to the motors.

What are the results?
Sixteen patients were managed with this technology, aged 6–78 (47.4±18.5) years. Treated anatomy included knees, tibias, ankles, and feet. Patients weighed 28–225 (80.7±23.1) kg with BMI 13.7–65.5 (31.5±11.3) kg/m². Pathology treated included three congenital deformities, two developmental deformities, one knee contracture following arthroplasty, one ankle equinus contracture, and nine malunion/nonunion deformities. The motors corrected flexion contractures, length, and deformities in all coronal, sagittal, and axial planes. All patients achieved the desired correction. There were two Autostrut–related issues: one patient (first generation motors) had the motors applied incorrectly, and one patient's machine (second generation motors) stopped adjusting prematurely which was corrected in the office by performing a device reset. In one patient, the motors appropriately stopped lengthening when a strut became loose from the frame (technical error, not Autostrut issue) and resumed lengthening upon strut replacement in the office. Ten patients had residuals programmed and uneventfully achieved following successful completion of their initial schedule. The knee and ankle contractures did not recur. Two patients had delayed union (one infected ankle fusion, one tibia nonunion) but achieved union following autograft supplementation. One patient (ankle contracture) had persistent fifth metatarsal wire tract osteomyelitis, eradicated with operative debridement and antibiotic paste injection.

What are your conclusions?
The Autostrut is a safe and reliable alternative to patient–managed strut adjustments. It can perform strut adjustments associated with the correction of contractures, length, and all three anatomic planes. Device–specific issues were rare, and uniformly caused the device to halt adjustments until reactivated by the clinician and technician. The motors automatically detected when struts were loose and inappropriate for continued lengthening, and alerted the patient. The motors all successfully achieved the programmed schedule and subsequent residual schedules. Future studies should focus on the patient's experience to understand the potential benefit of relieving the patients from this task, and also should investigate the possibility of automated reverse dynamization on bone healing.

Fully Automated Analysis of the Anatomical and Mechanical Axes from Pediatric Standing Lower Limb Radiographs using Convolutional Neural Networks

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What was the question?

Can convolutional neural networks (CNNs) perform lower limb alignment and axes analysis with performance comparable to trained orthopaedic surgeons?

How did you answer the question?

We used a set of CNNs based on the ResNet 18 and ResNet 50 architectures in combination with custom Matlab code to develop an automated workflow for the analysis of lower limb radiographs. CNNs were trained and validated on a set of pediatric standing lower limb radiographs. Results were then compared to manual measurements performed by orthopaedic surgery fellows.

What are the results?

CNNs combined with algorithms to find anatomical landmarks were used to extract mechanical axis parameters (mLFDA and mMPTA). Initial results compared favourably with those measured by orthopaedic surgery fellows. mLFDA measurements of 44 limbs showed a mean difference of –0.28 degrees with a standard deviation of 1.27 degrees. mMPTA measurements of 36 limbs showed a mean difference of 2.33 degrees and a standard deviation of 3.14 degrees. Full axis measurements were recorded to take approximately 2 seconds per radiograph to run on a consumer–grade laptop computer.

What are your conclusions?

CNNs are a promising approach to automating commonly performed, repetitive tasks, especially those pertaining to image processing. The time savings are particularly important in clinical research applications where large sets of radiographs are routinely available and require analysis. With further development of these algorithms, we anticipate significantly improved agreement with expert–measured results as well as the calculation speed. In the future, there is the potential to integrate these algorithms into routine clinical practice.

Outpatient Orthopaedic Trauma and Limb Deformity Surgery: Is it Safe?

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What was the question?

Over the course of the past 20 years, orthopedic surgery has experienced an increase in management of patients to the outpatient setting. Orthopaedic Trauma and Limb Deformity surgery have remained more frequently in the inpatient setting. The goal of our study was to evaluate the safety of complex outpatient operative fracture management and deformity correction with implementation of the Orthopedic Trauma Association (OTA) Guidelines for musculoskeletal pain.

How did you answer the question?

We retrospectively reviewed a consecutive series of primary and revision complex orthopedic trauma and limb deformity cases at an outpatient facility conducted by a single surgeon. The cohort consists of all cases performed by the orthopedic trauma surgeon in conjunction with the Certified Registered Nurse Anesthetist (CRNA) that led the opioid–sparing protocol. Patients were selected for regional anesthesia based on patient, surgeon and anesthesiologist preference. Comprehensive multimodal pain management regimen was prospectively implemented according to the OTA guideline. Case mix included peri–articular fractures, nonunions, deformity corrections, and osteomyelitis. All patients were followed for at least a year post–operatively to identify complications, emergency room visits, re–operations, calls to the office, pain control complaints, and medication refills.

What are the results?

151 patients were enrolled in this study. Fifty–five percent were males, with a mean age of 43. Seventy–five percent (113/151) received regional anesthesia at the time of surgery. There were no differences in use of regional anesthesia based on surgical site (upper extremity, lower extremity, foot/ankle, pelvis; p=0.27). Five patients (3.0%) were observed overnight including one patient having unplanned admission. Four patients (2.6%) returned to the Emergency Department (ED) within 1 month secondary to pain. None of these patients were admitted. 63/151 patients (42%) called the office for pain at some point during their care. Fifty–two of these patients (82%) were calling for routine guideline–concordant medication tapers to remain in accordance with state law. Eleven of the 63 patients (18%), which represented 7% of the whole cohort (11/151), called with pain complaints beyond routine medication taper request.

What are your conclusions?

With hospitals currently at capacity and bedspace limited secondary to global pandemic, orthopaedic trauma and limb deformity services have an opportunity to find safe alternatives to inpatient surgical care. Our study demonstrates that patients can be safely cared for within the outpatient setting for a range of complex orthopedic trauma conditions. Appropriate patient selection, utilization of regional anesthesia in select patients, proper pain management regimen per OTA CPG, and accessible communication make this possible.

Inter and Intra–Rater Reliability of the Checketts Grading System for Pin Site Infections across All Skin Colours

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What was the question?

Can the Checketts grading system be used reliably to visually grade minor pin site infections across all skin colours?

How did you answer the question?

De–identified photographs of minor pin site infections were sent out to orthopaedic surgeons (n=9) specialising in limb lengthening and reconstruction procedures, and to a group of patients (and their caretakers) who had EFDs in the past or were undergoing treatment with EFDs (n=8). Each study participant was asked to grade the pin site infections using the Checketts grading system, choose a treatment option, as well as rate their confidence in each assigned grade on a Likert scale from 0–4. The participants were also asked to choose a preferred treatment for each pin site. After a four–week period, the same pictures were sent to the participants again for grading.

For each of the three groups of raters (surgeons, parents and patients), reliability was calculated using the intraclass correlation coefficient for CGS, Fleiss' Kappa coefficients for inter–reliability for treatment, and Cohen's Kappa coefficients for intra–reliability for treatment. A sub–group analysis was also performed for the reliability of using this grading system in pin site infections in dark skin compared to light skin. Skin colour was assessed using the Fitzpatrick Scale.

What are the results?

Overall, the inter–rater reliability of the CGS between surgeons (n=9) was moderate (ICC=0.56) with good intra–rater reliability (ICC=0.85). The sub–analysis for skin colour showed a reduction in inter–rater reliability between surgeons when grading dark skin (ICC=0.46) compared to light skin (ICC=0.56)

The patient/caretaker group (n=8) showed moderate inter–rater reliability (ICC=0.50) and high intra–rater reliability (ICC=0.90) using the CGS, with no discrepancy between skin color.
The inter–rater (kappa= 0.30) and intra–rater (kappa=0.45) reliability of treatment decisions between the surgeons was poor, with similar inter–rater reliability for dark (kappa=0.26) compared to light skin (kappa=0.29). For the patient/caretaker group, the inter–rater (kappa= 0.23) and intra–rater (kappa=0.36) reliability of treatment decisions were also poor, with no modification for skin colour.

Overall, the surgeons' confidence in grading was low across both time points (median=1/4). The patient/parent group confidence in their grading was modest (median=2/4). For both groups, there was no modification in confidence based on skin colour.

Inter and Intra–Rater Reliability of the Checketts Grading System for Pin Site Infections across All Skin Colours *continued*

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What are your conclusions?
The CGS demonstrated good intra–reliability and moderate inter–reliability for surgeons but poor reliability for treatment decisions. This reliability was further reduced when evaluating darker skin. Overall, surgeons and patient/caretakers did not feel confident using the CGS to grade the photographs.

An accurate and reproducible scale for grading pin site infections has many relevant applications. First, an updated or modified grading system will increase the accuracy of diagnosing the severity of pin site infections. This should lead to a decrease in the need to return for in person visits as well as reduce the inappropriate use of antibiotics to treat infections. Furthermore, a revision to the Checketts criteria that increases the utility for all skin colours will aid in proper diagnosis and treatment regardless of skin colour, hopefully reducing a potential area of racial inequity within the medical system.

Second, a reliable scale is essential for future research on pin site infections, such as comparing the effects of different coating of the pins and wires used in EFDs or investigating alternative pin site care measures.

Third, as the Covid–19 pandemic has led to more virtual patient visits, photographs and video have become more commonplace for patient follow–ups with EFDs. This study indicates inadequate reliability and accuracy of this grading system with photographs, therefore warranting a revision to the Checketts Grading System.

Current Procedural Terminology (CPT) Coding in Pediatric Limb Reconstruction Surgery

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What was the question?

The field of pediatric limb lengthening and reconstruction is evolving at a rapid pace. Many surgical procedures and devices now available to surgeons were not in existence ten years ago. This confluence of factors can make accurate coding of limb lengthening and reconstruction surgeries difficult. For some procedures, such as the insertion of blocking screws or an internal lengthening nail, there are currently no existing CPT codes that describe the work done by the surgeon. For other procedures, there are CPT codes that only partially communicate the work that was done. Consequently, the purpose of this study was to 1) assess whether appropriate limb reconstruction codes currently exist and 2) determine whether there is agreement among experienced surgeons when applying these codes to similar cases.

How did you answer the question?

A REDCAP survey comprised of ten common pediatric limb reconstruction cases was sent to experienced pediatric limb reconstruction surgeons in the United States. (Appendix 1) Based on the description of each case, the surgeons were asked to code the cases as they normally would do in their practice. There were no limitations regarding the number of codes or the types of codes that each surgeon could choose to apply to the case. In addition, 9 additional demographic and general coding questions were asked to gauge the responding surgeon's coding experience. (Appendix 2) The results of the responses were analyzed using Pearson correlation coefficients and Kruskal–Wallis or Mann–Whitney U tests to compare responses among groups.

What are the results?

34 participants responded to the survey. The average years in practice of respondents was 11.6 years. 71% of the surgeons described themselves as working in an academic setting and 71% of the surgeons reported performing their own coding. 24% of respondents felt that adequate codes are available for their limb reconstruction cases. 44% of surgeons found it necessary to routinely use unlisted codes as part of the coding process but were successfully reimbursed for the unlisted codes only 14% of the time. 69% felt the currently available codes adequately represent the work they do when performing a limb lengthening or reconstruction case. 56% responded that all or a portion of their salary was based on RVU output.

Analysis of the coding responses for each of the ten cases demonstrated that the number of CPT codes reported for each cased ranged from 1–9. The average number of codes per case ranged from 1.2 to 3.6 with an average of 2.5 among all 10 cases. The total number of unique codes provided by the respondents for each case ranged from 5–20. Only 3 of the 10 cases had agreement > 75% for any single code and only 2 of the 10 cases had > 50% agreement on any combination of two codes.

What are your conclusions?

In conclusion, this study has documented that there is dramatic variation in coding methods among pediatric orthopedic limb reconstruction surgeons. Only 3 of the 10 cases included in the survey had agreement > 75% for any single code and only 2 of the 10 cases had > 50% agreement on any combination of two codes. This information highlights the need to improve the current CPT coding landscape. Possible solutions include developing new codes that better represent the work done, developing standardized guidelines with the existing codes to decrease variation, and improving CPT coding education with the development of limb reconstruction coding "champions".

Example	Case summary
1	4-year-old female with early onset Blount disease undergoing osteotomy and external fixation
2	2-year-old male with Paley Type 1b congenital femoral deficiency undergoing a hip reconstruction (Super Hip)
3	7-year-old male with Paley Type 1 fibula hemimelia undergoing a knee ligament reconstruction (Super Knee)
4	2-year-old male with Paley Type 3c fibula hemimelia undergoing a foot and ankle reconstruction (Super Ankle)
5	3-year-old male with congenital tibial pseudarthrosis undergoing reconstruction (first time surgery)
6	14-year-old female with 4 cm LLD secondary to Paley Type 1a congenital femoral deficiency treated with a femoral intramedullary lengthening nail
7	14-year-old female with 4 cm LLD secondary to Paley Type 1 fibula hemimelia treated with a tibial intramedullary lengthening nail
8	16-year-old male with valgus distal femur and 4 cm LLD secondary to distal femoral physeal injury undergoing acute deformity correction and gradual lengthening
9	14-year-old female with excessive femoral anteversion undergoing de-rotational femoral osteotomy
10	15-year-old female with varus and miserable malalignment undergoing ipsilateral proximal tibial osteotomy with a hexapod ex fix and IMN correction of the femur. (Only include the one side unless you would perform all 4 segments together.)

Appendix 2.

1) How many years have you been in practice?
2) Are you currently in a private practice or an academic setting?
3) Do you perform your own coding?
4) Do you feel there are a lack of adequate codes for limb reconstruction cases?
5) Do you use unlisted codes?
6) If yes, what percentage of the time are you successfully reimbursed for an unlisted code?
7) Is all or a portion of your salary base on RVU output?
8) Are you aware of changes made to your codes during the billing process?
9) Do you feel the current codes adequately represent the work you do when performing a limb reconstruction case?

Session V: Internal Lengthening Nails

Moderator: David Frumberg, MD

Radiographic Changes without Symptoms Predominate Following Limb Lengthening with a Weight Bearing Lengthening Nail

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What was the question?
The internal magnetic lengthening nail allowed near full weight bearing during femur and tibia lengthening but concerns for corrosion, pain, and radiographic changes led to the implant's recall. Despite the recall, it is important to understand the rate of these occurrences and their influence on overall success of the lengthening for future implant design. We therefore asked: what was the rate of patient–reported symptoms (localized pain), radiographic changes (either hypertrophy and/or lysis at either the telescopic junction and/or inner segment retention screws), and bone healing index for our cohort of lengthenings and shortenings/compressions.

How did you answer the question?
A retrospective chart review of all lengthening and shortening procedures at a single institution was performed. Nails were included if they had been subsequently removed, while retained nails were excluded. Along with demographic information, data included the time until the first radiographic changes were evident, the location and type of radiographic changes, if pain symptoms (not attributable to surgery or distraction) developed, the time to implant removal, and if the pain symptoms resolved with implant extraction. The bone healing index was calculated in days/cm for lengthenings.

What are the results?
Ninety–three nails were implanted for 90 lengthenings (78 femur and 12 tibia), and 3 femur shortenings. The cohort was predominantly male (n=87, female n=6). Stature lengthening was the indication in 49 femurs and 8 tibias, along with post–traumatic in 11 femurs and 2 tibias, congenital leg length discrepancy in 9 femurs, and other causes in 12 femurs and 2 tibias. Sixty seven (72%) of the bones developed radiographic changes, representing 59 (73%) femurs and 8 (66.7%) tibias, including osteolysis at the nail telescopic junction in 12 and at the inner segment screws in 13, bone hypertrophy at the junction in 12 and at the inner segment screws in 43, and both changes at the junction in 2 and at the inner screws in 3 patients. The average time to initial radiographic changes was 169 days (SD 104.8) in the femur and 248 days in the tibia (SD 104.8). Late onset pain developed in 10 femur lengthenings (10.8%), 3 of which resolved prior to nail removal (including 1 with no radiographic changes), and 7 of which resolved completely after nail removal. The mean weight of patients developing a radiographic or symptomatic abnormality was 69.3 kg (SD 12.7) versus 68.7 kg (SD 11.4) for those that did not. The affected vs unaffected bone healing index for femurs was 28.8±14.5 vs 28.8±16.1 days/cm (Student's t–test p=.998) and for tibias was 42.1±15.2 vs 92.7±32.0 days/cm but the sample was underpowered for meaningful statistic comparison. The mean time the nails were implanted were 458 days for those who developed an abnormality and 452 days for those that did not.

What are your conclusions?
The majority of patients who were implanted with a nail developed radiographic changes at the telescopic junction and/or locking screws in the inner segment. The rate of late onset pain was much lower, and always resolved with implant removal. The radiographic changes did not delay or impair bone consolidation and were not related to the weight of the patient. Lengthening limbs with nails that support near full weight bearing offers clear quality of life and mobility benefits to patients, so further elucidation of the cause of the radiographic changes and pain to improve the safety profile of the implants would be beneficial to restore such a treatment option for future patients.

Treatment of Angular Deformity and Limb Length Discrepancy with a Retrograde Femur Magnetic Intramedullary Nail: Fixator–Assisted, Blocking Screw Technique

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What was the question?

We investigated the accuracy of using a retrograde femur magnetic internal lengthening nail (MILN) with blocking screws for the correction of varus or valgus malalignment and leg length discrepancy (LLD). Specifically, we asked: 1) How accurate is the retrograde MILN at achieving planned limb lengthening? 2) How effective is using a retrograde MILN with blocking screws at correcting mechanical axis deviation (MAD) at the knee? Can a retrograde MILN with blocking screws normalize the mechanical lateral distal femoral angle (LDFA) and mechanical axis angle (MAA)? 4) What were the incidences of complications and reoperations using this technique?

How did you answer the question?

We performed a retrospective study of 39 retrograde femur lengthening nails and two [redacted] lengthening nails used to correct lower limb LLD and malalignment. Coronal plan deformity correction was performed acutely in the operating room based on preoperative templating of nail start site and blocking screw placement. Gradual limb lengthening was performed to treat LLD. Patients were followed clinically and radiographically at routine intervals to monitor bone healing. Preoperative LLD, MAD, and joint orientation angles were compared to values at the end of treatment and full bone consolidation. Complications of treatment necessitating reoperation (excluding hardware removal) were tracked.

What are the results?

There were 13 patients with preoperative genu varum and 28 patients with genu valgum malalignment. The varus cohort had a mean preoperative LLD of 29 ± 16mm LLD with 31 ± 22mm medial MAD. The valgus cohort had a mean preoperative LLD of 26 ±12mm and 19 ±9mm lateral MAD. All patients started with MAD>mm and 90% of patients started with LLD>5mm. The mean LDFA of the varus cohort was 98 ±12o and the MAA was 10 ±9o, while the mean LDFA of the valgus cohort was 82 ±4o with a MAA of 6 ±1o. Planned lengthening was achieved in 99% of the varus cohort and 100% of the valgus cohort. The bone healing index was 28 ±6 days/cm in the varus cohort and 35 ±22 days/cm in the valgus cohort. Final LLD were 9 ±12mm in the varus cohort and 5 ±5mm in the valgus cohort. The LLD was corrected to within 5mm in 69% of the varus cohort and 48% of the valgus cohort. A residual MAD > 5mm was present in 9 varus patients (69%) and 12 valgus patients (48%). Final LDFAs were 91 ±6 and 89 ±4o in the varus and valgus cohorts, respectively, while the MAA was corrected to 3 ±2o and 2 ±2o in each group, respectively. Ten patients underwent a total of 21 returns to the operating room. Most commonly, this involved percutaneous injection of bone marrow aspirate concentrate (BMAC) to bone regenerate exhibiting delayed union (6 patients). Three patients underwent an exchange nailing. Two of these cases were for mechanical failure of the MILN.

What are your conclusions?

Use of a retrograde MILN with a fixator–assisted, blocking screw technique is an effective means of acutely correcting coronal plane malalignment with the ability to then gradually correct LLD. Issues common to traditional Ilizarov techniques such as pin site infection and soft tissue irritation are avoided by the all–internal nature of this technology. The accuracy of deformity correction hinges on intraoperative execution of the preoperative plan, specifically related to nail start site, osteotomy location, and placement of blocking screws.

Table 1: Demographics and characteristics of patients treated for varus or valgus deformity and leg length discrepancy (LLD) using an internal retrograde femoral magnetic lengthening nail

	Varus Cohort	Valgus Cohort	
	n=13	n=28	p-value*
Gender (n, %)			
Men	8 (73%)	14 (52%)	
Women	3 (27%)	13 (48%)	
Age (years) Mean +/- SD	34.91 ± 11.68	25.52 ± 10.23	**0.03**
Follow up (months) Mean +/- SD	26.31 ± 17.33	25.22 ± 15.33	0.86
Etiology			
Congenital	5	14	
Trauma	3	10	
Other	2	3	
Unknown	1	1	
Direct LLD (mm) Mean +/- SD	27.27 ± 18.76	25.22 ± 11.12	0.74
Indirect LLD (mm) Mean +/- SD	29.09 ± 15.56	26.30 ± 12.09	0.60
LLD > 5mm (n, %)	10 (91%)	25 (93%)	
MAD (mm) Mean +/- SD	medial (+) 31.15 ± 21.53	lateral (-) -19.04 ± 8.66	**<0.001**
MAD > 5mm (n, %)**	13 (100%)	28 (100%)	
Mechanical axis angle Mean +/- SD	deg. Varus (+) 10.38 ± 9.01	deg. Valgus (-) -6.21 ± 2.59	**<0.001**
LDFA (degrees) Mean +/- SD	98.38 ± 11.82	82.46 ± 3.93	**<0.001**
MPTA (degrees) Mean +/- SD	88.15 ± 5.24	88.64 ± 2.82	0.76
Planned Lengthening (mm) Mean +/- SD	43.17 ± 21.75	29 ± 11.74	**0.05**
Latency (days) Mean +/- SD	6.62 ± 0.96	6.29 ± 1.30	0.37
Rate (mm/day) Mean +/- SD	0.78 ± 0.13	0.80 ± 0.12	0.67
Rhythm (events per day) Mean +/- SD	3.23 ± 0.52	3.39 ± 0.59	0.41
Blocking screws (n) Mean +/- SD	1.77 ± 0.44	1.75 ± 0.70	0.92

LLD = Leg length discrepancy; LDFA = Lateral distal femoral angle; MPTA = Medial proximal tibial angle
MAD = Mechanical axis deviation
*Two-sample t-Test assuming unequal variances (two-tailed P values)
**All MAD for varus knees was medial to the knee midline; all MAD for valgus knees was lateral to the midline

Table 2: Comparison of pre- and postoperative radiographic parameters after deformity correction and lengthening with a retrograde femur magnetic lengthening nail

	Varus Cohort (n=13)		
	Preop	Postop	p-value*
Direct LLD (mm) Mean +/- SD	27.27 ± 18.76	8.82 ± 13.39	**<0.001**
Indirect LLD (mm) Mean +/- SD	29.09 ± 15.56	9.36 ± 12.30	**<0.001**
LLD > 5mm (n, %)	10 (91%)	4 (36%)	
MAD (mm) Mean +/- SD	medial (+) 31.15 ± 21.53	8.69 ± 5.85	**<0.001**
MAD > 5mm (n, %)	13 (100%)	9 (69%)	
Mechanical axis angle Mean +/- SD	deg. Varus (+) 10.38 ± 9.01	3 ± 2	0.00342
LDFA (degrees) Mean +/- SD	98.38 ± 11.82	90.69 ± 5.74	0.00117

	Valgus Cohort (n=28)		
	Preop	Postop	p-value*
Direct LLD (mm) Mean +/- SD	25.22 ± 11.12	4.54 ± 5.25	**<0.001**
Indirect LLD (mm) Mean +/- SD	26.3 ± 12.09	5.04 ± 4.55	**<0.001**
LLD > 5mm (n, %)	25 (93%)	7 (29%)**	
MAD (mm) Mean +/- SD	lateral (-) -19.04 ± 8.66	7.24 ± 6.72	**<0.001**
MAD > 5mm (n, %)	28 (100%)	12 (48%)**	
Mechanical axis angle Mean +/- SD	deg. Valgus (-) -6.21 ± 2.59	2.2 ± 2.10	**<0.001**
LDFA (degrees)			**<0.001**
Mean +/- SD	82.46 ± 3.93	89.11 ± 3.94	

*Paired two-sample t-test for means (one-tailed P values)

**Analysis only includes patients who received postoperative bilateral hip to ankle radiographs

Table 3a: Type and number of complications encountered and reoperations required for patients undergoing mechanical axis and leg length correction using a retrograde femoral internal magnetic lengthening nail.

Patient	Number and Type of Complication	Number and Type of Reoperation*
1	Delayed union	2 BMAC injections
2	Delayed union	BMAC injection
3	Distal femur nonunion, broken locking screws and nail migrating into the knee joint	Nonunion repair with exchange nailing
4	2 arthrofibrosis requiring surgical release (1 in each knee)	2- B/L knee arthrotomies and lysis of adhesions
5	Recurring delayed union, arthrofibrosis, femur fracture after hardware removal	5- 2 BMAC injections, exchange nailing, knee arthrotomy/lysis of adhesions, ORIF femur
6	L nail malfunction, L and R nail mechanical failure, R femur delayed union	4- L exchange nailing, R and L exchange nailing, R BMAC injection
7	Delayed union	BMAC injection
8	Delayed union	BMAC injection
9	Postop DVT, L common peroneal nerve neurapraxia, delayed union, L equinus contracture	3- Nerve decompression, exchange nailing, gastrocnemius recession
10	Displacement of distal fragment, lateral translation, resultant valgus	Blocking screw insertion

*Excluding planned magnetic nail removal performed for all patients

Table 3b: Cumulatie tabulation of number and type of complication

Complication type	Frequency
Delayed union/nonunion	8
Soft tissue contracture	4
Hardware failure	4
Other	4
Total	20

Performance and Complications of a Titanium Internal Lengthening Nail: A Retrospective Review of 286 Bone Lengthening Events

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What was the question?
Femur and tibia lengthening are routinely performed with internal lengthening nails. The nail has revolutionized the field of limb lengthening with its ease of use and reliable distraction. Prior studies of the implant are either small, heterogeneous, or focus on a single type of lengthening. The purpose of this study was to analyze a large sample of bone distractions with meaningful subgroup analyses to evaluate key differences in outcomes and complications.

How did you answer the question?
A retrospective chart and radiographic review of all the [redacted] internal lengthening nails implanted at one institution from 9/1/2012 – 9/1/2020 were reviewed. Each lengthening event was considered separately from the time of implantation to the end of consolidation. Demographic data, preoperative bone deformity, operative approach (antegrade femur [AF], retrograde femur [RF], antegrade tibia [T]), acute deformity correction (coronal, sagittal, rotation), and the use of blocking screws was recorded. The outcome data calculated included the lengthening achieved (cm), the distraction index (DI, mm/day), the bone healing index (BHI, months/cm), reliability (number of successful treatment/implants required), postoperative joint orientation angles, mechanical axis deviation (MAD), and date of implant removal. Consolidation of the lengthening site was determined on biplanar radiographs when three of four cortices contained bridging bone two millimeters thick. Patient and implant complications were recorded. ASAMI bone and function scores were calculated.

What are the results?
There were 286 femur and tibia lengthening procedures performed (Table 1), including 164 AF with mean age 29.7 (SD 14), 67 RF with mean age 36.2 (SD 13.7), and 55 T with mean age 35.8 (SD 13.6) (Table 1). Forty of the procedures were bilateral (31 AF, 5 RF, 4 T). Forty–two were in patient less than or equal to 16 years of age (35 AF, 4 RF, 3 T). Congenital causes lead to lengthening in 50 AF, 18 RF, and 20 T, acquired causes (trauma, neoplasm, growth arrest, dysplasia, failed arthroplasty) in 52 AF, 43 RF, and 27 T, and stature lengthening in 62 AF, 6 RF, and 8 T. Acute deformity correction was performed in 23 (14%) of AF, 53 (79%) RF, and 19 (34.5%) T and blocking screws were utilized in 9 (5.5%) AF, 60 (89.5%) RF, 44 (80%) T. Lengthening achieved via AF averaged 4.43cm (SD 2.13) with DI 0.99 (SD 0.12) and BHI 0.89 (SD 0.68), via RF 3.44cm (SD 2.02) with DI 0.92 (SD 0.23) and BHI 1.21 (0.70), via T 3.86cm (SD 1.53) with DI 0.71 (SD 0.18) and BHI 1.47 (SD 1.03). On multivariate analysis, nail type (p=0.001, younger age (p=0.001), and lengthening only (no deformity correction, p=0.001) were associated with lower BHI. The reliability of AF was 92.7, RF 93.1, and T 94.8. ASAMI bone and function scores (out of 4) averaged 3.99 and 3.93 for AF, 3.97 and 3.76 for RF, and 3.98 and 3.79 for T. Deformity was induced in 8 (4.9%) AF, 2 (3.0%) RF, and 5 (9.1%) T. Additional operations for any reason were needed in 15 AF, 7 RF, and 6 T. There was a total of 3 nail that failed to distract. Implant or crown fracture occurred in 15 AF, 4 RF, and 1 T.

What are your conclusions?
Lengthening with the nail is a reliable technique for small to large lengthening events that is well tolerated by patients, can be combined with other deformity correction, and leads to excellent bone and functional outcomes. The bone healing indices are satisfactory for bone lengthening and comparable to historical studies of external fixation. Antegrade lengthening, younger age, and lengthening without acute deformity correction leads to lower bone healing indices. Lengthening must be monitored closely because complications can occur, including implant or crown fracture, locking bolt migration, or delayed consolidation.

	Antegrade Femur	Retrograde Femur	Tibia	p (affect on BHI)
N=	164	67	55	
Age (SD)	29.7 (14.0)	36.2 (13.7)	35.8 (13.6)	
Unilateral	102	57	47	
Bilateral	35	5	4	
Pediatric (</= 16)	35 (21.3%)	4 (6.0%)	3 (5.5%)	0.001
Etiology				
Congenital	50	18	20	
Acquired	52	43	27	
Stature	62	6	8	
Deformity Correction	23 (14%)	53 (79%)	19 (35%)	0.001
Coronal (n/avg deg)	6 / 18.2^{o}	49 / 8.86^{o}	13 / 8.69^{o}	
Sagittal (n/avg deg)	4 / 19.75^{o}	11/ 19.4^{o}	3 / 7.3^{o}	
Rotation (n/avg deg)	15 / 19^{o}	11/ 15.6^{o}	6 / 14.2^{o}	
Blocking Screws	9 (5.5%)	60 (89.5%)	44 (80%)	
Lengthening				
Centimeters (SD)	4.4 (2.1)	3.4 (2.0)	3.86 (1.53)	
Distraction Index (mm/day) (SD)	0.99 (0.12)	0.92 (0.23)	0.71 (0.18)	
Bone Healing Index (months/cm) (SD)	0.89 (0.68)	1.21 (0.70)	1.47 (1.03)	<0.0001
Reliability	92.7%	91.8%	94.8%	
ASAMI				
Bone	3.99	3.97	3.98	
Function	3.93	3.76	3.80	
Complications				
Deformity Creation	8 (4.9%)	2 (3.0%)	5 (9.1%)	
Additional Operations	15	7	6	
Dead Nail	2	1	0	
Bolt Migration	6	2	4	
Implant or Crown Fracture	15	4	1	
Exchanged to Static Nail	7	4	2	

Use of the Antegrade Femoral Nail in Pediatric Patients

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What was the question?

The internal magnetic lengthening nail is used commonly for adult femur lengthening given its accuracy, precise control of lengthening, and patient comfort throughout the process. Pediatric patients pose different considerations for lengthening given their open growth plates, at–risk vascular supply to the femoral head, and increased capacity to heal and consolidate bone. Currently, the nail is not FDA approved for use in children, although many practices continue to use it off–label. Is the antegrade femoral implant also efficient, reliable, and safe for femur lengthening in skeletally immature pediatric patients?

How did you answer the question?

We performed a retrospective chart review of all skeletally immature patients (defined by our practice as males 16 years and younger, females 14 years and younger) who underwent treatment with a antegrade femoral nail. We reviewed patient demographics, etiology, preoperative radiographic measurements, implant dimensions, lengthening goal, distraction rate, bone healing index, length achieved, postoperative radiographic measurements, and postoperative complications.

What are the results?

We implanted 30 antegrade femoral nails (all trochanteric entry) in 25 patients (11 males, 14 females), with an average follow up of 18.24 months. The average age at surgery was 13.55 years for males (8 years to 15 years), and 11.93 years for females (8 years to 14 years). Two patients presented with trauma–induced limb length discrepancies, 8 presented with limb length discrepancies related to Russell–Silver syndrome (RSS), 10 presented with non–RSS congenital limb length discrepancies, and 5 presented with congenital short stature (CSS). The average lengthening goal for all surgeries was 47.62 mm (15 mm to 80 mm), and the average length achieved was 47.63 mm (15 mm to 80 mm). 24 out of 25 patients (96%) achieved their lengthening goal within 5 mm. One patient finished lengthening 7 mm short of his goal. Average distraction rate was 0.97 mm/day (0.75 mm/day to 1 mm/day), and average bone healing index (time to consolidation/cm lengthened) was 19.69 days/cm (13.77 days/cm to 35.33 days/cm). No patients experienced avascular necrosis of the hip. Three patients experienced complications that required additional surgery, including a hip and knee flexor tendon lengthening, guided growth to correct a knee flexion contracture, and bilateral exchange nailing for implant fracture and delayed union. All complications were ultimately resolved without permanent deficits.

What are your conclusions?

The antegrade femoral nail can safely and efficiently manage large lower extremity lengthening in skeletally immature children. Concurrent angular or rotational deformity correction was also possible, and postoperative complications were infrequent and manageable.

Early Weight–Bearing Accelerates Regenerate Bone Mineralization: A Pilot Study Comparing Two Postoperative Weight–Bearing Protocols following Intramedullary Limb Lengthening using the Pixel Value Ratio

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What was the question?
Limb lengthening is increasingly accomplished by internal lengthening nails. Previous versions of the magnetic lengthening nails made from titanium alloy allowed limited weight–bearing. In contrast, the newer nails made of stainless steel allow increased weight–bearing. An objective comparison of the rate of healing of the regenerate bone based on the weight–bearing capabilities of these two types of lengthening nails has not been evaluated. The hypothesis for the study is that earlier commencement of full weight–bearing in patients treated with the stainless steel nail will lead to faster healing of the regenerate bone during intramedullary limb lengthening compared to those treated with the titanium nail.

How did you answer the question?
Thirty patients, divided into two groups of 15 each, underwent antegrade intramedullary lengthening of the femur using either a titanium or stainless steel magnetic lengthening nail between May 2017 and November 2020. The pixel value ratio (PVR) obtained from serial digital radiographs was used to quantitatively determine the regenerate bone's mineralization rate. We compared the rate of healing of the regenerate bone in both groups of patients using the PVR.

What are the results?
Patients treated with the stainless steel nail achieved unassisted full weight–bearing significantly earlier than patients treated with the titanium nail (12 weeks vs 17 weeks for stainless steel and titanium nail lengthened patients respectively, $p = 0.003$). There was no difference in the PVR between both groups of patients at the time of full weight–bearing ($p = 0.0857$). However, patients treated with the stainless steel nail attained a PVR of 1 significantly earlier than those treated with the titanium nail (0.0317).

What are your conclusions?
The stainless steel nail provides an earlier return of function and full weight–bearing compared to the titanium lengthening nail. Earlier commencement of weight–bearing ambulation leads to more rapid mineralization of the regenerate bone in patients undergoing intramedullary limb lengthening.

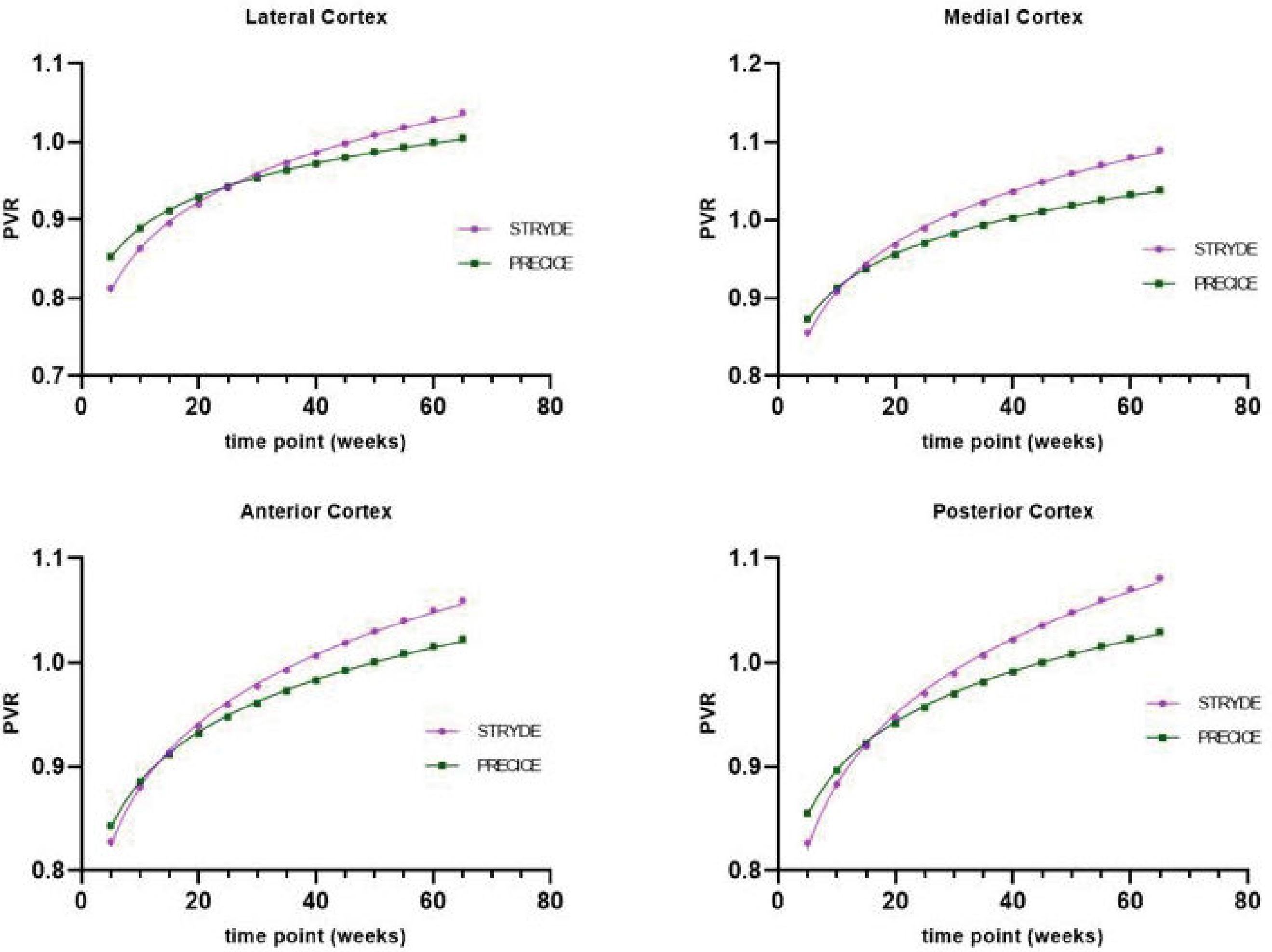

Fig. 1 Graphical comparisons between the rate of change of PVR for the various regenerate cortices between STRYDE® and PRECICE® nail lengthening patients.

Session VI: Pediatrics

Moderator: L. Reid Nichols, MD

The Effectiveness of Serial Casting in the Treatment of Recurrent Equinovarus in Children with Arthrogryposis

L. Reid Nichols, MD; Chris Church; Stephanie Butler; Jose de Jesus Salazar–Torres; John Henley; Maureen Donohoe; Freeman Miller; Christina Bourantas

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What was the question?

The most common foot deformity in children with arthrogryposis is clubfoot, which is typically stiffer than in the idiopathic clubfoot (IC). While the use of the Ponseti method in IC has lead to improved foot mobility and reduced invasive surgical procedures, there is currently limited information of the effectiveness of serial casting (SC) in arthrogryposis. The purpose is to determine the effect of serial casting in recurrent clubfoot in children with arthrogryposis on brace tolerance, foot position, patient reported outcome, and the need for surgery

How did you answer the question?

Children with arthrogryposis treated with serial casting to address persistent or recurrent equinovarus foot deformity were evaluated retrospectively comparing outcomes before, short (within 6 months, ST) and long term (between 6 and 14 months, LT) after end of serial casting. Outcomes included in this study were ankle PROM, dynamic foot pressure, the parent reported Pediatric Outcomes Data Collection Instrument (PODCI), brace tolerance, and the need for post–casting surgery. ANOVAs or paired t–tests were used to determine the effects of casting. Changes in brace tolerance before and after SC were analyzed using the Global Test for Symmetry.

What are the results?

Fifty children (6.3±3.5 years old) were casted 2.5±1.9 times, with a total of 214 serial casting episodes analyzed. Children were casted weekly for a period of 26±11 days followed by ST assessment 0.3±1 months post–casting, and LT assessment 8.5±2.7 months post–casting. Sixty–eight percent of children used AFOs, 28% KAFOs, and 4% in shoe or no orthoses. PROM showed improvement in ankle dorsiflexion and forefoot abduction in ST, returning to baseline measurements in LT (Table 1). Brace tolerance improved after casting (pre: good 30%, fair 22%, poor 48%, post: good 79%, fair 17%, poor 4%; $p<0.05$; Figure 1). With follow–up to 10.3±5.5 years of age, only 20% of feet required surgery. For those that required surgery, it was completed 4.7±3.2 years after casting was initiated. There were no significant changes in dynamic foot pressure, or PODCI results after serial casting except for an increase in the pain subtest ($p<0.05$).

What are your conclusions?

Traditionally foot deformities in children with arthrogryposis have been treated with surgical intervention, due to the rigidity and severity of the abnormal alignment. Serial casting in children with arthrogryposis is effective in improving PROM in the short term, but baseline measures recur in the longer term. Serial casting improves brace tolerance and delays the need for invasive surgical procedures in children with arthrogryposis.

Figure 1. Pre-post casting change in brace tolerance

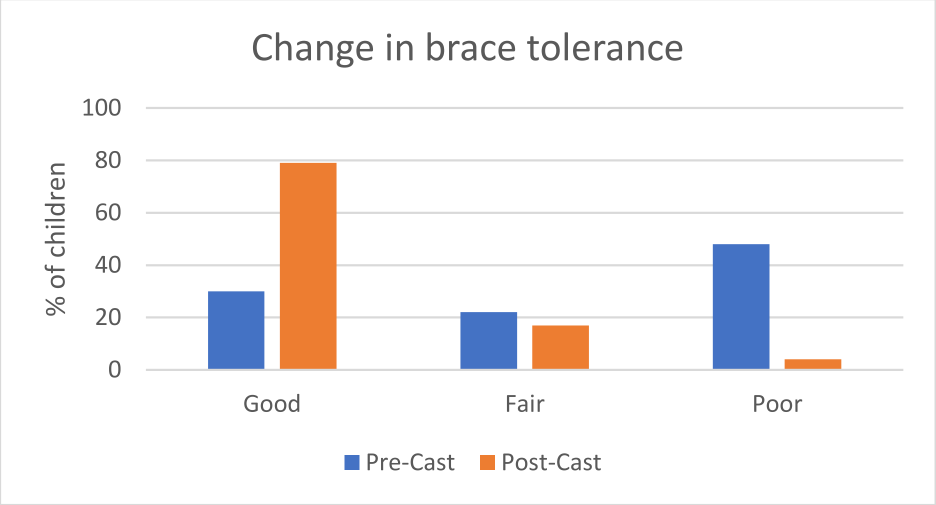

Table 1: Comparison of PROM at pre, ST, and LT post serial casting

	Pre		ST		LT		Pre vs ST	Pre vs LT	ST vs LT
	Mean	SD	Mean	SD	Mean	SD	P	P	P
Ankle Dorsiflexion PROM n=120	-11.0	12.1	-2.9	8.8	-8.4	11.1	1.92E-11	0.105	1.47E-.07
Forefoot Abduction PROM n=65	7.6	17.2	19.3	11.3	6.8	14.6	1.78E-06	0.9	2.54E-10

The Fate of Bent Telescopic Rods in Children with Osteogenesis Imperfecta: Do All Bent Rods Need to be Revised?

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What was the question?

Osteogenesis Imperfecta (OI) is a genetic disorder characterized by brittle bones and long bone deformity. Realignment and intramedullary rodding with telescopic rods can prevent fractures and correct deformity in OI patients. Rod bending is a reported complication of telescopic rods and a common indication for revision, however, the fate of bent lower extremity telescopic rods in the setting of OI has not been reported.

How did you answer the question?

Patients with OI at a single institution who underwent lower extremity telescopic rod placement with at least one–year follow–up were identified. Bent rods were identified and for those bone segments we collected location and angle of bend, subsequent telescoping, refracture, increasing angulation of bend and date of revision.

What are the results?

168 telescopic rods in 43 patients were identified. 46 rods (27.4%) bent during follow–up with average angulation of 7.3° (range 1–24°). 15.7% of rods in patients with severe OI bent compared with 35.7% in non–severe OI ($p=0.003$). The proportion of bent rods was different between independent and non–independent ambulators (34.1%, 20.5%; $p=0.035$). 27 bent rods (59%) were revised, with 12 rods (26%) revised immediately (within 90 days). The angulation of rods that were immediately revised was significantly higher than rods not immediately revised (14.6°, 4.3°, $p < 0.001$). Of the 34 bent rods not immediately revised, the average time to revision or final follow–up was 29.1 months. 25 rods (73.5%) continued to telescope, 14 (41%) increased in angulation (average 3.2°) and 10 bones (29%) refractured. Of these refractures, 5 were non–displaced with no increased angulation, 4 showed increased angulation but no loss of fixation, and one was a pilon fracture distal to a tibia rod; none prompted immediate rod revision. Two bones had multiple refractures.

What are your conclusions?

Bending is a common complication of telescopic rods in the lower extremities of patients with OI. It is more common in independent ambulators and patients with non–severe OI, possibly due to the increased demand placed on the rods. Rods with a small bend and maintained fixation can telescope and need not be an indication for immediate revision. About one third will refracture, but fixation was maintained and the refracture did not require immediate revision in our population. Understanding the fate of the bent lower extremity telescopic rods in the setting of OI can help reduce the overall surgical burden for OI patients during their growing years.

How Does Femoral Varus Deformity Respond to Guided Growth in Blount Disease?

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What was the question?
While Blount disease is primarily a disorder of the proximal tibia, femoral deformity frequently contributes to the overall varus alignment. How does the femoral varus deformity in Blount disease respond to guided growth, with/without lateral tension band plating (LTBP) to the femur?

How did you answer the question?
Retrospective radiographic review of 132 limbs undergoing LTBP for Blount disease between 2008–2018 at 7 centers was performed. All had tibial LTBP and 38 limbs also had femoral LTBP. Two additional limbs had medial femoral tension band plating for valgus deformity and were excluded from analysis. Digital standing anteroposterior radiographs were measured for preoperative alignment and postoperative correction of the mechanical lateral distal femoral angle (mLDFA) to ≤90 degrees. Follow up was ≥2 years unless the deformity corrected, skeletal maturity was reached, or they had other surgery. The 38 limbs having femoral LTBP were compared to 62 limbs with femoral varus (mLDFA>90 degrees) and no femoral LTBP. Additionally, 30 limbs that did not have preop–femoral varus were followed. Fisher exact tests were used for statistical analysis.

What are the results?
Following femoral LTBP, the mean mLDFA decreased from 97.3 degrees to 88.5 degrees. All femurs had some improvement, with 28 of 38 femurs (74%) achieving complete femoral correction. One limb, with late follow–up, overcorrected and required reverse (medial) femoral plating. For the 62 limbs with preop–mLDFA>90 degrees treated with only tibial LTBP, 19 of 34 limbs (56%) with diagnosis early–onset (<7years) and 4 of 28 limbs (14%) with late–onset (≥8years) completely corrected their femoral deformities during the study period. For limbs in Blount disease with pre–mLDFA>90 degrees, femoral LTBP statistically correlated with successful femoral varus correction in the late–onset group. (p<0.001) Thirty limbs, without preop–femoral varus (mLDFA≤90 degrees), had no change in their mean mLDFA of 87 degrees. However, 5 femurs (17%) ended with mLDFA> 90 degrees.

What are your conclusions?
Femoral LTBP is effective in correcting femoral varus deformity in Blount disease. For femoral varus associated with Blount disease, onset ≥8 years, femoral LTBP should be considered. Few femurs corrected with tibial LTBP alone and those who had femoral LTBP had statistically more successful femoral varus correction. In Blount disease, onset <7 years, with associated femoral varus, observation is warranted because 56% of femurs corrected without femoral intervention. Even those limbs with Blount disease, and normal femoral alignment, should be watched closely for the development of femoral varus, during tibial LTBP treatment.

Achondroplasia: The Ruse of Rhizomelia

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What was the question?

Are the lower extremities and/or upper extremities of patients with achondroplasia rhizomelic?

How did you answer the question?

A retrospective chart and radiographic review was performed of all patients with a diagnosis of achondroplasia who were seen at our clinic from 2010–2021. For the lower extremity analysis, a patient was included if they had a full–length, standing, anterior–posterior (AP) radiograph prior to their first lengthening or reconstructive surgery. Patients were excluded if their knees were flexed in the AP film. The lengths of the femurs and tibias were measured using two previously published methods (Anderson M & Green WT 1948; Maresh M 1943). For the upper extremity, a patient was included if they had an AP or lateral radiograph of the entire arm prior to any reconstructive/lengthening surgery. The lengths of the humerus, radius and ulna was then measured using a previously published method (Maresh M 1943). The femorotibial, humeroradial, and humeroulnar ratios were calculated and a randomly selected side was compared to age–matched, historic population data using a Mann Whitney U test with significance set at $p < 0.05$. The null hypothesis was that there no difference between the ratios in patients with and without achondroplasia.

What are the results?

123 patients with the diagnosis of achondroplasia were reviewed. 83 patients (40 female/43 male) met the inclusion criteria for the lower extremity analysis and 43 patients (24 female/19 male) met the inclusion criteria for the upper extremity analysis. The median age of the lower extremity cohort was 11 years (range 5 months – 31 years). The median age of the upper extremity cohort was 14 years (range 6 months – 23 years). The median right and left femorotibial ratio using the Anderson & Green measurement method was 1.27. There was no difference in proportionality between the two sides ($p = 0.4573$) and no difference between a randomly selected side and the Anderson & Green age–matched data ($p = 0.4464$). Using the Maresh measurement method, the mean right and left femorotibial ratio was 1.2. There was no difference in proportionality between the two sides ($p = 0.5815$) and no difference between a randomly selected side and the Maresh age–matched data ($p = 0.9965$). The median right and left humeroradial ratios were 1.20, the right humeroulnar ratio was 1.06 and left humeroulnar ratio was 1.07. There were no differences between the right and left humeroradial ratio ($p = 0.6137$) and humeroulnar ratio ($p = 0.2866$). The randomly selected sides were significantly lower than their age–matched humeroradial ratios (median 1.34, $p <.0001$) and humeroulnar ratios (median 1.25, $p <.0001$).

What are your conclusions?

Patients with achondroplasia do not have rhizomelic lower extremities and their femorotibial ratios are similar to age–matched subjects without achondroplasia. However, patients with achondoplasia do have rhizomelic upper extremities compared to age–matched subjects without achondroplasia. The term rhizomelia should not be used to describe the relationship between the femur and tibia.

Presidential Guest Lecture

Change

John Gerard Birch, MD

Session VII: Osteointegration

Moderator: Stephen M. Quinnan, MD

Removal of Press–Fit Transtibial Osseointegration Implants – A Discussion of Risk Factors and Outcomes

Shakib Al–Jawazneh; Jason Shih Hoellwarth, MD; Kevin Tetsworth, MD; Atiya Oomatia; Munjed Al Muderis, MD

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What was the question?
With the innovation of skeletal transcutaneous osseointegration, many problems commonly experienced by amputees with TSP can now be avoided: skin ulcers, dermatitis, intolerable perspiration, problems with socket fit and instability due to poor proprioception. Despite the demonstrated clinical benefits, concerns regarding potential complications following skeletal transcutaneous osseointegration have slowed its widespread adoption.
The primary goal of this study was to investigate the complications and technical issues associated with transtibial osseointegration implant removal due to any cause. The focus here will be on the press–fit ILP and OPL implants, including the indications for removal and patient outcomes following removal.

How did you answer the question?
A review of our osseointegration registry between November 2010 and March 2022 was performed. Inclusion criteria were patients who have undergone removal of a transtibial osseointegration implant due to any cause. Selected patients either had a follow–up of at least two years or had their index osseointegration surgery at least two years prior to when the study was performed. Patients who have had osseointegration at other anatomic levels, and patients who underwent simultaneous total knee replacement with transtibial osseointegration were excluded from the registry search.

What are the results?
There were a total of 182 transtibial osseointegration procedures performed during the study period, with 131 (72.0%) performed in males and 51 (28.0%) performed in females. The average age at first stage osseointegration procedure is 50.4 years (range 16.8–87.9, SD 14.1) and average BMI 28.8 (range 17.3–44.8, SD 5.8).

In the study cohort of 22 cases requiring implant removals, 12 (54.5%) were male and 10 (45.5%) were female. The average age at first stage osseointegration procedure in this cohort is 51.3 (range 37.4–82.6, SD 10.7) and average BMI 30.3 (range 21.9–40.9, SD 5.8).
When comparing rate of removals by sex, 12 of 131 (9.2%) males and 10 of 51 (19.6%) females who underwent transtibial osseointegration required an implant removed. Although men comprised the majority of removals, women had a greater relative risk (Fisher exact test p=0.032). BMI was not a significant risk factor leading to implant removal (p=0.220) and neither was age (p=0.690).

The average duration from time of osseointegration to removal was 2.6 years (range 0.1–6.8, SD 1.9) within this 11.5 year follow–up period. The most frequent indication was infection (54.6%, n=12) followed equally by pain (13.6%, n=3), aseptic loosening (13.6%, n=3) and implant fracture (13.6%, n=3), and lastly failure to integrate (4.6%, n=1). Of the 12 implants removed for infection, 1 (8.3%) had a known prior infection which led to the index amputation and 11 (91.7%) had amputations unrelated to infection. One patient in the study cohort died from an acute myocardial infarction in the post–operative period, secondary to pre–existing comorbidities. Of the 22 removals, 12 were reimplanted at the same anatomical level (10 were reimplanted within 6 months, 1 within 12 months, and 1 within 24 months). 11 of these cases currently wear

Removal of Press–Fit Transtibial Osseointegration Implants – A Discussion of Risk Factors and Outcomes *continued*

Shakib Al–Jawazneh; Jason Shih Hoellwarth, MD; Kevin Tetsworth, MD; Atiya Oomatia; Munjed Al Muderis, MD

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What are the results? *continued*
their prosthetic legs for more than 13 hours daily. 1 case was recently reimplanted and still completing their loading program.

Of the patients who were not reimplanted at the same anatomical level, 1 required proximal amputation with transfemoral osseointegration. 3 patients converted to traditional socket prostheses (TSP) due to pain, and 1 underwent proximal amputation and converted to TSP due to infection. 3 cases are currently awaiting transtibial osseointegration reimplantation, and 1 patient was deceased. 1 patient was lost to follow–up.

What are your conclusions?
Of 182 transtibial osseointegration procedures performed between November 2010 to March 2020, 22 cases required removals. The most frequent indication was infection, followed equally by pain, aseptic loosening and implant fracture, and lastly due to failure to integrate. Females were significantly at higher risk of requiring an implant removed, while BMI and age were not found to be significant. Of the cases that required removals, 12 were reimplanted and regained adequate use of their prostheses. There was one morbidity in the post–operative period, secondary to pre–existing comorbidities. Transtibial osseointegration surgery remains a good option for regaining mobility in amputees, however more research would be beneficial to identify additional risk factors leading to implant removal, as well as identifying the best method for removals and reimplantation.

Transcutaneous Osseointegration for Amputees with Short Residual Bone: Is there Increased Risk for Complications?

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What was the question?

Transcutaneous osseointegration for amputees (TOFA) provides improved mobility and quality of life for most patients versus a traditional socket prosthesis. One uncertainty regarding TOFA is whether a minimum residual bone length is necessary to achieve solid fixation and avoid infection, loosening, or other complications. The standard implant length is 160 mm and is frequently modified to be shorter to accommodate shorter residual bones. This study evaluated the relationship of the residual bone length and the occurrence of postoperative complications requiring operative intervention.

How did you answer the question?

A retrospective review of our osseointegration registry was performed: all patients whose index osseointegration was performed at least 12 months prior were included. Chart review included demographics and focused specifically on whether patients required additional surgery to manage infection (debridement with implant retention, or implant removal) or periprosthetic fracture. These adverse event rates were compared in two ways. First, using simple logistic regression analysis. Second, by stratifying patients as > 140 mm vs ≤ 140 mm (Fisher's exact test).

What are the results?

Sixty osseointegrated segments were included (57 patients, 3 bilateral amputees). The implant length averaged 129.4±31.1 (48–200) mm. One case of implanting a grossly undersized implant which fell out before loading was excluded (the patient's revision procedure was included, evaluated as a primary procedure). Six patients (10%) had an operation to manage infection, at lengths ranging from 130–160 mm (the middle 60%): five had debridement with implant retention, and one had implant removal. No implants below 130 mm (n=19, 32%) required debridement or removal. Three patients (5%) had periprosthetic fracture (all femurs), at lengths ranging from 140–160 mm (the middle 55%); no implants below 140 mm (n=22, 37%) had periprosthetic fracture. Regression identified no association between length and infection (p=.124) or periprosthetic fracture (p=.999). The dichotomized > 140 mm vs ≤ 140 mm rates of infection were 5/38=13.2% vs 1/22=4.5% (p=.400), and for fracture were 3/38=7.9% vs 0/22=0% (p=.292).

What are your conclusions?

Residual bone length does not appear to be associated with a risk for operative intervention for infection or for periprosthetic fracture following TOFA. One limitation of this study was that only one bone was under 60 mm, limiting the ability to evaluate risks for exceptionally short bones; that patient had neither fracture nor infection and is doing well.

Transfemoral Osseointegration for Amputees with Diabetes Mellitus

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What was the question?

Transcutaneous osseointegration typically provides significantly improved mobility and quality of life for amputees. The comorbidity of diabetes mellitus has traditionally been considered a contraindication to providing osseointegration. This study investigated that assumption with three questions. First, what are the post–osseointegration complications for amputees with diabetes mellitus? Second, what is the change in mobility; and third, what is the change in quality of life following press–fit osseointegration?

How did you answer the question?

A retrospective review of our prospective registry was performed. 20 patients had unilateral transfemoral osseointegration and were followed for at least two years. We reviewed their demographics, their unplanned surgical events, and compared their preoperative versus postoperative mobility (prosthesis wear hours, K–level, Timed Up and Go, 6 Minute Walk Test) and quality of life (SF36).

What are the results?

No systemic complications such as sepsis or death occurred. One patient's implant was undersized and failed to integrate at the index surgery but succeeded in a revision surgery. Three patients (15%) required soft tissue debridement. One patient sustained a periprosthetic fracture which was managed with open reduction and internal fixation with implant retention. Significant improvements were observed for preoperative wear hours (5.4±6.6 vs 9.3±5.7 hours, p=.053) and K–level (>K2 was 2/10=10% vs 17/20=85%, p&lt;.001). There were not significant changes for Timed Up and Go (13.8±7.1 vs 14.7±6.1 seconds, p=.714), 6 Minute Walk Test (208±178 vs 266±144, p=.292), SF36 Mental Component (47.9±13.8 vs 30.6±10.8, p=.606) SF36 Physical Component (30.6±10.8 vs 32.4 vs 10.1, p=.606).

What are your conclusions?

The risk and consequences of post–osseointegration complications for patients with diabetes mellitus is acceptable. While infection requiring debridement did occur in three patients, it did not result in implant removal. Systemic complications, namely sepsis, did not occur. It is curious that this cohort had limited mobility and quality of life improvements following osseointegration. However, the traditionally held concern that patients with diabetes mellitus are too risky to consider osseointegration is not substantiated by our results.

Developing an Infection Criteria for Osseointegration

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What was the question?
Osseointegrated prostheses offer amputees greater mobility, satisfaction, and usage compared to current standard socket–based options. Infection remains the most common complication. Although rare, there is still significant concern placed upon the risk of ascending infections due to the sequelae of septic implant loosening, failure, and removal. Unlike other orthopaedic reconstructive procedures, in particular total hip and knee replacements, there are no objective criteria for diagnosing infection. We aimed to create and evaluate a set of infection criteria for osseointegration, using a series of lower–limb osseointegration patients who required revision surgery for clinically apparent infection.

How did you answer the question?
A retrospective evaluation of patient records was performed to identify patients who underwent osseointegration and required additional surgery, either implant debridement or removal. These patients were stratified into infectious versus non–infectious etiologies by reviewing their clinical and laboratory data.

The proposed infection criteria were based on the prosthetic joint infection criteria from the Musculoskeletal Infection Society (MSIS). Clinical signs of infection included the presence of sinus tracts, peristomal erythema, pain with loading, or visible implant instability. Laboratory data included serum erythrocyte sedimentation rate, C–reactive protein, and white blood cell count. The determination of infection was distinguished by whether the intraoperative cultures were positive. The infected and non–infected cohorts were compared to determine any differences in age, gender, pre–existing comorbidities, or surgical indications.

What are the results?
A total of 63 osseointegration patients were identified requiring additional surgery. Among these patients, a total of 83 surgical episodes (31 removals, 52 debridements) were evaluated. Preliminary results indicate clinical signs such as the presence of purulence, pain and erythema serve as useful indicators of infection, whilst CRP and ESR are helpful discriminators. The most common organism discovered in superficial and deep cultures was Staphylococcus aureus. Positive deep cultures were associated with matching superficial cultures among 50% of deep infection episodes.

What are your conclusions?
Early findings suggest that clinical signs, laboratory markers and cultures can all be considered clinically useful tools for the detection of infection after osseointegration. The proposed infection criteria can provide a basis for a more standardised method of classifying infection after osseointegration.

Traveling Fellowship Presentation

Introduction by Jaclyn F. Hill, MD

Ahmed Hammouda, MD
Dr. Carlito C. Valera, Jr.

Session VIII: Pediatric Growth

Moderator: Jaclyn F. Hill, MD

The Modified Fels Knee Skeletal Maturity System in Prediction of Leg–Length Discrepancy

Dylan Kluck; Marina R. Makarov, MD; Raymond W. Liu, MD; Ryan Furdock, MD;
David Podeszwa, MD; Chan–Hee Jo; John G. Birch, MD

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What was the question?

Previous work has shown the White–Menelaus (W–M) method combined with Greulich and Pyle (G–P) skeletal age to be the most accurate means of predicting leg–length discrepancy (LLD) in an epiphysiodesis age cohort. G–P skeletal age requires an additional left hand/wrist radiograph, however, thereby increasing radiation exposure and health care expenditure. Using an AP knee radiograph, the Modified Fels (mFels) knee skeletal maturity system has recently been described and shown to be accurate in prediction of limb length when compared to chronological age–based predictions. There is limited data on the inter—observer reliability of this system, however, and its performance relative to the G–P skeletal age is unknown. We therefore sought to determine the inter–observer reliability of the mFels system and to compare prediction errors in LLD at skeletal maturity using the W–M method and either the mFels or G–P method skeletal age.

How did you answer the question?

A sample cohort of 20 left knee radiographs was reviewed by three blinded reviewers to determine mFels estimated skeletal age. Results were compared among reviewers to obtain inter–observer reliability. A separate cohort of 60 patients undergoing distal femur and/or proximal tibia epiphysiodesis for management of LLD was then reviewed. All patients had pre–operative scanograms and accompanying left hand–and–wrist radiographs and follow up to skeletal maturity. Predictions of short leg length (SL), long leg length (LL) and LLD at skeletal maturity were then performed using the W–M method and either G–P or mFels skeletal age. SL, LL and LLD estimates were compared with actual values obtained at skeletal maturity to determine prediction error between the two skeletal age measures.

What are the results?

In the sample cohort for mFels estimated skeletal age, ICC for quantitative variables and kappa for qualitative variables ranged from 0.70 to 0.73. The ICC for the overall mFels skeletal age estimate was 0.97 (Table 1). In the cohort of 60 patients undergoing epiphysiodesis, G–P skeletal age was on average 0.25 years older than mFels skeletal age (Table 2), most notable in females (Figure 1). Prediction errors between G–P and mFels skeletal age were all p <1cm different. For the overall cohort, G–P vs mFels errors were small (1–3mm) and only LLD was statistically significant. When looking at females and males separately, prediction errors for males using G–P and mFels were not statistically different. For females, G–P vs mFels errors ranged from 2–9mm, all of which were statistically significant (Table 2).

What are your conclusions?

The mFels skeletal age is a highly reproducible method of determining skeletal age in this cohort. Using the W–M formula for prediction of short leg, long leg and total leg–length discrepancy at skeletal maturity, prediction errors with mFels versus G–P skeletal age were comparable. Despite statistical difference in some predictions, all errors were p <0.5cm except for short leg prediction error in females, which approached 1cm. As such, further work is merited to optimize the accuracy of the mFels skeletal age when used to predict leg–length discrepancy at skeletal maturity, especially in females, as this method is a promising means of estimating skeletal age avoiding additional radiation and healthcare expenditure.

Table 1. Modified Fels (mFels) Skeletal Age Reliability Study (N=20)

mFels Quantitative Components	Rater 1	Rater 2	Rater 3	ICC	95%-L	95%-U
Tib E:M	0.7777	0.8524	0.8394	0.7307	0.5248	0.8721
Fib E:M	0.5547	0.7680	0.8104	0.7188	0.5132	0.8648
Estimated Skeletal Age	0.96	0.97	0.98	0.97	0.93	0.99

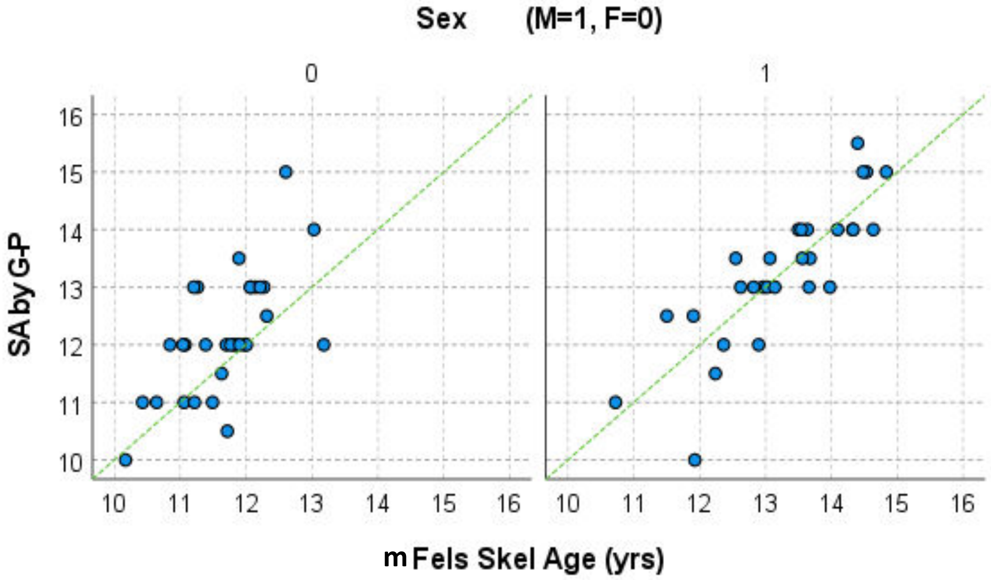
ICC based on averages between raters

Table 2. Paired Comparisons Between Skeletal Age and Prediction Error at Skeletal Maturity Using Greulich and Pyle and Modified Fels Skeletal Age and the White-Menelaus Method

Parameter	Group	G-P	mFels	T-test
Skeletal Age (yrs)	Entire Cohort (60)	12.70	12.45	**0.014**
	Females (31)	12.16	11.68	**0.002**
	Males (29)	13.28	13.27	0.983
Short Leg Prediction Error (cm)	Entire Cohort (60)	2.0 ± 1.5	2.3 ± 1.4	0.192
	Females (31)	1.4 ± 1.0	2.3 ± 1.3	**0.003**
	Males (29)	2.6 ± 1.7	2.3 ± 1.5	0.208
Long Leg Prediction Error (cm)	Entire Cohort (60)	1.4 ± 1.4	1.5 ± 1.2	0.499
	Females (31)	0.9 ± 0.7	1.3 ± 1.0	**0.025**
	Males (29)	1.9 ± 1.7	1.6 ± 1.4	0.168
LLD Prediction Error (cm)	Entire Cohort (60)	0.8 ± 0.6	1.1 ± 0.7	**0.020**
	Females (31)	0.8 ± 0.5	1.0 ± 0.7	**0.042**
	Males (29)	1.0 ± 0.7	1.1 ± 0.8	0.225

mFels = Modified Fels Skeletal age; G-P = Greulich and Pyle Skeletal Age

Figure 1: Skeletal Age Determined by Modified Fels versus Greulich and Pyle, Stratified by Gender



Comparison of "Human" and Artificial Intelligence Hand–and–Wrist Skeletal Age Estimation in an Epiphysiodesis Cohort

Marina R. Makarov, MD; Dylan Kluck, MD; Yassine Kanaan, MD; Chan–Hee Jo, PhD;
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What was the question?

We have previously shown in a cohort of 76 patients treated by epiphysiodesis that the White–Menelaus arithmetic formulae combined with skeletal age as determined from the Greulich and Pyle atlas) was the most accurate method of predicting long and short leg lengths and residual leg length discrepancy (LLD) at maturity. The relevance of the Greulich and Pyle atlas in a "more modern" population has been questioned. We sought to determine if an on–line machine–learned artificial intelligence (AI) hand–and–wrist skeletal age estimation provided consistent readings and how these readings influenced prediction of epiphysiodesis outcome in this cohort.

How did you answer the question?

Jpeg images of the immediate preoperative hand–and–wrist films of the 76 subjects were produced, and independently submitted by two authors to an on–line AI skeletal age website (http://physis.16bit.ai/), and results recorded. After verifying the readings by both methods (AI and Greulich/Pyle atlas) by the senior author, we compared accuracy of predicted long leg (after epiphysiodesis), short leg, and residual LLD, using the White–Menelaus formulae and either the Greulich and Pyle atlas or the AI reading.

What are the results?

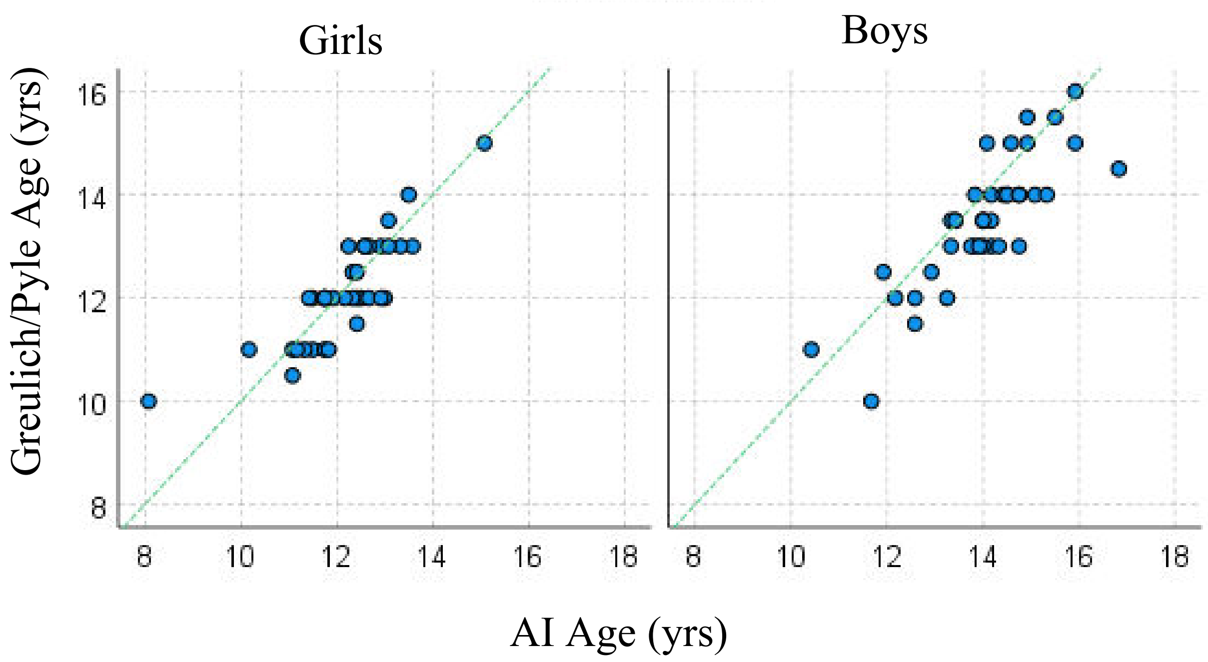
The AI skeletal age readings as submitted by two authors had an ICC of 0.99. AI skeletal age was generally older than by the Greulich and Pyle atlas, averaging 0.5 years more in boys, and 0.1 years in girls (Table, Figure). The prediction accuracy was improved with AI readings in all areas (long leg, short leg, LLD for the entire cohort, and by gender (boys and girls); these differences reached statistical significance for short leg prediction error, and residual LLD in the entire cohort and boys (Table). Residual LLD was underestimated >1.0 cm (range, 1.0–3.2 cm) in 26/76 and overestimated >1 cm (range, 1.0–1.3) in 3/76, using the Greulich and Pyle atlas. In comparison, residual LLD was underestimated >1.0 cm (range, 1.1–2.2 cm) in only 10/76 using the AI skeletal age, and overestimated >1 cm (range, 1.3–1.6 cm) in 3/76.

What are your conclusions?

The AI method of determining hand–and–wrist skeletal age was highly reproducible in this cohort and improved leg length and residual discrepancy prediction accuracy compared to traditional individual comparison with the Greulich and Pyle atlas. This improvement could be explained either by more accurate estimation of skeletal age using a much larger database in machine–learning AI environment, and/or the use of a more current patient population. At the same time, these predictions remain an imperfect science.

Table. Comparison of Skeletal Age as determined by Greulich/Pyle Atlas and AI, and long leg, short leg, and residual LLD prediction errors in 76-subject epiphysiodesis cohort.

Parameter	**Group**	**Greulich/Pyle**	**AI**	**p-value**
Skeletal age (yrs)	Entire Cohort (76)	12.8 ± 1.3	13.1 ± 1.5	<0.01
	Females (36)	12.1 ± 1.0	12.2 ± 1.1	0.70
	Males (40)	13.5 ± 1.2	14.0 ± 1.2	<0.01
Short Leg Prediction error (cm)	Entire Cohort (76)	2.0 ± 1.4	1.4 ± 1.3	<0.01
	Females (36)	1.5 ± 0.9	1.1 ± 1.0	0.02
	Males (40)	2.5 ± 1.7	1.8 ± 1.5	0.01
Long Leg Prediction error (cm)	Entire Cohort (76)	1.3 ± 1.3	1.1 ± 1.2	0.09
	Females (36)	0.9 ± 0.7	0.7 ± 0.6	0.12
	Males (40)	1.7 ± 1.5	1.5 ± 1.4	0.31
LLD prediction error (cm)	Entire Cohort (76)	0.9 ± 0.6	0.6 ± 0.5	<0.01
	Females (36)	0.8 ± 0.5	0.6 ± 0.6	0.13
	Males (40)	1.0 ± 0.7	0.6 ± 0.4	<0.01



Does the Technique of Lengthening Effect Physeal Growth İn Patient with Achondroplasia? Comparison of the Simultaneous and Consecutive Surgery

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What was the question?

The effect of lower extremity lengthening on physeal growth is still controversial. It is surgeons choice to perform bilateral simultaneous femur and tibia lengthening or lengthening surgery separately for the bilateral femur followed by bilateral tibia lengthening. The question was; if there are some degree of physeal growth disturbance with lengthening, is it more prominent with more aggresive simultaneous four segment lengthening?

How did you answer the question?

Twenty–six patients were included who operated in our clinic between 1995 and 2005 for limb lengthening and followed up until age of 16 for complete skeletal maturity. Fourteen patients with bilateral lengthening of the femur and tibia at the same time were named as simultaneous lengthening (SL). Twelve patients with bilateral lengthening of the femur and then bilateral tibia lengthening seperately were named consecutively lengthening (CL). All patients were followed until completion of growth. The physeal arrest was measured using predicted length (investigated with the multiplier method), the total amount of lengthening and final length.

What are the results?

Mean lower limb lengthening was 145 mm (48,5%) and 151 mm (46,6%) for simultaneous and consecutive groups respectively. For lower extremity length, the SL reached 527,6 mm while expected was 447,3 mm. Considering 151 mm lengthening, the mean growth disturbance for the SL was 70,7 mm. The CL group revealed a mean of 47,5 mm disturbance. For total height comparison, disturbance was 80,5mm and 65,4mm respectively.

What are your conclusions?

Although simultaneous four segment lengthening have more physiological physeal disturbance effects compared to consecutive operations, there was no statistical difference between the two groups.

Can Zometa Lines be Used to Study Growth in Patients With Congenital Pseudarthrosis of the Tibia?

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What was the question?
What is the effect of reconstructive surgery on lower extremity growth in patients with congenital pseudarthrosis of the tibia?

How did you answer the question?
A retrospective chart and radiographic review was performed for all patients with a diagnosis of congenital pseudoarthrosis of the tibia (CPT) who underwent surgical reconstruction at our clinic from 2013 – 2022. Patients were included in the study if they had received at least one dose of Zometa prior to reconstruction. If the Zometa infusion date was unknown or if a patient did not have postoperative radiographs available for review, they were excluded. When available, radiographs from the 3, 6, 12, 18 and 24 month postoperative visits were analyzed. For each visible Zometa line (Z–line) in the operative and nonoperative femur and tibia, the distance from the center of the Z–line to the center of the physis was measured. A two–way, random effects, absolute agreement, single rate intraclass correlation coefficient (ICC) was calculated for the measurement of the Z–lines. Growth rates were calculated for the distal femoral and proximal tibial growth plates, and the operative and nonoperative rates were compared. Comparisons were performed with Kruskall–Wallis test, and multiple comparisons were performed with Wilcoxon Rank Sum and Bonferroni correction. Significance was set at $p < 0.05$.

What are the results?
Fifty–one patients were included in the final analysis. The ICC for Z–line measurement was good to excellent at 0.92 (95% CI 0.88–0.94). The first table in Figure 1 shows the percentage of Z–lines that were visible and able to be measured at each physis and time period. The distal femoral Z–lines and proximal tibial Z–lines were consistently visible (over 60%); therefore, further analysis was limited to those physes. The second table in Figure 1 outlines the mean growth rates for the operative and nonoperative distal femoral and proximal tibial physes. On the operative side, the proximal tibia physis demonstrated a significantly higher growth rate at the 3, 6, and 12 month intervals compared to the 18 month interval ($p = 0.0100$, $p = 0.0059$, $p=0.0264$). There were no differences in growth rates between any two time points for the operative distal femur ($p = 0.2234$) , nonoperative distal femur ($p = 0.0742$) or nonoperative proximal tibia ($p = 0.7286$). When comparing the operative to the nonoperative physes, the operative proximal tibia had significantly higher growth rates at 3, 6 and 12 months ($p=0.0001$, 0.0026, 0.0011). The operative distal femur had a significantly higher growth rate at 3 months ($p=0.0115$).

What are your conclusions?
Measuring Z–line distance from its respective physis is a reproducible way to quantify growth at that physis as evident by the high inter–rater reliability in our study. Z–lines were most reliably seen at the distal femur and proximal tibia physes while Z–lines in the proximal femur were seen less than 30% of the time. Higher growth rates observed for the operative distal femur and proximal tibia physes compared to the nonoperative physes may represent temporary growth stimulation of the operative side. This growth stimulation effect is most evident in the first year after reconstructive surgery.

Percentage of Z-lines Identified

Month Followup		Nonop PF	Op PF	Nonop DF	Op DF	Nonop PT	Op PT	Nonop DT	Op DT
	3	30	17	72	86	67	84	61	59
	6	15	14	76	100	73	86	73	42
	12	14	9	65	87	66	93	59	48
	18	10	13	65	89	65	82	68	37
	24	9	9	78	96	78	73	74	31

Mean Growth Rate for Distal Femur and Proximal Tibia Physes (mm/month)

Month Followup		Nonop DF	Op DF	Nonop PT	Op PT
	3	1.48	1.8	0.91	1.41
	6	1.83	1.49	0.95	1.43
	12	1.73	1.75	0.97	1.27
	18	1.32	1.61	0.85	0.86
	24	1.37	1.43	1.1	1.04

PF= Proximal Femur
DF-Distal Femur
PT=Proximal Tibia
DT=Distal Tibia

The History of ASAMI–North America and ASAMI International

Dror Paley, MD

Session IX: Trauma and Foot/Ankle

Moderator: J. Spence Reid, MD

Memorial of James C. Binski, MD

John D. Wyrick, MD

Validation of a Novel Bone Defect Classification

Geoffrey Marecek, MD; Julie Agel; Stephen M. Quinnan, MD; Ashley Levack; Eric Meinberg, MD; Mitchell Bernstein, MD; Stephen Wallace, MD; Roberto Hernandez–Irizarry, MD; Michael Githens

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What was the question?

A novel bone defect classification system that mimics the familiar AO/OTA fracture classification has been described. Evaluation by the authors demonstrated good reliability. However, it remains to be seen if the system is valid across a range of defects and by different surgeons. We sought to validate this classification system.

How did you answer the question?

Two rounds of analysis were performed. In the first, ten (10) bone defects were classified using the novel classification system by a panel of six (6) surgeons, including the original author. In the second, fifteen (15) bone defects were classified by a panel of eight (8) surgeons. The panels consisted of members of the OTA classification committee and/or members of both OTA and LLRS. For the second round, a calibrated measurement scale was provided and surgeons were instructed to classify the defect as presented, or after resection of nonviable bone. Analysis was performed using a two–way random effects model with absolute agreement to determine the intraclass correlation coefficient (ICC). Surgeons also rated their confidence in their rating from 1 – 3, with 3 as "very confident."

What are the results?

In round 1, ICC for the entire code for average measures (as a group agreement) was 0.903 (95% CI 0.772, 0.972; 0.001). Cronbach's alpha = 0.91. ICC coefficient for the groups (i.e. D1,D2,D3) for average measures was 0.902 (95% CI 0.769, 0.972; 0.001). Cronbach's alpha = 0.91. ICC for the subcategories (i.e. a,b,c) was 0.666 (95% CI 0.242, 0.901; 0.004). Cronbach's alpha = 0.69.

In round 2, The ICC for the entire code using average measures was 0.949 (95% CI 0.897,0.980; 0.001). Cronbach's alpha = 0.96). The ICC for the D1,D2,D3 part of the code was 0.935 (95%CI 0.869,0.975; 0.001). Cronbach's alpha = 0.95). The ICC for the a,b,c part of the code was 0.878 (95% CI 0.758, 0.952; 0.001). Cronbach's alpha = 0.89)

7 out of 8 raters ranked their confidence in the assigned classification rating for each case (1 - 3). The mean confidence for all cases was 2.46 (range 1.86 – 3) with one case (#3) a D3C achieving full confidence and complete agreement from all raters.

What are your conclusions?

The novel bone defect classification system is reproducible by surgeons familiar with bone defects. Agreement is improved with use of a calibration scale and guidelines for the timing of classification. We recommend these modifications are included.

Fibular Displacement Predicts Tibial Malrotation in Simulated Tibia–Fibula Fractures

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What was the question?

Tibial malrotation commonly occurs with medullary nailing of diaphyseal tibia fractures. Fibular alignment is often used as a surrogate for proper tibial rotation intraoperatively. The purpose of this study is to determine if fibular alignment is a reliable marker of accurate tibial rotation.

How did you answer the question?

Deidentified CT scans of 20 subjects with normal tibial anatomy were selected. Using imageJ software, we simulated osteotomies at 3 sites (proximal third, mid–diaphysis, distal third). We overlaid adjacent CT slices and rotated them around the central axis of the tibia in 5° increments of external (ER) and internal rotation (IR). At each increment, measurements of fibular overlap were taken from anteroposterior (AP) and lateral (LAT) views. To simulate fixation of the fibula, we repeated rotation around the axis of the fibula with and without a simulated medullary implant in the tibia.

What are the results?

Earliest loss of fibular contact occurred at 24° ER, 22° IR at the proximal site. Contact was lost at 25° ER, 28° IR at the proximal site on AP view, and 42° ER, 29° IR at the proximal site on LAT view. The threshold for lost contact was lower on AP view in ER, and on LAT view in IR. Mean fibular contact at each 5° increment was similar for ER and IR. Fibular contact was reduced to 50% at either 10–15° of rotation in ER and IR at all sites.
Tibial canal contact was lost at 24° of both ER and IR when rotation was performed around the fibula. With a virtual medullary implant, mean maximal rotation was 6°.

What are your conclusions?

Surgeons should be aware that 20° or more of malrotation is likely present when fibular contact is lost during medullary nailing of the tibia. Greater than 50% loss of contact should raise suspicion for malrotation. A fixed fibula and medullary implant theoretically preclude significant malrotation.

A Clinical Comparison of Complex Ankle Arthrodesis using Two Fixation Techniques: Ilizarov External Fixation versus Intramedullary Arthrodesis Nail

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What was the question?

Complex ankle arthrodesis may be defined as an ankle fusion that is at high risk of delayed or non–union secondary to patient co–morbidities and/or local ankle and hindfoot factors. Complex ankle arthrodesis represents a challenge to the Orthopaedic Foot and Ankle surgeon, with a high reported major complication rates including delayed unions or non–unions. . Ilizarov external fixation and intramedullary arthrodesis nails are often used to achieve successful union in these cases. The purpose of this study was to determine: 1) If Tibiotalarcalcaneal (TTC) fusion nails are clinically equivalent to Circular external fixation with the Ilizarov method to achieve bony fusion in complex ankle fusions? 2) What are possible risk factors for nonunions in these patients? 3) What happens to the patients who have non–unions?

How did you answer the question?

We retrospectively reviewed 91 patients who underwent complex ankle fusions using the Ilizarov technique with circular external fixation from 1999 to 2008, as well as 37 patients who underwent complex ankle fusions using a Tibiotalarcalcaneal (TTC) fusion nail between 2016 and 2020 at our institution by our senior authors (AF, SRR). Patient demographics were recorded, including etiology of arthritis, Cierny–Mader Host type, significant co–morbidities including Diabetes mellitus, Charcot neuroarthropathy, peripheral vascular disease, and history of smoking, history of infection or presence of open wounds at time of index surgery. The primary outcome assessed was successful bony union at the fusion site. Secondary outcomes included time to union, AOFAS hindfoot scores, complications and need for revision surgery.

What are the results?

Fusion was achieved in 76/91 patients (78%) treated with a frame vs 33/37 patients (89%) treated with a TTC fusion nail. There was no significant difference between TTC fusion nails and frames for complex ankle arthrodesis in terms of union rate, time to union, need for revision surgery and complication rates, with different complication profiles noticed in each treatment group. There was significantly poorer union rates in both cohorts in smokers ($p < 0.001$) and patients with open wounds at time of index surgery ($p=0.001$). AOFAS scores were significantly worse with increasing patient age ($p=0.039$) and type B hosts ($p=0.022$).

What are your conclusions?

TTC fusion nails appear to be non–inferior to external fixation using the Ilizarov technique to achieve complex ankle arthrodesis, with each technique having their advantages and disadvantages.

Increased Posterior Tibial Slope Increases Difficulty for Suprapatellar Nailing

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What was the question?
Intramedullary nailing (IMN) with the suprapatellar approach (SP) has become a widely accepted method for treating tibial shaft fractures. However, radiographic patellofemoral variations including trochlear dysplasia have been linked to technical challenges. This study aimed to evaluate the association between preoperative radiographic knee measurements and the difficulty of obtaining an adequate nail starting point (NSP).

How did you answer the question?
A retrospective review of patients who underwent SP IMN for a tibial shaft fracture at an urban level 1 trauma center (10/2014–9/2018) was performed, and only cases with archived intraoperative fluoroscopic images were included. Adequate nail starting point (accuracy) and the number of images taken (difficulty) were evaluated. Radiographic measurements included tibial tuberosity – trochlear groove distance (TT–TG), sulcus angle (SA), Insall–Salvati ratio (IS), femoral joint angle (FJA), tibial joint angle (TJA), tibiofemoral angle (TFA) and posterior tibial slope (PTS). Chi–squared analysis, logistic regression analysis, and bivariate Pearson Correlation were performed to identify significant radiographic associations with accuracy and difficulty of obtaining an adequate NSP. Statistical significance was set at a level of 0.05.

What are the results?
Forty–two cases (19% female, 37.29±16.54 years) met inclusion criteria. 19 (45%), 14 (33%) and 9 (21%) were proximal, middle, and distal 1/3rd shaft fractures, respectively. Mean number of images taken during navigation to the NSP was 26.46±17.59 (adequate: n=34, mean images 24.36±15.01; not adequate: n=8, mean images 35.15±25.14). Radiographic measurements describing trochlear morphology (TT–TG, SA) and IS, FJA and TJA, showed no significant correlation with accuracy or difficulty. However, a higher PTS (14.17±5.04) correlated with increased fluoroscopic images taken, demonstrating increased difficulty with increasing PTS (r=0.361, p=0.02).

What are your conclusions?
Our study demonstrated no significant relationship between radiographic patellofemoral variations and technical difficulty in obtaining an adequate NSP with SP IMN. We postulate that increased PTS primarily interferes with the sagittal position of the correct NSP and creates an anatomic “barrier” to the anterior margin of the articular surface. Increased PTS is associated with increased difficulty in obtaining the correct NSP in SP IMN of tibial shaft fractures – careful preoperative evaluation and advances in surgical instrumentation and technique may help mitigate this surgical challenge.

Session X: Miscellaneous

Moderator: Mitchell Bernstein, MD

Correlation Between Femoral Neck Version, Sagittal Femoral Bowing Angle, and Sagittal Offset of the Femoral Head from the Distal Femur Axis in an Osteological Collection

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What was the question?

Radiographic analysis of lower limb alignment is crucial for the planning and evaluation of deformity correction. Assessment in the sagittal plane is often overlooked compared to the coronal plane due to decreased apparency of deformity when full length views are not obtained, challenges with limb positioning, and because coronal deformity has a higher contribution to outcome. Particularly, there is a lack of research regarding position of the femoral head in the sagittal plane in relation to axial plane measurements such as femoral neck version, and how sagittal femoral bowing angle (sFBA) may contribute.

How did you answer the question?

Twenty–five each of high (1–2 standard deviations above mean), normal (2.5 degrees below to 2.5 degrees above the mean), and low (1–2 standard deviations below the mean) version femurs were randomly selected from an osteological collection database, photographed, and measured for sagittal femoral bowing angle and sagittal offset of femoral head from the distal femur axis. Lines were drawn within the proximal and distal quartiles of the shaft to measure sagittal femoral bowing angle (Figure). The offset of the distal quartile line and the femoral head was also measured. High intra– and inter–observer correlations were established. The relationship between parameters was assessed using the Pearson coefficient (r).

What are the results?

Mean femoral neck version for high, normal, and low version femurs were 27.5 (95% confidence interval [CI]: 26.4–28.6), 12.4 (95% CI: 11.8–13.0), and –6.1 (95% CI: –7.1– –5.2) degrees, respectively. Mean sFBA for high, normal, and low version femurs were 11.4 (95% CI: 10.1–12.7), 11.7 (95% CI: 10.6–12.7), 12.0 (95% CI: 11.1–12.9) degrees, respectively. Means for sagittal offset of the femoral head from the distal femur axis were 15.3 (95% CI: 10.9–19.8), 24.2 (95% CI: 20.6–27.7), and 29.6 (95% CI: 26.6–32.5) mm. Sagittal offset of the femoral head from the distal femur axis was found to be highly correlated with sFBA (r=0.78), and only mildly with femoral neck version (r=0.52). sFBA and femoral neck version share no relationship (r=0.05).

What are your conclusions?

The lack of association between sagittal femoral bowing angle and femoral neck version, and mild association between sagittal femoral head offset and femoral neck version, supports the ability to separately analyze sagittal plane deformity and rotational deformity. The stronger association between sFBA and sagittal femoral head offset underscore the importance of full–length lateral radiographs, as imaging limited to the knee will not account for the effect of bowing on offset and limit the ability to properly plan the final sagittal mechanical axis of the lower extremity.

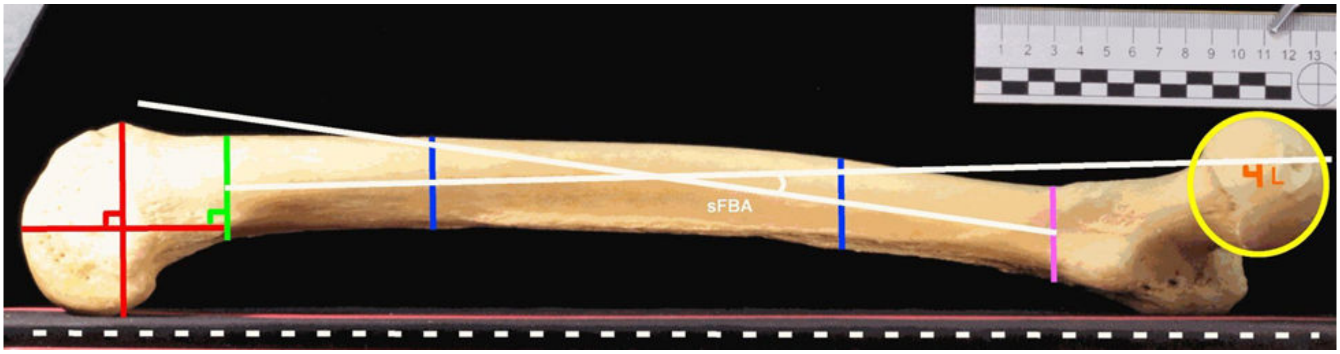

Figure: A lateral view of the femur is used to determine sFBA and sagittal offset of the femoral head from the distal femur axis (L). First, the position of the distal metaphysis-diaphysis transition line (shown in green) is determined to be one antero-posterior width of the femoral condyle away from the joint line (shown in red). Next, the position of the proximal metaphysis-diaphysis transition line (shown in magenta) is determined to be just inferior to the trochanter. The transition lines are then used to find the 25th and 75th quartile lines (shown in blue). Distal and proximal femur axes (shown as white continuous lines) are drawn to intersect midpoints of each quartile line. sFBA is the angle between these two axes. Lastly, the sagittal offset of the femoral head from the distal femur axis (L) is marked as the orthogonal line between the distal femur axis and center of the femoral head (shown in orange). The white dashed line is the horizontal plane in which all quartile lines are perpendicular to.

Survey of Adult Function after Blount Disease in Childhood: An Exercise in Futility?

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What was the question?

Few studies evaluate long–term (adult) function in patients treated for Blount disease. We sought to document radiographic and functional status of such patients 20–30 years after treatment.

How did you answer the question?

All patients operated at our institution for Blount disease between 1984–1995 with adequate records and radiographs were reviewed. We attempted to contact all eligible subjects for an IRB–approved call–back study over a 4–year period. Call–back investigation included health history, physical examination, clinical photographs, radiographs of the lower extremities, and patient–reported outcome measures (PRO's), including the Lysholm Knee Score, SF–12, and UCLA Activity Score.

What are the results?

106 patients with 164 affected extremities were eligible for call–back. 31 (29.2%) had a criminal record, 18 of sufficient gravity to preclude invitation to return. Of the remaining 88 patients, 40 (45.5%) could not be contacted despite an intensive 4–year effort. Of the 48 with valid contact information, 11 (22.9%) were reported as deceased, 20 (41.7%) did not respond or failed to show for assessment, and 1 declined to participate. 16 subjects (33.3% of those with valid contact information; 15.1% of the initial cohort) with 23 affected extremities returned 22–31 years post index surgery. These included 9 females and 7 males, 8 each with infantile and adolescent Blount disease, average age 36 years (range, 27–43). One subject was normal weight; one was overweight;14 were obese (body mass index (BMI) average 45.8, range 23.9–67.6). Mechanical axis deviation (MAD) ranged from –2 to 4. Patient–reported outcomes (PRO's) (Lysholm Knee Score; SF–12 Mental and Physical Function; Satisfaction with Life Scale) were completed in 15 subjects (1 with infantile Blount disease did not complete them). Physical Score correlated most strongly and inversely with BMI ($p<0.01$). Satisfaction with Life correlated strongly and inversely with MAD ($p=0.02$) and radiographic osteoarthritis of the knee (OA) ($p=0.02$), but not BMI. There were no statistically significant associations of MAD, BMI, or radiographic OA with Lysholm or mental scores. There also was no correlation between severity of radiographic OA and MAD ($p=0.46$) or BMI ($p=0.52$). There were no differences in PRO's based on gender or disease type (infantile or adolescent).

What are your conclusions?

There was a disproportionate rate of death in this cohort. BMI and severity of MAD were the most important determinants of patient reported outcomes, but did not predict corresponding radiographic severity of knee osteoarthritis. Contrary to previous long–term studies, worse radiographic and functional outcomes were not seen in infantile cases compared to adolescent cases in this small cohort.

Management of obesity and other socio–economic characteristics are likely the most important aspects of treatment of patients with Blount disease. Meaningful long–term functional studies of pediatric orthopedic conditions require registries and regular prospective longitudinal follow up into adulthood.

Table. Spearman's Correlation with Patient-Reported Outcome Measures (N=15*).

	Mechanical Axis Deviation (MAD)		**Knee Osteoarthritis**		**Body Mass Index (BMI)**	
	r	**P-value**	***r***	**P-value**	***r***	**P-value**
Lysholm Score	-0.11	0.70	-0.41	0.13	-0.39	0.15
SF-12 Physical Score	-0.39	0.15	-0.14	0.62	-0.80	**<0.01**
SF-12 Mental Score	0.173	0.54	-0.41	0.13	-0.05	0.86
Satisfaction with Life	-0.61	**0.02**	-0.61	**0.02**	-0.29	0.29

*Seven subjects with Infantile Blount's and eight with Adolescent Blount's.

Publications Rates of Abstracts presented at LLRS Annual Meetings

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What was the question?

Annual scientific meetings are intended in part to provide initial dissemination of research findings directly to meeting participants. However, eventual publication of research findings is important for dissemination to the broader medical and scientific communities. Many orthopaedic subspecialty societies have reported eventual publication rates from their convened annual meetings which range from 43% (North American Spine Society, NASS) to 55% (Orthopaedic Research Society, ORS). The Limb Lengthening and Reconstruction Society (LLRS) annual meetings show case important research and case studies in the field of limb reconstruction pertinent to an international community of surgeons. The purpose of this analysis is to determine the publications rates of abstracts from LLRS annual meetings.

How did you answer the question?

Annual meeting programs from the 24th and 26th LLRS annual meetings from 2014 and 2016, respectively, were cataloged. Listed abstract titles and authors were then queried in PubMed to determine if a corresponding work was published in an indexed journal up to December of 2021. Year of publication was noted for papers determined to correspond to a presented abstract.

What are the results?

In 2014, 52 abstracts were presented at the 24th LLRS annual meeting. Twenty–nine (56%) went on to publication. In 2016, 47 abstracts were presented at the 26th LLRS annual meeting. Twenty–seven (57%) went on to publication. The year of the annual meeting to the year of publication was on average 1.7 years. Ten publications (10%) between the years were published in the same year as the meeting; however, two abstracts from 2016 seemed to correspond to a publication from years prior to the meeting. The longest time to publication was six years following the presented annual meeting.

What are your conclusions?

The LLRS annual meeting abstracts lead to a corresponding publication at rates rivaling, if not exceeding, other orthopaedic subspecialty societies. This suggests in part that the LLRS annual meeting features high quality research worthy of peer reviewed publication. However, there are opportunities to improve these rates by continuing to promote the LLRS partnering journals, The Journal of Limb Lengthening and Reconstruction and Strategies in Trauma and Limb Reconstruction. On going searches are including subsequent years of annual meetings and searches specific to the LLRS supported journals.

Ipsilateral Healthy Segment Response to Leg Length Discrepancy

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What was the question?

Adaptation to angular deformity in one segment of the leg is commonly identified in the healthy adjacent segment, for example, the development of partially–compensating distal femoral valgus in patients with infantile Blount Disease. What appears to be much less documented is how a healthy segment adapts to concomitant shortening in an ipsilateral affected segment. We have previously reported modest femoral overgrowth (averaging 0.5 cm) in patients with unilateral infantile Blount Disease, and an aggravating femoral shortening in patients with adolescent Blount Disease. We sought to identify if and to what extent, healthy ipsilateral leg segments responded to affected segment shortening in a variety of pediatric disorders.

How did you answer the question?

From an extensive database of patients with leg–length discrepancy (LLD) treated by epiphysiodesis, we identified subjects with a known diagnosis affecting one lower extremity segment only (femur or tibia) and adequate radiographs (scanograms) prior to any treatment related to the LLD. We documented the etiology of affected segment growth disturbance; the age of the subject at radiographic assessment; the interval between that assessment and onset of the disorder (where possible); and measured all four lower extremity segments independently. We then compared the affected–side healthy segment length to the contralateral. We deemed ipsilateral healthy segment overgrowth or shortening of ≥ 0.5 cm. as clinically significant.

What are the results?

260 patients met inclusion criteria, including 154 boys and 106 girls. The average age at radiographic analysis was 11.9 years. The etiology of segment shortening was AVN of the hip in 60; Legg–Perthes disease in 30, congenital pseudarthrosis variant in 51, physeal trauma in 77, and posteromedial bow in 42. With the exception of congenital pseudarthrosis of the tibia variants, ipsilateral healthy segment shortening was more common than overgrowth (Table), typically of modest magnitude. Notable findings included mild ipsilateral tibia shortening (0.7 ± 0.8 cm) in 11/30 (37%) patients with Legg–Perthes disease, and no cases of ipsilateral tibial overgrowth; modest femoral shortening in patients with posteromedial bow of the tibia (10/42 (24%), 0.8 ± 0.7 cm) with less common ipsilateral femoral overgrowth (6/42 (14%), 0.8 ± 0.4 cm); and variable ipsilateral healthy segment response after physeal trauma: (21/77 (27%) with shortening, and 13/77 (17%) with overgrowth of modest degree (range, 0.5–1.9 cm). In congenital pseudarthrosis of the tibia, 16/51 patients (31%) demonstrated ipsilateral femoral overgrowth averaging 1.2 cm. (range, 0.5–2.5 cm), while 11/51 (22%) had mild ipsilateral shortening averaging 0.9 cm. (range, 0.5–3.2 cm).

What are your conclusions?

While there are individual exceptions, on average the healthy segment of unilateral single–segment disorders causing leg length discrepancy does not grow appreciably more than the contralateral to compensate for leg length discrepancy in patients with AVN of the hip, Legg–Perthes disease or isolated physeal trauma. The femur is not a significant component of shortening in patients with congenital posteromedial bowing of the tibia. Approximately one–third of patients with congenital pseudarthrosis of the tibia variants did demonstrate modest ipsilateral femoral overgrowth.

Table. Ipsilateral Healthy Segment Response to Shortening, by Diagnosis/Location.

Diagnosis (#)	**Ipsilateral Healthy Segment Response**				
	Healthy Segment	**Shortening ≥ 0.5 cm**		**Overgrowth ≥ 0.5 cm**	
		#/%	Average (range) (cm)	#/%	Average (range) (cm)
AVN of the hip (60)	Tibia	16 (27%)	1.2 ± 0.8 (0.5-3.2)	6 (10%)	0.6 ± 0.2 (0.5-0.9)
Legg-Perthes Disease (30)	Tibia	11 (37%)	0.7 ± 0.8 (0.6-2.2)	None	n/a
Congenital Pseudarthrosis of the tibia variants (51)	Femur	11(22%)	0.9 ± 0.8 (0.5-3.2)	16 (31%)	1.2 ± 0.6 (0.5 - 2.5)
Posteromedial bowing of the tibia (42)	Femur	10 (24%)	0.8 ± 0.7 (0.5-2.3)	6 (14%)	0.8 ± 0.4 (0.5-1.3)
Physeal trauma, femur (48)	Tibia	13 (27%)	1.2 ± 1.0 (0.5-3.7)	6(13%)	0.8 ± 0.2 (0.5-1.1)
Physeal trauma, tibia (29)	Femur	8 (28%)	1.1 ± 0.6 (0.5-2.3)	7 (24%)	0.7 ± 0.5 (0.5-1.9)