30th Annual Scientific Meeting

Limb Lengthening and Reconstruction Society:

ASAMI–North America

July 16 & 17, 2021

www.llrs.org

LLRS: ASAMI–North America

Future Meetings

AAOS Specialty Day

March 26, 2022

Chicago, IL

31st Annual Scientific Meeting

July 15 & 16, 2022

Hilton Portland Downtown

Portland, OR

Upcoming AAOS Meeting

2022 Annual Meeting

March 22–26, 2021

Chicago, IL

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

Limb Lengthening and Reconstruction Society

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

First Vice President and Program Chair

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

Program Committee

Raymond W. Liu, MD

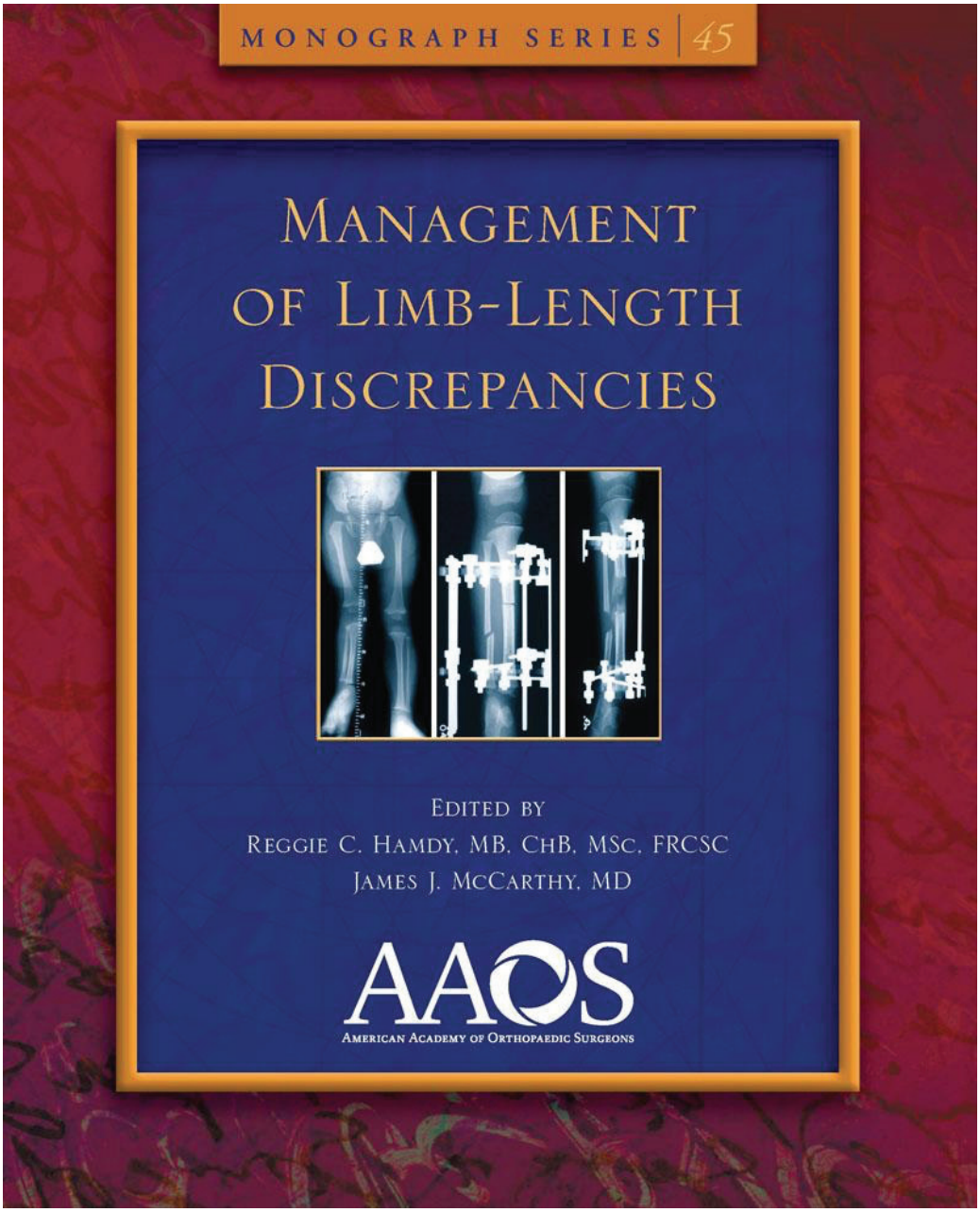
Austin T. Fragomen, MD

L. Reid Nichols, MD

Karen R. Syzdek, Executive Director

Management of Limb–Length Discrepancies

Reggie Hamdy and Jim McCarthy (Eds.)



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https://www.wolterskluwer.com/en/solutions/ovid/14440

Pediatric Lower Limb Deformities

and

Limb Lengthening and Reconstruction Surgery Case Atlas Series

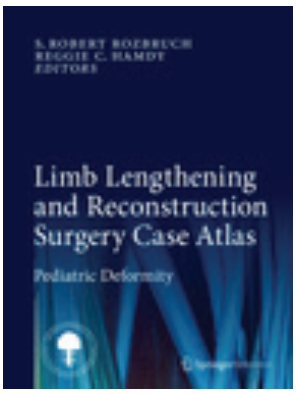
Pediatric Lower Limb Deformities

Sanjeev Sabharwal (Ed.)

Pediatric Deformity

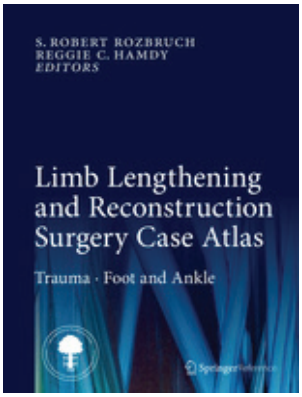
S. Robert Rozbruch and

Reggie C. Hamdy (Eds.)



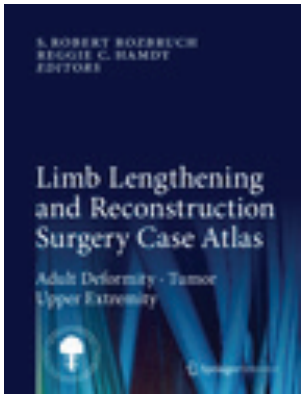
Trauma • Foot and Ankle

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



Adult Deformity • Tumor
Upper Extremity

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



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Limb Lengthening and Reconstruction Society

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

Please join us!

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Portland, OR

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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

2019–2021 Officers and Executive Board

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Kevin W. Louie, MD, Chair
J. Spence Reid, MD

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David Frumberg, MD

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J. Spence Reid, MD

Traveling Fellowship Chair
Jaclyn F. Hill, MD

Limb Lengthening and Reconstruction Society

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

30th Annual Scientific Meeting

Objectives

Upon completion of LLRS's 30th 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 30th 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 30th Annual Scientific Meeting may not have received the approval of the appropriate federal authority, LLRS supports the use of techniques with the requisite government approval only.

Faculty Disclosure

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

Limb Lengthening and Reconstruction Society

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

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Thank you for the In–kind Donation

Baltimore Limb Deformity Course

Limb Lengthening and Reconstruction Society

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

Exhibitors

(listed in alphabetical order)

The LLRS thanks the following entities for their generous support.

LIFEBRIDGE HEALTH
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; www.deformitycourse.com

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.

bodycad Bodycad is on a mission to revolutionize the world of orthopedics with proprietary software and orthopaedic solutions designed to consider each person's unique anatomy. With surgeon-based planning capabilities, Bodycad realizes endless possibilities for surgeons to provide patients with the best possible care. Quebec City, Canada.

BONESUPPORT™ BONESUPPORT develops and markets CERAMENT®, an innovative range of radiopaque injectable osteoconductive and drug–eluting bioceramic products that have a proven ability to heal defects by remodeling to host bone in six to twelve months. CERAMENT® BONE VOID FILLER and the CERAMENT BEAD TRAY are commercially available in the US.

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.

DePuy Synthes Companies, part of the Medical Devices & Diagnostics (MD&D) segment of Johnson & Johnson, offers an uparalleled 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.

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The Precice System consists of a novel adjustable state–of–the–art intramedullary device that utilizes a remote control for non–invasive limb lengthening, fracture fixation and bone transport.

Orthofix is a diversified, global medical device company focused on developing and delivering innovative repair and regenerative solutions to the spine and orthopedic markets. 469–742–2500; 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.

For the surgeon's 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. www.smith–nephew.com; 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.

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 6, 2021**. *Your responses are needed for CME credit to be valid.*

https://www.surveymonkey.com/r/LLRS2021

Limb Lengthening and Reconstruction Society

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

Continuing Medical Education

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

The American Academy of Orthopaedic Surgeons designates this live activity for a maximum of 9.5 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!

31st Annual Scientific Meeting

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Hilton Portland Downtown

Portland, OR

Please complete the evaluation online at

https://www.surveymonkey.com/r/LLRS2021

on or before **August 6, 2021**.

Limb Lengthening and Reconstruction Society

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

Disclosures

Planning Committee

Austin Thomas Fragomen, MD, FAAOS (New York, NY)
Submitted on: 04/06/2021
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant; Paid presenter or speaker
Smith & Nephew: Paid consultant; Paid presenter or speaker
Synthes: Paid consultant; Paid presenter or speaker

Raymond W Liu, MD, FAAOS (Cleveland, OH)
Submitted on: 04/27/2021
AAOS: Board or committee member
American Academy of Pediatrics, Orthopaedic Subsection: Board or committee member
Journal of Pediatric Orthopedics: Editorial or governing board
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: 06/03/2021
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

Karen R Syzdek (Austin, TX) - STAFF
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Faculty

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Muhammad Adeel Akhtar, MD (United Kingdom)
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Shane Ahern (Ireland)
(This individual reported nothing to disclose); Submitted on: 04/26/2021

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(This individual reported nothing to disclose); Submitted on: 04/01/2021

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(This individual reported nothing to disclose); Submitted on: 06/03/2021

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Submitted on: 06/04/2021
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

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(This individual reported nothing to disclose); Submitted on: 06/09/2021

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(This individual reported nothing to disclose); Submitted on: 04/05/2021

Anirejuoritse Bafor, FACS, MD
Submitted on: 04/27/2021
Bayer: Research support
Morison industries: Research support

Gonzalo F Bastias, MD (Chile)
(This individual reported nothing to disclose); Submitted on: 03/27/2021

Douglas N Beaman, MD, FAAOS
Submitted on: 04/07/2021
Limb Lengthening and Reconstruction Society: Board or committee member

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Submitted on: 06/03/2021
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant
Orthofix, Inc.: Paid consultant
Smith & Nephew: Paid consultant

Pablo Ignacio Besser Sr
(This individual reported nothing to disclose); Submitted on: 03/27/2021

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Submitted on: 03/31/2021
American Academy for Cerebral Palsy and Developmental Medicine: Board or committee member
Journal of Children's Orthopaedics: Editorial or governing board
Journal of Pediatric Orthopedics: Editorial or governing board
Pediatric Orthopaedic Society of North America: Board or committee member

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(This individual reported nothing to disclose); Submitted on: 03/31/2021

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(This individual reported nothing to disclose); Submitted on: 04/27/2021

Isabella Bozzo
(This individual reported nothing to disclose); Submitted on: 04/01/2021

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(This individual reported nothing to disclose); Submitted on: 06/03/2021

Emily Canitia, NP (Cleveland, OH)
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Angel Chen (Novato, CA)
Submitted on: 06/03/2021
Ultragenyx: Employee; Stock or stock Options

Alexander Cherkashin, MD (Dallas, TX)
Submitted on: 04/12/2021
Orthofix, Inc.: IP royalties; Paid consultant

Harpreet Chhina, MSc (Canada)
(This individual reported nothing to disclose); Submitted on: 04/01/2021

Elizabeth Cho, BA (Cleveland Heights, OH)
(This individual reported nothing to disclose); Submitted on: 04/26/2021

Milind Madhav Chaudhary, MS (India)
Submitted on: 06/08/2021
Wolters Kluwer Health - Lippincott Williams & Wilkins: Editorial or governing board

Anthony Cooper, FRCS (Ortho) (Canada)
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Canadian Orthopaedic Association: Board or committee member
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: 04/26/2021

Jason Philip Aaron Corban, MD (Canada)
(This individual reported nothing to disclose); Submitted on: 06/03/2021

Mark T Dahl, MD, FAAOS (Minneapolis, MN)
Submitted on: 06/04/2021
Nuvasive: Paid consultant
Stryker: IP royalties; Paid consultant

Felipe Gonzalo Diaz Sr
(This individual reported nothing to disclose); Submitted on: 03/27/2021

ANDRONIKI DRAKOU, MS (Orth), MSc
(This individual reported nothing to disclose); Submitted on: 06/08/2021

Scott Douglas, MD
(This individual reported nothing to disclose); Submitted on: 03/29/2021

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(This individual reported nothing to disclose); Submitted on: 04/26/2021

David S Feldman, MD, FAAOS (West Palm Beach, FL)
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orthopediatrics: IP royalties; Paid consultant

Jill C Flanagan, MD, FAAOS (Atlanta, GA)
Submitted on: 04/27/2021
AAOS: Board or committee member
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant
Orthofix, Inc.: Paid consultant

Jonathan A Forsberg, MD, PhD, FAAOS (Washington, DC)
Submitted on: 04/26/2021
Prognostix AB: Stock or stock Options
Solsidan Group, LLC: Employee; Paid consultant
Zimmer: Unpaid consultant

Austin Thomas Fragomen, MD, FAAOS (New York, NY)
Submitted on: 04/06/2021
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant; Paid presenter or speaker
Smith & Nephew: Paid consultant; Paid presenter or speaker
Synthes: Paid consultant; Paid presenter or speaker

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

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American Academy for Cerebral Palsy and Developmental Medicine: Board or committee member
Limb Lengthening and Reconstruction Society: Board or committee member
Orthofix, Inc.: Paid consultant
Orthopediatrics: Paid consultant
Ultragenyx: Paid consultant

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Nicholas Patrick Gannon, MD (Minneapolis, MN)
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Susan Mengxiao Ge, MD
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Mina Gerges, BA
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Martin G Gesheff, MS (Baltimore, MD)
(This individual reported nothing to disclose); Submitted on: 03/29/2021

Roy Gigi, MD
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Orthopaedic Research Society: Board or committee member

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Luis Flavio Goncalves, MD
(This individual reported nothing to disclose); Submitted on: 03/31/2021

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Globus Medical: Paid consultant
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Yajing Hao
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Biocomposites: Other financial or material support
Bonus BioGroup: Paid consultant
DePuy Synthes: Other financial or material support
MHE Coalition: Other financial or material support
Nuvasive: Paid consultant
Orthofix, Inc.: Other financial or material support; Paid consultant
OrthoPediatrics: Other financial or material support; Paid consultant
OrthoSpin: Paid consultant
Pega Medical: Other financial or material support
Smith & Nephew: Other financial or material support; Paid consultant
Stryker: Other financial or material support
WishBone Medical: Paid consultant
Zimmer Biomet: Other financial or material support

Jason Shih Hoellwarth, MD
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Aaron Huser, DO
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Christopher August Iobst, MD, FAAOS (Columbus, OH)
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Nuvasive: Paid consultant
Orthofix, Inc.: Paid consultant
Smith & Nephew: Paid presenter or speaker

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(This individual reported nothing to disclose); Submitted on: 06/06/2021

Kayla M Jaime
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Synthes: Paid consultant

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Meghan Kelly, MD (New York, NY)
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American Orthopaedic Foot and Ankle Society: Board or committee member

Anne Klassen, PhD (Canada)
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Derrick Knapik, MD
(This individual reported nothing to disclose); Submitted on: 06/03/2021

Søren Kold, MD, PhD (Denmark)
Submitted on: 04/26/2021
Limb Lengthening and Reconstruction Society of the Nordic Countries: Board or committee member

Jacek Kopec, MD, MSc, PhD (Canada)
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Richard W Kruse, DO, FAAOS (Wilmington, DE)
Submitted on: 06/04/2021
AAOS: Board or committee member
Clinical education Medical Advisory Board: Board or committee member
orthopaediatrics: Paid consultant
osteogenesis imperfecta foundation: Board or committee member
Pediatric Orthopaedic Society of North America: Board or committee member

Andy Kuo
(This individual reported nothing to disclose); Submitted on: 04/26/2021

Omolade Ayoola Lasebikan, MBChB, MD, MPH (Nigeria)
(This individual reported nothing to disclose); Submitted on: 06/07/2021

Gillian Lauder, MBChB
(This individual reported nothing to disclose); Submitted on: 03/04/2021

Carl Laverdiere
(This individual reported nothing to disclose); Submitted on: 06/03/2021

Don Li, MS
(This individual reported nothing to disclose); Submitted on: 04/26/202

Jane Li (United Kingdom)
(This individual reported nothing to disclose); Submitted on: 04/01/2021

Feng-Chang Lin, MD (Chapel Hill, NC)
(This individual reported nothing to disclose); Submitted on: 06/03/2013

Raymond W Liu, MD, FAAOS (Cleveland, OH)
Submitted on: 04/27/2021
AAOS: Board or committee member
American Academy of Pediatrics, Orthopaedic Subsection: Board or committee member
Journal of Pediatric Orthopedics: Editorial or governing board
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

Gregory A Lundeen, MD, FAAOS (Reno, NV)
Submitted on: 06/04/2021
DJ Orthopaedics: Paid consultant
Foot and Ankle International: Editorial or governing board
OIC: Stock or stock Options
ROC Foundation: Board or committee member
Smith & Nephew: Other financial or material support
Stryker: Paid consultant; Paid presenter or speaker; Research support
Techniques in foot and ankle surgery: Editorial or governing board
Tissuetech: Research 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 16, 2021

7:15 a.m.	Registration Opens
7:15–8:00 a.m.	Continental Breakfast – **Visit Corporate Partners**
8:00–8:05 a.m.	Welcome/Introduction/Disclosure

Session I: Internal Lengthening Nails I
Moderator: Kevin Louie, MD

8:05–8:11 a.m.	Radiographs of 366 Removed Limb Lengthening Nails Reveal Differences in Bone Abnormalities Between Different Nail Types *Christopher A. Iobst. MD*
8:12–8:18 a.m.	Radiographic Changes following Lengthening with Nail *Aaron Huser, DO*
8:19–8:25 a.m.	Biopsy Confirmed Focal Osteolysis in a Stainless–Steel Lengthening Device* – *Philip K. McClure, MD*
8:26–8:32 a.m.	Clinical Compatibility of Magnetic Resonance Imaging with Magnetic Intramedullary Nails* – *Lee Zuckerman, MD*
8:33–8:41 a.m.	Discussion

Session II: Internal Lengthening Nails II
Moderator: J. Spence Reid, MD

8:42–8:48 a.m.	Complications in Elective Removal of 271 Bone Lengthening Nails *Christopher A. Iobst. MD*
8:49–8:55 a.m.	Intramedullary Distraction Osteogenesis followed by Osseointegration for Amputees with Short Residual Femurs *Jason Shih Hoellwarth, MD*
8:56–9:02 a.m.	The Incidence and Management of Deep Vein Thrombosis and Pulmonary Embolism following Cosmetic Stature Lengthening with Steel Weightbearing Intramedullary Nails *Jason Shih Hoellwarth, MD*
9:03–9:09 a.m.	Implantable Nail Lengthening in Patients with Enchondromastosis *Aaron Huser, DO*
9:10–9:18 a.m.	Discussion

**indicates remote presentation*

Session III: Osseointegration
Moderator: S. Robert Rozbruch, MD

9:19–9:25 a.m.	Osseointegration following Lower Limb Amputation due to Malignant Cancer – *Jason Shih Hoellwarth, MD*
9:26–9:32 a.m.	Transtibial Osseointegration Confers Mobility Benefits with Limited Complications* – *Munjed Al Muderis, MB, ChB*
9:33–9:39 a.m.	Osseointegration for Transfemoral Amputees with prior Total Knee Arthroplasty Complications* – *Kevin Tetsworth, MD*
9:40–9:47 a.m.	Discussion
9:48–10:14 a.m.	Refreshment Break – **Visit Corporate Partners**

Session IV: Pediatrics I
Moderator: David Frumberg, MD

10:15–10:21 a.m.	Burosumab Improves Lower Limb Alignment in Children with X–Linked Hypophosphatemia – *David Frumberg, MD*
10:22–10:28 a.m.	Multicenter Series of Deformity Correction using Guided Growth in the Setting of Osteogenesis Imperfecta – *Jeanne M. Franzone, MD*
10:29–10:35 a.m.	What are the Risk Factors for Rebound Deformity after Correction of Lower Extremity Valgus deformities using Tension Band Plates in Skeletal Dysplasia? – *Armagan Can Ulusaloglu*
10:36–10:42 a.m.	Prediction Matrix for Radial Head Subluxation/Dislocation in Patients with Multiple Hereditary Exostosis – *Aaron Huser, DO*
10:43–10:51 a.m.	Discussion

Session V: Basic Science
Moderator: Jessica C. Rivera, MD, PhD

10:52–10:58 a.m.	An Ovine Study of Locked Intramedullary Implants Across the Distal Femoral Growth Plate – *Kouami Amakoutou, MD*
10:59–11:05 a.m.	Can Manipulation of the Mechanical Environment Improve Regenerate Bone Healing During the Consolidation Phase of Distraction Osteogenesis? *Christopher A. Iobst, MD*
11:06–11:12 a.m.	To Minimize Biological (Thermal) Damage during Cortical Bone Drilling – an Experimental Parameters for Optimal Bone Drilling *Hla Moe Thaya, MD*
11:13–11:19 a.m.	Can the Expression of Interleukin–6 by the Local Lymphocytes be Used as a Biomarker for Fracture Healing? – A Pilot Study and Ongoing Practice* *Androniki Drakou, MD*

**indicates remote presentation*

11:20–11:28 a.m. Discussion

Special Session: Limb Deformity Care in Low and Middle Income Countries
Moderator: Raymond W. Liu, MD

11:29–11:35 a.m. Building a Limb Deformity Practice in Nigeria*
Emeka Izuagba, MD

11:36–11:42 a.m. LLRS Efforts to Improve International Care – *Raymond W. Liu, MD*

11:43–11:49 a.m. Pediatric Orthopaedic Observerships in North America for International Surgeons: Perceived Barriers and Opportunities for Visitors and Hosts
Sanjeev Sabharwal, MD

11:50 a.m.–12:00 p.m. Fostering Limb Deformity Care with the SIGN Network*
Richard Gellman, MD

12:01–12:10 p.m. Discussion

12:10–1:05 p.m. Lunch

Session VI: Patient Reported Outcomes
Moderator: Harold van Bosse, MD

1:06–1:12 p.m. Concurrent Validity of DASH and PROMIS Scores in Transhumeral Amputees – *Samir Sabharwal, MD*

1:13–1:19 p.m. Concurrent Validity of Q–TFA with PROMIS & Prosthetic Wear Time in Transfemoral Amputees – *Samir Sabharwal, MD*

1:20–1:26 p.m. Functional Outcomes in the Treatment of Fibula Hemimelia –
The 5–year Experience of a Regional Children's Hospital*
Njalalle Baraza, MD

1:27–1:33 p.m. Establishing the Content Validity of LIMB–Q Kids – A New Patient–Reported Outcome Measure for Children with Lower Limb Deformities*
Harpreet Chhina, PhD

1:34–1:40 p.m. Prospective Multi–Center Comparison of Modified Scoliosis Instruments and PODCI in Pediatric Limb Deformity Patients: A Preliminary Study
Raymond W. Liu, MD

1:41–1:50 p.m. Discussion

1:51–2:40 p.m. Difficult Case Presentation
Moderator: L. Reid Nichols, MD

2:41–3:05 p.m. Refreshment Break – **Visit Corporate Partners**

**indicates remote presentation*

Session VII: Pediatrics II
Moderator: David Podeszwa, MD

3:06–3:12 p.m.	3D–Printed Cutting Guides for Lower Limb Deformity Correction in the Young Population – *Roy Gigi, MD*
3:13–3:19 p.m.	Magnetic Internal Plate Lengthening of the Femur and Tibia in Children: A Preliminary Report – *Mark T. Dahl, MD*
3:20–3:26 p.m.	Systematic Isolation of Key Parameters for Estimating Skeletal Maturity on AP Hip Radiographs – *Ryan J. Furdock, MD*
3:27–3:33 p.m.	The Utility of the Modified Fels Knee Skeletal Maturity System in Limb Length Prediction – *Ryan J. Furdock, MD*
3:34–3:40 p.m.	Clinical Outcomes Following Surgical Hip Dislocation for Paediatric Hip Pathologies: A Prospective Cohort Study* – *Shane Ahern, MD*
3:41–3:51 p.m.	Discussion
3:52–4:02 p.m.	Traveling Fellowship Presentation Introduction by Austin T. Fragomen, MD *Dr. Omolade Lasebikan* *Sarah Nossov, MD* *Daniel Stinner, MD*
4:03–4:45 p.m.	Business Meeting – **LLRS Members only**
5:30 p.m.	Buses depart for President's Reception
6:30–9:30 p.m.	President's Reception aboard Atlantis
9:45 p.m.	Buses depart for Hotel

Saturday – July 17, 2021

7:30 a.m.	Registration Opens
7:30–8:00 a.m.	Continental Breakfast – **Visit Corporate Partners**
8:00–8:05 a.m.	Announcements

Session VIII: Adult Deformity
Moderator: Stephen M. Quinnan, MD

8:06–8:12 a.m.	Hexapod Circular External Fixators may Produce Superior Regenerate Bone, A Lower BHI, and Less Post Residual Deformity when Compared with Classic Circular Fixators When Used for Bone Transport or Lengthening Through Malunions *Austin T. Fragomen, MD*
8:13–8:19 a.m.	Indications and Outcomes of One Staged Two–Level Femur Osteotomies – *Joshua Buksbaum*
8:20–8:26 a.m.	Correction of Extra–articular Limb Deformity Before Total Knee Arthroplasty – *Stephen Wallace, MD*
8:27–8:33 a.m.	Dual Femoral and Tibial Osteotomies for Large Lower Extremity Deformities – *Stephen Wallace, MD*
8:34–8:42 a.m.	Discussion
8:43–9:45 a.m.	Presidential Guest Speaker* **Horses for Courses: Choosing the Right Osteotomy for OA Knee** *Milind M. Chardhary, MD*
9:45–10:00 a.m.	Refreshment Break – **Visit Corporate Partners**
10:01–10:30 a.m.	Poster Session – please visit each poster

Session IX: Foot/Ankle and Trauma
Moderator: Douglas Beaman, MD

10:31–10:37 a.m.	Augmentation of Internal Fixation with Multiplanar External Fixator in High–Risk Hind Foot Fusion Patients – *Meghan Kelly, MD*
10:38–10:44 a.m.	Reconstruction of Severe Tibia Pilon Fractures Using Distraction Histiogenesis – *Roberto Hernandez–Irizarry, MD*
10:45–10:51 a.m.	Unconstrained External Fixation Hinges in Joint Repair: Initial Clinical Experience – *Alexander Cherkashin, MD*
10:52–10:58 a.m.	Long–Term Self–Reported Functional Outcomes following Unilateral Major Lower Extremity Combat Injury: Preliminary Results from the METALS II Study Group – *Jessica C. Rivera, MD, PhD*

10:59–11:07 a.m.	Discussion

Session X: Miscellaneous
Moderator: Jill C. Flanagan, MD

11:08–11:14 a.m.	Prophylaxis and Treatment of Infection in Complex Extremity Reconstruction using Antibiotic Loaded Ceramic Coated Interlocking Intramedullary Nails – *Emilie–Ann Downey, MD*
11:15–11:21 a.m.	Preventative Multimodal Analgesia for Patients Undergoing Lower Limb Reconstruction with External Fixators; A Prospective Study of Postoperative Pain* – *Alice Wang, MD*
11:22–11:28 a.m.	A Novel Formula to Accurately Predict the Change in Tibial–Tuberosity to Trochlear–Groove (TTTG) Distance Following Supratubercle Osteotomy of the Tibia* – *Isabella Bozzo, MDCM (c), M. Eng*
11:29–11:35 a.m.	Applications and Error Ratios of Calibration Techniques in EOS and Teleoroentgenogram for Length Measurement: A Comparative Study *Ali Asma, MD*
11:36–11:44 a.m.	Discussion
11:45 a.m.–12:10 p.m.	President's Remarks and Introduction of 2021–2022 President
12:10 p.m.	Adjourn

Radiographs of 366 Removed Limb Lengthening Nails Reveal Differences in Bone Abnormalities Between Different Nail Types

Christopher A. Iobst, MD; Markus Winther Frost; Soren Kold; Jan Rolfing; Ole Rahbek; Anirejuoritse Bafor; Molly Duncan
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What was the question?
Limb lengthening using internal lengthening nails has become increasingly popular. However, recently the adverse events and high frequencies of radiographic changes noted with the [redacted] lengthening nail have raised concerns about the use of internal lengthening nails. Therefore, the aim was to compare the prevalence of radiographic bone abnormalities between [redacted], [redacted] and [redacted] nails prior to nail removal.

How did you answer the question?
This study was performed as retrospective case series from three centers. Patients were included if they had either of the three limb lengthening nails removed. Standard orthogonal radiographs immediately prior to nail removal were examined for bone abnormalities at the junction of the telescoping nail ends, at the sites of interlocking screws/pegs and at the blocking screw sites.

What are the results?
In total, 306 patients (138 females) had 366 limb lengthening nails removed. The mean (SD, min–max range) from nail insertion to radiographic evaluation was for 434 days (SD 381, 36 – 3015 days). 77% (20/26) [redacted] nails had bone abnormalities at the interface compared with only 2% (4/242) of [redacted] and 1% (1/98) of [redacted] nails ($P<0.0001$). In addition, the extent of bone abnormalities were more pronounced in the [redacted] nails compared with the other nails. The bone reaction around the interlocking screws/pegs occurred at the interlocking screw/peg in the thin part of the nail. The reaction was mainly cortical hypertrophy and the frequency of bone reaction at the interlocking screw/peg was significantly higher for the [redacted] nail ($p<0.05$). In multiple cases bony overgrowth covering the interlocking screws/pegs were noticed. No bone abnormalities related to blocking screws were observed.

What are your conclusions?
Bone abnormalities at the interface of telescoping nail parts were seen in the majority of [redacted] nails, but only very rarely with [redacted] or [redacted] nails. Of clinical relevance, the low prevalence of radiographic changes at the junctional interface of 242 evaluated [redacted] and 98 evaluated [redacted] nails at the time of nail removal does not seem to warrant clinical concerns.

Radiographic Changes following Lengthening with Nail

Aaron J. Huser, DO; Craig Robbins; Jason Hoellwarth; Dror Paley
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What was the question?
What are the radiographic changes seen in the bone after lengthening with nail?

How did you answer the question?
A retrospective chart and radiographic review was performed on all patients who underwent limb lengthening at our institution from May 2018 to June of 2020. Patients were included if they had undergone limb lengthening with a nail and had >6 month followup. Demographic and clinical data was obtained from the medical record. Radiographs were reviewed from their preoperative appointment through consolidation and following nail removal if available. Specific attention was paid to the locking screw sites, the lengthening site and the nail junction; changes were classified as hypertrophic, lytic and mixed. Additional data evaluated included length achieved and nail parameters such as length and size.

What are the results?
141 patients with 252 limb segments were lengthened with the nail at our institution and 122 limb segments had >6 month followup within our system for analysis. 74 segments were stature lengthening, 19 segments had a congenital limb deficiency diagnosis, 8 segments had acquired limb length discrepancies from trauma or infection and 21 segments had a diagnosis classified as other (polio, skeletal dysplasia, etc.). 87 of the segments were femurs and 35 were tibias. 78/122 segments had radiographic changes. 49 (40%) segments demonstrated hypertrophy, 3 (2%) segments demonstrated lysis and 26 (21%) segments had both lysis and hypertrophy. The average time from surgery to lytic findings (either combination or pure lysis) was 1 year (range 6mo – 2 years.) In stature cases, bilateral limb segments, 59/74 segments demonstrated some sort of radiographic change and made up 75% of all the cases with radiographic changes.

What are your conclusions?
This radiographic review was one of the data points for the decision to voluntarily recall the nail. Our radiographic data along with examination of a few post–removal nails leads us to believe this is a wear phenomenon. The changes at the junction, in our series, start to appear after lengthening is finished. We believe that during the consolidation period, the nail junction is no longer telescoping and micromotion at this single site causes wear of the Biodur. Most interestingly, is the preponderance of findings in the stature patients. These patients are undergoing bilateral, simultaneous lengthenings and we hypothesize that these patients likely cycle through their nail with more force then the unilateral lengthenings (as they have a limb that was not operated on and can bear a greater amount of the weight), and that is why we see the majority of changes in this population.

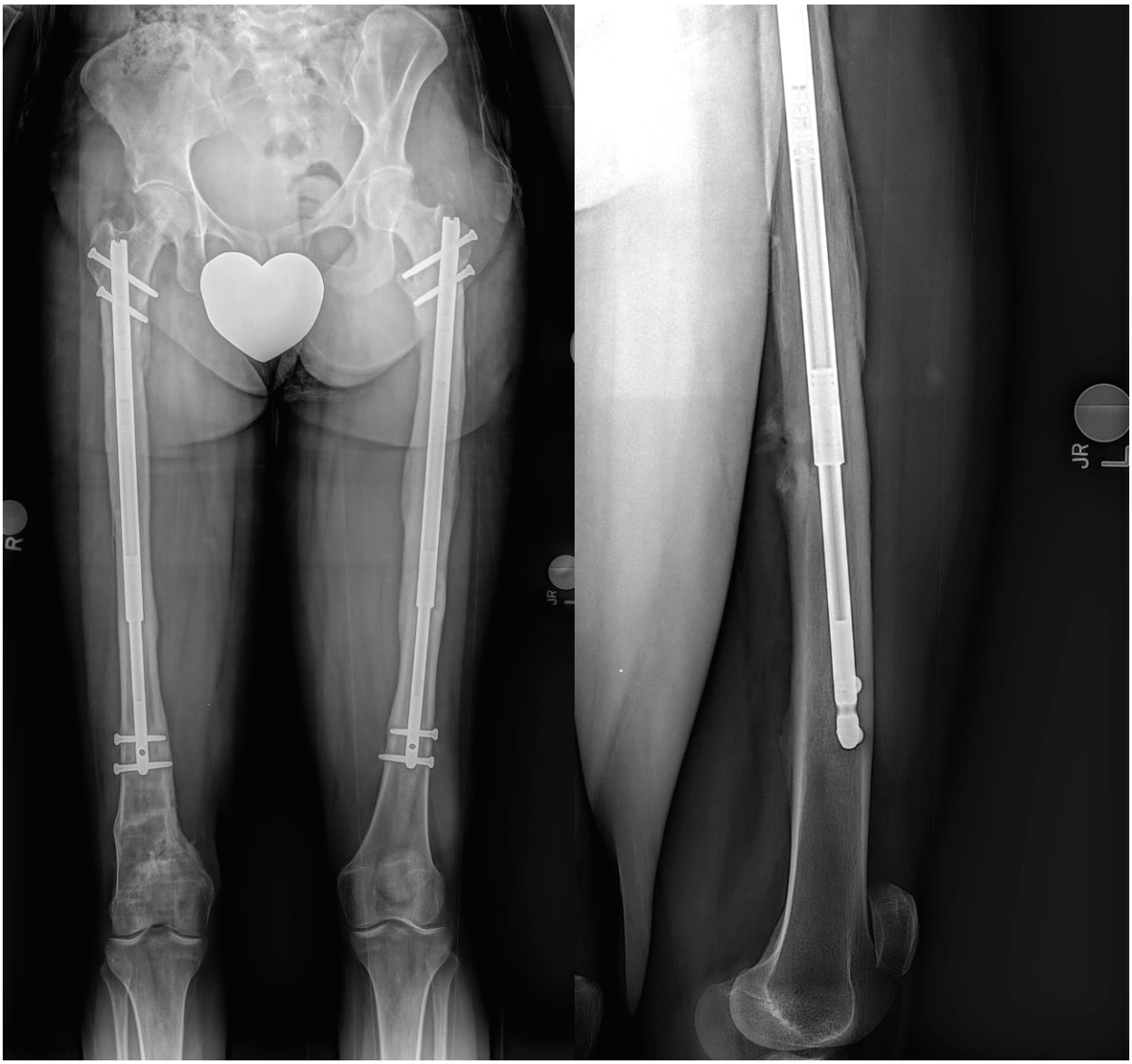

Figure 1: Two views of a patient being lengthened with a [redacted] nail. On the AP there is hypertrophy at the junction. On the lateral there is lysis with erosion of the posterior cortex

Remote Presentation

Biopsy Confirmed Focal Osteolysis in a Stainless–Steel Lengthening Device

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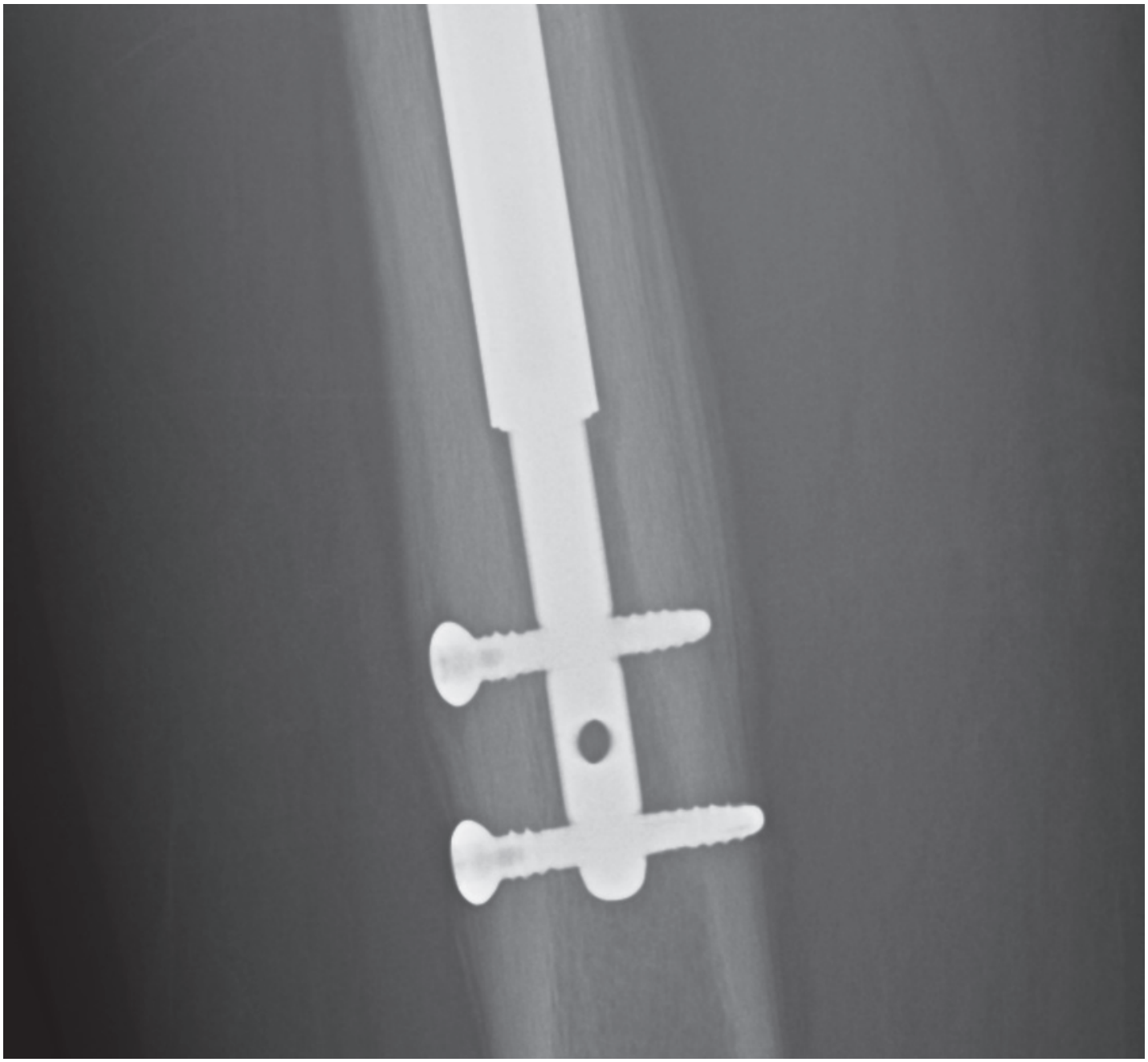
What was the question?
Magnetic, telescoping intramedullary lengthening devices are the preferred treatment for limb length discrepancies. However, routine radiographic review of a stainless–steel device demonstrated soft tissue and bony changes suggestive of an osteolytic process. Therefore, we sought to examine stainless–steel limb lengthening devices. We specifically asked: (1) what is the incidence of osteolysis? And (2) is a new osteolysis classification system valid and reliable?

How did you answer the question?
We retrospectively reviewed all radiographs of patients implanted with a stainless–steel intramedullary lengthening nail between December 2018 and December 2020 at a single institution. A total of 57 nails in 44 patients were radiographically examined with an average follow–up of 6.2 months. The incidence of osteolysis was determined by reviewing all available radiographic films. A novel classification system was developed for osteolysis in magnetic limb lengthening nails: class I was defined as periosteal reaction at (a) male–sided screw, (b) modular junction, or (c) both; class II was defined as osteolysis around modular junction without cortical penetration; class III was defined as osteolysis around modular junction with cortical penetration. Standing anterior–posterior and long leg lateral films were rated according to the proposed classification system by 5 orthopedic surgeons. Inter–rater agreement was evaluated using Intraclass Correlation Coefficient. In a separative analysis, 4 patients' stainless–steel lengthening devices (2 intramedullary, 2 external fixation) underwent routine explantation with concomitant intraoperative biopsy. Biopsies were taken from the area adjacent to the modular junction and formally analyzed by an independent pathologist.

What are the results?
The incidence of periosteal reaction and osteolysis was 36.8% and 17.5%, respectively. Nails with progression to osteolysis increased to 34.6% (9/26) when examining nails with at least a 6–month follow–up. ICC testing yielded good inter–rater agreement for the novel classification system (average measure: 0.860, 95onfidence interval 0.828–0.888). In the separate histologic analysis, all 4 specimens demonstrated an abundance of particulate debris, including fine brown–to–black particles taken up by macrophages, as well as large crystalline fragments with a green–yellow color – consistent with the presence of chromium. In one nail, there was also abundant clear, refractile, non–birefringent material consistent with silicone debris. Postoperative evaluation of the same explanted nail demonstrated significant corrosion at the modular junction.

What are your conclusions?
The modular junction of a stainless–steel lengthening device is susceptible to osteolytic changes. Given that the average onset of osteolysis was less than 1 year, providers should remain cautious



Remote Presentation

Clinical Compatibility of Magnetic Resonance Imaging with Magnetic Intramedullary Nails

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What was the question?
Currently, the use of magnetic resonance imaging (MRI) in patients with a magnetic intramedullary nail in place is not recommend per the manufacturer. This study evaluated whether any side–effects were observed clinically in patients who underwent MRI with a magnetic intramedullary nail in place.

How did you answer the question?
A retrospective review of all patients who had a magnetic intramedullary nail in place and underwent testing with an MRI was performed. The time spent in the MRI suite, strength of the MRI magnet, and sequences performed were evaluated in addition to whether the MRI had to be stopped secondary to the patient developing pain at the site of the nail. Radiographs evaluated for any activation of the nails or failure of hardware. Performance of the motor was also evaluated if the patient subsequently underwent lengthening or bone transport.

What are the results?
Nine patients were identified who were in the MRI suite on 16 different dates. Eight patients had a lengthening nail in place while one patient had a bone transport nail in place. Multiple sequences were obtained including T1, T2, proton density and diffusion weighted imaging. Each patient spent an average of 44 minutes in the MRI suite (range 23 to 77) with a total of 699 minutes recorded. One patient had five whole body MRI's that included the nail within the field of view which precluded any meaningful imaging of that portion of the extremity. Two patients did not complete the MRI secondary to pain from separate fracture sites and two patients did not complete their MRI due to claustrophobia. No patients reported pain at the site of their magnetic nails. No nails had any evidence of activation or hardware failure. Two patients, including the bone transport nail patient were imaged with a 3T magnet, while the remaining patients were imaged with a 1.5T magnet. The patient with the bone transport nail subsequently underwent transport with no complications or change in rate identified.

What are your conclusions?
Other than being unable to image the region where the magnetic nail was placed, no patients developed pain or had a complication related to the nail while in the MRI suite. Prior in vitro studies have demonstrated that a 3T magnet decreases the strength of the internal motor in these nails. Clinically, this did not occur in the one patient who underwent bone transport after being imaged with a 3T magnet. Further studies could include evaluating the nails after retrieval to determine if there is any adverse effect on the nail.

Complications in Elective Removal of 271 Bone Lengthening

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What was the question?
The [redacted] and the [redacted] nail are the two most commonly used intramedullary lengthening nails. The manufacturer of each nail recommends removal of the implant after completion of treatment. Despite the need for removal of each nail, the authors are not aware of any prior publications documenting the results of standard intramedullary lengthening nail removal. Therefore, the aim of this study was to examine the intraoperative and postoperative complications of elective intramedullary lengthening nail removals.

How did you answer the question?
After obtaining Institutional Review Board approval, a retrospective chart review of patients operated with intramedullary lengthening nails at two limb reconstruction centers was performed. Data retrieved from the patient charts included patient demographics, nail–information, and any complications occurring at or after nail removal. Only lower limb lengthening with [redacted] and [redacted] or [redacted] nails that had an elective nail removal were included.

What are the results?
A total of 271 elective nail removals were included in the study. Complications occurred during 3 % of the nail removals and in 13 after nail removal. There were 18 reported cases with postoperative knee pain. All these patients had nail removal through the knee joint, representing 8% of the retrograde femur nail removals and 7% of the tibia nail removals. 4 postoperative fractures occurred of which 2 needed surgery. 11% of femur removals and 26% of tibial removals sustained a complication.

What are your conclusions?
This study emphasizes the importance of adequate follow–up of the bone lengthening patient even after the nail has been removed. It also shows that the recommended removal of IMN lengthening nails must be included in studies reporting on the overall risks of complications using bone lengthening nails.

Intramedullary Distraction Osteogenesis followed by Osseointegration for Amputees with Short Residual Femurs

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What was the question?
Percutaneous EndoProsthetic Osseointegration for Limbs (PEPOL) facilitates improved quality of life (QOL) and objective mobility for most amputees discontent with their traditional socket prosthesis (TSP) experience. Some amputees desiring PEPOL have residual bone much shorter than the currently marketed press–fit implant lengths of 14–16 cm, potentially a risk for failure to integrate. We report on the techniques used, complications experienced, the management of those complications, and the overall mobility outcomes of seven patients who had femur distraction osteogenesis (DO) with a Freedom nail followed by PEPOL.

How did you answer the question?
Retrospective evaluation of a prospectively maintained database identified seven patients (3 males) who had transfemoral DO in preparation for PEPOL with two years of follow–up after PEPOL. Five patients had traumatic causes of amputation, one had perinatal complications and one was performed to manage necrotizing fasciitis.

What are the results?
The average age at which DO commenced was 39.8±15.8 years, and five patients had their amputation more than ten years prior (average 23.1±20.6 years). Due to the starting length of the residual femurs being short compared to the 14 cm Freedom nail, each patient required either a cerclage cable or locking plate and screw customized linkage to secure the bone to the proximal and/or distal end of the nail. The residual femurs on average started at 97.6±42.7 mm and were lengthened 49.0±16.3 mm, 98±45% of goal (99±161% of the original bone length). Four patients (57%) had a complication requiring additional surgery: four events of inadequate regenerate were managed with continued lengthening to desired goal followed by autograft placement harvested from contralateral femur reaming; one patient had the cerclage wires break which required operative replacement. All patients had osseointegration performed, at 382±83 days after the initial lengthening nail surgery. One patient withdrew from study, declining follow–up evaluation. Whereas one patient had K–level >2 before DO, at a mean of 3.4±0.6 (2.6–4.4) years following osseointegration all six remaining patients had K–level >2. The 6 Minute Walk Test remained essentially unchanged (244±95 vs 237±95 meters). Patient self–rating of prosthesis function, problems, and amputee situation did not significantly change from before distraction osteogenesis to after osseointegration. Six patients required additional surgery following osseointegration: six to remove fixation plates placed to maintain distraction osteogenesis length at osseointegration; three required irritation and debridement for infection, including one patient whose implant was removed due to infection which led him to withdraw from further participation.

What are your conclusions?
Extremely short residual femurs which make TSP use troublesome can be lengthening with externally controlled telescoping nails, and successfully achieve osseointegration. However, it is imperative to counsel patients that additional surgery to address inadequate regenerate or to remove painful hardware used to maintain fixation may be necessary. This may improve the amputee's expectations before beginning on a potentially arduous process.

The Incidence and Management of Deep Vein Thrombosis and Pulmonary Embolism following Cosmetic Stature Lengthening with Steel Weightbearing Intramedullary Nails

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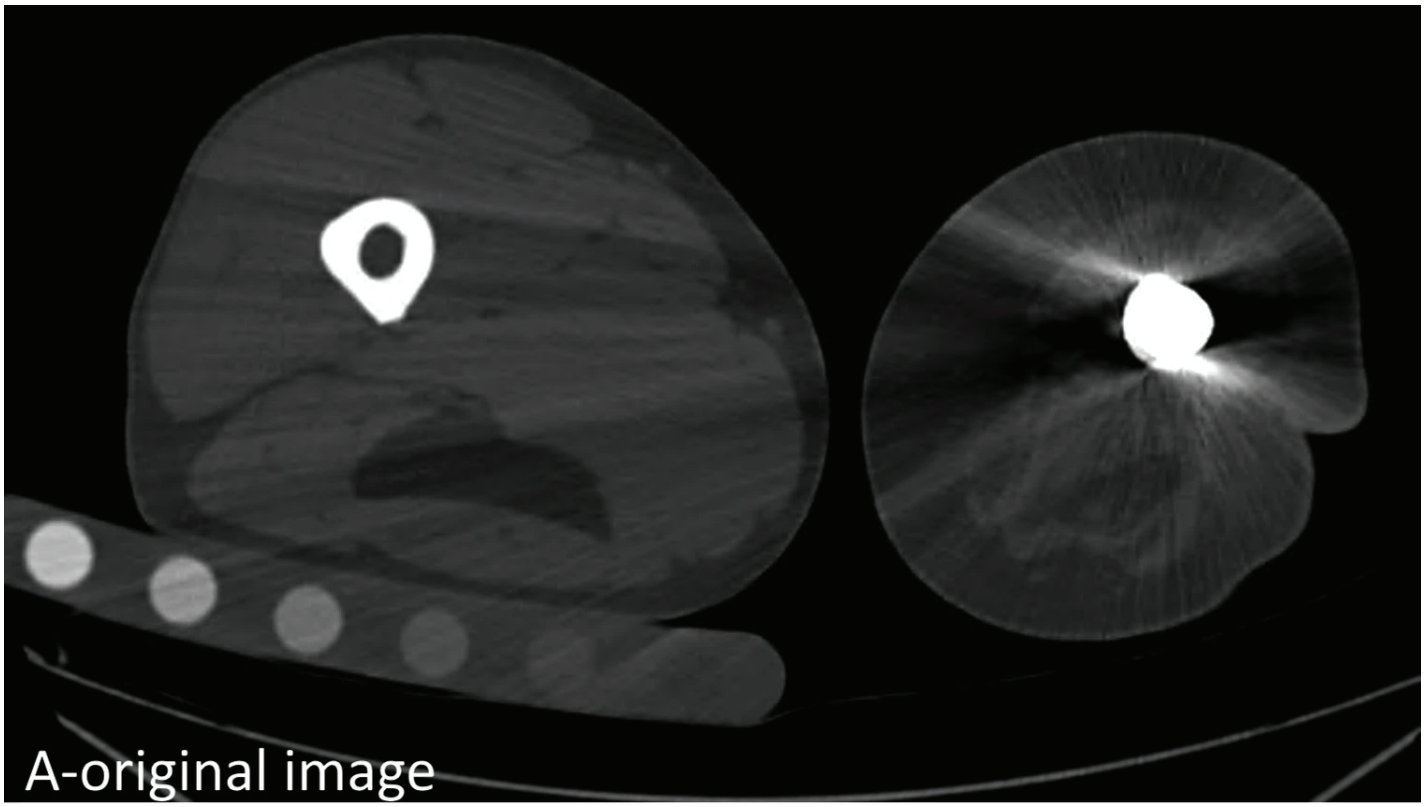
What was the question?
Cosmetic stature lengthening (CSL) can be provided to patients with stature dysmorphia using externally controlled intramedullary telescopic nails. Only one previous article describes the rate of deep vein thrombosis (DVT) (1/51, 2%) or pulmonary embolism (PE) (0%), but this cohort was treated using limited weight–bearing nails. Because the nail allows immediate full weight bearing and presumably greater ambulatory potential, the rate of DVT and PE may be expected to be lower, but this has never been investigated. This investigation aimed to evaluate the incidence and timing of deep vein thrombosis (DVT) and pulmonary embolism (PE) for patients undergoing (CSL) with nails, as well as the chemoprophylaxis and treatment regimens.

How did you answer the question?
Charts of all patients who had bilateral femur or tibia osteoclasis and intramedullary nail lengthening with nails were reviewed. Only CSL patients were included: those with conditions such as achondroplasia or limb deficiency were excluded, as were patients who had lengthening with any other device. All patients who had symptoms such as calf swelling were referred for bilateral lower extremity duplex ultrasound evaluation and those with a positive result were counted for this study. Inpatient and outpatient charts were also evaluated for signs or symptoms concerning for PE such as dyspnea or tachycardia. Between May 2018 and February 2021, 153 CSL surgeries were performed for 126 patients in 130 independent episodes. 23 patients had tibia CSL followed by femur CSL 3 weeks later; these were defined as the same episode for this study. Additional episodes were 95 femur–only CSL, 12 tibia–only CSL, (4 patients had femur CSL followed by tibia CSL one year later, so were each counted two episodes). Postoperative pharmacologic DVT prophylaxis was as follows. 4 patients had rivaroxaban 10 mg daily; 125 patients had aspirin and one patient had a multi–agent regimen due to immediate postoperative complications.

What are the results?
There were 9 CSL episodes complicated by a confirmed DVT occurring on average at 62.6±21.4 (range 42–104) days. It is most notable that before January 2020, 0/66 CSL episodes were complicated by DVT; including that patient, 9/64 (14%) subsequent episodes were complicated by DVT (Fisher exact test p=0.001). All were male. 8 had aspirin chemoprophylaxis, one took rivaroxaban due to aspirin allergy. 8 had femur–only lengthening, one had staged tibias–then–femurs CSL. 2 smoked or vaped. All reported being ambulatory since the day following surgery. All had attended physical therapy five days weekly during the entire lengthening period including after their DVT diagnosis. All remained ambulatory following the DVT diagnosis. Post–DVT anticoagulation therapy was managed by a consultant hematologist who stopped aspirin and started rivaroxaban twice daily for three weeks then once daily for a period determined individually. No PEs occurred.

What are your conclusions?
The protocol to use aspirin for nail–based CSL was determined based on voluminous recent hip and knee arthroplasty literature identifying aspirin as equally effective, convenient, and more cost–effective compared to stronger oral anticoagulants. It was believed that the nail could facilitate ambulation and confer a similar DVT risk profile as arthroplasty patients. This protocol appeared effective prior to COVID–19. However, since January 2020, there has been a high rate of DVT following nail CSL. Interestingly, whereas nearly all post–arthroplasty DVTs occur within 2 weeks, all our CSL DVTs occurred after at least 6 weeks. While contributing causes can only be speculated, the COVID–19 era presents increased risks of DVT to patients undergoing nail CSL, and postoperative DVT chemoprophylaxis may need to adjust in response. Fortunately, a post–DVT protocol of converting from aspirin to rivaroxaban, remaining ambulatory and continuing physical therapy without change, and continuing lengthening to goal did not result in any progression of DVT to PE.



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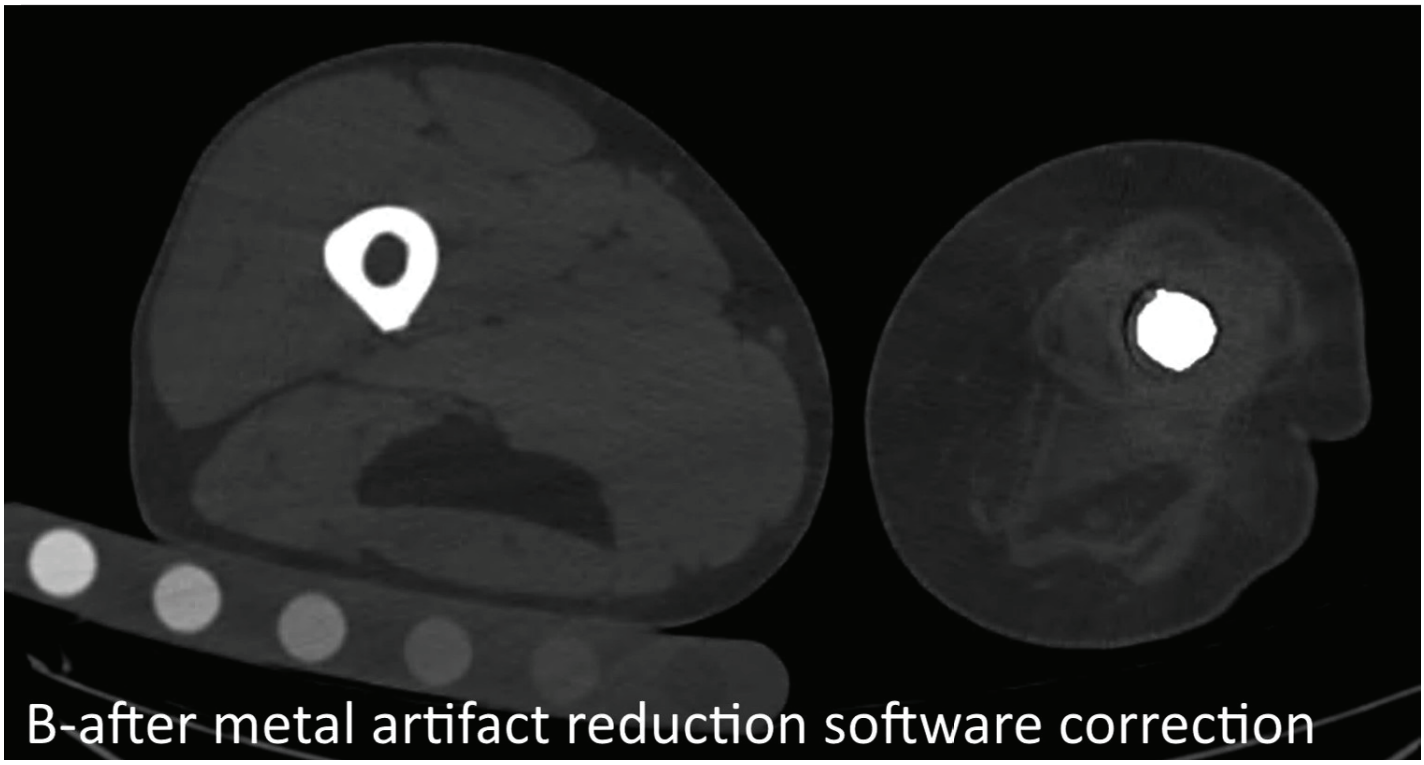

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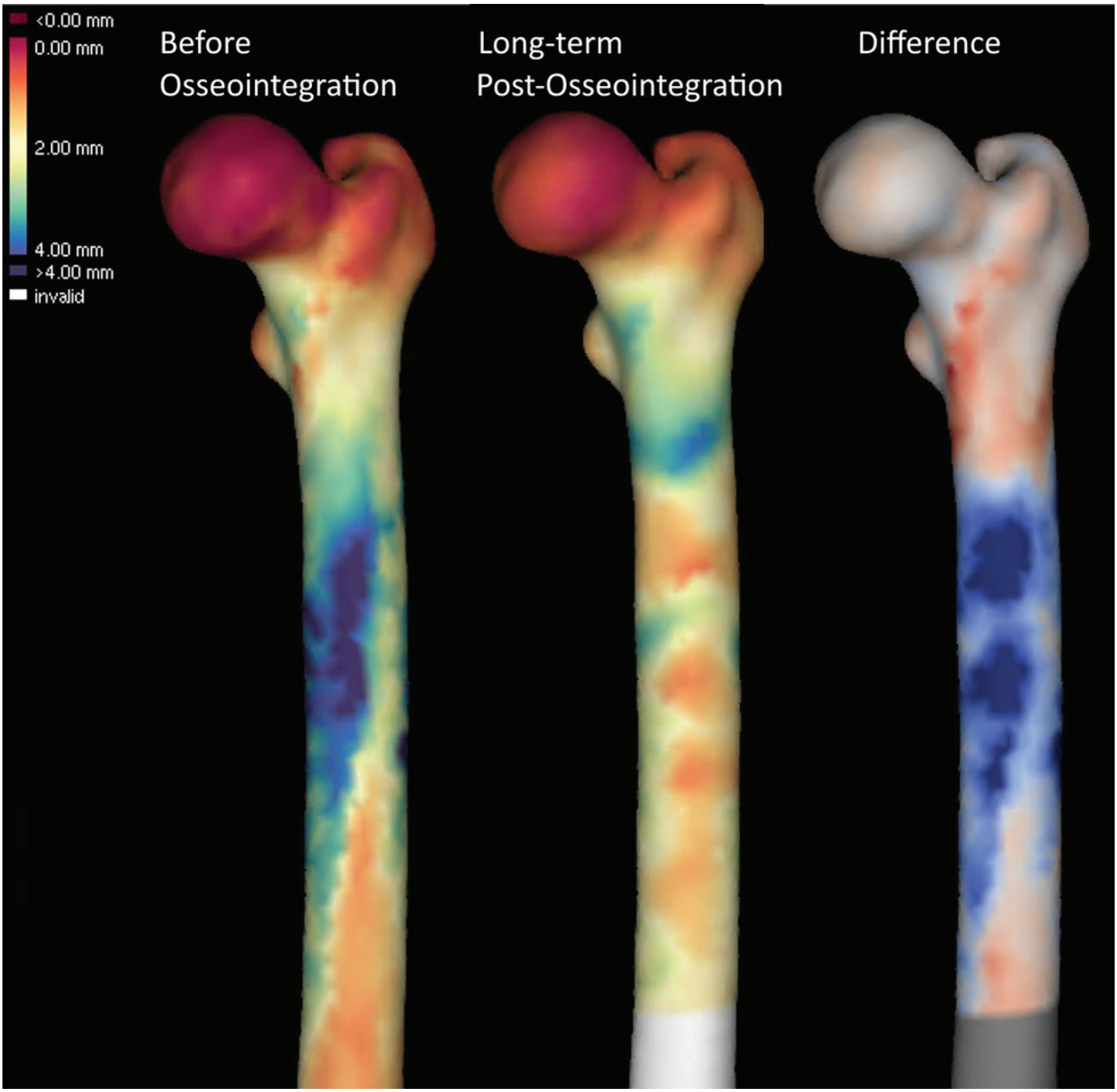
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Implantable Nail Lengthening in Patients with Enchondromastosis

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What was the question?
What are the results and complications of lengthening with an implantable nail in patients with enchondromatosis?

How did you answer the question?
A retrospective chart and radiographic review was performed on all patients with enchondromatosis (Ollier's, Maffucci's, etc.) treated at our institution from May 2012 to March of 2021. Patients were included if they had undergone limb lengthening with an implantable, lengthening nail. Demographics, lengthening rate and rhythm and complication data were obtained from the patient's chart. Radiographic analysis included length achieved, osteotomy location and locking screw location. Healing indices were calculated.

What are the results?
A total of seven patients with 14 limb segments were included in the study. Six patients were diagnosed with Ollier's and one patient was diagnosed with Maffucci's. The mean age of the patients was 10 years (range 7–18 years). Twelve femurs and two tibias were lengthened with implantable, lengthening nails. The mean lengthening rate was .9mm/day (.6 – 1.0mm/day) in the femurs, 1mm/day in one tibia and .75mm/day in the other tibia. The mean amount of length achieved was 50.1mm in the femurs. Both tibias that were lengthened achieved 50mm. The mean healing index was 28 days/cm (range 19–49days/cm) in the femurs. One tibia had a healing index of 30 days/cm and the other tibia was 22 days/cm. The location of 13/14 of the distal locking screw clusters were in enchondromas (intralesional) and one was just outside the enchondroma (perilesional). 12/14 proximal locking screw clusters were intralesional and two were extralesional. Eight of our corticotomies were perilesional and six were extralesional. The only complication in the Ollier's patient was a knee extension deformity contracture requiring botox injection, manipulation under anesthesia and therapy; this patient was concurrently undergoing ipsilateral tibial lengthening with a frame. The patient with Maffucci's underwent femoral lengthening twice. Both times the nail migrated proximally and distally through the enchondromas halting lengthening prematurely (Fig 1).

What are your conclusions?
Enchondromatosis is rare disease affecting approximately 1:100,000 people. To our knowledge, this if the first case series examining implantable, lengthening nails in this population (Dr. Baumgart has previously published on a single patient). We were able to achieve, on average, 50mm in each segment that was lengthened. Concerns in the external fixation literature have been raised regarding stability of intralesional fixation during lengthening. In our Ollier's patients, the majority of distal and proximal locking screws were intralesional and none of the patients experienced the nail pushing through the enchondromas. On the contrary, both times we attempted to lengthen the femur in the Maffucci's patient the nail pushed through the enchondromas (Fig 1). Although, our sample size is small, the healing index in our patients is equal to or improved compared other motorized, intramedullary series. Lengthening in Ollier's patients with implantable, lengthening nails appears to be relatively safe in experienced hands.

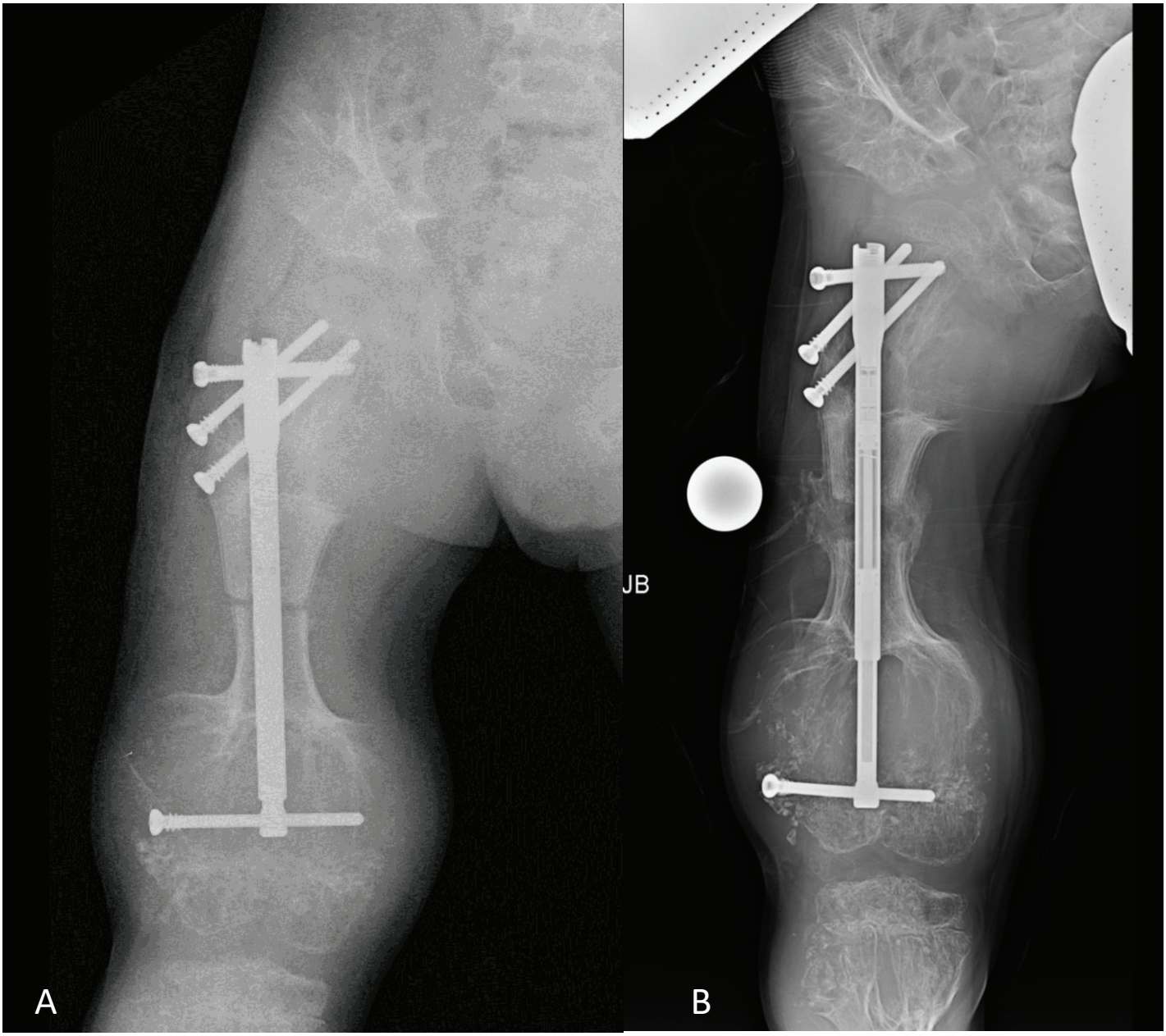

Fig 1: **A.** Patient with Maffucci's prior to initiating lengthening **B**. 5 weeks after lengthening, both distal and proximal screws have migrated, and the length achieved by the nail is different then the healing osteotomy

Osseointegration following Lower Limb Amputation due to Malignant Cancer

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What was the question?
Amputation is a treatment option for lower limb tumors when limb salvage surgery is not possible. Transfemoral osseointegration has proven a reliable and preferable rehabilitation option for many amputees who are dissatisfied with their traditional socket prosthesis. Prior radiation therapy has typically been considered a hard exclusion criterion against providing osseointegration. Our aim was to study the outcomes following osseointegrated (OI) reconstruction in lower limb amputees following treatment of tumors.

How did you answer the question?
Thirty–five patients (aged 22 to 81 years) with above knee amputation as a result of treatment following tumor who underwent OI reconstruction between 2012 and 2020 were followed up for a mean of 5 years. Pre–and postoperative clinical and functional outcomes (pain, prosthetic wear time, mobility, walking ability, and quality of life) and adverse events (infection, fracture, implant failure, revision surgery, and death) were prospectively recorded.

What are the results?
The tumors included osteosarcoma in 22, chondrosarcoma in 2, Ewing's sarcoma and myxoid liposarcoma in 2 patients each, and assorted other tumors. The mean time between amputation and osseointegration was 20 years. All patients' mobility improved following OI reconstruction. SF–36 physical component score improved from 44 to 46. The average Q–TFA global score improved from 43 to 71, average prosthetic score improved from 60 to 82, average mobility score improved from 62 to 67 and average problem score decreased from 39 to 14. The average time up and go (TUG) test improved from 12 to 10 seconds in mobile patients and average 6–minute walk test improved from 295 to 377 meters. 4 patients who were wheelchair bound were able to walk and their average TUG test was 12 seconds and average 6 min walk test was 248 meters. There was no mortality, although 2 patients each had fracture, and aseptic loosening and 1 had infection, post–operatively. 8 patients had radiotherapy and 2 of those patients had revision OI; 1 for infection and 1 for aseptic loosening.

What are your conclusions?
The most common tumor resulting in amputation in our study cohort was osteosarcoma in 22 patients (63%). 25% patients who had radiotherapy required revision OI due to complications. Four wheelchair–bound patients following lower limb amputation as a result of treatment for tumor achieved and maintained independent and patients previously using traditional socket prosthetics (TSPs) reported improvement in mobility and quality of life. OI reconstruction improved patient mobility following above knee amputation and should be considered in selective patients as an alternative to traditional socket mounted prosthesis.

Remote Presentation

Transtibial Osseointegration Confers Mobility Benefits with Limited Complications

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What was the question?
Transfemoral osseointegration consistently improves amputee quality of life (QOL) and mobility. Transtibial osseointegration (TTOI) is understudied: only six publications exist, describing 27 total procedures. This study asks: what are the differences in the subjective and objective outcomes, and complications following TTOI?

How did you answer the question?
We prospectively followed all skeletally mature adults who either 1) reported pain or mobility dissatisfaction with their transtibial socket prosthesis (TSP); 2) had an intact limb with incapacitating pain, complex deformity, or profound distal weakness, whose functional capacity was considered improvable by amputation; or 3) were recent amputees preferring osseointegration to TSP rehabilitation. Short Form 36 (SF–36) and modified Questionnaire for Persons with a Transfemoral Amputation (QTFA) surveys, physician examinations, Timed Up and Go (TUG), and Six Minute Walk Test (6MWT) were performed before osseointegration and postoperatively for at least two years.

What are the results?
102 procedures were performed for 91 patients. Statistically significant improvements following osseointegration: prosthesis use (>13 daily hours 40% versus 86%, p<.001), SF–36 physical component score (40.1±9.5 versus 50.3±11.4, p“Good” 35% versus 69%, p<.001), K–level (1.4±.9 versus 3.0±.5, p<.001), TUG (9.9±2.6 versus 8.2±1.7 seconds, p<.001), and 6MWT (339±94 versus 437±117 m, p<.001). Complications: thirteen patients (13%) required surgical debridement only, another 9 (9%) eventually required implant removal, including 2 patients (2%) who required transfemoral amputation for infection. Unplanned refashioning and nerve reinnervation occurred in 8 patients (8%) each. No periprosthetic bone fractures occurred. One patient died due to atherosclerosis–induced myocardial infarction after nearly three years.

What are your conclusions?
TTOI confers subjective and objective improvements for the majority of transtibial amputees experiencing difficulty using a TSP. Complications are manageable and should decrease with surgical and implant improvements.

Remote Presentation

Osseointegration for Transfemoral Amputees with Prior Total Knee Arthroplasty Complications

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What was the question?
Total Knee Replacement (TKR) reliably improves pain and quality of life (QOL). Deep infection can occur, which may sometimes result in transfemoral amputation if less drastic management is unsuccessful. Patients using a traditional socket prosthesis (TSP) may experience socket–residuum interface problems resulting in reduced prosthetic use and poor QOL. Osseointegrated (OI) reconstruction can overcome many of these problems and is often associated with superior mobility and QOL compared to TSP use. This study investigated the ambulatory and QOL outcomes following osseointegrated reconstruction in transfemoral amputees as a result of failed TKR.

How did you answer the question?
A review of our osseointegration database identified ten patients (aged 46 to 78 years) who had transfemoral amputation due to complications associated with an infected TKR. The OI surgeries were performed between 2011 and 2019 and patients were followed for a mean of 5.5 years. Pre– and postoperative clinical and functional outcomes (ambulatory ability and quality of life) and adverse events (unplanned surgeries and death) were prospectively recorded.

What are the results?
All patients' mobility improved following OI reconstruction. SF–36 mental component score improved from 40 to 55. The average Q–TFA global score improved from 28 to 61, average prosthetic score improved from 37 to 73, average mobility score improved from 55 to 58 and average problem score decreased from 50 to 25. The average time up and go (TUG) test improved from 43 to 26 seconds in mobile patients. 6 patients who were able to walk before OI achieved an average TUG of 9.67 seconds and an average 6 min walk test of 325 meters. At the most recent follow–up, 6 patients were ambulatory, one independently and the other five others with walking. Unplanned surgeries included: one hip fracture reconstruction (with retained implant) following periprosthetic fracture; one debridement for soft tissue infection; 2 explantations with subsequent revision OI; and 5 patients requested neurectomy for persistent pain. 2 patients died of unrelated causes.

What are your conclusions?
Osseointegration can provide significantly improved mobility and QOL for patients dissatisfied with their function and lifestyle using a TSP following transfemoral amputation as management for TKR infection. Notably, even patients who were confined to a wheelchair achieved ambulation. Infection requiring debridement or removal remains a complication without an immediate solution but addressing symptomatic neuromas at initial OI can reduce the unexpected additional surgery rate for many patients.

Burosumab Improves Lower Limb Alignment in Children with X–Linked Hypophosphatemia

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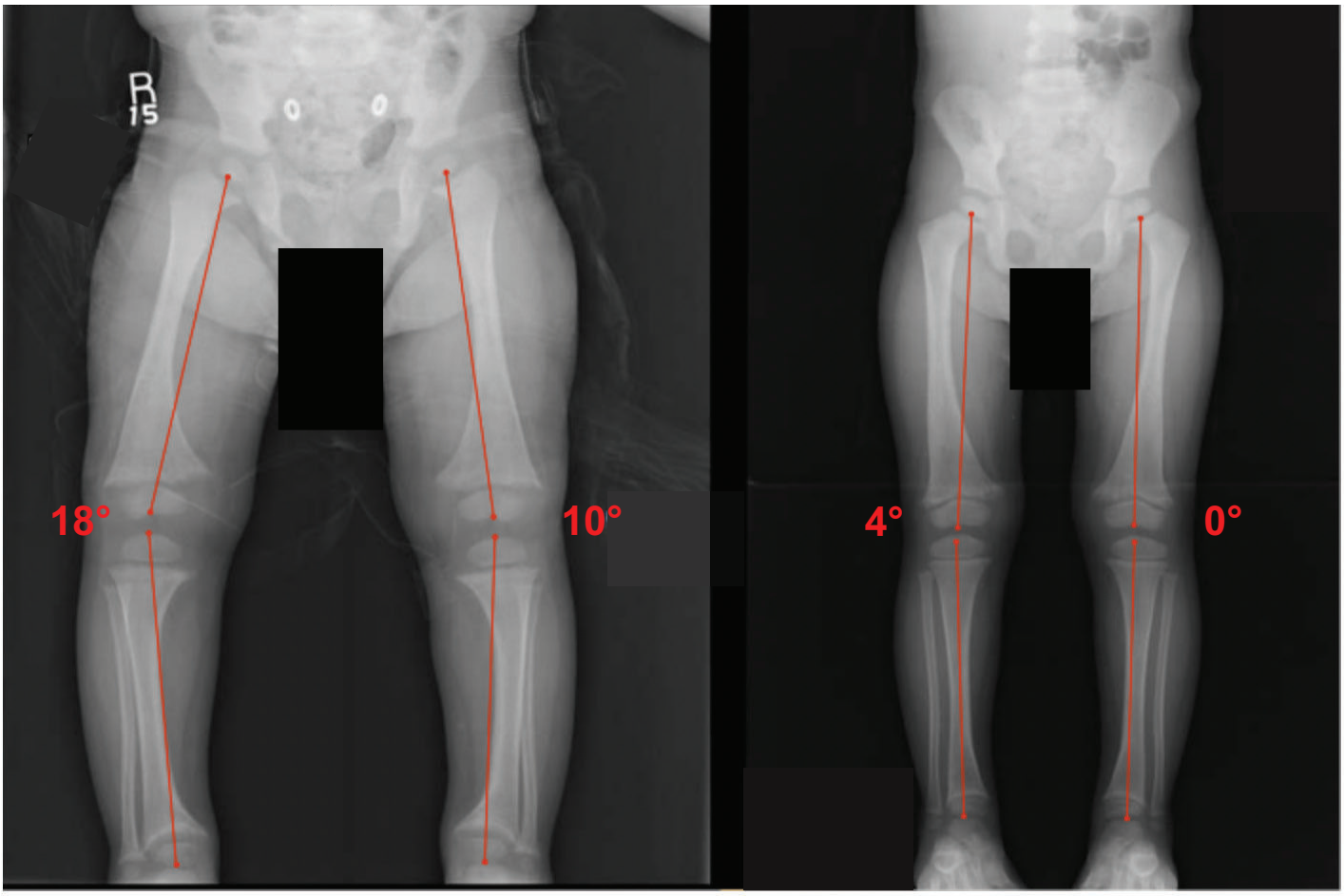
What was the question?
Lower limb angular malalignment is commonly observed in X–linked hypophosphatemia (XLH), a rare musculoskeletal disease of FGF23 excess. Because angular deformity persisting into adulthood may play a role in the development of osteoarthritis, chronic pain, and other complications, surgical realignment is frequently recommended. Historically, adults with XLH have undergone acute correction with osteotomy, whereas more recent approaches in children frequently employ guided growth surgery (hemiepiphysiodesis) for the gradual correction of coronal plane deformities. We hypothesized that treatment with burosumab, a fully human monoclonal antibody against FGF23, would improve lower limb alignment toward age–matched normal values and decrease the need for surgery in children with XLH.

How did you answer the question?
In the phase 2 study, UX023–CL205 (NCT02750618), treatment with burosumab improved rickets in 13 children with XLH aged 1–4 years (Whyte MP, et al. Lancet Diabetes Endocrinol. 2019;7(3):189−199). In this retrospective review, coronal standing lower limb radiographs from all 13 children (26 lower limbs) were evaluated before and 64 weeks after initiation of burosumab to assess mechanical axis deviation (ie, extent of malalignment), limb proportions, and joint line angles.

What are the results?
At baseline, 25 (96%) limbs had varus lower limb malalignment; 26 (100%) limbs had varus deformity of the femur and 12 (46%) had tibial deformity. After 64 weeks of treatment with burosumab, a trend toward normalization of varus deviation was observed, with 10 of 25 (40%) lower limbs obtaining age–matched normal values reflective of neutral alignment (ie, no longer within range for surgical intervention; see figure). Correction during the study period was 5° (velocity, 0.34°/month) for distal femur and 3.7° (velocity, 0.25°/month) for proximal tibia. Burosumab improved the femur–tibia angle by a mean of 53.8 mong 25 limbs (baseline, 13°; week 64, 5.7°). The ratio of tibia to femur length was not significantly changed (–1.4%), suggesting that longitudinal growth of the femur and tibia is proportional.

What are your conclusions?
In summary, treatment with burosumab in young children with XLH resulted in clinically meaningful improvements in lower limb coronal plane alignment after 64 weeks. These data suggest that burosumab therapy should be initiated in young children with XLH before surgeons consider guided growth surgery. The XLH Disease Monitoring Program (NCT03651505), a prospective, multinational, outcomes study spanning 10 years, will enable longitudinal investigation of the time required for maximum alignment benefit by burosumab.

Figure. Improvement in femur-tibia angle after 64 weeks of treatment with burosumab in a 1.6-year-old boy with XLH



Baseline Week 64

Multicenter Series of Deformity Correction using Guided Growth in the Setting of Osteogenesis Imperfecta

Jeanne M. Franzone, MD; Maegen J. Wallace, MD; Kenneth J. Rogers, PhD, ATC; Richard W. Kruse, DO, MBA
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What was the question?
The mainstay of deformity correction and fracture prevention for patients with osteogenesis imperfecta (OI) includes osteotomies and intramedullary rodding. Guided growth offers a less invasive means of deformity correction and has been described in the setting of skeletal dysplasias. Our purpose is to report a multicenter series of guided growth procedures in the setting of OI.

How did you answer the question?
A retrospective review of OI patients at three institutions from April 2012–April 2019 identified patients who underwent guided growth for angular deformity correction with a minimum one–year follow–up or full deformity correction and removal of the guided growth hardware. Clinical characteristics, deformity measurements and complications were collected. Distal femur and proximal tibial hemiepiphysiodeses were performed using figure–of–eight plates and screws; distal tibial medial hemiepiphysiodeses were performed using cannulated screws. Preoperative and postoperative joint angle measurements included the lateral distal femoral angle (LDFA), medial proximal tibia angle (MPTA) and lateral distal tibial angle (LDTA). Frequency and descriptive statistics were completed.

What are the results?
Fifteen OI patients (average age 11.8 years, range 6.5–16.3, 11 males, 4 females) underwent 30 guided growth procedures with a mean follow–up of 3.3 years (SD 1.8). OI Types included: I–5, III–3, IV–4, V–3. All patients received routine bisphosphonate treatment. Preoperative and postoperative mean joint angles include: 8 distal femur medial hemiepiphysiodesis (83.5°,88.3°), 2 distal femur lateral hemiepiphysiodesis (95.2°,89.5°), 7 proximal tibial medial hemiepiphysiodesis (95.3°,91.1°), 3 proximal tibial lateral hemiepiphysiodesis (84.0°,92.3°), 10 distal tibia medial hemiepiphysiodesis (73.3°,83.9°). For the distal femur and proximal tibial guided growth procedures, the mean change in mechanical axis deviation was 25.2mm (SD 30.1). Twelve of the 30 (40.0%) procedures were performed in the setting of an intramedullary rod. One patient demonstrated backout of the epiphyseal and metaphyseal screws of a distal femoral medial figure–of–eight plate. It was revised to a larger plate with longer screws and removed upon completion of deformity correction.

What are your conclusions?
Guided growth may be used as an effective means of angular deformity correction with dysplastic OI bone. In this series, presence of an intramedullary rod did not preclude the use of a guided growth technique. To date, one of the 30 procedures demonstrated screw backout. Given the short stature associated with OI, consideration may be given to perform a guided growth procedure at an early enough age to allow time for correction.

What are the Risk Factors for Rebound Deformity after Correction of Lower Extremity Valgus deformities using Tension Band Plates in Skeletal Dysplasia?

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What was the question?
What is the rebound deformity rate in lower limb valgus deformity in skeletal dysplasia after growth modulation using Tension Band Plate? What are the risk factors for rebound deformity?

How did you answer the question?
All SkD patients who had valgus lower limb deformities treated by Tension Band Plating (TBP) at distal femur or/and proximal tibia at single center were reviewed retrospectively. Inclusion criteria were (1) minimum 2 year follow up after the TBP removal or having revision surgery for rebound deformity, (2)implant removal age for girls ≤ 14years and boys ≤ 16 years. Exclusion criteria were any patients who had a femoral/tibial osteotomy during TBP treatment or follow up. The change of 3 more degrees of mLDFA and/or MPTA was accepted as rebound deformity and analyzed statistically.

What are the results?
Thirty patients (59 limbs; 52 femur physes and 29 tibia physes) met our criteria. Average of follow up time was 41.1 months. Of 52 femur, 38 (73%) femurs and of 29 tibias, 10 (34.4%) tibia experienced rebound deformities. Gender and BMI did not influence the development of rebound deformities (See Table 1) Femurs had more predisposition for rebound than tibias (p=0.001). Patients in the rebound group were younger compared to the non–rebound group (7.9±2.6, 9.5±2.2 years respectively) (p=0.006). Time to TBP removal was shorter in rebound vs non–rebound group (17.8±7.1, 23±14.9 months) respectively (p=0.039). Overcorrected limbs had more rebound deformity than those without overcorrection (p=0.004). The difference in growth velocity of lower limb in rebound vs non–rebound group approached statistical significance (p=0.053). Patients with epiphyseal dysplasias had more rebound than metaphyseal dysplasia but this was not statistically significant (p=0.142).

What are your conclusions?
Risk factors of rebound deformity in SkD included TBP surgery at a younger age (<8 years), Patients with femoral deformities, faster correction (shorter duration of TBP implantation) and those who overcorrected had a higher prevalence of rebound deformity. This may be related to rapid growth/relatively higher growth potential.

Prediction Matrix for Radial Head Subluxation/Dislocation in Patients with Multiple Hereditary Exostosis

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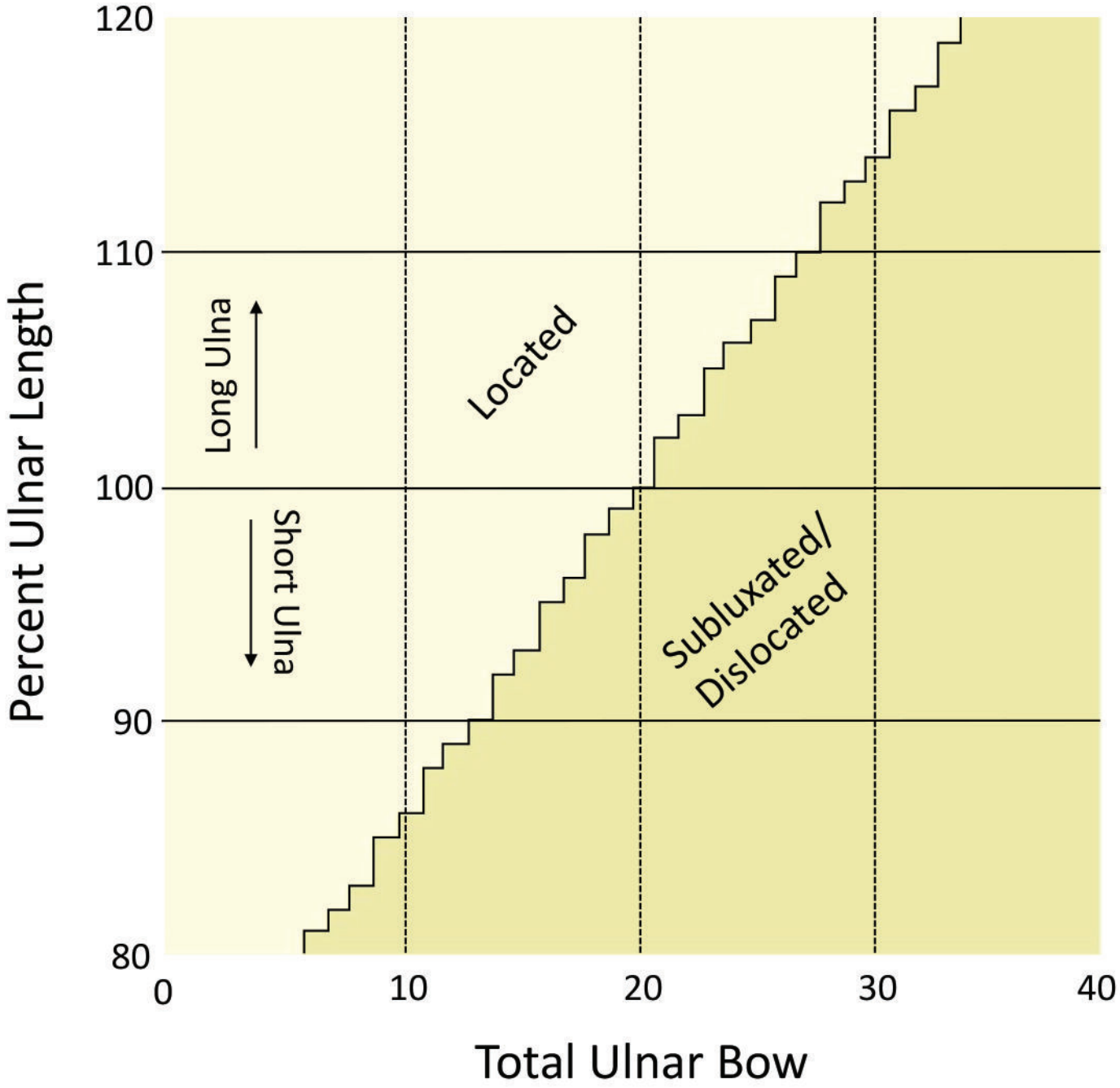
What was the question?
What are the radiographic variables that are predictive of radial head subluxation/dislocation (RHS/D) in patients with multiple hereditary exostosis (MHE)?

How did you answer the question?
A retrospective chart review was performed on all patients with MHE treated in our clinic between April 2007 and December 2019. Only one forearm was included for each patient to eliminate the effects of correlated data within groups. Clinical range of motion data were collected from the charts. Measurements were performed on the radiographs and included: percent ulnar length (PUL), total radial bow (TRB), total ulnar bow (TUB), the presence of distal ulnar osteochondromas and status of the radiocapitellar joint (located, subluxated, or dislocated).
The range of motion and radiographic measurements were compared between groups using a Kruskal–Wallis H test to determine differences in group distributions. Post–hoc analysis was performed using Dunn's test for multiple comparisons. All post–hoc reported p–values were adjusted for multiplicity. Pearson correlation coefficient was performed using the radiographic measurements. A binomial regression was performed to predict RHS/D. The significant predictors were then analyzed across a range of values. A matrix was created that predicts status of the radiocapitellar joint (located vs. subluxation/dislocated) in relationship to the significant variables analyzed.

What are the results?
A total of 88 patients were included in the study. 70 forearms had located radiocapitellar joints, 10 had subluxated radiocapitellar joints and 8 had dislocated radiocapitellar joints. There were significant differences in the located group compared to the subluxated in pronation ($p<.05$) and when comparing the located group to the dislocated group in pronation ($p<.05$), supination ($p<.01$) and extension ($p<.005$). The mean PUL in the located group was 109%, subluxated group was 98 nd dislocated group was 92%. The mean TUB in the located group was 13°, subluxated group was 22°, and dislocated group was 22°. The mean TRB in the located group was 15°, subluxated group was 53°, and dislocated group was 28°. The PUL, TUB and TRB were significantly different when comparing located and subluxated/dislocated group ($p<.0001$); however, using binomial regression only PUL and TUB were able to distinguish between the located group and the subluxated/dislocated group. Both these measurements were significant predictors of subluxation/dislocation ($p<.01$). This information was used to develop the prediction matrix for RHS/D which was able to correctly identify 98% of the cases in our series (Fig 1.)

What are your conclusions?
Previous studies have highlighted the importance of ulnar length in terms of radiocapitellar dislocation in patients with MHE. This is the first study to highlight ulnar bow as a contributing factor to radiocapitellar instability. Additionally, the methods used take into consideration the effect of correlative data on statistical analysis; this has not been performed in previous studies evaluating the radiocapitellar joint in MHE. Lastly, the prediction matrix (Fig 1) allows the surgeon to plot the patient's radiographic parameters and determine if the patient is at risk of subluxation/dislocation which may affect elbow range of motion and the decision to prophylactically treat the elbow/forearm to prevent dislocation.


120
110
100
90
80
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10
20
30
40
Percent Ulnar Length
Total Ulnar Bow
Long Ulna
Short Ulna
Located
Subluxated/
Dislocated

An Ovine Study of Locked Intramedullary Implants Across the Distal Femoral Growth Plate

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What was the question?
The ability to place a retrograde femoral nail across the distal femoral growth plate could broaden fracture and reconstructive surgery options in children. Recent preliminary clinical studies have utilized this approach for fracture care in resource poor countries and for limb lengthening in growing children with distal femoral deformity. Previous animal data suggested that up to 7% of the distal femoral physis could be violated with a retrograde implant without growth arrest or inhibition. However, with an intramedullary implant locked in the metaphysis, the bone will grow such that the end of the nail passes from the epiphysis to the metaphysis. The consequences of this effect at the physis are not well understood.

How did you answer the question?
Retrograde femoral nails measuring 8mm in diameter with metaphyseal interlocks were inserted through the distal femoral physis of one hind–limb ten 3–month old sheep. Physeal violation from implant placement was calculated based on the ratio of the nail width to the physeal width on anteroposterior and lateral radiographs obtained pre–operatively. Four sheep were sacrificed at five months, and six sheep were sacrificed at nine months. Both the surgical and contralateral control hind–limbs were harvested and measured from the superior aspect of the femoral head to the femoral condyles. Histological analysis at the physis was also conducted.

What are the results?
Results: Mean growth plate violation was 5.4% (range, 3.4–7.4%). The nail had completely migrated across the physis in all specimens (Figure 1). In the specimens sacrificed at 5 months following implant placement, there was a mean of 6mm (range, 3–8mm) of shortening in the surgical limb when compared to control limbs, while histologic assessment demonstrated evidence of bony bridging at the periphery of the deficit created when the nail passed across the physis (Figure 2). In the specimens sacrificed at 9 months, there was a mean of 4mm (range, 2–5mm) of limb shortening. No angular deformities were found.

What are your conclusions?
Conclusion: Placement of a retrograde femoral nail with a metaphyseal interlocking resulted in implant migration across the physis in all specimens. Mean femoral shortening in surgical limbs was smaller in the nine month versus five month specimens, suggesting that the physis regained normal function despite evidence of bony bridging at the periphery. As such, retrograde femoral nailing can be considered a viable surgical option in skeletally immature patients for fracture care or deformity correction without significant growth–related complications. Any patients treated with retrograde nailing require careful clinical follow–up to assess the function of the physis with the expectation of a small loss of femoral length as the nail passes across the physis.

Can Manipulation of the Mechanical Environment Improve Regenerate Bone Healing During the Consolidation Phase of Distraction Osteogenesis?

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What was the question?
Reverse dynamization describes the process of changing the mechanical environment surrounding callus from flexible to rigid. Previous studies have shown this process accelerated bone healing in small and large animal models. It is still unknown how reverse dynamization can affect regenerate bone maturation during the consolidation phase of distraction osteogenesis. This study aims to determine whether reverse dynamization can accelerate the mineralization and remodeling of regenerate bone during the consolidation phase of limb lengthening.

How did you answer the question?
Eighteen neutered male Spanish cross goats underwent an identical surgical procedure: application of a circular external fixator followed by midshaft tibial osteotomy. Each goat tibia was lengthened 2 cm following a 7 day latency period with an identical rate and rhythm (0.25 mm three times/day). The goats were divided into three groups based on the fixation stability: a) Static (S; n=6) – 4 threaded rods for the entire study period (rigid fixation); b) Dynamized (D, n=6) – 4 threaded rods containing 3D–printed dynamizers, allowing 2 mm axial continuous micromotion throughout the study period(flexible fixation); c) Reverse Dynamization (RD; n=6) – started with 3D printed dynamizers allowing 2 mm axial micromotion (flexible fixation) until the end of distraction period, and then switched to threaded rods during consolidation ((rigid fixation). The goats were euthanized after 8 weeks of the consolidation period, and both hind limbs of each goat were evaluated using X–rays, MicroCT, and mechanical testing (still in progress).

What are the results?
Radiographic results showed earlier bone formation in the D and RD groups, having initial flexible fixation, compared to the S group. Moreover, there was evidence of accelerated consolidation in the RD group compared to the S and D groups. These results were confirmed by MicroCT analysis after 8–weeks of the consolidation period, where the RD group had reduced callus size, less bone volume, but higher bone mineral density compared to the SF and DF groups. This appearance is characteristic of advanced remodeling; returning closest to the values of intact bone (Figure 1).

What are your conclusions?
These findings confirm that the proposed regimen of Reverse Dynamization significantly accelerated regenerate bone mineralization and remodeling compared to the static and dynamized group. This indicates that the manipulation of the mechanical environment surrounding the distraction regenerate may help to decrease the bone consolidation phase during limb lengthening. Furthermore, if reverse dynamization can be employed in the clinical setting, it will allow for earlier removal of the fixation devices and shorter rehabilitation after frame removal.

To Minimize Biological (Thermal) Damage during Cortical Bone Drilling: An Experimental Parameters for Optimal Bone Drilling

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What was the question?
Bone drilling remains one of the most common steps in many different surgical specialties including orthopedic surgery. The biological and mechanical impacts of this action has been well studied. But details into minimizing negative impacts of this procedure is still not well understood. The aim of our study is to identify the best possible practice in bone drilling procedure.

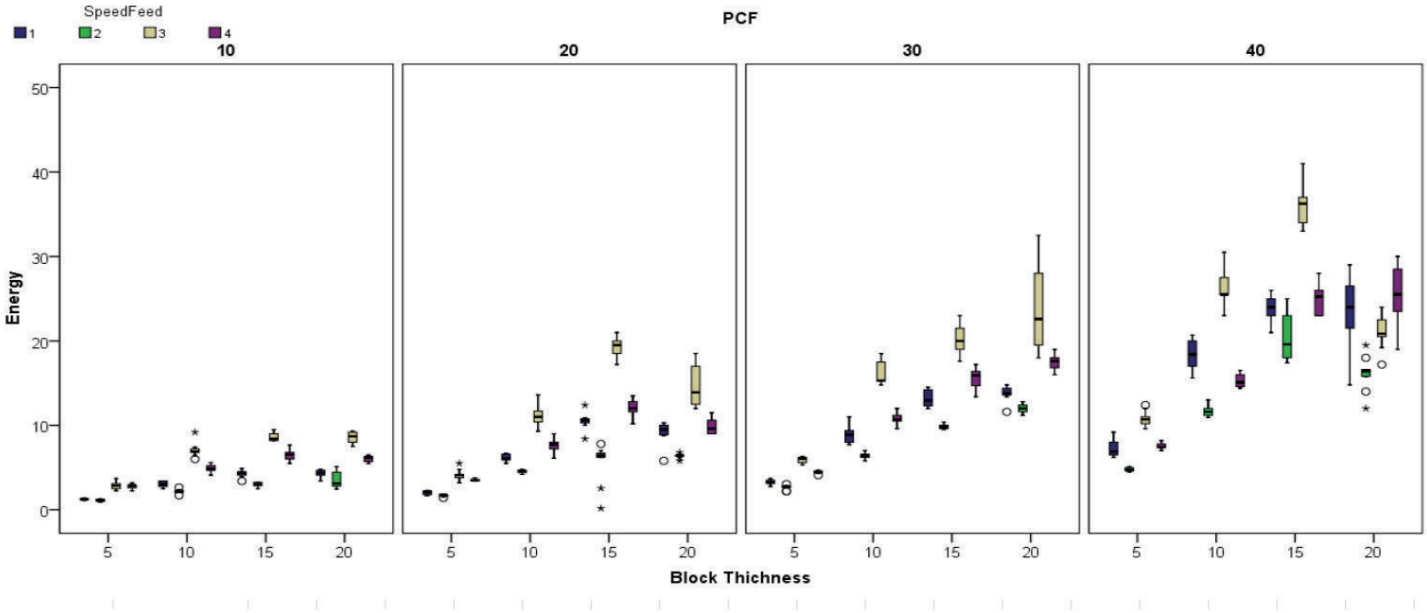
How did you answer the question?
Relevant literatures relating to bone drilling, thermal necrosis, drill bit designs, and drilling techniques were reviewed. Drillings were performed with different drill bit sizes on a standard material with known densities and thickness. A customized computerized drill was used to achieve desire drill depth, speed, feed rate and measured energy requirement, and an infrared thermal camera was used to measure temperature generated. An attempt was made to identify a drilling method in minimizing temperature rise during bone drilling. We investigated using Rigid Polyurethane Foams (RPF) from Sawbones (Pacific Research Laboratories, Vashon, WA, USA).
For our rotary drill, we used custom made computerized drill (Smart Medical Devices, Inc. Las Vegas, NV, USA). This is a dual motor drill (20) which can employ drill speed and feed rate, and linear distance of intended drill depth (mm) independently. The computer software can continuously measure drilling energy and drilling torque from starting point to at the end of intended depth. The torque, and energy on the y axis was plotted visually on a monitor with the drill bit depth and time on the x–axis. A total of 880 drillings (drill bits from DeWalt industrial company) 640 drillings using 3.2 mm drill bits: 40 drillings per each density, for each four different densities: (5, 10, 15 and 20 mm thickness and 10, 20, 30, 40 pounds per cubid foot (pff) blocks). 240 drillings for 4.8 mm drill bits (thickness of 5, 10, 15 mm for 30 and 40 pcf blocks) drillings

Statistical Analysis
One–way ANOVA followed by Tukey's multiple comparisons test

What are the results?
Lowest energy utilized = (low speed and High feed rate): Method 2
Lowest temperature rise = Low speed and high feed rate, (for both 3.2 and 4.8 mm drill): Method 2
Highest temperature = almost always high speed/low feed rate (Method 3)
Highest energy consumption = almost always High speed/ low feed rate (Method 3)

What are your conclusions?
This experiment proves that both speed and feed rate during drilling have individual and combine effects on temperature change. Increasing the speed without advancing the drill bits have highest energy cost and generates highest temperature. Lower speed and higher feed rate drilling is least heat generating and least energy consuming. These patterns were consistent. Temperature rise during bone drilling can be as high as 100°C and above. There is enough evidence to prove that high temperature can have significant consequences.
We believe this experiment will provide a foundation for study of relationship between speed, feed rate and density and thickness during bone drilling. To conclude, we would recommend low speed and high feed rate drilling pattern. We noted high speed drillings have negative impacts.

Graph 1.


SpeedFeed
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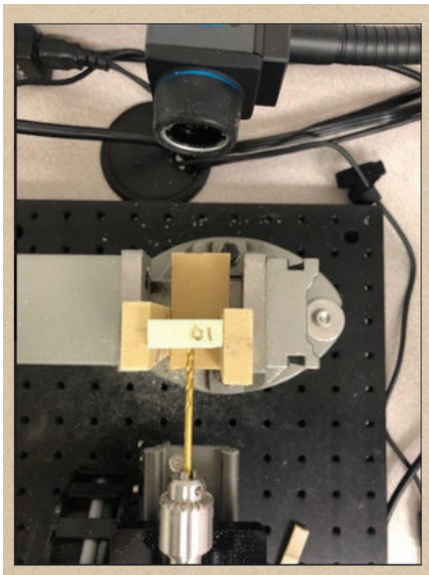

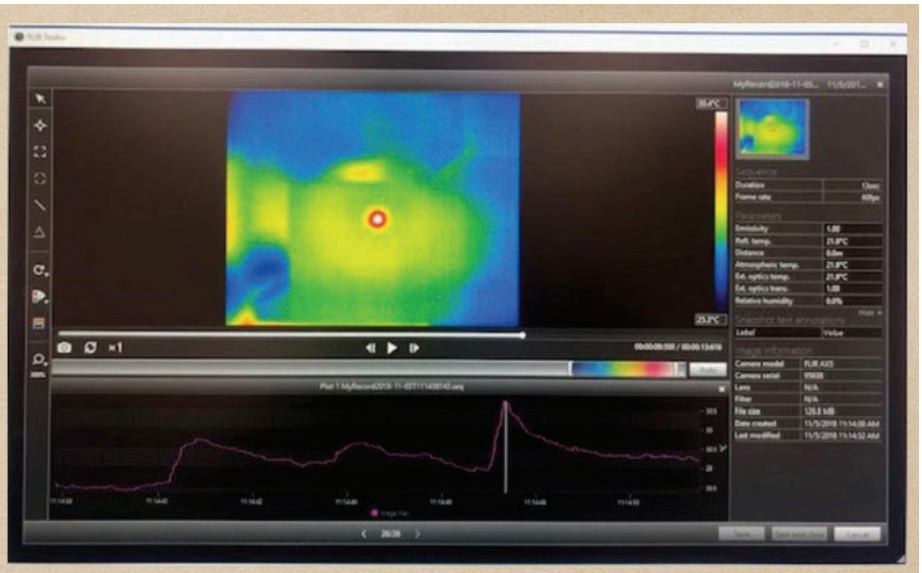

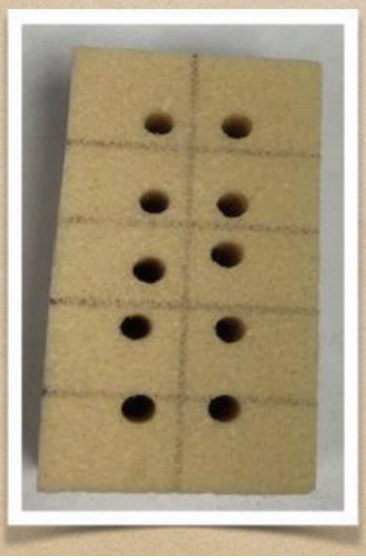

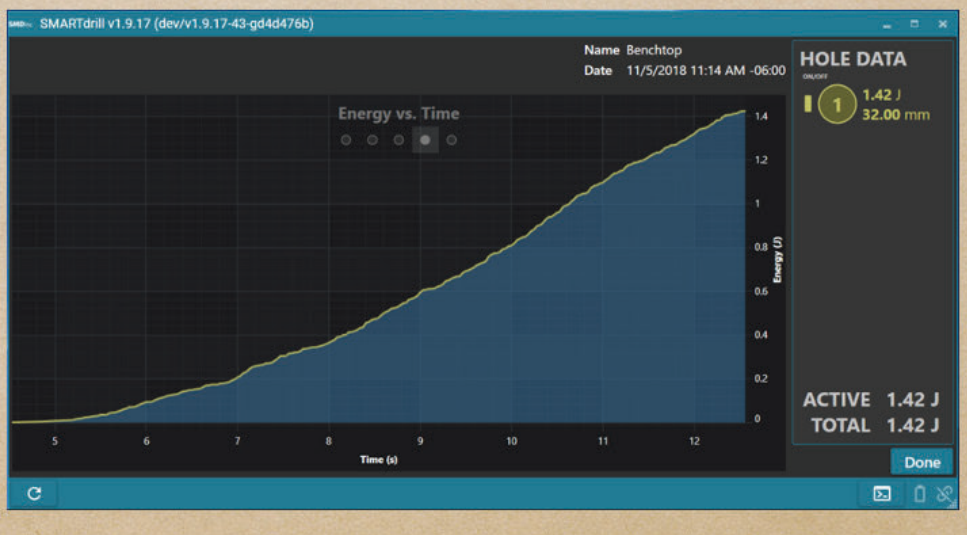
SMARTdrill v1.9.17 (dev/v1.9.17-43-gd4d476b)
Name Benchtop
Date 11/5/2018 11:14 AM -06:00
HOLE DATA
1.42 J
32.00 mm
Energy vs. Time
Energy (J)
Time (s)
ACTIVE 1.42 J
TOTAL 1.42 J
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Drill Bit DeWalt 3.2

ert		RPM				
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1	5 mm					
	1	35.7	2.75			36.3
	2	35.5	3.5			37.2
	3	34.6	3.7			37.5
	4	35.1	3.5			37
	5	34.3	3.1			39.6
	6	34.6	3.1			39.8
	7	35.1	3.35			40.1
	8	34.5	can't record			39.4
	9	36.2	3.4			38.2
	10	38.1	3.1			38.9
2	5 mm					
	1	34.4	2.65			34.5
	2	35.2	2.75			35.1
	3	34.8	2.8			35.5
	4	34.9	2.65			36
	5	35	2.8			35.8
	6	35.5	2.2			35.8
	7	34.8	2.9			36.7
	8	34.1	2.7			36.2
	9	35.3	3.05			36.6
	10	35	2.2			36.6
3	10 mm					
	1	43.5	7.8			42.6
	2	43.8	7.7			44.2
	3	45.2	8.4			47.4
	4	44.3	9.4			46.6
	5	46.8	9.8			54.5
	6	48.4	11			51.1
	7	46	8			59.5
	8	40.6	8.8			53.1
	9	40.3	9.2			61.4
	10	39.4	9			60.5

Remote Presentation

Can the Expression of Interleukin–6 by the Local Lymphocytes be Used as a Biomarker for Fracture Healing? – A Pilot Study and Ongoing Practice

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What was the question?
It is well documented in the literature that inflammation and pro–inflammatory cytokines inhibit osteogenesis. However, interleukin–6 exhibits a pleiotropic effect, and it is shown that it induces osteogenic transformation of mature osteoblasts during bone remodeling. We aimed at investigating possible correlations between inhibition of progression of healing of complex fractures and the expression of pro–inflammatory cytokines at local tissue level.

How did you answer the question?
We have retrospectively identified two groups of patients between 2017–2019 who suffered compound fractures of the tibia or femur (Gustillo I &II). Group A consisted of four patients who were treated with either osteosynthesis or primary arthrodesis by the use of an external circular fixator. The outcome under investigation was "fracture healing." Group B consisted of four patients treated by an external circular/monolateral fixator and bone transport due to bone loss of four to six centimeters. The docking sites were grafted openly. The outcome under investigation was "healing of the docking site."Baseline demographics and clinical and operative details were recorded. Actively infected cases were excluded from the study.At six months from baseline surgery and at the time we removed the frame (based on radiological findings of bone remodeling), we performed: Skin tissue biopsies over the fracture site and along the track of the afferent lymph vessels. Detection of expression of pro–inflammatory cytokine IL–6 on these tissue samples was performed by Immunohistochemistry (peroxydase technique).

What are the results?
In four patients the lymphocyte number per HPF and the intensity of staining for IL–6 were high (+3). In three patients the lymphocyte number per HPF and the intensity of staining for IL–6 were moderate (+2). The outcome in all patients with high or moderate expression of local IL–6 was "healing". The outcome in patients with weak IL–6 (+1) expression was the development of pseudarthroses, following frame removal, despite the radiological and clinical impression of healing.

What are your conclusions?
It is possible that tissue expression of IL–6 at the beginning of the bone remodeling phase following a fracture can be used as an auxiliary biomarker of bone healing.
Combining classical radiographic evidence of healing/remodeling with this biomarker we facilitate decision making: "REMOVE" (frame) or "RETAIN and ADJUST". For the time being, we have incorporated the use of this biomarker in our practice.

Special Session

Limb Deformity Care in Low and Middle Income Countries

Building a Limb Deformity Practice in Nigeria*
Emeka Izuagba, MD

LLRS Efforts to Improve International Care
Raymond W. Liu, MD

Pediatric Orthopaedic Observerships in North America for International Surgeons: Perceived Barriers and Opportunities for Visitors and Hosts
Sanjeev Sabharwal, MD

Fostering Limb Deformity Care with the SIGN Network*
Richard Gellman, MD

Pediatric Orthopaedic Observerships in North America for International Surgeons: Perceived Barriers and Opportunities for Visitors and Hosts

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What was the question?
Despite recommendations for high–income countries to partner with low–income and middle–income countries to expand surgical access, little is known about the barriers faced by international surgeons (IS) who participate in short–term clinical observerships in North America and those encountered by their North American (NA) hosts.
Our primary aim was to assess the barriers perceived by IS who participated in a pediatric orthopaedic–focused observership and their NA hosts. Additionally, we sought to identify opportunities for improvement based on feedback by the IS and NA hosts. We believe the results of this study will provide an impetus to further enhance the value of these clinical observerships, as orthopaedic surgeons strive to develop and strengthen contextual and sustainable global partnerships with their peers.

How did you answer the question?
Surveys were distributed to IS who participated in a pediatric orthopaedic observership in North America from 2009 to 2019 and their NA hosts to assess the perceived barriers faced by both partners and identify possible opportunities for further improvement.

What are the results?
Responses were received from 181 IS and 46 NA hosts. IS reported facing a variety of barriers prior to, during, and after completion of their NA observership such as financial burden, language and cultural barriers, and challenges with local accommodations and transportation. Only 49% of IS reported that their NA hosts had sought feedback from them. Barriers noted by the NA hosts included financial burden, logistic challenges with hosting, language barriers, and lack of support from their co–faculty/staff. At least 43% of NA hosts reported that their observership program was unfunded. Based on the survey responses, potential areas that may enhance the observership experience include funding support, creating a centralized databank of pediatric subspecialty opportunities available at each sponsoring institution, pre–visit orientation for the visiting surgeon, inclusivity by addressing language and cultural barriers, improving access to observing surgical procedures, obtaining post–visit feedback, and creating a virtual community of international visitors and NA hosts for ongoing exchange of ideas and resources.

What are your conclusions?
Both the IS who participate in a pediatric orthopaedic clinical observership and their NA hosts identified limited funding as a major barrier. There are several opportunities for enhancing this unique learning experience and exploring the role of contextual remote learning for all participants. Further studies are needed to investigate the value of clinical observerships for IS including the downstream consequences of such opportunities on capacity building, bidirectional learning, and improving patient care.

Concurrent Validity of DASH and PROMIS Scores in Transhumeral Amputees

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What was the question?
Among transhumeral amputees, do select domains of the Patient Reported Outcomes Measurement Information System (PROMIS) correlate with traditionally used patient reported outcome measures (PROMs) – the Disabilities of Arm, Shoulder, and Hand (DASH) Score and the Defense and Veterans Pain Rating Scale (DVPRS)?

How did you answer the question?
After obtaining IRB approval, we prospectively administered DASH, DVPRS, and PROMIS (Upper Extremity, Pain Interference, and Pain Behavior domains) testing to patients presenting for consideration of osseointegration after transhumeral amputation. Concurrent validity was assessed via Pearson's correlation testing. Data analysis was conducted in IBM SPSS v27.0, with significance defined at a=0.05.

What are the results?
We obtained PROMs from 10 participants (Table 1). The mean DASH score of the cohort was 32.8 (SD 23.3). The mean DVPRS score was 1.8 (SD 1.5). The mean PROMIS scores were 33.8 (SD 5.3), 50.5 (SD 7.3), and 50.6 (9.8) for Upper Extremity, Pain Interference, and Pain Behavior domains, respectively. Pearson's testing demonstrated a significant, inverse correlation between DASH and PROMIS Upper Extremity scores ($r=-0.85$, $p=0.002$). There was also significant correlation between DVPRS and PROMIS Pain Interference scores ($r=0.69$, $p=0.03$). The PROMIS Pain Behavior domain did not significantly correlate with either traditionally used PROM.

What are your conclusions?
PROMIS Upper Extremity and Pain Interference scores demonstrated significant concurrent validity with traditional measures (DASH and DVPRS) of patient–reported outcome among trans–humeral amputees. Demonstrating moderate to strong correlation with traditional PROMs (DASH and DVPRS), PROMIS Upper Extremity and Pain Interference domain scores are valid measures of HRQoL in the trans–humeral amputee population. Looking forward, PROMIS may better serve our efforts to track the outcomes of future interventions—such as residuum lengthening, targeted muscle reinnervation, and osseointegration—for these patients.

Concurrent Validity of Q–TFA with PROMIS & Prosthetic Wear Time in Transfemoral Amputees

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What was the question?
Does the Questionnaire for Persons with a Transfemoral Amputation (Q–TFA), a validated, traditionally used patient–reported outcome measure (PROM), significantly correlate with select Patient Reported Outcomes Measurement Information System (PROMIS) domains and self–reported prosthetic wear time in transfemoral amputees presenting for consideration of osseointegration?

How did you answer the question?
After obtaining IRB approval, we prospectively administered Q–TFA (including Use, Mobility, Problems, and Global Health subscores) and PROMIS (including Physical Function, Pain Interference, and Pain Behavior domains) testing to patients presenting for consideration of osseointegration after transfemoral amputation. We also asked participants to report prosthetic wear time, in hours per week. Concurrent validity was assessed via Pearson's correlation testing. Data analysis was conducted in IBM SPSS v27.0, with significance defined at alpha=0.05.

What are the results?
We obtained data for 39 participants. The mean Q–TFA subscores of the cohort were: Use – 37.9 (SD 39.0); Mobility – 58.9 (SD 23.7); Problems – 43.1 (SD 17.0); Global Health – 39.6 (SD 18.4). The mean PROMIS domain scores of the cohort were: Physical Function – 38.6 (SD 4.0); Pain Interference – 57.2 (SD 8.1); Pain Behavior – 56.1 (6.8). The cohort's mean prosthetic wear time was 39.8 hours per week (SD 44.5). Pearson's testing demonstrated significant correlation between: Q–TFA Use and self–reported prosthetic wear time ($r=0.81$, $p<0.001$); Q–TFA Mobility and PROMIS Physical Function ($r=0.44$, $p=0.009$); Q–TFA Problems and PROMIS Pain Interference ($r=0.60$, $p<0.001$); Q–TFA Global Health and PROMIS Physical Function ($r=0.35$, $p=0.04$). Q–TFA Problems also correlated significantly with PROMIS Pain Behavior ($r=0.34$, $p=0.04$) and significantly, inversely, with PROMIS Physical Function ($r=–0.39$, $p=0.02$).

What are your conclusions?
PROMIS and self–reported prosthetic wear time exhibit significant concurrent validity with the Q–TFA in our population of transfemoral amputees. Computerized adaptive testing, such as PROMIS, has multiple advantages over legacy PROMs, including ease of administration and reduction of question burden. Looking forward, PROMIS may better serve our efforts to track the outcomes of future interventions—such as residuum lengthening, targeted muscle reinnervation, and osseointegration—for these patients.

Remote Presentation

Functional Outcomes in the Treatment of Fibula Hemimelia – The 5–year Experience of a Regional Children's Hospital

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What was the question?
Fibula hemimelia (FH) is a musculoskeletal disorder characterised by a lower limb failure of longitudinal formation. The aim of our study was to assess the health related quality of life of patients with FH at our centre. In this presentation we report the 5 year patient and parent reported health related quality of life outcomes of 30 patients with FH.

How did you answer the question?
Data was prospectively collected as part of an observational study of children with limb deformities. Ethics approval was obtained from the institutional research ethics board. All patients with a diagnosis of FH who presented to us within the 5 year period (January 2015 – October 2020) were invited to participate in the observational study. Consent was obtained from the parents and legal guardians. Assent was obtained from patients between the ages of 7–18 years. Health related quality of life scores were gathered using the PedsQL, a generic quality of life questionnaire encompassing physical, social, emotional and school functioning.

What are the results?
In total, there were 114 completed PedsQL scores (52 child self–reports and 62 parent–proxy reports). The median PedsQL score was 82.0 [67.0 – 88.7]. The scores were taken at a median of 7 months after the most recent surgery, and 23.7% of the scores were taken when an external fixator lengthening frame was on. The median number of surgical procedures was 2 (range 2–10). For every surgery, there was an increase in the normalised score by 0.17 but from the p value this was not statistically significant. With each month post surgery, there was a drop in the normalised score by 0.04, but again this was not statistically significant. The parent normalised score was 1.36 worse than the child score across the board, and this was statistically significant ($p=0.003$). With each year the child grew, the normalised score dropped by 0.03 (not statistically significant). When the multivariate model was applied and adjusted for confounders, the normalised score of a patient with an external fixator frame was 3.61 below that of a patient without a frame ($p<0.001$).

What are your conclusions?
Early results of the patients with complete scores points towards an improvement in child reported function after targeted operative treatment. Parent proxy scores are generally lower than child reported scores, especially when an external fixator frame is in situ. Parents overestimate or children under report their health related quality of life burden. There is a need for a validated patient reported outcome measure for these patients.

Remote Presentation

Establishing the Content Validity of LIMB–Q Kids – A New Patient–Reported Outcome Measure for Children with Lower Limb Deformities

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What was the question?
Is the content of the newly developed PROM, LIMB–Q kids, comprehensive, comprehensible and relevant to the patients with lower limb deformities?

How did you answer the question?
Individual semi–structured interviews were conducted with children with lower limb deformities from Australia, Canada, and the USA. Feedback interviews were also done with the clinical experts including the orthopaedic surgeons, physiotherapists, occupational therapist, nurses, psychologists and prosthetists from Australia, Canada, Ethiopia, India, UK and the USA. Interviews were done in rounds which allowed us to make edits to the items after each round of interviews. During the cognitive debriefing interviews, children were asked to comment on wording of the items, instructions and response options. Interviewed children were also asked about the relevance of items to them and whether they could relate the concepts covered in the items to their own experiences of having a lower limb deformity. Children were asked to tell us anything about their leg that was important to them but has not been included in the items.
The clinical experts were asked to comment on the comprehensibility of items, instructions, recall period and response options. They were asked to identify items that they thought might be difficult for their patients to understand, suggest alternate wording/more commonly used words, and identify items that they thought were irrelevant for this patient population and could be potentially deleted. All interviews were recorded and transcribed verbatim. Analysis of the interviews was conducted using the reparative approach representing the 'Inspect and Repair' model. This approach includes closely examining the transcribed interviews and expert input and summarising edits after each interview and expert input.

What are the results?
40 interviews were conducted (17 patients ages 8–17 years, 4 parent, and 19 experts). A total of five rounds of interviews were conducted. After the first round of interviews, 91% of the items remained unchanged. Five new items were added. After the second round of interviews, 82% of the items remained unchanged. Twelve new items were added and 4 items were dropped. A new scale, the Ankle Symptoms Scale with 8 items was added after round 2 as suggested by the experts. After the third round of interviews, 89% of the items remained unchanged. Seventeen items were added and 7 items were dropped. Out of the 17 items added, 15 were for the individual symptom scales. Fifteen out of the 17 items that required changes during this round were only edited slightly to simplify the items further and reduce the F–K grade reading level. During round 4, 3 patients with amputations, 3 parents of children with amputations, and 7 experts reviewed the Leg Symptoms Scale for any additional items that need to be added for children with amputations. Three items were added to the Leg Symptom Scale at this time. During round 5, the final version of LIMB–Q Kids had 158 items and was tested in one patient. No further changes were required based on patient feedback at this time.

What are your conclusions?
Cognitive debriefing interviews and expert review allowed us to identify items that required re–wording, as well as identifying new items. This process was helpful for refining the items included in LIMB–Q Kids before the field–testing in a larger sample of children. Overall feedback from children and experts showed that the new PROM is comprehensive, understandable by the target patient population, has relevance to this patient population and will be able to measure change longitudinally. LIMB–Q Kids is a new PROM for children with lower limb deformities. It may be used to measure outcomes that matter to children with lower limb deformities from the perspective of the child.

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

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What was the question?
Patient–reported outcome (PRO) instruments are important in modern research, but there are no validated PROs specific for pediatric limb deformity (LD) patients. We compared limb deformity modifications of two commonly used scoliosis instruments, the Early Onset Scoliosis Questionnaire (LD–EOSQ, used for ages 0–10 years) and the Scoliosis Research Society Questionnaire (LD–SRS, used for ages 11–18 years), to the Pediatric Outcomes Data Collection Instrument (PODCI), which is well validated and widely utilized in general pediatric orthopaedics.

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

What are the results?
For 18 children ages 10 years and younger there were comparable scores for both instruments (Table 1) and high correlation between LD–EOSQ Quality of Life and PODCI Global function (R2=0.89). For 20 children ages 11–18 years there were lower scores for the limb deformity instruments (Table 2), and correlation between comparable domains ranged from R2 values of 0.59 to 0.78. There was minimal correlation between most instrument scores and LLRS AIM, with the strongest correlations between LLRS AIM and LD–SRS Function/Activity (R2=0.44) and LLRS AIM and PODCI Pain/Comfort (R2=0.17) (Tables 1–2).

What are your conclusions?
The limb deformity modified outcome instruments correlated well with PODCI questionnaires on most comparable domains. In adolescents the LD–SRS had lower scores than PODCI. This fits well with the expectation that adolescents should be more affected by their limb deformity than younger children, and suggests that LD–SRS might better capture limb deformity patient issues as compared to PODCI. Increased correlation between LD–SRS Function/Activity and LLRS AIM further suggests that LD–SRS may better reflect limb deformity outcomes versus PODCI.

Table 1

Children 10 Years and Under (N = 18, Mean Age 8.2 ± 2.7 years)				
PRO Domain	LD-EOSQ Quality of Life	PODCI Global Function	LD-EOSQ Family Impact	PODCI Happiness
Score	3.8 ± 0.8	3.7 ± 0.9	3.8 ± 0.8	3.9 ± 1.3
Correlation between instruments (R^2)	0.89		0.35	
Correlation with LLRS AIM (R^2)	0.01	0.08	0.09	0.09

Table 2

Children 11 – 18 years (N = 20, Mean Age 15.0 ± 2.9 years)						
PRO Domain	LD-SRS Function/ Activity	PODCI Mobility and Sports	LD-SRS Pain	PODCI Pain/ Comfort	LD-SRS Mental Health	PODCI Happiness
Score	2.1 ± 0.9	4.1 ± 0.9	1.7 ± 0.6	3.6 ± 1.5	2.2 ± 1.1	4.0 ± 1.1
Correlation between instruments (R^2)	0.62		0.78		0.59	
Correlation with LLRS AIM (R^2)	0.44	0.17	0.03	0.01	0.05	0.01

Difficult Case Presentation

Moderator: L. Reid Nichols, MD

3D–Printed Cutting Guides for Lower Limb Deformity Correction in the Young Population

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What was the question?
We describe the implementation of this technology in young patients who required a corrective osteotomy for a complex three–plane (oblique plane) lower–limb deformity.

How did you answer the question?
Radiographs and computerized tomographic (CT) scans (0.5 mm slices) were obtained for each patient. The CT images were imported into post–processing software, and virtual 3D models were created by a segmentation process. Femoral and tibial models and cutting guides with locking points were designed according to the deformity correction plan as designed by the surgeon. The models were used for preoperative planning and as an intraoperative guide. All osteotomies were performed with the PSI secured in the planned position.

What are the results?
A total of 17 patients (9 males and 8 females, average age 14.7 years [range 8–24]) comprised the study group. All of the PSI were excellent fits for the planned bone surfaces during surgery. The osteotomies matched the preoperative planning simulation and allowed for easy fixation with pre–chosen plates. No intra– or postoperative complications were encountered. Surgery time was shortened (101 minutes) and intraoperative blood loose was less compared to historical cases. Clinical and radiographic follow–up findings showed highly satisfactory alignment of the treated extremities in all 17 patients.

What are your conclusions?
The use of 3D–printed models and patient–specific cutting guides with locking points increases accuracy, shortens procedure time, reduces intraoperative blood loss, and improves the outcome of osteotomies in young patients with complex oblique bone deformities.

Magnetic Internal Plate Lengthening of the Femur and Tibia in Children: A Preliminary Report

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What was the question?
Limb lengthening in young children has historically been performed with external fixation until an age at which femoral anatomy allows for intramedullary lengthening (generally 9–10 years) or skeletal maturity permits tibial lengthening. A newly developed magnetic internal plate lengthener (MIPL) has been developed, which may have a role in limb lengthening for younger patients. This report aims to report preliminary results of its use at a single specialty center.

How did you answer the question?
We prospectively evaluated a consecutive series of 10 pediatric patients with congenital limb deficiencies who underwent MIPL of the femur or tibia between September 2020 and January 2021. Outcomes included all clinical and surgical details, all radiographic parameters (pre– and post–lengthening deformity analysis, lengthening details), modified Clavien–Dindo classification of complications, implant parameters and surgeon observations, and LLRS–AIM index of limb deformity for all patients.

What are the results?
Ten pediatric patients underwent 10 MIPLs (7 femur, 3 tibia) the study period. Mean patient age was 8.3 years (range 2–14), including 6 males and 4 females. Average lengthening achieved was 4.1 cm (range 3.5 – 4.5). By the modified Clavien–Dindo classification, there were 5 complications (Grade III in 3 patients, Grade I in 2 patients). All patients undergoing tibial lengthening experienced valgus and procurvatum during lengthening, including 2 reoperations (repeat tibial corticotomy in one patient for premature consolidation, repeat fibular osteotomy in another). Two femora experienced varus deformities (<10°) at the telescopic junction of the implant during lengthening, which did not undergo treatment. Weightbearing was initiated at an average of 15 weeks (range 8–24). The average LLRS AIM index was 5.8 (range 2–8) among all patients, suggesting “moderate complexity” of cases.

What are your conclusions?
Magnetic internal plate lengthening appears to hold promise for surgical lengthening of the femur and tibia in young patients. Questions remaining to be explored include best practices for implant application, the quality and character of bone regenerate, the role for additional fixation at implant removal, and weight–bearing protocols. The observations and complications reported herein provide the authors with insight toward further improvements to these devices.

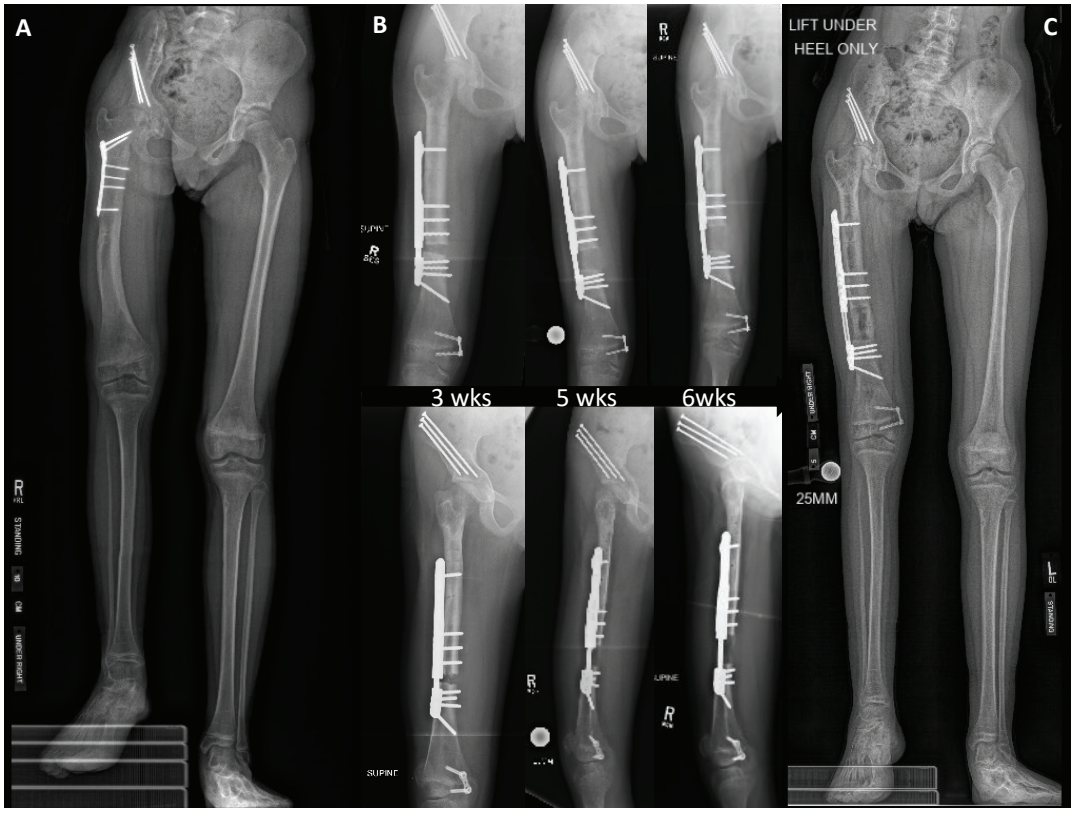

Figure. 9 year old female with PFFD and fibular hemimelia, status multiple right limb reconstructive procedures and lengthenings. She underwent magnetic internal plate lengthening.

A) Preoperatively, a 10 cm discrepancy is present, with diaphyseal femoral varus.
B) Images during lengthening. Acute deformity correction was performed concomitantly.
C) Result after 4.4 cm lengthening, with a 5.2 cm residual discrepancy.

Systematic Isolation of Key Parameters for Estimating Skeletal Maturity on AP Hip Radiographs

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What was the question?
The ability to estimate skeletal maturity using a hip radiograph could be useful in the treatment of scoliosis, slipped capital femoral epiphysis (SCFE), and lower limb deformity (LLD). A fast, accurate, and reproducible method is not available. We sought to determine if evaluation of an AP hip radiograph could allow for skeletal age estimation equivalent or superior to the Greulich and Pyle Atlas (GP).

How did you answer the question?
Fourteen hip radiologic parameters, including the five parameters from the modified oxford system, were evaluated on serial AP hip radiographs from three years before to two years after the skeletal age associated with 90% of final height, a validated skeletal maturity gold standard which correlates with the timing of peak height velocity. The GP left hand bone age was obtained for comparison. Stepwise linear regression and generalized estimating equation analyses were used to isolate key hip and demographic parameters, creating the "Optimized Oxford" skeletal maturity system. The accuracy of the Optimized Oxford system in predicting years from 90% of final height was evaluated and compared to systems of demographics only, the Modified Oxford, demographics + Modified Oxford, and demographics + GP.

What are the results?
284 hip radiographs from 41 girls (range: 7–15 years) and 38 boys (range: 9–17 years) were included. Following multivariate analyses, five of the original fourteen hip radiographic parameters remained significant. The predictions made by the Optimized Oxford model had greater accuracy and fewer outlier predictions (predictions >1 year off from actual years from 90% of final height) than the demographics only and Modified Oxford only models (p.05; Table 1).

What are your conclusions?
High precision in skeletal maturity estimation can be achieved by using chronological age, sex, and five hip radiographic parameters. This skeletal maturity system may have clinical utility when applied to scoliosis, SCFE, and LLD patients.

Table 1. Comparison between predicted vs. measured (true) years from 90% of final height

	Modified Oxford	**Age + Sex**	**Age + Sex + Modified Oxford**	**Age + Sex + GP**	**Optimized Oxford** (Age + Sex + Hip Parameters)
Mean prediction discrepancy ± SD, *yrs*	0.61 ± 0.5	0.49 ± 0.37	0.43 ± 0.34	0.42 ± 0.32	0.39 ± 0.31
Mean prediction discrepancy p-value*	**<.001**	**<.001**	**0.015**	0.188	-
% of outlier predictions (>1 year off)	24.30%	9.5%	4.8%	5.3%	4.6%
Outlier predictions p-value*	**<.001**	**0.010**	0.903	0.629	-
R^2	0.726	0.853	0.884	0.895	0.903

*All p-values are in comparison to Optimized Oxford

The Utility of the Modified Fels Knee Skeletal Maturity System in Limb Length Prediction

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What was the question?
Predicting ultimate lower extremity length is important in the treatment of lower limb discrepancy (LLD). Utilizing skeletal age over chronological age has been shown to significantly improve the prediction of ultimate lower extremity length. The most widely used skeletal maturity systems utilize left hand and wrist radiographs, necessitating additional imaging in most cases. The recently described Modified Fels knee skeletal maturity system relies on AP knee radiographs to estimate skeletal age reliably and accurately via imaging that is always available in LLD patients. We sought to evaluate the utility of the Modified Fels knee skeletal maturity system in ultimate limb length prediction when applied to standing hips to ankles radiographs in a modern adolescent clinical population.

How did you answer the question?
The medical records of all patients treated at our institution over a 20–year period with unilateral lower extremity pathology and hips to ankles radiographs available both before and after reaching skeletal maturity were reviewed. Skeletal maturity was defined by closed distal femoral, proximal tibial, and proximal fibular physes. The femoral, tibial, and lower extremity length was measured in all radiographs. Measurements obtained after reaching skeletal maturity were used to define the ultimate femoral, tibial, and lower extremity lengths of each subject. The Modified Fels knee skeletal maturity system was applied to all radiographs taken prior to maturity to estimate skeletal age. The accuracy of three widely utilized lower extremity length prediction systems was compared when utilizing estimated skeletal age versus chronological age inputs. Cross sectional and longitudinal statistical analyses were performed. Statistical significance was set at p&0.05.

What are the results?
247 radiographs (109 prior to maturity) from 47 patients were eligible for inclusion. Patient demographics and measured ultimate femoral, tibial, and lower extremity length are summarized in Table 1. On cross–sectional analysis, linear mixed effects modeling using skeletal ages was uniformly associated with higher (improved) R2 values than chronological age–based models (Table 2). On longitudinal analysis, skeletal age models had lower Akaike information criterion (AIC) values than chronological age models in all cases, similarly indicating superior performance.

What are your conclusions?
In treatment of LLD, the Modified Fels knee skeletal maturity system can be readily applied to available imaging to improve the prediction of ultimate femoral, tibial, and lower extremity length. This skeletal maturity system may have significant utility in estimation of ultimate limb length discrepancy and determination of appropriate timing of epiphysiodesis.

Table 1: Summary Statistics of True (Measured) Leg Length

Variable	n	Mean	SD	Median	CV[a]
Skeletal age (years)	43	11.28	2.1	11.3	0.19
Chronological age (years)	43	11.56	2.0	11.4	0.17
Ultimate Femoral Length (mm)	43	489	43	491	0.09
Ultimate Tibial Length (mm)	43	386	38	385	0.10
Ultimate Lower Extremity Length (mm)	42	874	80	877	0.09

[a]Coefficient of Variation

Table 2: Comparison of Predicted Lengths Using Coefficient of Determination (R^2) Obtained from Linear Mixed Effects Models

	Ultimate Femoral Length		Ultimate Tibial Length		Ultimate Lower Extremity Length	
	Skeletal Age Prediction	Chorological Age Prediction	Skeletal Age Prediction	Chorological Age Prediction	Skeletal Age Prediction	Chorological Age Prediction
	R^2	R^2	R^2	R^2	R^2	R^2
Multiplier Method	0.843	0.787	0.883	0.798	0.869	0.820
White-Menelaus	0.847	0.822	0.891	0.856	0.860	0.836
Growth Remaining	0.828	0.793	0.877	0.790	0.870	0.813

Higher R^2 means better fit.

Remote Presentation

Clinical Outcomes Following Surgical Hip Dislocation for Paediatric Hip Pathologies: A Prospective Cohort Study

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What was the question?
Surgical Hip Dislocation (SHD) is a powerful tool in the armamentarium of any surgeon treating conditions affecting the hips of children presenting with sequelae of a number of common conditions including Perthes and SUFE Risks associated with the procedure are well described. We investigated to assess if SHD is associated with significant surgical risk and if it improved clinical outcomes for patients

How did you answer the question?
We conducted a prospective cohort study. We reviewed 20 patients (10 males, 10 females; mean age, 13.2 years; range, 8–17 years) with symptomatic hip pathology between 2017 and 2021. All patients underwent a surgical hip dislocation approach and femoral head–neck osteochondroplasty, Head Split osteotomy or both. Clinical improvement was assessed using the WOMAC index. The minimum follow–up was 7 months (mean, 22 months; range, 7–42 months).

What are the results?
WOMAC scores improved at final follow–up from (10 to 3 for pain, 33 to 10 for function, and 4 to 2 for the stiffness subscales). No patients had osteonecrosis, implant failure, deep infection, or nonunion.

What are your conclusions?
Surgical Hip Dislocation, in the short term, we found improvement in WOMAC scores with a low complication rate.

Traveling Fellowship Presentation

Introduction by Austin T. Fragomen, MD

Dr. Omolade Lasebikan

Sarah Nossov, MD

Daniel Stinner, MD

Hexapod Circular External Fixators May Produce Superior Regenerate Bone, A Lower BHI, and Less Post Residual Deformity when Compared with Classic Circular Fixators When Used for Bone Transport or Lengthening Through Malunions

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What was the question?
How do classic circular external fixators behave comparted with hexapod circular fixators when performing bone transport reconstruction or malunion correction with lengthening?

How did you answer the question?
This was a retrospective multicenter study. HSS, NY, NY enrolled 137 patients that underwent either bone transport or malunion correction and lengthening using the [redacted] or [redacted] hexapod external fixators. Hosp Governador Celso Ramos, Brazil, enrolled 90 patients for identical treatment indications using a classic circular external fixator with hinges and threaded rods. Demographics were recorded for both groups. Outcomes were measured using several criteria: bone healing index (BHI), final bone alignment, and regenerate quality (modified Li score). Statistics were provided by a neutral source (Dublin, IRE).

What are the results?
The demographics showed some significant differences: the Brazil cohort had larger bone defects (6.7cm v 5.0cm, p=0.03) and more true bone transports as opposed to shortening–lengthening type. The BHI for classic was 87.8 and hexapod was 59 (p=0.000). The regenerate quality was better in the hexapod group (A=66, B=30, C=3 for hexapod; v A=56, B=26, C=19 Classic, p=0.003). The alignment parameters were closer to normal in the hexapod group (MPTA p=0.002, PPTA p=0.005, ADTA p=0.038). The ASAMI Bone score was higher in the hexapod cohort (90 v 74, p=0.0004).

What are your conclusions?
These data show a superior performance of the hexapod frame over the classic including quality of regenerate. These results need to be taken with some caution because the patients treated in Brazil were more severely traumatized with larger bone defects. Criteria for frame removal may differ in these two centers. Authors suggest use of the hexapod for bone transport and malunion if it is available. Results for both techniques are excellent if performed by experts.

Indications and Outcomes of One Staged Two–Level Femur Osteotomies

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What was the question?
Complex deformities of the femur can be difficult to manage, and require correctional osteotomies to reduce pain, improve gait mechanics, and optimize limb alignment. Although the correction of complex lower extremity deformities through simultaneous femoral and tibial osteotomies has been well documented in the literature, the safety and efficacy of correcting large femoral deformities through multiple osteotomies has yet to be described. This study explores whether one staged two–level femur osteotomies are safe and effective at correcting complex deformities of the femur.

How did you answer the question?
Patients who underwent one staged two–level femur osteotomies at our practice were identified via a REDCap database search for inclusion. Demographics, indications for surgery, pre and post–operative patient function, radiographic measurements, surgical technique and data, post–operative courses, and patient satisfaction were recorded. Successful two–level correction was defined as achieving union at both osteotomy sites without complications, unplanned surgery, or residual deformity.

What are the results?
19 patients and 23 total femurs who underwent one staged two–level femoral osteotomies were identified via a REDCap database search. These patients were followed up for a mean of 14.8 months. In all patients, there were no deep venous thromboses, pulmonary emboli, non–unions, or infections. One patient who underwent unilateral two–level femoral osteotomy required an unplanned procedure to correct a soft tissue contracture. According to our methods, 18/19 patients (95%), and 22/23 femurs treated with one staged two–level femur osteotomies met the criteria for successful correction.

What are your conclusions?
22/23 femurs and 18/19 patients were treated successfully with one staged two–level femoral osteotomies, demonstrating that this technique is a safe and highly effective tool for correcting complex deformities of the femur with favorable results.

Correction of Extra–articular Limb Deformity Before Total Knee Arthroplasty

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What was the question?
Extra–articular deformities about the knee mandate special considerations when planning total knee arthroplasty (TKA). Poor limb alignment may increase perioperative complications and cause early implant failure after TKA. Correction of the limb alignment prior to arthroplasty may delay or even prevent the need for TKA by improving the anatomic and mechanical axes. This study analyzes a series of patients with primary knee arthritis in the setting of extra–articular femoral and tibial deformities that underwent staged deformity correction prior to TKA.

How did you answer the question?
Thirty–seven limb segments in 31 patients (average age: 48 years; range 31 – 64) who underwent surgical correction of femoral and tibial extra–articular deformity in preparation for ipsilateral total knee arthroplasty. Deformity surgery was performed by one of two senior surgeons and consisted of either acute or gradual correction with a plate/screw construct, static intramedullary nail, internal lengthening nail, external hexapod system, or monolateral lengthening rail. Patient demographics, physical examinations, as well as global and segment radiographic deformity measurements were compared both preoperatively and postoperatively. Severity of knee arthritis was classified according to the Kellgren and Lawrence classification. Complications and unplanned return to surgery were monitored as well as if each patient proceeded to TKA after deformity correction.

What are the results?
Trauma was the most common reason for extra–articular limb deformity (70%) followed by congenital etiologies (15%). Unifocal deformities were present in 24 patients (16 femur and 8 tibia) while 6 patients (12 segments) had deformities in both femur and tibia. One patient had a double level deformity in the femur. Average distance from the joint line to the deformity center was 202mm in the femur (70 – 295) and 111mm in the tibia (60 – 130). For deformities that had a global varus alignment (average MAD 52mm medial), there was an average segment correction of 13° in the coronal plane and 11° in the sagittal plane with a 27mm change in leg length discrepancy (LLD). For global valgus correction (average MAD 35mm lateral), there was an average segment correction of 14° in the coronal plane and 6° in the sagittal plane with a 13mm change in LLD. (Table 1). After an average 2.3 year follow up (minimum 1 year after corrective surgery), only 18 out of 31 patients proceeded with total knee arthroplasty at time of follow up.

What are your conclusions?
Extra–articular deformities in the femur and tibia generate abnormal mechanical forces through the knee that can advance osteoarthritis. Failure to correct these deformities prior to TKA can lead to early implant failure. Staged deformity correction improves limb alignment and may prevent peri–operative complications during TKA due to normalized anatomy and soft tissue tension. It may also delay or even avoid joint replacement surgery depending on the severity and manifestation of the patient's knee arthritis.

Table 1 - Preoperative and Postoperative Radiographic Deformity Measures				
	Varus (n = 19)		Valgus (n = 12)	
	Preop	Postop	Preop	Postop
Global Deformity				
MAD (mm)	52 medial (20 - 84)	19 (1 - 44)	35 lateral (6 - 85)	23 (2 - 59)
mTFA (°)	16 (5 - 26)	6 (0 - 11)	10 (2 - 23)	6 (0 - 18)
mLDFA (°)	95 (75 - 104)	89 (79 - 92)	87 (77 - 93)	87 (79 - 94)
mMPTA (°)	90 (78 - 102)	88 (84 - 96)	94 (87 - 101)	89 (88 - 92)
PPTA (°)	79 (59 - 98)	77 (58 - 86)	78 (71 - 87)	79 (71 - 82)
LLD (mm)	31 (8 - 44)	4 (0 - 8)	23 (12 - 50)	10 (3 - 16)
JLCA	8 varus (1 - 34)	5 (0 - 10)	3 valgus (0 - 11)	2 (1 - 5)
Segment Deformity				
Coronal Plane				
Angulation (°)	16 (5 -39)	3 (0 - 8)	16 (4 - 24)	2 (0 - 5)
Translation (mm)	7 (0 -14)	1 (0 - 4)	11 (0 - 32)	0 (0)
Sagittal Plane				
Angulation (°)	16 (0 - 39)	5 (0 - 12)	9 (0 - 26)	3 (0 - 7)
Translation (mm)	13 (2 - 27)	3 (0 - 6)	9 (0 - 14)	1 (0 - 3)

*Values listed as Average (Range); MAD - mechanical axis deviation; mTFA - mechanical tibiofemoral angle; mLDFA - mechnical lateral distal femoral angle; mMPTA - mechanical medial proximal tibial angle; PPTA - posterior proximal tibial angle; LLD - leg length discrepancy; JLCA - joint line convergence angle

Dual Femoral and Tibial Osteotomies for Large Lower Extremity Deformities

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What was the question?
Correction of large lower extremity deformities increases concern regarding bone healing and soft tissue tension. Gradual correction with an external fixation device is often seen as a patient nuisance and has specific complications such as pin tract infections. Acute correction of large deformities through a single osteotomy has the potential to produce sizable bony gaps and places undue soft tissue tension that may lead to nonunion or nerve palsy. This series investigates the radiographic and clinical outcomes after correction of large lower extremity deformities with dual distal femoral and proximal tibial osteotomies.

How did you answer the question?
This is a single–institution, retrospective case series of 21 extremities in 18 consecutive patients who underwent concurrent distal femoral and proximal tibial osteotomies with acute coronal plane correction and internal fixation by one of two senior surgeons. Acute fixation was performed using either plate or intramedullary nail constructs. Patient physical examinations and radiographic measurements including mechanical axis deviation (MAD) and mechanical tibiofemoral angle (mTFA) were compared both pre– and post–operatively. Accuracy of the correction was calculated using a predetermined MAD goal of neutral, undercorrection, or overcorrection that was based on the preoperative clinical decision of the attending surgeon. Complication events such as peripheral nerve palsy, nonunion, superficial and deep infection, deep vein thrombosis, compartment syndrome as well as unplanned return to surgery were recorded. Preoperative and postoperative Patient Reported Outcome Measures in Surgery (PROMIS) and Limb Deformity Scoliosis Research Society (LDSRS) scores were analyzed and compared.

What are the results?
The average patient age was 37.4 years (20.9 to 65 years) with a median follow up of 14.5 months for 13 primary varus deformities (average MAD = 64.5mm medial; mTFA = 17.3° varus) and eight primary valgus deformities (average MAD = 44.6mm lateral; mTFA = 14.8° valgus) (Table 1). The MAD and mechanical tibiofemoral angle were corrected on average 56.3mm and 16.5° in varus deformities and 44.6mm and 13.3° for valgus deformities. Overall accuracy was 92.9% of the intended correction goal. There was no significant difference in knee range of motion before and after surgery, and there was no incidence of knee instability or symptomatic patella baja. Both PROMIS and LDSRS scores had postoperative differences that were above the meaningful clinical threshold minimums (Table 2). Two patients developed peri–incisional cellulitis that resolved with antibiotics, otherwise, there were no incidences of nonunion, deep vein thrombosis, compartment syndrome, deep infection, or peripheral nerve palsies. No patients had unplanned surgery in either the early or late phases of healing.

What are your conclusions?
This series demonstrates that large lower extremity coronal plane deformities can be acutely corrected through simultaneous femoral and tibial osteotomies. Dividing the overall correction decreases the need for large bony wedges and avoids excessive soft tissue tension to minimize complications like nonunions and nerve palsies. This technique has been shown to clinically improve patient reported outcomes with accurate mechanical axis neutralization while avoiding external fixation, which often requires lengthy treatment times with more frequent follow up. Although dual osteotomies with internal fixation are not appropriate for every case, it should be considered for patients with large coronal plane deformities.

Table 1 - Patient Demographics and Preoperative Characteristics		
Gender		
Female	10	
Male	11	
Age (years)	37 (21 - 65)	
BMI	32 (19 - 53)	
Unilateral	15	
Bilateral	3 (6 extremities)	
	Varus (n = 13)	Valgus (n = 8)
MAD (mm)	65 (24 - 99)	45 (24 - 73)
mTFA (°)	17 (7 - 25)	15 (9 - 20)
mLDFA (°)	95 (90 - 102)	82 (78 - 86)
mMPTA (°)	81 (75 - 88)	93 (88 - 96)
Knee ROM Arc (°)	128 (115 - 140)	129 (90 - 150)
CD Index	0.9 (0.7 - 1.1)	1.1 (0.7 - 1.4)

*Values listed as Average (Range); BMI - body mass index; MAD - mechanical axis deviation; mTFA - mechanical tibiofemoral angle; mLDFA - mechnical lateral distal femoral angle; mMPTA - mechanical medial proximal tibial angle; ROM - Range of Motion; CD - Caton-Dechamps Index

Table 2 - Patient Reported Outcomes		
	Preoperative	Postoperative
PROMIS		
Pain Intensity	51.7	43
Physical Function	39.9	45.3
Pain Interference	60.1	53.3
Estimated Utility Score	0.7	0.7
Global Mental Health Score	52.3	55
Global Physical Health	45.4	47.3
LDSRS		
Function	3.3	4.1
Mental Health	4	4.3
Pain	3.4	4.1
Self-Image	3.2	4.2
Total	3.5	4.2

*Values listed as Average; PROMIS - Patient Reported Outcome Measures in Surgery; LDSRS - Limb Deformity - Scoliosis Research Society

Presidential Guest Speaker

Introduction by Austin T. Fragomen, MD

Horses for Courses: Choosing the Right Osteotomy for OA Knee
Milind M. Chaudhary, MD

Poster Session

Please visit each poster display

Poster Presentation

Antegrade Femoral Lengthening with Simultaneous Hemiepiphysiodesis Reduces Surgical Burden for Patients with Congenital Femoral Deficiency

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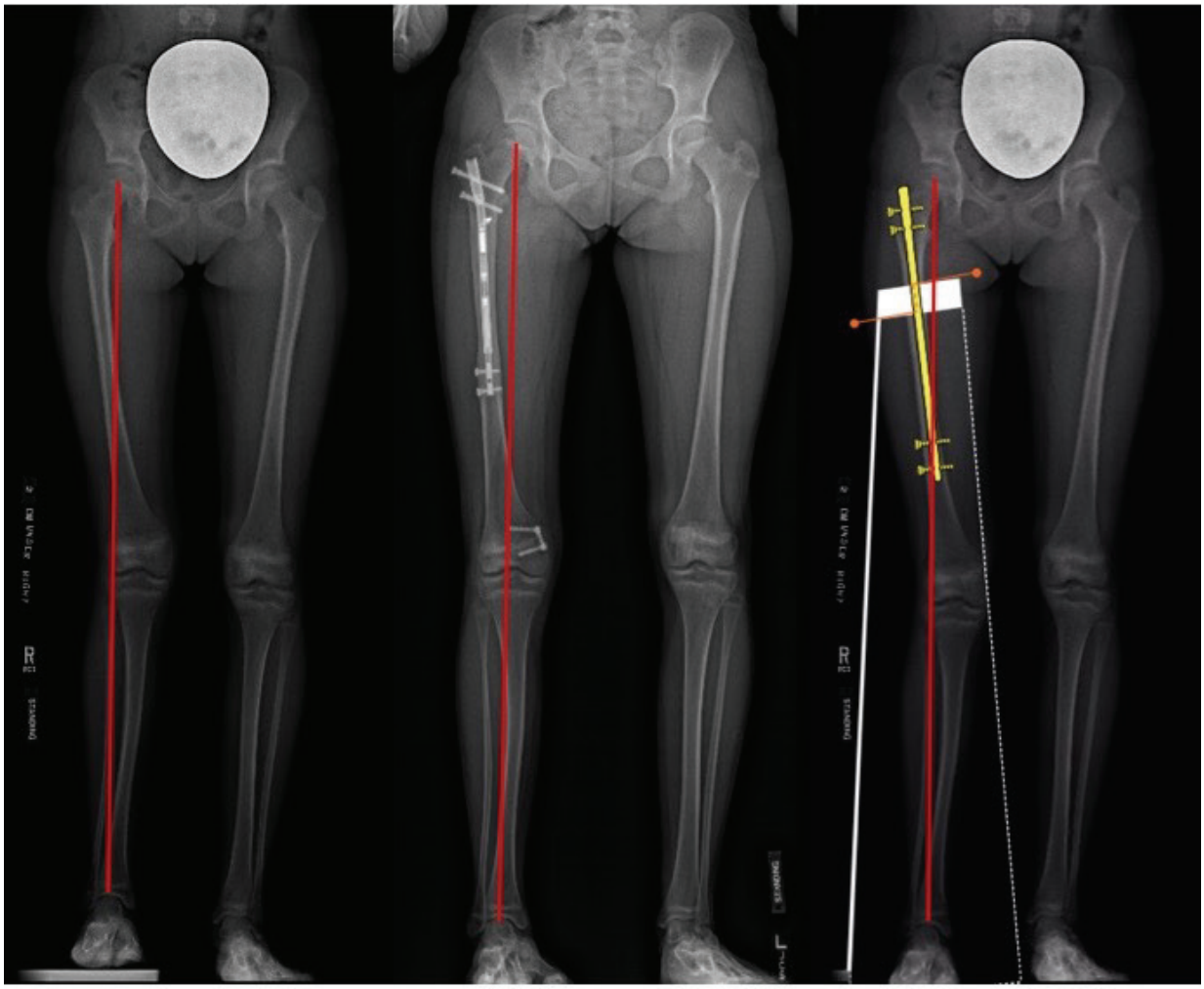
What was the question?
Antegrade motorized intramedullary lengthening of the femur and medial distal femur hemiepiphysiodesis (MDFH) are commonly performed treatments for children with congenital femoral deficiency (CFD). There are no reports of the results of these procedures when performed simultaneously with respect to reducing surgical burden for patients. We evaluated the extent to which combining these procedures reduced the number of surgical interventions while achieving both lengthening and deformity correction.

How did you answer the question?
We retrospectively reviewed a consecutive series of pediatric patients with CFD undergoing antegrade, motorized intramedullary femoral lengthening with combined MDFH between 2008 – 2020. Each lengthening plus MDFH was compared to its simulated counterpart (i.e. the same lengthenings in the same patients minus MDFH, with final radiographic parameters assessed by Bone Ninja). Outcomes included mechanical axis deviation (MAD), coronal femoral–tibial angle (CFTA), mechanical lateral distal femoral angle (mLDFA), and medial proximal tibial angle (MPTA). By convention, valgus was positive and varus negative. The total number of operations required for placement and removal of all implants was also recorded. Summary statistics are reported with student's t–test used to evaluate differences between the cohorts.

What are the results?
Ten patients with CFD underwent 12 lengthenings plus MDFH during the study period. Mean patient age was 12.3 years, including 6 males and 4 females. Average radiographic measurements at the time of nail removal in the cohort undergoing both operations were MAD = –4.8 mm ± 8.8, CFTA = –1.0º ± 3.9, mLDFA = 89.3º ± 2.7, MPTA = 89.3º ± 1.7. Average radiographic measurements for the simulated cohort were: MAD = 16.6 mm ± 12.3, CFTA = 6.4 º ± 4.7, mLDFA = 83.0 º ± 4.3, MPTA = 89.2 º ± 1.9. Significant differences, $p < 0.05$, were found between the cohorts for MAD, CFTA, and LDFA. The guided growth implant was both implanted and removed with the nail in 8 of 12 lengthenings. The actual patient cohort averaged 2.3 surgeries while the simulated cohort would require between 3 and 4 surgeries to achieve both lengthening and deformity correction as separate procedures.

What are your conclusions?
Medial distal femur hemiepiphysiodesis paired with antegrade intramedullary femoral lengthening reduces surgical burden for patients and families. The total number of operations to achieve both lengthening and deformity correction is minimized as implants can often be implanted and removed simultaneously.



Preop Final with MDFH Without MDFH

Poster Presentation

Angular Deformity after Temporary Epiphysiodesis for Leg Length Discrepancy

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What was the question?
What is the potential for angular deformity that may be created as a result of temporary epiphysiodesis and what are the associated factors after temporary epiphysiodesis around the knee?

How did you answer the question?
Records of patients who underwent temporary epiphysiodesis of either the distal femur or proximal tibia or both between 2000 and 2020 were reviewed. The Mechanical Axis Deviation (MAD) was measured on preoperative and last follow up radiographs. Surgical complications were reported. Data was analyzed using Fisher's exact test and paired t–tests. An angular deformity was defined as having a MAD greater than 10 mm.

What are the results?
A total of 13 limbs from 12 individuals were included in the study. Mean age at the time of surgery was 11.2 ± 2.3 years. Mean postoperative follow up was 5 ± 2 years. The procedure was performed only on the distal femur in six limbs (6/13=46%), only on the proximal tibia in two limbs (2/13=15%), and on both distal femur and proximal tibia in five limbs (5/13=38%). For the whole group, the mean MAD change over follow up was 14 ± 9 mm. Of the femoral only procedures, four limbs (4/6=67%) had medial direction of MAD change, and two limbs (2/6=33%) had lateral MAD change. Of the two limbs with tibial only procedures, one limb (1/2=50%) had medial direction of MAD change and one limb (1/2=50%) had lateral direction of MAD change. Of the combined femoral and tibial procedures, one limb (1/5=20%) had no MAD change, and four limbs (4/5=80%) had lateral MAD change. At the last follow up, 77% (10/13) of limbs had MAD greater than 10 mm from neutral, which they did not have before surgery.

What are your conclusions?
This study suggests that, for patients with limb length discrepancy, temporary epiphysiodesis around the knee with tension band plating might result in mechanical axis deviation. This finding needs to be expected with caution especially when this procedure is planned for patients who are close to skeletal maturity. Utilizing temporary epiphysiodesis as opposed to permanent drill epiphysiodesis for these patients may increase the potential for introducing an angular deformity.

Study ID	Age at Surgery (years)	BMI at Time of Surgery (kg/m2)	Sex	Surgical Region	Surgical Limb Side	Pre-Operative MAD (mm)	Pre-Operative mLDFA or mPTA (°)	Final MAD (mm)	Final mLDFA or mPTA (°)	Change in MAD (mm)	Direction of Change	Length of Follow Up (months)
1	9	23	Female	Both	Right	0	84	0	87	0	None	55
2	14	25	Male	Femur	Right	0	88	11	91	11	Lateral	35
2	14	30	Male	Tibia	Right	16	86	0	90	16	Lateral	75
3	13	24	Male	Femur	Right	0	88	10	88	10	Medial	103
4	11	18	Female	Tibia	Left	8	91	0	90	8	Medial	24
5	11	20	Male	Both	Right	9	90	35	80	26	Lateral	71
6	12	23	Male	Both	Right	0	84	22	87	22	Lateral	84
7	7	17	Female	Femur	Left	0	85	10	85	10	Medial	39
8	8	32	Female	Femur	Left	19	90	18	85	1	Medial	71
9	12	36	Female	Femur	Left	0	83	11	82	11	Lateral	33
10	10	14	Female	Both	Right	13	91	0	90	13	Lateral	19
11	11	18	Female	Both	Right	0	92	23	95	23	Lateral	61
12	14	21	Male	Femur	Right	0	90	31	96	31	Medial	97

Table 1. Individual subject limb characteristics

Variable	% (proportion)
Surgical side	
Left	31% (4/13)
Right	69% (9/13)
Surgical Location	
Distal Femur	46% (6/13)
Proximal tibia	15% (2/13)
Both distal femur and proximal tibia	39% (5/13)
Surgeries resulting in MAD change >10 mm	77% (10/13)
Sex	
Male	46% (6/13)
Female	54% (7/13
	Mean ± SD
Age at the time of surgery, years	11.2 ± 2.3
BMI (kg/m2)	23.2 ± 6.2
Pre-operative MAD, mm	4.9 ± 7.1
Final MAD, mm	13.1 ± 12.0
Change in MAD, mm	14.0 ± 9.4
Follow up times, years	5.2 ± 2.3

Table 2.0 Subject demographics

Poster Presentation

Uniplanar versus Multiplanar Hexapod External Fixation for Complex Tibial Diaphyseal Fractures

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What was the question?
Are there any differences in fixator time, overall alignment, functional results and complications between complex tibial shaft fractures treated with uniplanar versus hexapod ring fixation?

How did you answer the question?
We performed a retrospective study including patients with tibial shaft fractures definitively managed with external fixation between March 2012 and February 2020 in a Level I trauma center. Patients were treated with both LRS/Procallus uniplanar fixation system (Orthofix, Verona, Italy) or Taylor Spatial Frame (Smith and Nephew, Memphis, TN). Indication for primary treatment with external fixation at the discretion of the treating surgeon. Demographic, type of fracture and frame time data were collected. Complications and additional procedures were also noted. Functional outcomes were evaluated using the Lower Extremity Functional Score (LEFS). Time to union as well as tibial alignment in the anteroposterior and lateral axis was radiologically assessed.

What are the results?
Thirty–two patients were included in the study with 23 patients conforming the uniplanar group (UNI) and 9 patients in the multiplanar hexapod group (HEX). The mean age was 33 years and the most common mechanism of injury was open fracture secondary to gunshot wound in both groups. Both groups were comparable without statistical differences in terms of sex, age and open fractures. The most common type of fracture in both groups was AO/OTA 42.C3. Anteroposterior mean alignment was 10 degrees in valgus in the UNI group and 1 degree valgus in the HEX group. The mean Lateral alignment was 9º antecurvatum in the UNI group and neutral alignment in the HEX group. (p0,05).

What are your conclusions?
Definitive management of tibial shaft fractures with external fixation is an effective treatment in complex cases. In this study, there were no statistically significant differences in functional results comparing the use of uniplanar versus multiplanar hexapod fixators at a minimum of one–year follow–up. However, the hexapod group resulted in superior sagittal plane alignment as well as inferior time to union and frame time.

Poster Presentation

Congenital Synostosis of the Knee: Outcomes of Limb Reconstruction Surgery

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What was the question?
What is the mid–term outcome of limb reconstruction in patients with congenital synostosis of the knee?

How did you answer the question?
A retrospective review of a cohort of patients with congenital synostosis of the knee presenting to two institutions between 1997 and 2016 was performed.

What are the results?
Eight patients (13 knees) with a median age at presentation of 29 months (range 1–62) were included. Seven patients had associated syndromes with upper extremity involvement. Patients presented with a median knee flexion deformity of 100° (range 60 to 130°), limb length discrepancy, and delayed walking ability. The average age at definitive surgery was 52 months (range 14 to 110). Gradual correction and lengthening with a circular external fixator was performed in ten knees, and fusion was undertaken as an index procedure in three knees. The median follow–up was 146 months (range 40 to 204 months). Eight of 13 knees required a revision procedure for recurrence of flexion deformity. After revision, neutral sagittal alignment was achieved in five of the eight knees. Three of the knees undergoing revision had residual knee flexion deformities ranging from 13° to 40°. In the five limbs that did not undergo a revision procedure, the median residual knee flexion deformity was 20° (range: 10 to 20°). Median limb length discrepancy at final follow–up was 2 cm (range: 0–8 cm). Seven of eight patients maintained community ambulation at final follow–up with one patient able to perform home ambulation. Four problems, 14 obstacles, and one complication were identified in seven patients.

What are your conclusions?
This study is the largest series on patients with congenital knee synostosis and outlines a reconstructive approach to optimize ambulatory function. Reliable correction of the deformity associated with congenital knee synostosis was achieved at a median follow up of over 12 years, but revision was required for recurrence of knee flexion in eight of 13 knees. Importantly, all patients maintained community or home ambulation at final follow–up.

Poster Presentation

Accuracy of Multimodality Fetal Imaging (US, MRI, and CT) Compared to Referring Ultrasound Imaging for Congenital Musculoskeletal Anomalies

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What was the question?
At an institution that has a department specializing in fetal imaging, is multimodality imaging performed by US and MRI, with CT performed in selected cases more accurate than imaging done by outside referral ultrasound scans?

How did you answer the question?
We retrospectively reviewed 40 patients at our institution between 2015 and 2020 that had a total of 122 musculoskeletal anomalies and 39 non–musculoskeletal anomalies seen on prenatal imaging. Each patient had an ultrasound from the referring center and MRI (n=40), US (n=30), and CT (n=2) at our institution. They were all seen and assessed postnatally. The referring ultrasound and multimodality imaging at our institution were compared to the postnatal diagnosis to evaluate for diagnostic accuracy. Sensitivity, specificity, positive predictive value, negative predictive value for each diagnostic approach were calculated and compared using the McNemar's test with a significance level of $p<0.05$.

What are the results?
With regard to musculoskeletal anomalies, the referring ultrasound had a sensitivity of 55.7 nd a specificity of 95.3ompared to a sensitivity of 81.1 nd a specificity of 97.2 or multimodality imaging ($p<0.001$). For non–musculoskeletal anomalies, referring ultrasounds had a sensitivity of 35.9 nd a specificity of 96.5% while multimodality imaging had a sensitivity of 87.2 nd 95.7% ($p<0.001$).

What are your conclusions?
Based on our cohort of 40 patients, multimodality imaging was more sensitive to diagnose both skeletal and non–skeletal anomalies compared to the referral ultrasound scan. Multimodality imaging has great utility in detecting congenital anomalies in utero and can be used to inform parents of their child's diagnosis. Educating parents on the nature of the disease, the survival chances of the fetus, and subsequent development abnormalities are essential as they allow patients to prepare to give proper care to the child.

Poster Presentation

Early Experience with the Orthospin Automatic Struts Shows Promising Results

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What was the question?
What has the early experience been with the orthospin automatic struts for limb lengthening and deformity correction?

How did you answer the question?
Our center has performed 11 cases with the orthospin automatic adjusting struts using the [redacted] system. The goal is to provide an update on the accuracy, utility, and safety of this new technology. As this is a very new system, formal study with adequate followup cannot be provided at the time of writing this abstract. However, providing an update on two surgeons experience to the membership is of value. Metrics to be calculated immediately prior to the conference include BHI and EFI. Case examples will be shared. A system for recording pain and pin infections will also be discussed.

What are the results?
The orthospin struts used with the [redacted] system has provided accurate bony corrections in a normal amount of time with typical EFI and BHI. Pain during the adjustment period has been lower than when using the manual struts for [redacted]. Number of adjustments per day on each strut has evolved from 4 times per day to 16 times per day. The system has changed from the G1 (n=7) to the G2 (n=4). Workflow and the ability to interpret radiographs have improved with G2. Pin infections seem to be less common. The units are heavy and create some knee strain. Patients are very happy with not having to adjust. There have been no rogue struts. The motor straps can fall off dislodging the motors. The G2 prevents any mis–wiring of the system seen in one G1 case in our series.

What are your conclusions?
These automatic struts provide accurate and timely corrections. Patients embrace them and not having to perform adjustments. Pain level may be less. This is a significant contribution to the field of limb deformity.

Poster Presentation

Applicability of the Modified Fels and Optimized Oxford Skeletal Maturity Estimation Systems to the Modern Pediatric Population

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What was the question?

The Modified Fels knee and Optimized Oxford hip skeletal maturity systems were recently developed using the same historical, mostly white, pediatric population used to produce the Greulich and Pyle skeletal age atlas (GP). While these systems have respectively demonstrated performance superior or equivalent to GP in skeletal age estimation in historical patients, their applicability to modern pediatric populations of different races has not yet been evaluated. We sought to determine if these novel knee and hip skeletal maturity systems require modification prior to their use in modern orthopaedic practice.

How did you answer the question?

We reviewed our institution's electronic medical record for AP knee and hip radiographs of four groups of children: White males, Black males, White females, and Black females. Radiographs taken from the peripubertal years were evaluated, defined as age 9 to 17 years in males and 7 to 15 years in females. Following reliability analyses, five non–pathologic radiographs for each age and joint were randomly selected from each group for evaluation with the appropriate skeletal maturity system. For each group, the skeletal age estimates made by the Modified Fels knee system and Optimized Oxford hip system were plotted against the chronological age associated with each radiograph. The mean discrepancy between each group's chronological age and estimated skeletal age was determined and compared to the other modern groups and the historical cohorts. Following normality testing, paired t–tests or Wilcoxon signed–rank tests were performed, as appropriate. A Bonferroni correction was applied to account for multiple testing. Significance was set at $p<.05$.

What are the results?

A total of 392 modern radiographs were evaluated (196 knees, 196 hips). All seven Modified Fels knee parameters and all five Optimized Oxford hip parameters had inter– and intra–rater reliability coefficients at or above 0.7, indicating good to very good reliability. For the Modified Fels knee skeletal maturity system, White males (Δ0.74 years, $p<.001$), Black males (Δ0.69 years, p.05 for all; Figure 1). No differences were found along racial lines for either the Modified Fels knee or the Optimized Oxford hip systems ($p>.05$ for all).

What are your conclusions?

The Modified Fels knee skeletal maturity system can be applied to modern pediatric populations without correction in White females, and after moderate corrections in White males, Black males, and Black females. The Optimized Oxford hip skeletal maturity system can be applied to modern pediatric patients without adjustment.

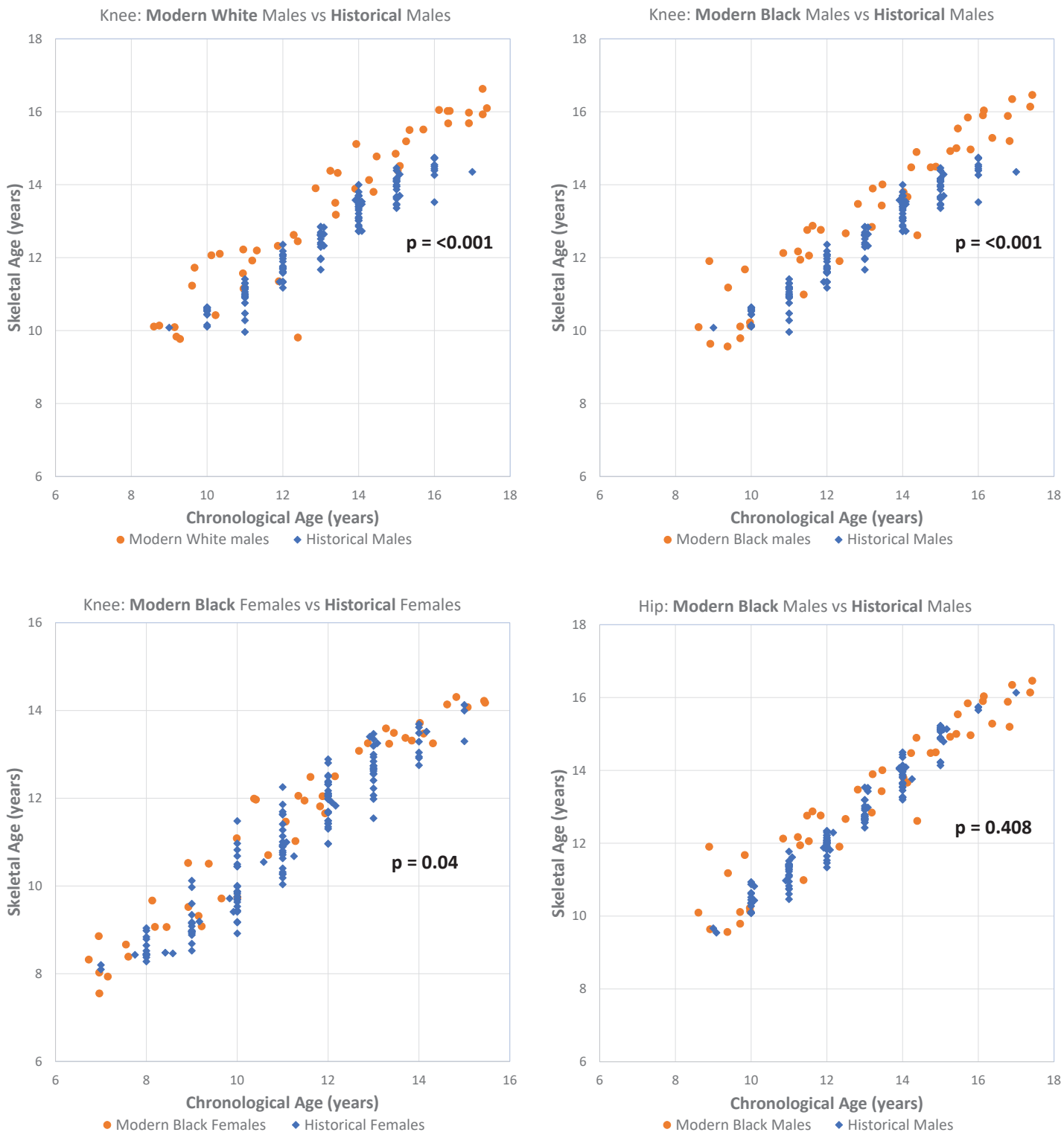

Figure 1. Comparisons of Modified Fels knee and Optimized Oxford hip skeletal maturity systems in modern and historical populations. All three comparisons showing differences between modern and historical cohorts in the knee are shown. For the hip no differences were found, and a representative plot is provided.

Poster Presentation

Efficacy and Safety of "Sleeper Plate" in Temporary Hemi–Epiphysiodesis and the Observation of "Tethering"

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What was the question?
Guided growth is a common treatment option for correcting coronal lower limb deformities in a growing child. Removal of hardware is necessary in order to prevent overcorrection in the skeletally immature patient. Traditionally, the entire hardware was removed, however, more recently there has been a trend to remove only the metaphyseal screw, leaving the plate and epiphyseal screw in situ. The rationale is that it is a less invasive procedure to remove and, if necessary, re–insert the metaphyseal screw if the patient rebounds, i.e. the angular deformity re–occurs. The aim of this study is to examine the rates of rebounding to the original deformity, over–correction due fibro–osseous scarring at the implant site (tethering) and stability of correction in patients with sleeper plate vs. patients with all hardware removed.

How did you answer the question?
We performed a retrospective review of all patients undergoing guided growth between February 2014 and December 2020. In that period, 144 plates were inserted in 78 patients. 69 Plates still in situ were excluded, the remaining were divided into group 1 with implant removal after correction and group 2 with sleeper plate. We examined for the rate of stability, rebounding and over correction (tethering).

What are the results?
Group 1 consisted of 50 plates that were removed post correction and group 2 consisted of 25 sleeper plates. In group 1, 10 plates (20%) required further correction via plate re–insertion or corrective osteotomies after implant removal. In group 2, 13 plates (52%) remained stable with sleeper plate, 9 plates (36%) required screw re–insertion due to rebound, and 3 plates (12%) showed tethering/over correction. In the tethered plates, we found the implants to be embedded in the periosteum and metaphyseal bone would grow onto the plate, effectively tethering the metaphyseal screw hole and then result in the epiphyseal screw migrating closer to the physis.

What are your conclusions?
The sleeper plate is an acceptable treatment strategy for coronal deformities around the knee. Patients with sleeper plates were closely monitored. Younger patients have a higher risk of rebounding and may require screw re–insertion. Tethering is a potential complication that occurs in a small subset and must be disclosed to patients. Surgeon must ensure that the plate is placed in an extra–periosteal location, screws are placed away from physis, and use bone wax after metaphyseal screw removal. We stress the importance of close post–operative follow up to identify tethering early and prevent over correction.

Poster Presentation

Customized Metal Artifact Reduction Software improves Computed Tomography Measurement of Cortical Bone Density and Thickness near Osseointegration Implants: A Pilot Study

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What was the question?
Computed tomography (CT) can allow bone modeling and quantitative assessment of cortical thickness and density. Metal implants degrade CT imaging clarity, impairing the computed imaging reconstruction, a phenomenon referred to as "artifact." We developed a post–acquisition metal artifact reduction software (MARS) algorithm which consistently provides better clarity than most commercially available solutions, and when paired with a standard density phantom facilitates quantitative bone density assessment. This pilot study investigated 1) to what extent our MARS could allow clear modeling of amputated femurs throughout the entire residual and native contralateral femur following osseointegration with two common implants (one titanium alloy, the other cobalt–chrome alloy); 2) how does cortical bone thickness and density change over several years in the osseointegrated femur; and 3) how do the femoral neck densities of the amputated and native femur compare in the long term following osseointegration?

How did you answer the question?
Five patients who recently had osseointegration with titanium implants were scanned with a phantom included to provide a technical feasibility and provide an immediate postoperative baseline control cohort. Five other patients who had osseointegration with cobalt–chrome implants over five years ago were selected for re–imaging, and their new scans were compared to their preoperative scans. The customized MARS modeling was performed to create three dimensional models which were used for all measurements and calculations.

What are the results?
1) The custom MARS rendered excellent model resolution of the cortical bone at all locations of the operated bone (surrounding and also far from the metal implant) and on both the operated and native contralateral bone. The visual clarity was similar for both the titanium alloy and cobalt–chrome alloy cohorts.
2) In the long term osseointegration cohort, the cortical thickness of the bone proximal to the implant (femoral head, neck, and intertrochanteric region) was clearly thicker than it was before osseointegration. The MARS allowed fine enough artifact reduction to identify that the cortical thickness immediately surrounding the osseointegration implants was thinner than prior to surgery; it is uncertain whether this represents bone volume loss over time or if it is due to cortical bone removed when preparing the intramedullary canal during surgery. Density calculations were unable to be completed in time for this submission. They will be completed before July 2021.
3) The question of femoral neck density could not be answered yet, as density calculations were unable to be completed in time for this submission. They will be completed before July 2021.

What are your conclusions?
The customized MARS provides clear model renderings of cortical bone for both titanium–alloy and cobalt–chrome alloy solid intramedullary osseointegration implants at all regions of the scan. Cortical bone thickness can be quantitatively measured and compared over serial scans. Cortical bone density can be calculated, but the calculations could not be completed before the submission deadline; they will be completed prior to July 2021. It is anticipated that this customized MARS, when paired with a radiographic phantom, can render models sufficient resolution to quantify cortical bone thickness and density even immediately surrounding solid metal implants. This may allow noninvasive serial evaluation of patients to assess the morphology and health of bone remodeling following osseointegration.

Poster Presentation

The Incidence and Management of Clinically Symptomatic Fat Embolism following Cosmetic Stature Lengthening with Steel Weightbearing Intramedullary Nails

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What was the question?
Fat embolism syndrome (FES) is characterized by severe pulmonary distress following fracture or intramedullary instrumentation; patients may also exhibit neurologic symptoms and/or petechial rash. A discernible proportion of patients appear to require supplemental oxygen following cosmetic stature lengthening (CSL), which may be due to clinically significant fat embolism (CSFE), though not outright FES. Only one article reported fat embolism–type symptoms in CSL patients (2/51 patients, 4%). However, the symptoms, sequelae, and risk factors were not evaluated in depth. This investigation aimed to evaluate the incidence, symptoms, management, and risk factors associated with clinically CSFE and FES in patients undergoing CSL with nails.

How did you answer the question?
The immediate postoperative admission record was reviewed for 153 CSL surgeries performed for 126 patients between May 2018 and February 2021, looking for objective signs and subjective symptoms of CSFE or FES. CSL was defined as bilateral same–level bone lengthening performed for patients with height dysmorphia without a discernible diagnosis such as achondroplasia or limb deficiency. CSFE was determined to occur if patients fulfilled three criteria: 1) supplemental oxygen required beyond the first postoperative evening, 2) sustained tachycardia above 100 beats per minute, and 3) finger–measured pulse oximetry was unable to remain above 93% on room air or patients had persistent coughing.

What are the results?
There were 8 postoperative CSFE events (5.2%), including one FES (0.7%). The FES patient exhibited mental status changes (confusion) but had no skin, buccal, or conjunctival petechiae. No risk factors could be identified by regression analysis of patient age, sex, height, weight, bone lengthened, nail size, or estimated intramedullary canal volume. The rate of CSFE vs no CSFE for the following variables were: gender (male 7/114, 6.1%; female 1/31, 3.2%), bone (femur 6/115, 5.2%; tibia 2/30, 6.7%), age (Yes 28.9±10.4 vs No 32.1±10.7 years). Patients experiencing CSFE required more longer supplemental oxygen than non–CSFE patients (2.7±1.5 vs 0.3±0.5 days, Student's t–test $p<.001$). The duration of inpatient care postoperatively was not statistically different (4.3±1.8 vs 3.7±0.7, $p=0.061$). Three CSFE patients were transferred to an elevated care level: two for one day with only face mask oxygen necessary, and the FES patient who required emergency extracorporeal membrane oxygenation (ECMO). Computed tomography of the pulmonary arteries identified no occlusive thromboemboli. 43 of 145 non–CSFE postoperative admissions (29.7%) had 1–4 days of recurrent tachycardia, but without any supplemental oxygenation requirement, and never developed postoperative sequelae. All patients eventually proceeded with lengthening.

What are your conclusions?
The overall rate of CSFE following CSL was 5.2%, and one patient of 153 experienced an apparent true FES. CSFE was associated with a longer supplemental oxygen requirement but not a statistically longer postoperative hospital admission. Like FES, CSFE remains a diagnosis of exclusion, and in our cohort could be best diagnosed with two criteria (supplemental oxygen required beyond the first postoperative evening, followed by finger–measured pulse oximetry unable to remain above 93% on room air or persistent coughing and sustained tachycardia above 100 beats per minute) and corroborated by persistent tachycardia. Isolated tachycardia occurred in 29.7% of patients with no clinically relevant sequelae. The elevation of care for three patients, in particular the one who required ECMO, underscores the importance of careful postoperative evaluation and having the availability to rapidly escalate care when needed.

Poster Presentation

Osseointegration for Diabetic Patients: The Risk of Infection versus the Reward of Mobility

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What was the question?
The most common reason for lower extremity amputation worldwide is as management of complications from diabetes mellitus. The typical rehabilitation option for these patients is a traditional socket prosthesis (TSP), but many have trouble with TSP use. Osseointegration has proven beneficial for the majority of patients with TSP dissatisfaction, but diabetes generally has been considered a relatively strong contraindication due to concerns mainly of infection risk. This study aimed to investigate three major outcomes categories for lower extremity amputees with diabetes who had osseointegration for at least two years: 1) what is the rate of debridement and of implant removal; 2) how does patient prosthesis wear time and mobility change; 3) how does the patient's perception of using a prosthesis change (based on the Questionnaire for Persons with a Transfemoral Amputation, QTFA)?

How did you answer the question?
A review of our prospectively collected osseointegration database was performed which identified 13 patients who had transfemoral (9) or transtibial (4) osseointegration from 2013–2018 (all unilateral), who were diabetic, and who were followed for at least two years. The rate and timing of infection requiring debridement or device removal was evaluated. Additionally, the following metrics were compared from their preoperative consultation versus their most recent evaluation: daily prosthesis wear hours, Timed Up and Go (TUG), Six Minute Walk Test (6MWT), QTFA Mobility score, QTFA Problem score, and QTFA Global score.

What are the results?
Thirteen patients had a follow–up of at least two years, for an average of 4.2±1.5 years. One patient died of pre–existing pulmonary fibrosis complications four years after osseointegration.
Six patients (46%) required at least one surgical debridement, at an average of 1.3±1.1 years. Three patients (23%) had the implant removed due to aseptic loosening or infection, at an average of 1.9±1.1 years. Three patients did not wear a TSP prior to osseointegration. The other 10 reported wearing the TSP 5.9±7.8 hours daily. Following osseointegration, 11 patients wore their prosthesis, reporting 10.8±5.3 hours (p=0.09). Prior to osseointegration, 4/10 (40%) wore the TSP >8 hours daily, versus 11/13 (85%) after (p=.04). Five patients were physically able to complete mobility tests before osseointegration; 11 patients were able at their most recent evaluation. The TUG improved, but not significantly (11.2±4.1 versus 15.3±14.2 s, p=0.28). The 6MWT remained unchanged on average (287±160 versus 276±110 m, p=0.88); but the proportion of patients able to walk >100 m improved (5/13 (31%) before versus 11/13 (54%) after, p=0.04). The QTFA Problem score significantly improved (42.2±28.0 versus 21.2±18.8, p=.03). The QTFA Mobility score remained unchanged (55.9±17.8 versus 60.1±13.6, p=.50). The QTFA Global score improved (37.8±25.1 versus 69.0±18.9, p

What are your conclusions?
The risk of infection requiring debridement (46%) or implant removal (23%) is relatively high compared to the rates for all–cause osseointegration with a press–fit implant. However, the proportion of patients who were ambulatory significantly improved and was maintained through 2+ years. Interestingly, although the QTFA did not identify improved overall mobility, the QTFA identified the prosthesis–associated problem burden to have improved and the patients' global perception of amputee life to have improved. Patients may need to be counseled that having diabetes may increase their risk of eventual infection and implant removal, but they may achieve mobility improvements, particularly if they have TSP–related problems which prevent them from ambulating.

Poster Presentation

Retrograde Extramedullary Lengthening of The Femur using a Lengthening Nail: Technique and Results

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What was the question?
Previous reports have described using extramedullary placement of an intramedullary lengthening nail in an antegrade fashion. We have utilized a technique placing an intramedullary lengthening nail in a retrograde extramedullary location for lengthening of the femur in skeletally immature patients.

How did you answer the question?
After obtaining Institutional Review Board approval we retrospectively reviewed 5 skeletally immature patients who had significant length discrepancy of the femur and had lengthening using a magnetic lengthening nail placed in an extramedullary location. We reviewed these patients based on age, sex, magnitude of the length discrepancy, amount of length gained, the duration of healing, time to hardware removal as well as the presence of complications. A detailed description of the surgical technique was also presented.

What are the results?
The mean age of the study group was 7.2±2.7 years (4 – 10 years). There were 3 female and 2 male patients. The mean length discrepancy was 6.5±3.7 cm (3.5 – 11 cm). An average of 3.46±0.4 cm of length was gained (13% of bone length) without the need for any supplemental fixation. We achieved simultaneous acute deformity correction and lengthening in 2 patients who had associated distal femoral valgus deformities. Patients were full weight bearing in 12 weeks on average and could have hardware removed as early as 21 weeks following surgery. We observed no complications during a mean follow up period of 19.2 months.

What are your conclusions?
Retrograde extramedullary lengthening of the femur using a lengthening nail is an 'off–label' option that should be considered for limb length equalization in skeletally immature patients. It avoids the inconvenience of external fixation and can be used to simultaneously correct deformities of the distal femur. Although the total amount of length gained is modest, we believe it is a promising limb lengthening technique that merits further investigation.

Poster Presentation

Radlink GPS Reliably Measures Mechanical Axis Deviation and Joint Orientation Angles During HTO and DFO Correction Surgery

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What was the question?
The ability to measure lower extremity alignment parameters intraoperatively theoretically is the weak link in the execution of operative planning and has the potential to improve deformity correction accuracy. Radlink Inc. (Radlink) is a system that uses intraoperative fluoroscopic calibration to allow stitching of multiple images and alignment measurements. This study evaluates how well intraoperative MAD, LDFA, and MPTA measurements using Radlink correlate with postoperative standing radiograph measurements, furthermore, how did Radlink compare with the rigid alignment rod for predicting postoperative MAD.

How did you answer the question?
Patients undergoing acute coronal plane deformity correction using distal femur and/or proximal tibia osteotomy were measured intraoperatively post–correction using the Radlink system and an alignment rod from the center of hip to center of ankle. Radlink uses a long ruler laid over the hip, knee and ankle. Static fluoroscopic images are taken of the hip, knee and ankle and stitched using Radlink software. This allows for measurement of the mechanical axis and joint orientation angles. Postoperative measurements of MAD, LDFA, and MPTA were made using standard standing 51” radiographs at an average of Pearson’s correlation statistic was used to determine how accurately the alignment rod and Radlink predicted the postoperative radiographic measurements.

What are the results?
Thirty–one patients had alignment rod and Radlink measurements after coronal plane deformity correction. The alignment rod predicted postop MAD with moderate correlation and was statistically non–significant, r = 0.3507, p=0.0574. Radlink predicted postop MAD with moderate correlation that was statistically significant, r =0.4901, p=0.006. Radlink measurements were strongly correlated to both LDFA (r =0.7118, p

What are your conclusions?
Radlink measurements are better at predicting postoperative radiographic MAD than an alignment rod and demonstrate a strong correlation with postoperative MPTA and LDFA measurements. We rely on this system to judge the quality of our corrections for HTO and DFO surgeries.

Poster Presentation

Our Experience in Treating Complex Open Tibia Fractures with Ilizarov External Fixation: A Retrospective Study of 23 Patients

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What was the question?
Finding out the outcome of ilizarov ring fixation of complex open tibia fractures

How did you answer the question?
Outcome measures included time to union, rates of union, nonunion, malunion, infection and implant failure a consecutive series of 23 patients with open tibia fractures (two AO41A3, six AO43C and 15 AO42C) treated with an Ilizarov external fixation at our level I trauma center were retrospectively reviewed between 2014 and 2020

What are the results?
Seventeen patients went on for complete fracture union within average time of 19.6 weeks. The mean age was 31.78 and ranged from 8 to 88. The mean follow–up duration was 10.5 months. Six patients developed nonunion and required further surgical intervention, eventually all of them went on for complete union. Nine patients developed mild malunions. There were no lower limb amputations, implant failures or deep infections

What are your conclusions?
The Ilizarov ring fixation is considered a safe method in terms of avoiding osteomyelitis, compartment syndrome or amputations. It is also considered a reliable method as it allows early mobilization and early fracture union with low rate and minimal malunion

Poster Presentation

The Outcome of Pilon Fractures Treated with External Ilizarov Fixation: A Retrospective Study of 12 Cases

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What was the question?
Finding out the outcome external ilizarov fixation of pilon fractures.

How did you answer the question?
Outcome measures included time to union, rates of union, nonunion, malunion and infection
We retrospectively reviewed a consecutive series of type OTA–type 43–B and 43–C pilon fractures treated at our level I trauma center between 2014 and 2020. 12 patients were found who underwent external Ilizarov fixation

What are the results?
The mean age was 42.5 and ranged from 20 to 72. Eight patients had open pilon fracture. Seven patients had severe comminuted pilon fracture (43–C3). Eight patients had complete fracture union at a mean time of 13.5 weeks. Four patients developed nonunion and required further surgical treatment. Two patients underwent ankle arthrodesis due to severe osteoarthritis. Four patients had mild malunion. Eight patients were initially treated with spanning external fixation and staged wound debridement followed by external Ilizarov fixation. No deep wound infection,osteomyelitis or amputaion were found during the follow–up period

What are your conclusions?
The use of staged treatment in conjunction with Ilizarov frame achieves low rates of deep wound infection and stable fixation that allows immediate mobilization for OTA–type 43–B, 43–C and open pilon fractures

Poster Presentation

Evaluation of Calibration Methods for Development of Skeletal Maturity Systems

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What was the question?
Estimation of skeletal maturity is critical for decision–making in many pediatric orthopedic conditions, including scoliosis and limb length discrepancy. Development of a skeletal maturity estimation system requires a data set with a "gold standard" measurement from which to calibrate the system's estimations. Nearly all existing systems have used chronological age or Peak Height Velocity (PHV) as their gold standard. Recently, 90% of final height was identified as a novel gold standard that can be more easily and accurately implemented than PHV on a longitudinal data set. We sought to determine if a knee skeletal maturity system calibrated with 90% of final height performs better than one calibrated with PHV or chronological age.

How did you answer the question?
A well–documented longitudinal growth collection was queried. 133 serially obtained, peripubertal AP knee radiographs and their associated gender, chronologic age, femoral length, and tibial length from 38 subjects were collected. The age at which each subject reached 90% of final height and PHV was recorded. Fourteen radiographic parameters were measured on each knee radiograph. Stepwise linear regression and generalized estimating equation (GEE) analyses were used to produce three skeletal maturity prediction models, respectively calibrated with 90% of final height, PHV, and chronologic age gold standards. Those models were used to estimate the skeletal age associated with each knee radiograph. The accuracy of the skeletal age estimates produced by each model were compared. Next, those skeletal age estimates were used to predict ultimate femoral and tibial length via the Multiplier, White–Menelaus, and Growth Remaining methods. The accuracy of lower limb length predictions at maturity produced by each model were compared.

What are the results?
The model calibrated with 90% of final height produced more accurate estimates of skeletal maturity than the PHV or chronological age models (mean prediction discrepancy 0.31 vs. 0.42 vs. 0.61 years; p.05); both performed better than the chronological age model ($p<.05$; figure 1).

What are your conclusions?
This analysis demonstrates that skeletal maturity models calibrated with a gold standard of 90% of final height perform as well as those calibrated with PHV in lower limb length prediction, with potential to outperform PHV when applied to other orthopaedic conditions.

Table 1. Final Limb Length Prediction

	Multiplier Method			White-Menelaus			Growth Remaining		
	90% of Final Standing Height	**Peak Height Velocity**	**Chronological Age**	**90% of Final Standing Height**	**Peak Height Velocity**	**Chronological Age**	**90% of Final Standing Height**	**Peak Height Velocity**	**Chronological Age**
Mean Prediction Discrepancy: Femoral Length, *mm*	11.1	11.4	20.6	19.6	19.6	18.1	19.6	19.6	18.1
p-value*	-	0.271	**<0.001**	-	1.00	0.1090	-	0.96	1.00
Outlier Predictions: Femoral Length‡	6.0%	7.5%	33.1%	29.3%	30.1%	27.1%	29.3%	30.1%	27.1%
p-value*	-	1.00	**0.001**	-	1.00	1.00	-	1.00	1.00
Mean Prediction Discrepancy: Tibial Length, *mm*	9.7	9.8	10.2	7.7	7.7	10.1	7.7	7.7	10.1
p-value*	-	1.00	1.00	-	0.93	**<0.001**	-	1.00	**<0.001**
Outlier Predictions: Tibial Length^	13.3%	12.2%	17.3%	6.1%	7.1%	17.3%	6.1%	7.1%	17.3%
p-value*	-	1.00	1.00	-	1.00	**0.046**	-	1.00	**0.03**

*All p-values are compared to the 90% of final standing height model. The Benjamini-Hochberg procedure has been applied to address multiple testing.

‡ Outlier femoral length predictions were defined as those that were >26.8 mm off from actual ultimate femoral length. 26.8 mm = overall mean femoral length prediction discrepancy + 1 standard deviation

^ Outlier tibial length predictions were defined as those that were >19.0 mm off from actual ultimate tibial length. 19.0 mm = overall mean tibial length prediction discrepancy + 1 standard deviation

Poster Presentation

The Role of Prophylactic Peroneal Nerve Decompression in Patients with Severe Valgus Deformity at the time of Primary Total Knee Arthroplasty

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What was the question?
Common peroneal nerve (PN) palsy after total knee arthroplasty (TKA) is a devastating complication. Although many authors suggest delayed or immediate PN decompression after TKA in these patients, little is known about the role of prophylactic peroneal nerve decompression (PPND) at the time of TKA. Our aim to report the results of PPND in high–risk patients at the time of TKA.

How did you answer the question?
A retrospective study reviewing 9 patients (10 knees) who underwent PPND at the time of TKA was conducted. Patients who had severe valgus deformities (≥15° of femorotibial angle and not fully correctable by examination under anesthesia) with or without flexion contractures were included. The PPND performed through a separate 3–4 centimeter incision at the time of TKA. Patients' demographics, preoperative and postoperative anatomical and mechanical alignments, rang of motion, operative time, postoperative neurological function and complications were recorded.

What are the results?
The mean preoperative femortibial angle was 20° (range; 15° to 33°) and the mean postoperative femrotibial angle was 6.3° (range 5° to 9°). Mean preoperative flexion contracture was 9 (range 0 to 20) and mean residual contractures was 1.2° (range; 2° to 5°). All patients had completely normal motor and sensory neurological function
postoperatively and no complications related to PPND were reported. All patients followed the standard physical therapy protocol after TKA without modifications

What are your conclusions?
PPND at the time of TKA is an option to minimize the risk of PN palsy in high–risk patients. This approach can be considered for patients undergoing TKA in selected high–risk patients with severe valgus deformity.

Remote Presentation
Poster Presentation

Early Experience with Nail: Immediate versus Delayed Weight Bearing

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What was the question?
Motorized remote–controlled intramedullary nails have grown in popularity over the past decade, largely replacing external fixation as the standard for limb lengthening. The is the latest such device, and contrary to its predecessor, patients can be advised to bear weight immediately postoperatively. Is there a difference in (1) weight bearing status, (2) consolidation index, and (3) postoperative complications between early and late nail insertion recipients?

How did you answer the question?
We retrospectively identified 26 patients treated with the nail at a single institution between December 2018 and March 2020. Early (n=15) and late (n=11) nail insertion recipients were then identified. The early nail insertion period was prior to August 2019, and the late insertion period was August 2019 through March 2020. Surgeon orders for the early nail insertion group directed patients to delay weight bearing, in contrast to the direction to bear weight immediately for the late nail insertion group. Outcomes measured included patient demographics, procedural demographics, consolidation index, weight bearing status, and postoperative complications.

What are the results?
Patients in the early insertion group were significantly younger than those in the late insertion group (15 vs. 32 years, p=0.002). Time to full weight–bearing did not significantly differ between the early and late groups (57.6 ± 22.1 days vs. 48.9 ± 36.7 days, p=0.462). Distraction index (0.63 ± 0.1 vs. 0.60 ± 0.2, p=0.619) and consolidation index (30.4 ± 22.6 vs. 55.0 ± 40.2, p=0.058) did not differ significantly between the groups. In the early insertion group, four complications were reported: two osteomyelitis infections (femur and tibia) in the same patient and two neurovascular injuries (femur and tibia) in the same patient. In the late insertion cohort, two delayed wound infections and one hardware removal were reported.

What are your conclusions?
Surgeon direction to immediately bear weight postoperatively did not result in a significantly shorter time to self–reported full weight bearing. Although time to full weight bearing was not significantly different in both groups, a larger study may have shown a difference. While we might have anticipated faster healing in the earlier weightbearing cohort, we did not observe this in our study. Future studies should compare weight bearing status between the nail and its

Abstract Title:
Early Experience with the [redacted] Nail: Immediate versus Delayed Weight Bearing

Table 1: Comparison of Patient Demographics, Procedural Demographics, and Outcomes Between Early Insertion and Late Insertion [redacted] Groups

N (%)	Early [redacted] Patients (n=15)	Late [redacted] Patients (n=11)	P-value
Age (SD)	15 (1.9)	32 (19.3)	**0.002**
Sex			0.864
Male	12 (80%)	7 (64%)	
Female	3 (20%)	4 (36%)	
Race			0.580
Caucasian	12 (80%)	10 (91%)	
African American	3 (20%)	1 (9%)	
Body Mass Index (SD) (kg/m^2)	21.8 (4.6)	24.4 (5.8)	0.252
Etiology			0.078
Congenital	11 (73%)	5 (45%)	
Idiopathic	4 (27%)	3 (27%)	
Traumatic	0	3 (27%)	
Laterality			0.008
Left	2 (13%)	7 (64%)	
Right	13 (87%)	4 (36%)	
Lengthening Site			0.394
Femur	10 (67%)	6 (55%)	
Tibia	5 (33%)	5 (45%)	
Preoperative Limb Length Discrepancy (cm)	5.8 (1.9)	3.5 (1.5)	**0.003**
Target Length (cm)	4.2 (1.2)	3.6 (1.5)	0.268
Nail Length (mm)	309.1 (39.2)	304.5 (40.6)	0.597
Nail Diameter (mm)	10.7 (0.8)	11.1 (1.0)	0.399
Length of Surgery (minutes)	224.6 (73.2)	182.5 (9.2)	0.252
Length of Stay (SD) (days)	2.2 (0.4)	2.5 (1.5)	0.403
Rate of Lengthening (SD) (mm/day)	0.83 (0.2)	0.80 (0.1)	0.765
Distraction Index (SD)	0.63 (0.1)	0.60 (0.2)	0.619
Consolidation Index (SD)	30.4 (22.6)	55.0 (40.2)	0.058
Time to Full Weight Bearing (SD) (days)	57.6 (22.1)	48.9 (36.7)	0.462

cm: centimeters; mL: milliliters; mm: millimeters; POD: post-operative day; SD: standard deviation

Poster Presentation

Influence of Imaging Modality on Accuracy of Intramedullary Lengthening

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What was the question?
Intramedullary lengthening has become increasingly common due to the advent of magnetic lengthening nails. In contrast to external fixators, where direct control of lengthening offers feedback regarding actual length gained, the magnetic intramedullary lengthening nail does not "report back" actual length gained. As a result, radiographs are necessary to evaluate length gained. Various imaging technologies can be used, both plain radiographs and EOS scans. What are the effects of the imaging device, calibration method, and measurement location when determining length gained with a lengthening intramedullary nail?

How did you answer the question?
An imaging study was conducted on a bone model to determine the accuracy of measuring the length gained using a lengthening intramedullary nail. The model was imaged with both digital radiography and EOS (EOS Imaging, Paris, France) under the following conditions: 1) nail at set lengths (10, 30, 50, and 70 mm), and 2) simulated hip flexion contracture (0°, 15°, and 30°). Three observers (two attendings and one resident) conducted independent measurements of each imaging combination of conditions utilizing four calibration methods (magnification ball, nail width, female nail, and no calibration) and four measurement locations (distraction gap, full nail, male nail, and spindle). In total, 1,152 measurements were recorded (384 per rater). Accuracy of length measurements was determined by calculating the absolute difference between the rater–measured lengths and the actual set length. Independent sample T test and the Kruskal–Wallis test were used for analysis. Statistical significance was set at $p<0.05$.

What are the results?
EOS is more accurate than digital radiographs when comparing absolute difference between imaging method: 6.0±7.8 vs. 13.9±19.4 ($p<0.01$) including non–calibrated values and 6.2±8.0 vs. 7.2±5.9 ($p<0.01$) excluding non–calibrated values. Calibration method ($p<0.01$) and measurement location ($p<0.01$) had a significant effect on absolute difference. Hip flexion contracture did not have a significant effect across all measurements ($p=0.13$), but it did have a significant effect on EOS measurements alone ($p<0.01$) and digital radiograph measurements alone ($p<0.01$). The median (range) values of measurement location based on distraction gap, male nail, spindle, and full nail were 2.5 (0–16.8), 5.1 (0.2–50.1), 5.8 (0.01–26), and 10.3 (0.2–95.3), respectively. The median (range) values of calibration method based on female nail, nail width, magnification ball, and no calibration were 4.4 (0.01–28.0), 5.4 (0.02–62.5), 5.4 (0–38.0), and 6.9 (0.2–95.3).

What are your conclusions?
We recommend either EOS scans or calibrated digital radiographs for the evaluation of intramedullary lengthening to ensure accurate correction. Calibration is helpful in EOS scans, but if the patient is able to stand upright in the scanner, it does not seem to be necessary.

Poster Presentation

Predictors of Osteolysis in a Stainless–Steel Lengthening Device

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What was the question?
Osteolysis is a potentially devastating phenomenon in patients with internal hardware; however, this process is poorly understood in the setting of limb lengthening. We sought to examine the predictive factors of postoperative osteolysis in a consecutive patient cohort with lower extremity stainless–steel nails. We specifically asked: is patient age, sex, weight, implanted bone, and time to full weight bearing predictive for the development of postoperative osteolysis?

How did you answer the question?
We retrospectively reviewed all radiographs of patients implanted with a stainless–steel intramedullary lengthening nail between December 2018 and December 2020 at a single institution. A total of 57 nails in 42 patients were radiographically examined with an average follow–up of 5.6 months. The incidence of osteolysis was determined by reviewing all available radiographic films. Multivariate binomial logistic regression was used to test for predictive factors of osteolysis and included: age greater than 16 years, sex, weight greater than 150 pounds, implanted bone (femur/tibia), and time to full weight bearing greater than 75 days.

What are the results?
A total of 10 nails (17.5%) in 9 patients were determined to have osteolysis at the modular junction with an average time to osteolysis of 241 days from implantation. Multiple risk factors were assessed to predict the development of osteolysis. Age greater than 16 years old ($p = 0.021$), and weight greater than 150 pounds ($p = 0.038$) were statistically significant predictors of osteolysis. Other measured factors included male sex ($p = 0.627$), femoral nail implantation $p = 0.704$), time to full weight bearing greater than 75 days ($p = 0.096$), and postoperative thigh/leg pain after 3 months from surgery ($p = 0.929$).

What are your conclusions?
A significant portion of patients with implanted stainless–steel intramedullary nails were found to develop osteolysis after 3 months from operation. Associated factors found to be predictive of this phenomenon included age greater than 16 years and weight greater than 150 pounds. Given the nuance of these findings, providers should remain cautious when evaluating this patient population.

Poster Presentation

The Use of Circular External Fixation for Pediatric Metadiaphyseal Fractures of the Femur and Tibia: A Preliminary Report

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What was the question?
High energy metadiaphyseal fractures of the femur and tibia in pediatric patients represent a challenging subset of fractures to treat. Such fractures may terminate near or involve the physis, which limits bone available for conventional internal fixation. In patients with a compromised soft tissue envelope, closed management with casting may not be possible. In such circumstances, we have employed circular or semi–circular external fixation with double–hinged rapid–adjust struts. These constructs were applied with and without knee or ankle spanning. The purpose of this study was to evaluate the indications and outcomes following circular external fixation treatment of pediatric metadiaphyseal fractures of the femur and tibia.

How did you answer the question?
A retrospective chart analysis was performed to identify all patients treated with a circular or semi–circular TL–Trauma External Fixator (Orthofix SRL, Verona, Italy) at single pediatric institution from 2008 to 2020. Thirteen patients with metadiaphyseal fractures of the distal femur, proximal tibia, or distal tibia were identified for inclusion. Age at fracture, mechanism of injury, indication for external fixation, fracture characteristics, weight bearing status in fixator, time to union, return trips to the operating room(OR), and complications were included for analysis.

What are the results?
9 patients with metadiaphyseal tiba fractures, 1 proximal and 8 distal, were identified for inclusion. Average age at injury was 11.3 years. Motor vehicle collision related trauma was the most common mechanism of injury (6). Associated soft tissue injury/compromise (6) was the most common indication for external fixator treatment. 6 fractures were closed and 3 were open. All patients had an associated ipsilateral fibula fracture. There were 16 return trips to the OR for non–fracture related reasons. 4 patients underwent 1 additional OR trip for fixator revision to permit flap coverage, fracture healing assessment, or fibular fixation. There was no loss of tibial reduction in any patient. 5/9 patients did not undergo additional fixator or fracture related procedures following initial fixator application. All fixator constructs were considered stable for weightbearing. Average time to union was 82.2 +/– 40.1 days and average time in the fixator was 94.1 +/– 36.9 days. 1 patient experienced a minor complication of metatarsal pin loosening requiring removal in clinic and 3 patients experienced delayed union (defined as fracture union > 90 days from initial treatment), but none required an additional procedure. 4 patients with distal metadiaphyseal femur fractures were included. Average age at injury was 10.2 years. Motor vehicle collision related trauma (2) and a failure of previous internal fixation (2) were the indications for external fixator treatment. 3 fractures were open and 1 was closed. No patient underwent knee spanning and all fixator constructs were considered stable for weight bearing. No patient returned to the OR for fixator revision or loss of reduction, however 2 patients underwent iliac crest bone grafting for delayed union. One patient experienced arthrofibrosis of the knee requiring lysis of adhesions at the time of fixator removal. Average time to union was 174.3 +/–116.0 days and average time in fixator was 175 +/– 115.6 days.

The Use of Circular External Fixation for Pediatric Metadiaphyseal Fractures of the Femur and Tibia: A Preliminary Report *continued*

Zachary Meyer

What are your conclusions?
Circular external fixation can be utilized for treatment of pediatric metadipahyseal fractures of the femur or tibia and is particularly useful in the setting of associated soft tissue compromise or limited bone stock for conventional internal fixation. In this preliminary evaluation, it is notable that all circular fixator constructs maintained femoral and tibial reduction after the index application, which limits fracture related return trips to the operating room. Additionally, all constructs were considered stable enough to permit weight bearing. Delayed union occurred in 38% of the patients included in the study, which is in part attributable to the significant soft tissue injury sustained at the time of fracture but may also be related to the treatment approach. Further studies are needed to determine the indications for, benefits of, and complications following circular external fixation treatment of pediatric meta–diaphyseal femur and tibia fractures relative to monolateral external fixation and internal fixation treatment.

Poster Presentation

Novel Application of the Internal, Magnetically–Controlled, Telescopic Nail to the Extramedullary Femur in the Skeletally Immature Patient: Early Results

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What was the question?
Large predicted congenital limb discrepancies necessitate earlier intervention to mitigate pain and dysfunction. Traditional techniques such as external fixation have fallen out of favor, and both the size and morphology of the young congenital femur preclude more modern internal devices. A novel application of the intramedullary lengthening nail has been conceived by applying it in an extramedullary fashion to the lateral femur in conjunction with an internal rod to maintain intramedullary stability. We present our early results utilizing this technique.

How did you answer the question?
We retrospectively identified patients undergoing internal extramedullary femoral lengthening by a single surgeon. These patients underwent femoral osteotomy with placement of an intramedullary nail and a nail placed in a subvastus lateralis position. Chart and imaging review was undertaken by two fellowship–trained pediatric orthopedic surgeons. Data collected included age at treatment, underlying diagnosis, final length achieved, and anteroposterior and lateral diameter of the femoral canal. Instrumentation characteristics included extramedullary nail type, length, diameter, and interlock screw construct. Surgical time and estimated blood loss were recorded.

What are the results?
Twelve patients with a median age of 9 years (4–14 years) underwent internal extramedullary femoral lengthening between July 2019 and June 2020. All patients had congenital femoral deficiency, and the median lengthening goal was 5 cm. Femoral canal diameter measured a median of 9.5 mm coronally and 7 mm sagittally. Nails were utilized with either 10.7–mm (n=10) or 8.5–mm (n=2) diameter. Variable interlocking screw constructs were used, and 4.0–mm (n=3) or 4.8–mm (n=9) diameter SLIM nails were implemented. Median operative time was 151 minutes (110–341 minutes) with median estimated blood loss of 137.5 mL (50–300 mL). Follow–up was a median of 3.7 months (0–6.3 months). Among eight patients completing lengthening, the median length achieved was 5.1 cm (3.5–8 cm). Seven complications were noted in six patients. These included soft–tissue infection treated with intravenous antibiotics (n=1) or operative debridement (n=1), nail bending (n=2), soft–tissue contracture (n=2), and failure of distal interlocking screw requiring revision (n=1).

What are your conclusions?
Goal length was achieved in all patients who completed their program during the study period. While complications were seen in half the patients, this compares favorably to femoral lengthening performed with monolateral fixators. Our early–term results suggest that this technique is safe and efficacious and that a future prospective comparative study with monolateral fixators is justified.

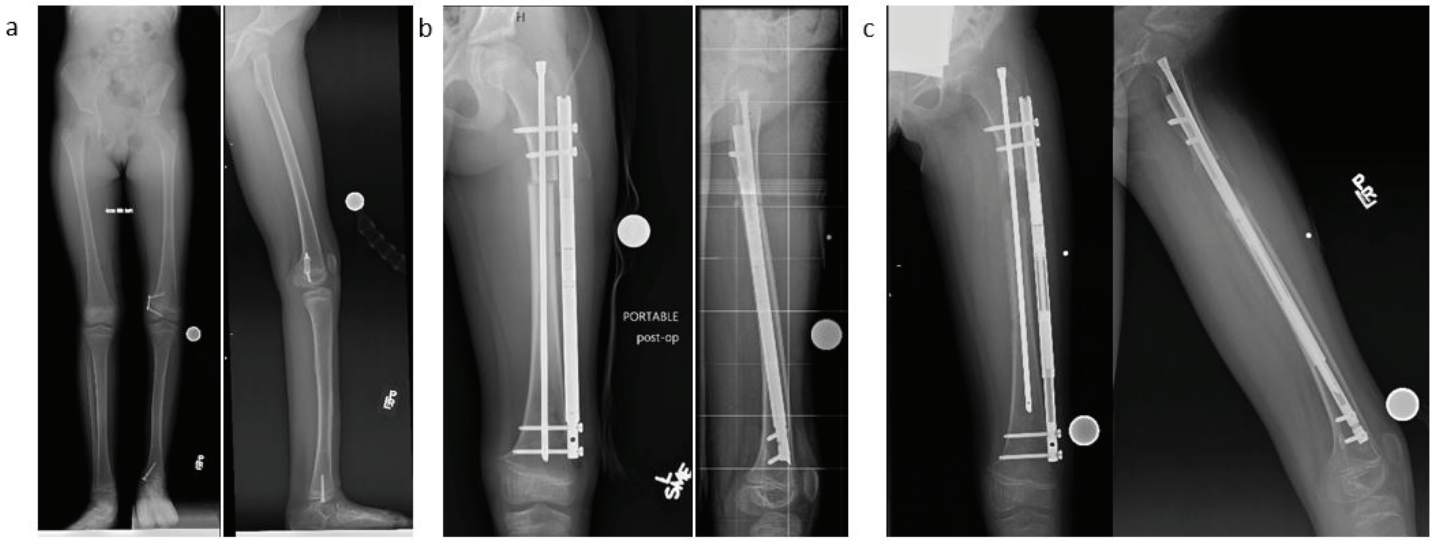

Figure. (a) AP and lateral long leg radiographs of eight year old with congenital femoral deficiency and 4.5 cm leg length discrepancy. Goal lengthening was 4 cm. (b). Immediate postoperative AP and lateral radiographs demonstrate internal extramedullary femoral lengthening with 10.7 x 275 mm retrograde straight PRECICE nail and two 5.0 mm screws proximally and two 4.0 mm screws distally. 4.8 mm SLIM nail was utilized for intramedullary stabilization. (c) AP and lateral follow up radiographs two months after surgery demonstrate 4.2 cm of lengthening.

Poster Presentation

A Novel Passive Dynamization Device and Method for Patients with Weight Bearing Limitations

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What was the question?
The positive effect of axial interfragmentary micromotion (dynamization) on successful fracture healing and new bone formation is well recognized. One of the essential components of successful dynamization is weight bearing. Loading during weight bearing provides the desired amount of bone segment axial motion. In some clinical situations, however, a patient is not allowed to bear weight and/or the amount of axial loading is limited, thus diminishing interfragmentary micromotion. Those situations may include non–ambulatory patients, postoperatively prescribed partial weight bearing, and overly rigid external fixation (i.e., an all thick, half–pin construct). The purpose of this study was to investigate whether passive axial loading with dynamization is sufficient to produce the same clinical/radiographic effect as active axial loading with dynamization in a patient with circular external fixation.

How did you answer the question?
Controllable passive dynamization of bone fragments for a patient with limited weight bearing was achieved by 4 dynamization modules allowing up to 3 mm of axial movement and two pneumatic cylinders incorporated to external fixation device. A portable air compressor powered the device by providing 2–3 cubic feet of compressed air per minute at 60 PSI of pressure. An adjustable regulator was used to control the pressure from the source which in turn determined the amount of force produced by the pneumatic cylinders. An adjustable low frequency square wave generator was used to turn the solenoid valve on and off at a rate of approximately 0.3–0.5 hertz to simulate a typical loading pattern during normal gait. A remote ON/OFF switch was included in the system to allow the patient to turn the unit on and off.

What are the results?
The passive dynamization device and method were validated in a 17–year–old male patient who underwent treatment for a large unstable lateral femoral condyle OCD lesion and associated 7° distal femoral valgus, 5° proximal tibial varus and 30° internal tibial torsion. For coronal and axial plane deformity correction as a preparation to proposed osteochondral allograft, he underwent an acute distal femoral osteotomy with internal plate fixation and proximal tibial/fibular osteotomy with application of circular external fixation. Acute correction of the proximal tibial varus and the 30° of external rotation was done under SSEP nerve monitoring in 3 sequential steps intraoperatively. Due to the distal femoral osteotomy, the patient was toe touch weight bearing for 6 weeks, which precluded that standard full weight bearing typically prescribed for a tibial osteotomy treated with a circular external fixator. Therefore, four external dynamization modules allowing 2 mm of vertical movement between the rings were incorporated into the frame construct and passive dynamization was applied for 20 minutes, 3–5 times per day for 6 weeks. Radiographic examination 6 weeks post–op revealed normal callus formation with typical appearance and level of mineralization.

What are your conclusions?
Desired amount of axial loading required for fracture healing and new bone formation while using rigid circular external fixation can be provided passively to patients with weight bearing limitations. Incorporation of axial dynamization modules to external fixation frame construct allows to control amount of longitudinal movement between the rings to achieve desired amount of axial micromotion.

Poster Presentation

Nanoparticulate Silica Surface Modification on Threaded Metal Pins Inhibits MRSA Growth

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What was the question?
The purpose of this study is to determine if threaded pins with a nano–ceramic silica surface modification would be bactericidal to MRSA.

How did you answer the question?
Five stainless steel (SS) and five titanium (Ti) Caspar pins were coated with silica nanoparticles. Then the pins were incubated in MRSA broth. After the MRSA incubation, the pins were tested for bacterial presence by EM evaluation (to look at the physical evidence of bacteria), turbidity (to examine bacterial reduction or expansion). Two additional SS and Ti Caspar pins served as controls.

What are the results?
multiple colonies and clusters of MRSA were visible on the uncoated control SS pin (figure 1A). Significantly fewer MRSA bacteria were identified on the silica–coated SS pin (figure 1B). The nano–silica–coated pins had no cytotoxic effect on eukaryotic cells.

What are your conclusions?
nanoparticulate silica surface modification on threaded metal pins inhibits MRSA growth. Further study is required to determine the utility of silica surface modification in trauma applications and other orthopaedic areas which use implants.

Poster Presentation

AutoStrut: A Novel Smart Robotic System for External Fixation Device for Bone Deformity Correction – Preliminary Result

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What was the question?
The purpose of this study was to introduce a novel robotic system that executes automatic adjustment of the struts.

How did you answer the question?
Ten patients were treated for various bone deformities using a hexapod external fixator with Auto Strut system. This new system automatically adjust the fixator struts according to hexapod computer–assisted correction plan. During each visit, the progress of the correction was assessed (clinically and radiographically) and reading of the strut scale numbers was performed and compared to the original treatment plan.

What are the results?
All patients completed treatment during the follow up period achieving all planned correction goals, except from one patient who switched to manual struts due to personal preference. The device alarm system was activated once with no device related adverse events.Duration of distraction ranged between 10 and 90 days with a distraction index ranged between 8 and 15 days/cm. Regenerate consolidation time was 1–7 months. 48 struts of eight patients were recorded and analyzed. 94% of the final strut number readings presented a discrepancy of 0–1 mm between planned and actual readings, indicating high precision of the automatic adjustment.

What are your conclusions?
This study presents preliminary result, showing that Auto Strut can successfully replace the manual strut adjustment providing important advantages that benefit the patient, the caregiver, and the surgeon.

Poster Presentation

An Algorithmic Approach to Limb Salvage in Chronic TKA PJI Complicated by Fracture or Soft Tissue Compromise Using Antibiotic Coated Intramedullary Nailing: A Case Series and Literature Review

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What was the question?
In patients with recalcitrant TKA PJI who sustain a fracture, or experience substantial soft tissue compromise about their prosthesis, what limb–preserving treatment options remain and when should these options be employed?

How did you answer the question?
We present a case series of 5 patients with recalcitrant TKA PJI despite multiple debridements and chronic suppressive antibiotic therapy. All patients expressed adamant interest in limb salvage instead of amputation. The challenges posed in this series include periprosthetic fracture about an infected TKA (N=2), infection in the setting of significant soft tissue compromise requiring flap reconstruction (N=2), and total extensor mechanism failure (N=1). These cases were used to formulate an illustrative algorithm for addressing each of the above challenging scenarios. We utilized the following approach for treatment. All patients underwent explant of existing implants at the time of presentation, with insertion of a PMMA cement spacer impregnated with Vancomycin and Gentamycin. Calcium sulphate impregnated with vancomycin and gentamycin was placed into the tibial and femoral intramedullary canal and a long knee spanning intramedullary fusion nail was inserted. All patients were allowed to weight bear as tolerated and underwent 6 weeks of IV antibiotic therapy. Subsequently, patients were treated with either reversal to a revision TKA or retention of their implant. Outcome measures at 1 year follow up include eradication of infection, ambulatory status, presence of chronic pain, and wound breakdown.

What are the results?
Of the 5 patients in this series, 4 patients were ambulatory at 1 year with or without the use of assistive devices. 3 patients had clinical and laboratory–proven eradication of infection and 2 of these patients underwent reversal to revision TKA. Two patients remained on chronic suppressive antibiotics – one of these patients required repeat wound debridement and skin flap coverage. 3 Patients retained their intramedullary fixation. At 1 year follow up no patients reported chronic pain in their affected leg.

What are your conclusions?
We present a complex case series of 5 patients with chronic, recalcitrant TKA PJI, treated with intramedullary knee spanning fusion, antibiotic spacer placement, and intramedullary instillation of antibiotic impregnated calcium sulfate. We review the relevant recent literature and describe an algorithm for treatment management of this difficult scenario. Treatment consists of either reversal to revision TKA following eradication of infection, conversion to conventional knee arthrodesis, or retention of IM fixation with antibiotic spacer. Our series represents among the most complex challenges within the field of limb salvage orthopaedic and the proposed methods of treatment appear to provide these patients relief from chronic pain, preservation on ambulatory status, and acceptable infection control.

Poster Presentation

Early Results of the use of a Bone Transport Nail after Tumor Resection

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What was the question?
The purpose of this study was to evaluate the initial results of using a bone transport nail after tumor resection.

How did you answer the question?
A retrospective review of all patients who had a bone transport nail placed after tumor resection was performed. Length and location of transport, complications and formation of regenerate were evaluated.

What are the results?
Five patients were identified. The average age of the patient was 34 (range 13–70) and average follow–up was 12 months (range 6–24). Four femurs were treated and one tibia. The average length of transport was 12.2 cm (range 3.6 to 18). Four patients underwent primary tumor resection while one patient was treated for a failed intercalary allograft. Three patients underwent transport while on chemotherapy. No patients had radiation to the operative site. Two patients utilized all internal cable assisted transport. Three patients have completed transport while two patients are still completing transport. Two patients had a backing out of their distal interlocking screws and one required revision. One nail fractured after prolonged weight bearing while waiting to complete transport. Four patients required a screw exchange and/or recharge to complete transport. Two patients required screw placement through the regenerate to complete transport. Regenerate was abundant in two patients who had their rate increased and was delayed in two patients, including one patient who was undergoing tibial transport and was not on chemotherapy. Otherwise, no evidence of local recurrence of tumor, infection or other complications were identified.

What are your conclusions?
Regenerate formed in all patients, although the rate at which it formed was variable. Hardware complications were minor except for the fractured nail that occurred after a prolonged period of weight bearing. There were no issues with transport, but the optimal latency and transport rate is unclear due to the variability of regenerate formation.

Augmentation of Internal Fixation with Multiplanar External Fixator in High–Risk Hind Foot Fusion Patients

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What was the question?
Achieving adequate fixation is a critical component for successful fusion, however, this can be compromised in the setting of risk factors such as open trauma, infection, osteoporosis and neuropathic arthropathy resulting in ankle non–union rates as high as 38%. These failures may be magnified by difficulty with weightbearing non–compliance. While the use of multiplanar external fixation (MEF) alone can be utilized – it can often require an extended period of time within the frame – up to 28 weeks in published studies. We hypothesized that supplementation of MEF with internal fixation, will provide adequate stability resulting in improved fusion rates while allowing for early weight bearing and reducing time in an MEF.

How did you answer the question?
Eleven patients were identified that demonstrate significant risk factors for a successful fusion (acute infection, charcot, neuropathy, smoking, history of non–union) that were treated with internal fixation augmented with MEF. Patients with an active infection underwent surgical irrigation and debridement, placement of an antibiotic spacer and a course of intravenous antibiotics prior to placement of internal fixation. In these cases, MEF was placed at the time of surgical irrigation and debridement to allow for stability. In those patients without an active infection, both the internal fixation and MEF were placed at the same time. Internal fixation construct was based on surgeon preference. Patients were allowed to transfer weight bear at the time of surgery and could advance as tolerated after 2 weeks. CT was utilized to assess fusion. Outcomes measured were fusion rate and occurrence of internal fixation infection.

What are the results?
The mean age of patients was 51.5 (range 26–70), eight patients had diabetes, two were current smokers, two were former smokers, two patients had open trauma, one patient had peripheral neuropathy and one patient had a history of a non–union. Eight patients had an active infection and underwent irrigation and debridement, placement of antibiotic spacer and MEF during antibiotic treatment. Nine patients underwent intramedullary nail fixation and two patients underwent plate and screw constructs. CT demonstrated fusion in all patients (100%). The mean time for external fixation was 64 days (range 41–109). Two patients (18%) developed pin site infections that were successfully treated with oral antibiotics and there were no cases of infected internal fixation.

What are your conclusions?
The findings of the current study suggest high rates of hind foot fusion with the use of internal fixation augmented with MEF in a complex patient group with identified risk factors for non–union including an active infection. The addition of internal fixation reduced the overall time within the frame compared to studies using frame alone that are available in the literature. Furthermore, despite the use of MEF in the setting of an active infection there were no incidences of infected internal fixation when augmentation was placed. The use of hybrid fixation can be an effective method of hindfoot fusion in the setting of non–union risk factors, including active infection, and have the benefit of reduced time within MEF and allows for earlier weight bearing.

Reconstruction of Severe Tibia Pilon Fractures Using Distraction Histiogenesis

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What was the question?
Severe tibia pilon fractures are difficult to treat and often lead to poor outcomes. Articular damage, bone loss, and soft tissue injury pose numerous challenges for the treating surgeon. The method of articular reduction and reconstruction using proximal distraction histiogenesis has been proposed as an effective treatment option. Our research shows the results of an expert limb reconstruction and periarticular fracture surgeon in the management of tibia pilon fractures using this technique.

How did you answer the question?
A retrospective cohort of patients treated by a single surgeon over a 20 year period was analyzed.

What are the results?
Results: From 1993 to 2013 a total of 48 severe tibia pilon fractures (OTA 43–C) were treated with this method by a single surgeon (JJH). Average age was 41.8 + 10.2 (range 21–67), and 90% of patients were male. Thirty–one fractures (65%) were open at presentation. Thirty–six patients (75%) underwent proximal to distal transport, and 12 patients underwent shortening an average of 2.5 cm (range 1–4 cm). Of the proximal transport patients, 14 (39%) were transport to arthrodesis (tibio–talar). Twenty–five (52%) of patients required proximal lengthening in their reconstruction. For soft tissue management, Twelve patients (25%) required free tissue transfer, 3 patients (6%) underwent split thickness skin grafting, four patients (8%) were treated with local modalities, and 9 patients (19%) underwent transport to closure. Average external fixator time was 12 + 4 months (range 5–22.5). Average transport length was 5.6 + 2.9 cm (range 1–13.5). The average distraction index for the entire cohort was 2.5 + 1.7 months/cm (range 0.9–12.5 months/cm). Two patients (4%) developed pin site infections. Fourty–three (90%) of patients went on to union. Five patients (10%) had a nonunion that needed further surgery, of these, 3 needed a second circular external fixator.

What are your conclusions?
Treatment of severe tibia pilon fractures is challenging, even with modern techniques. Distraction osteogenesis is a powerful tool and can aid in successfully treating severe tibia pilon fractures.

Unconstrained External Fixation Hinges in Joint Repair: Initial Clinical Experience

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What was the question?
There are two different methods to provide protected joint motion with an external fixator: constrained or unconstrained. A constrained method uses a hinge device to create a single static axis, which requires precise alignment with the axis of joint rotation to avoid impingement. Unfortunately, many joints do not have a single static axis. In such articulations the axis of rotation changes with motion thereby precluding the ability of constrained hinges to be accurately aligned with the joint axis. Consequently, some degree of arthrodiastasis is usually necessary to avoid impingement when a constrained construct is employed. The unconstrained method does not use any hinges. This allows joints to rotate around their natural axis thereby allowing the axis to change during motion. The absence of a hinge, however, can lead to undesired articular motion resulting in shear forces or subluxation. Ideally, an unconstrained hinge device (Fig. 1) that also maintains joint distraction (offloading) during motion would dynamically accommodate natural changes in the axis of rotation while limiting undesired forces during articular motion. This study analyzes our initial clinical experience with such a construct in various joint restoration procedures.

How did you answer the question?
We reviewed the results of treatment of various joint pathologies across three different institutions. Patients underwent placement of unconstrained hinges after acute or gradual joint distraction. The hinges allowed joint motion exercises to be performed while in the external fixation device. A total of 19 patients aged 8 to 39 years at fixator application were analyzed. These patients had varied pathology including: ankle degenerative joint disease of various etiologies (5), talar osteochondral defect (3), fibular hemimelia (2), neuromuscular clubfoot with rigid equinus (2), residual clubfoot with rigid equinus (1), equinus deformity in linear scleroderma (1), aseptic necrosis of talus (1), talipes calcaneovalgus (1), ankle contracture in melorheostosis (1), elbow contracture with a humeral defect after osteomyelitis (1) and knee contracture in the setting of femoral deformity correction and lengthening (1). The initial design of the hinges (model 1) underwent modifications throughout this study. The changes included: improving the stability in the coronal plane while preserving the ability to provide smooth unconstrained flexion and extension (model 2) and further increasing the resistance to shear forces (model 3).

What are the results?
Goals of treatment were achieved in all 19 patients. The unconstrained hinges provided joint protection and allowed motion exercises. All patients with ankle hinges were able to fully weigh bear in the frame without any discomfort. There was no loss of motion following treatment but not necessarily any improvement in motion. Three patients had device complications. One of the hinges (model 1) was broken in two patients and one hinge (model 2) was deformed under a heavy load in another patient. These were all ankle applications. All hinge complications happened close to the end of treatment. They required hinge exchange and did not affect the final result. Based on these device issues, the device was modified (model 3) and there were no further device related complications after this design change.

What are your conclusions?
Novel unconstrained hinges provide the ability to offload and protect joints during motion exercises for various types of joint pathology. They are easy to apply and did not create any discomfort for the patients in this series. During the study the initial design was improved to increase durability. There was no loss of motion and goals of treatment were achieved in all patients.

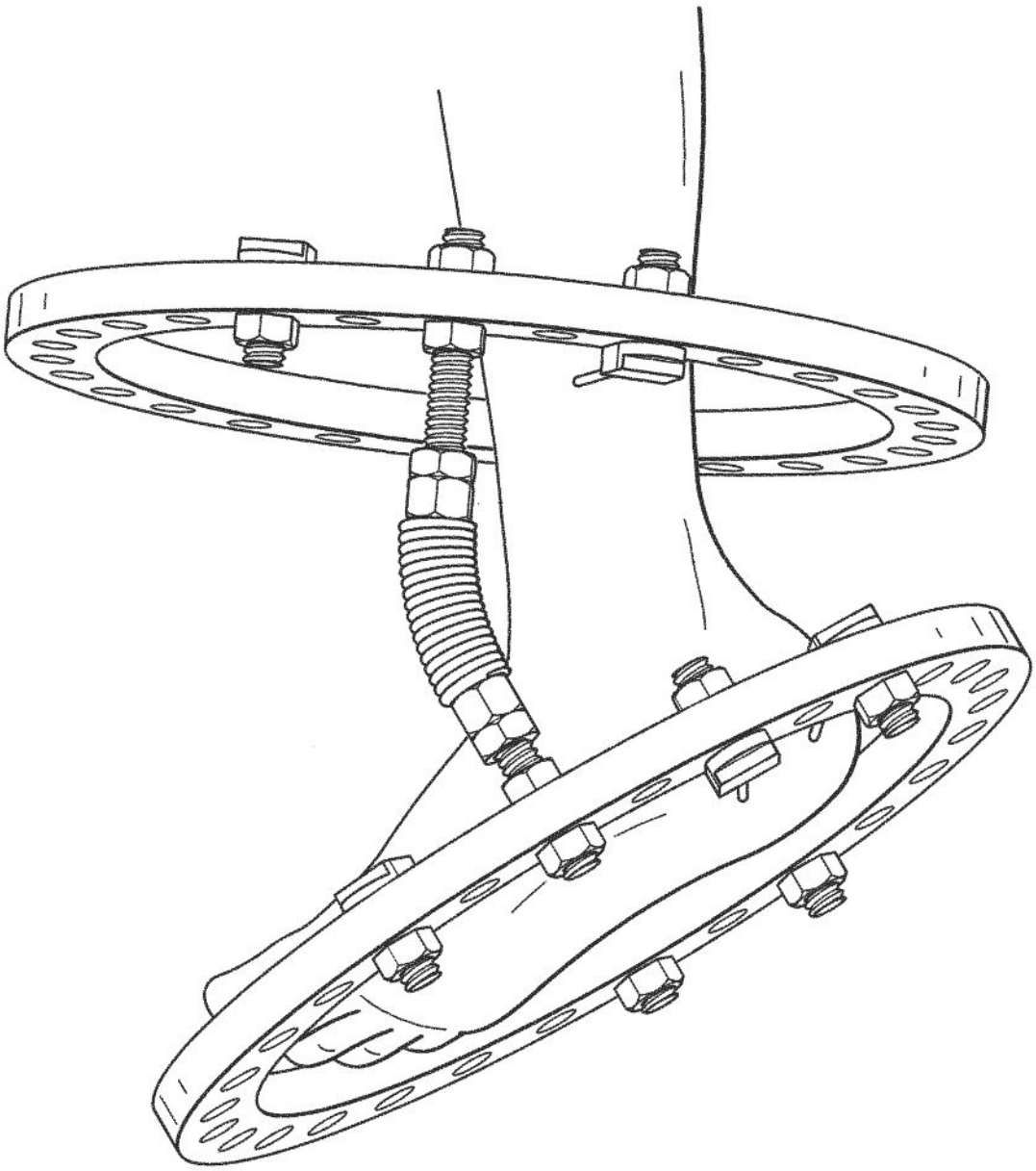

Fig. 1. An unconstrained hinge positioned at the ankle joint

Long–Term Self–Reported Functional Outcomes following Unilateral Major Lower Extremity Combat Injury – Preliminary results from the METALS II Study Group

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What was the question?
The Military Extremity Trauma Amputation/Limb Salvage (METALS) study published in 2013 described the self–reported outcomes of patients with combat sustained major lower extremity trauma at an average 38.9 ±13.7 months post–injury. Using the Short Musculoskeletal Function Assessment (SMFA), this study suggested better SMFA outcomes for patients with amputation versus reconstruction, though all patients regardless of limb status experienced significant decrements in function compared to population norms. In this study, we followed the METALS cohort several years later to determine whether functional outcomes change over time and whether differences in outcome by treatment persist.

How did you answer the question?
All patients who were initially interviewed as part of the METALS study were contacted by telephone at an average of 157.0 ± 14.5 months post–injury . We were able to locate and interview a total of 277 individuals for an overall response rate of 64%. Preliminary results herein compare the overall SMFA Dysfunction score together with the Activities of Daily Living and Mobility sub scores of the SMFA at Time 1 (initial interview) and Time 2 (follow–up interview). An increase in SMFA score indicates greater degree of dysfunction and a 6 point change was considered a difference. Populations norms have been reported to average 12.7 for Dysfunction, 11.8 for Activities of Daily Living scales, and 13.6 for Mobility.

What are the results?
Included in this preliminary analysis, are 85 patients who underwent unilateral lower limb reconstruction and 81 patients who underwent unilateral lower limb amputation. SMFA overall Dysfunction Score [mean (standard deviation)] for reconstruction patients at Time 1 and Time 2 interviews was 30.7 (15.9) and 31.8 (16.8), respectively with 26 oing better and 26 oing worse; amputation patients' SMFA Dysfunction at Time 1 and Time 2 was 20.7 (14.0) and 25.7 (13.1), respectively, with 19 oing better but 42 oing worse. Activities of daily living scales for unilateral reconstruction patients at Time 1 averaged 29 (19.6) and Time 2 30.3 (21.7) with 30 oing better and 37 oing worse. For unilateral amputees, activities of daily living results at Time 1 20.2 (18.8) and Time 2 25.2 (17.5) with 23 oing better and 37 oing worse. Time 1 and Time 2 Mobility scores were 38.5 (20.8) and 38.5 (21.0), respectively, for limb reconstruction patients [34 oing better, 24 oing worse]; and 25.4 (17.7) and 31.9 (15.9), respectively, for amputation patients [23 oing better, 55 oing worse].

What are your conclusions?
Major lower extremity trauma is associated with poor functional outcomes at an average of 13 years post–injury relative to population norms. These preliminary results at a timepoint quite distal to injury in US combatants suggests that self–reported functional and outcomes may decline with time, especially for patients undergoing early amputation. Differences in outcomes between patients undergoing amputation versus reconstruction found at Time 1 appear to be somewhat attenuated at Time 2. Controlled analyses of these are ongoing to describe if clinical meaningful changes in outcomes occur over time.

Prophylaxis and Treatment of Infection in Complex Extremity Reconstruction Using Antibiotic Loaded Ceramic Coated Interlocking Intramedullary Nails

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What was the question?
PMMA antibiotic–coated interlocking intramedullary nails (ACC–IMN) used for long bone osteomyelitis is well supported in the literature. Despite good clinical success, many clinical shortcomings of this technique remain. Synthetic calcium sulfate has emerged as a promising antibiotic carrier that is not as technically demanding to use in combination with a locked intramedullary nail. The primary aim of this study is to report on our recent experience with antibiotic calcium sulfate coated interlocking intramedullary nails (ACS–IMN) to eradicate infection as well as to prevent infection in high risk patients. The secondary aim is to compare the results of our cohort where ACS–IMN were use with curative intend with a prior cohort of patients treated with ACC–IMN.

How did you answer the question?
We retrospectively reviewed the medical records and radiographs of our patients treated from January 2010 to August 2017 who underwent a limb salvage procedure for infection cure (union or fusion) with ACC–IMN and patients treated from May 2017 to June 2020 with the use of ACS–IMN for infection prophylaxis or infection cure. We reviewed patient demographics, including host–type, pre–operative infecting organism, intra–operative cultures, as well as our main outcomes: infection control rate, achievement of union/fusion, limb salvage rate and overall complication rate.

What are the results?
Thirty three patients were treated with ACS–IMN. Mean patient age was 50 years (range 22–74 years). Mean follow–up period was 18.7 months (range 5.29–48.9 months). 12 patients (36.4%) were Cierny–Mader Host type A versus 21 patients (63.5%) type B hosts. ACS–IMN was used in 9 patients (27.3%) with goal of infection cure and in 24 patients (72.7%) for infection prophylaxis. In the infection prophylaxis group, the indication for ACS–IMN use was either a history of recent infection at the operative site in 14 patients (58.3%), presumed infected non–union in 9 patients (37.5%) and immunocompromised host infection prophylaxis in 1 patient (4.2%). In the 24 patients ACS–IMN was used as infection prophylaxis, there was a 100% (24/24 patients) prevention of infection rate, 90.9% union rate (20/22 patients) and 100% (24/24 patients) limb salvage rate.
Nine patients were treated with ACS–IMN to eradicate infection and were compared to a cohort of twenty–eight patients treated with ACC–IMN. In the ACS–IMN group, 6/9 patients (66.7%) were type B hosts versus 19/28 patients (67.9%) in the ACC–IMN group (p=1). The infection was eradicated in 7/9 patients (77.8%) in the ACS–IMN group versus 21/26 patients (80%) in the in ACC–IMN group (p=0.44) . Bone union/fusion was achieved in 8/9 patients (88.9%) in the ACS–IMN group versus 21/24 patients (87.5%) in the ACC–IMN group (p=0.11). The limb salvage rate in the ACS–IMN group was 100% (9/9 patients) versus 89% (2528 patients) in the ACC–IMN group.

What are your conclusions?
ACS–IMN is a safe technique for long bone infection prophylaxis or cure in the context of a complex lower extremity reconstruction. Although, this is our preliminary data, it appears that ACS–IMN results are promising and could be comparable to ACC–IMN for treatment of long bone osteomyelitis. Future studies with a larger cohort of patients are required to confirm these expectations.

Remote Presentation

Preventative Multimodal Analgesia for Patients Undergoing Lower Limb Reconstruction with External Fixators – A Prospective Study of Postoperative Pain

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What was the question?
Limb reconstruction with external fixators is painful for the paediatric population. Appropriate pain management is important to promote effective healing while minimizing adverse events. The objective of this prospective study is to evaluate a preventative multimodal analgesia regimen designed to reduce opioid requirements.

How did you answer the question?
A prospective cohort of patients undergoing lower limb reconstruction surgery (LRS) were managed through an evidence–informed multimodal analgesia guideline (MMAG). A retrospective control cohort was included for descriptive comparison. Outcome measures included intraoperative and postoperative opioid administration, postoperative pain scores, time to achieve mobilization milestones, duration of hospital stay, and postoperative complications. Surveys were conducted to obtain patient reported experiences on pain management.

What are the results?
21 patients were in the prospective cohort. 8 patients were retrospective control. For the MMAG group and control, 606.51 [409.09, 1345.39] mcg/kg and 2559.02 [1876.56, 3223.96] mg/kg, respectively of intraoperative opioids were administered. In the first 48 hours postoperatively, the MMAG group was given 11.61 [7.25, 20.08] mcg/kg/hr of opioids. The control group was given 23.53 [15.47, 28.39] mcg/kg/hr. Median level of pain (0–10) in the first 48 hours postop was 2.0 [1.0, 2.0] and 2.0 [1.4, 3.0] for MMAG group and control respectively. The MMAG group achieved mobilization milestones earlier than clinically expected. 14/15 MMAG patients surveyed found pain management effective; 12/15 did not have unwanted side effects associated with pain medications. No compartment syndrome occurred.

What are your conclusions?
This multimodal analgesia regime applied to patients undergoing lower limb LRS with external fixators provided effective pain control, early mobilization, and minimal side effects. This can guide future implementation strategies extending to orthopaedic procedures beyond LRS for the paediatric population.

Remote Presentation

A Novel Formula to Accurately Predict the Change in Tibial–Tuberosity to Trochlear–Groove (TTTG) Distance Following Supratubercle Osteotomy of the Tibia

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What was the question?
Supratubercle tibial rotational osteotomies can be a useful adjunct in patellar stabilizing procedures. It can simultaneously address an increased tibial–tuberosity to trochlear–groove (TTTG) distance and excessive external tibial torsion. Recently, an investigation published by Jud et al. (2020) used computer assisted modelling to empirically determine that 1 degree of internal tibial rotation resulted in 0.68 mm of decrease in TTTG. However, this method has yet to be externally validated and does not take into account individual variations in anatomy. Thus, the question at hand is whether a novel mathematical model that takes individual anatomic parameters is superior at predicting the change in TTTG length following supratubercle osteotomy.

How did you answer the question?
A novel trigonometric equation was derived to calculate the change in the TTTG based on the degree of rotation with a supratubercle osteotomy. To validate the equation, bilateral pre–operative CT scans of the lower extremity of 15 patients (30 knees) with excessive external tibial torsion and patella–femoral instability were used to simulate derotations of 5, 10 and 15 degrees (total number of simulated derotations = 90). Axial CT views were uploaded into the image analysis software ImageJ (NIH, Bethesda MD), which was then used to overlay the images of the tibial tubercle and trochlear groove and measure the baseline TTTG. Using the same program, the tibial derotations, which involved internally rotating the distal tibial segment, were simulated and the resulting "true" change in TTTG was measured. We used this "true" measurement to assess the accuracy of estimates of TTTG change following supratubercle osteotomy using various methods. First, we used our patient–specific formula to estimate the TTTG change following 5–degree rotational increments. Second, we used the empirical relationship established by Jud et al. (2020) to calculate estimated TTTG change. Comparison of the mean changes in TTTG using each method and further statistical analysis was performed using SPSS (IBM, Armonk NY).

What are the results?
Following 5, 10 and 15 degrees of simulated tibial derotation, the mean "true" change in TTTG as determined by our image overlay technique was 1.73 mm, 3.62 mm and 5.47 mm, respectively. Using our novel formula, the mean values were calculated to be 1.65 mm, 3.4 mm and 5.23 mm. The TTTG change estimation proposed by Jud et al. (2020), resulted in values of 3.4 mm, 6.8 mm and 10.2 mm for each incremental derotation of 5 degrees. A one–way ANOVA test showed that the differences between the measures obtained with each of these methods was significantly different ($p<0.001$). However, the results of the students t–test revealed that the difference between the "true" measurements and the values obtained using our novel formula were not statistically significant for the 5, 10 and 15 degree of derotation ($p=0.62$, $p=0.31$, $p=0.37$). Conversely, the t–test demonstrated that "true" values were significantly different from the values obtained using the estimation proposed by Jud et al. ($p<0.001$).

What are your conclusions?
Our novel equation, which employs individual anatomic parameters, precisely and accurately predicted the change in TTTG following simulated supratubercle tibial osteotomy. The predicted TTTG change was grossly overestimated using the linear relationship proposed by Jud et al. (2020) when compared with both the "true" TTTG change and the one calculated with our novel equation. Therefore, we may not be performing as much correction as pre–operatively planned. Developing an equation that incorporates dimensions obtained from patient–specific pre–operative CT scans accounts for the uniqueness of each patient's anatomy and provides more accurate assessments of the potential correction following tibial supratubercle osteotomies. This study demonstrates an accurate relationship between internally rotating the distal segment of the tibia with a supratubercle osteotomy and the linear decrease in the TTTG in patients with patellar instability caused by excessive external tibial torsion and high TTTG.

Applications and Error Ratios of Calibration Techniques in EOS and Teleoroentgenogram for Length Measurement; A Comparative Study

Ali Asma, MD; Louise Reid Nichols; Armagan Can Ulusaloglu; James Richard Bowen; Faaiza Kazmi; Barbara Drozdowski; Kenneth Rogers
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What was the question?
There will be significant differences between EOS and Teleroentgenogram calibration technique's errors.

How did you answer the question?
This study aims to determine errors in common techniques used to measure lower limb lengths in children. Precision and instrument errors in length measurements were studied utilizing a "phantom" with long cassette radiographs (teleroentgenogram) with a radiopaque ruler calibration/magnification ball(magball)/magnification strip(magstrip) and the more modern low dose radiation methods of EOS with internal calibration/magball/ magstrip(Figure 1 and 2). The goal is to measure a 70 cm line in phantom grid and 70 cm metallic rod (average length of the lower extremity of 10 year old boy in 50 percentile) in three phases. In Phase 1, the length measurements were performed in an EOS unit with internal calibrations, a magball/magstrip in various scan positions, and measurement with TraumaCAD software (Brainlab, Munich, Germany). In Phase 2, the measurements were repeated utilizing a single radiation "shot" teleroentgenogram. In Phase 3, an orthoroentgenogram was utilized with a radiopaque ruler (1 cm–collimated grid by Lead Tell Co.). The reliability and validity of measurements were calibrated by four physicians (a radiologist, senior orthopedic attending, and two orthopedic fellows).

What are the results?
In Phase 1 of the study, five different calibration techniques in EOS were utilized. The mean values, standard deviations, and magnification errors are summarized in Table 1.
The significant results are:
1. Internal calibration of EOS into Fuji and TraumaCAD was the most accurate. The mean difference in measurement per 70 cm(700 mm) was 0.599 mm (0.085%), when magball is at the center, 0.560 mm (0.080%) when magball is on the side, 0.563 mm (0.080%) when magball is anterior to the subject. The standard deviation between measurements was less than 0.37 mm which shows consistent intra/interobserver agreement.
2. Manual calibration of magball in TraumaCAD has the worst accuracy (695 mm ± 17.73 mm– when the magball was anterior to the subject, 710.33mm ±10.22 mm when magball at the center, 709.99mm5± 8.74 mm when the magball was positioned at the side for 700 mm real length measurement. The standard deviations between measurements were 17.73, 10.22, 8.74 and coefficient of variation were 0.025, 0.014, 0.012 respectively, which shows the consistent intra/interobserver disagreement.
3. Manual calibration of magstrip in TraumaCAD has less magnification error and standard deviations than manual calibration of the magball in TraumaCAD (mean 703.2 mm ±0.904 mm vs 710.33mm ±10.22 mm when magball is at the center).
4. Automatic calibration of magball in TraumaCAD had a magnification error of 1.25% when ball at the center, 1.24% with the ball at the side and –1.82% with ball positioned anteriorly. The mean difference was 708.74mm± 0.23 mm when magball is placed at the center, 708.71mm ± 0.238 mm when magball is located at the side, 712.71mm ±2.01 mm when ball is anterior to the subject for 700 mm real length measurement

In the second phase of the study, conventional radiographic techniques were utilized for single–shot digitally stitched teleroentgenogram. In the second phase the magball was placed in up, middle, lower, anterior and side positions(Figure 3). The magstrip was positioned in the side position. A radiopaque ruler (internal grid meter) was utilized in the side position. The mean values, standard deviations and magnification errors were summarized in Table 2
1. The worst measurements are when magball or magstrip were not used for calibration at teleroentgenogram. The magnification error was around with a mean length of 757.49±0.0166 mm.

Applications and Error Ratios of Calibration Techniques in EOS and Teleoroentgenogram for Length Measurement; A Comparative Study *continued*

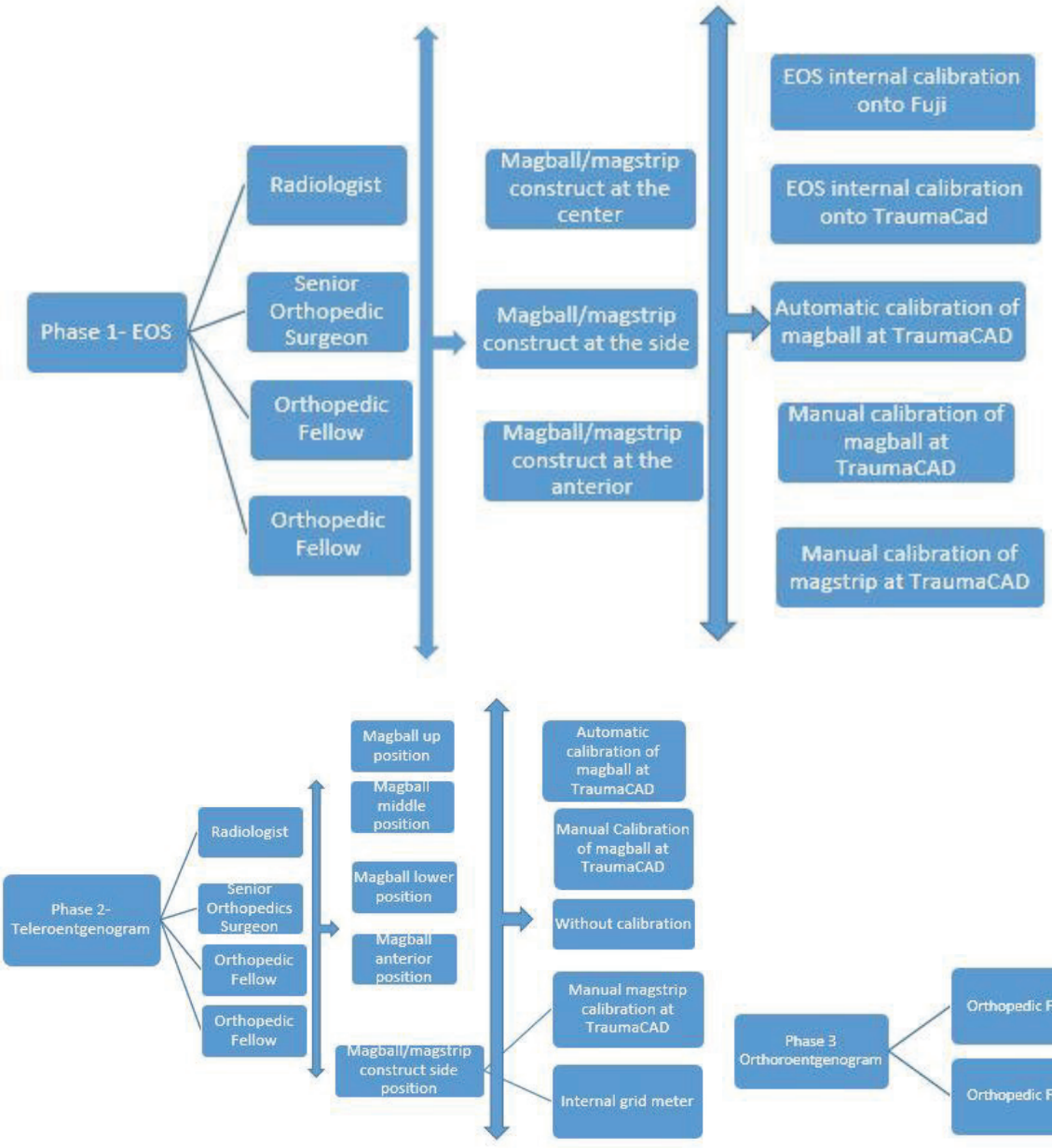
Ali Asma, MD

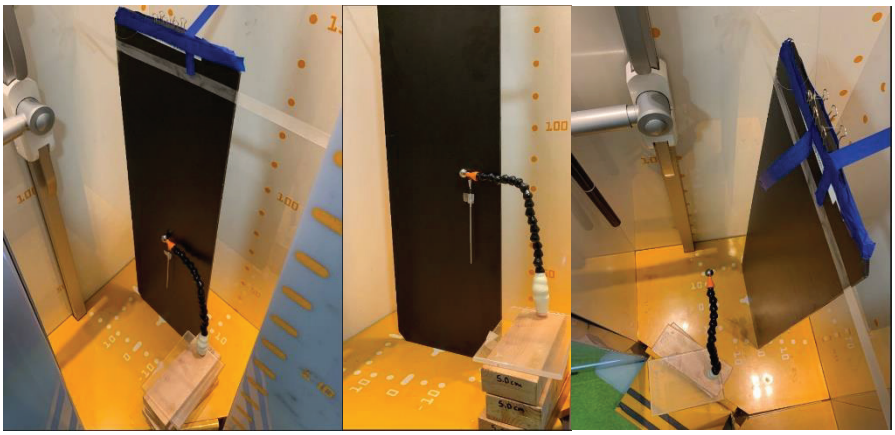
2. Magball automatic calibration in TraumaCAD was better than the magball manual calibration. This was true for the magball in all of the following positions: up, middle and lower.

3. The x–ray tube was placed directly across the upper part of the 70 cm rod. The magball automatic calibration when magball in up position and right across the x–ray beam was very accurate(magnification error= –0.09%, 699.377±0.190) as similar as to EOS internal calibration(magnification error= –0.09%). This was due to decreased divergence of x ray beam.
4. When the magball was placed in an anterior position in the middle (672.978mm ±0.195mm, magnification error= –3.86%), it's comparison to magball in the middle and close to the subject (694,467±0.174 magnification error = –0.79%) showed that anterior movement of magball increases error ratio and decreases the real length of the subject.
5. The manual magstrip calibration in Phase 2 has a 2.21% magnification error with a 0.326 mm standard deviation (715.492mm ±0.326 mm). The standard deviation for manual magball calibration in the same image was approximately 6.60 mm (709.004mm ± 6.60 mm). Although the mean value of the magball calibration was closer to the known length of 70 cm, the variation between the measurements was responsible for this result. The magstrip calibration was more reliable due to consistent agreement between measurements with low standard deviation. However, the magstrip calibration had 2.21% magnification error.

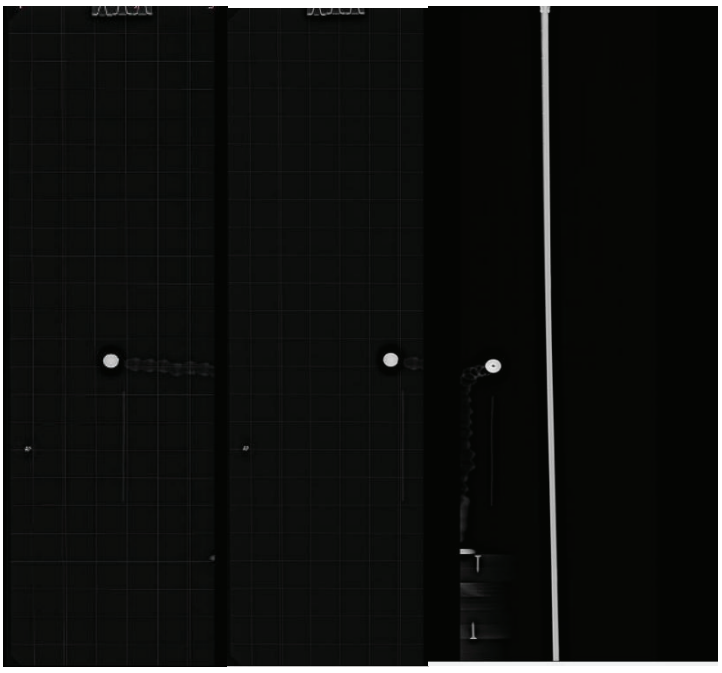
In Phase 3, two investigators performed the 70 cm metallic rod measurement with three shot orthoroentgenogram. The mean measurement value was 701.87±0.17. The magnification error of 0.26% was close to but not as good as EOS internal calibration (–0.09%).

What are your conclusions?
Although teleroentgenogram (single x–ray exposure with long cassette) and EOS allow anatomical and angular measurements, leg length measurements have variable errors of accuracy. Teleroentgenograms are very convenient and readily available. However, length measurement errors occur secondary to radiation beam divergence. All imaging modalities require standard references for length measurements (such as internal ruler, external ruler, magball, magstrip, etc.). Measurements of references may be performed manually or by computer–based systems, such as TraumaCAD. EOS measurements utilizing internal references had excellent accuracy (for a 70 cm real length, magnification error of 0.09%, mean measurement value of 699.4±0.28 mm and insignificant intra/ interobserver difference). Teleroentgenogram with a magball reference (positioned in planes at the level of roentgenographic beam beside the item to be measured) and measurements performed by automatic calibration by a TraumaCAD program results in accuracy of 712.8±0.18 mm, magnification error of 1.83% with insignificant intra/ interobserver difference. Teleroentgenogram with a magball or magstrip reference (positioned in planes at the level of roentgenographic beam beside the item to be measured) and measured manually showed the magball have the higher intra/interobserver variance than magstrip with a 6.60 mm and 0.33 mm standard deviation respectively. The length by manual measurement by the magstrip has the accuracy of 715.49±0.33 mm and magnification error of 2.21%. Orthoroentgenogram is accurate with magnification error of 0.26 ut does not allow to make anatomical analysis and is also radiation costly. EOS is very accurate for length measurement while the teleroentgenogram is almost as accurate if an automatic calibration of computer–based analysis is utilized. If manual calibration is utilized the length measurement is less accurate and the magball is more variable than the magstrip.


Phase 1- EOS
Radiologist
Senior Orthopedic Surgeon
Orthopedic Fellow
Orthopedic Fellow
Magball/magstrip construct at the center
Magball/magstrip construct at the side
Magball/magstrip construct at the anterior
EOS internal calibration onto Fuji
EOS internal calibration onto TraumaCad
Automatic calibration of magball at TraumaCAD
Manual calibration of magball at TraumaCAD
Manual calibration of magstrip at TraumaCAD
Phase 2- Teleroentgenogram
Radiologist
Senior Orthopedics Surgeon
Orthopedic Fellow
Orthopedic Fellow
Magball up position
Magball middle position
Magball lower position
Magball anterior position
Magball/magstrip construct side position
Automatic calibration of magball at TraumaCAD
Manual Calibration of magball at TraumaCAD
Without calibration
Manual magstrip calibration at TraumaCAD
Internal grid meter
Phase 3 Orthoroentgenogram
Orthopedic Fellow
Orthopedic Fellow



A B C



D E F

Figure 2: The position of magball/magstrip construct inside EOS according to phantom grid. **A**- Construct is at the center of phantom grid. **B**- Construct is at the side of the phantom grid **C**- Construct is at the anterior of the phantom grid. **D** is the x-ray (EOS) image of position A. **E** is the x-ray(EOS) image of position B, **F** is the lateral x ray(EOS) image of position C.

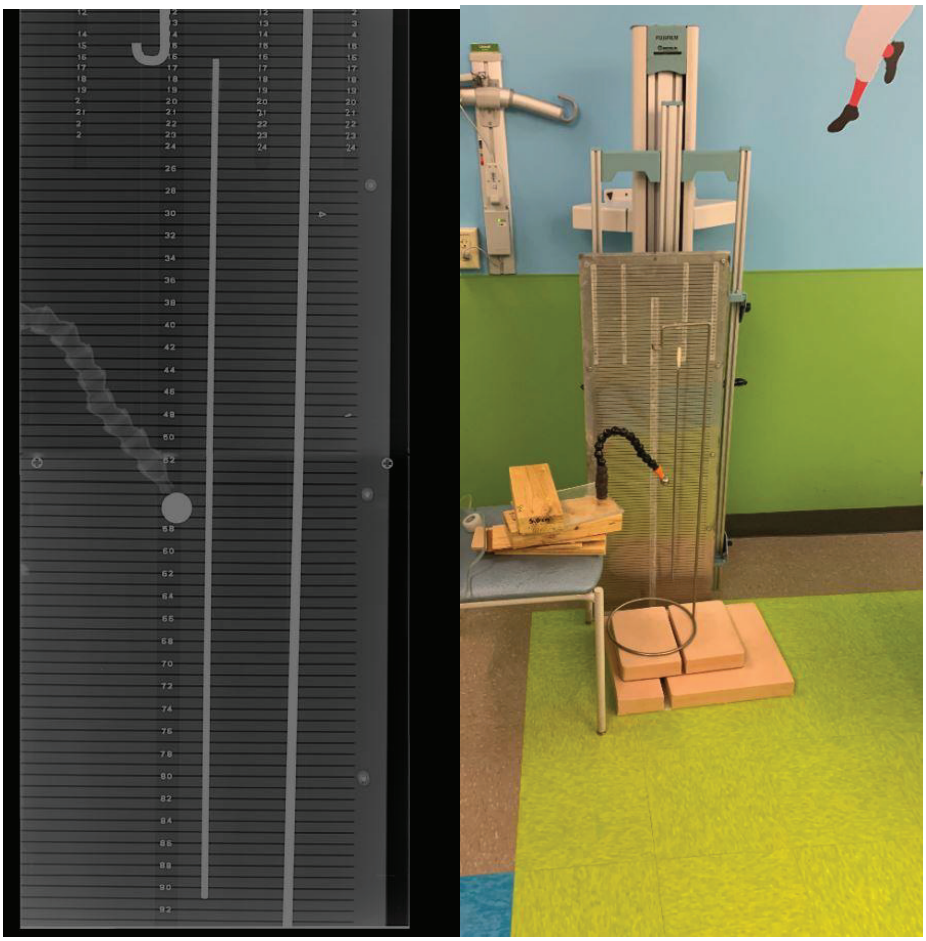
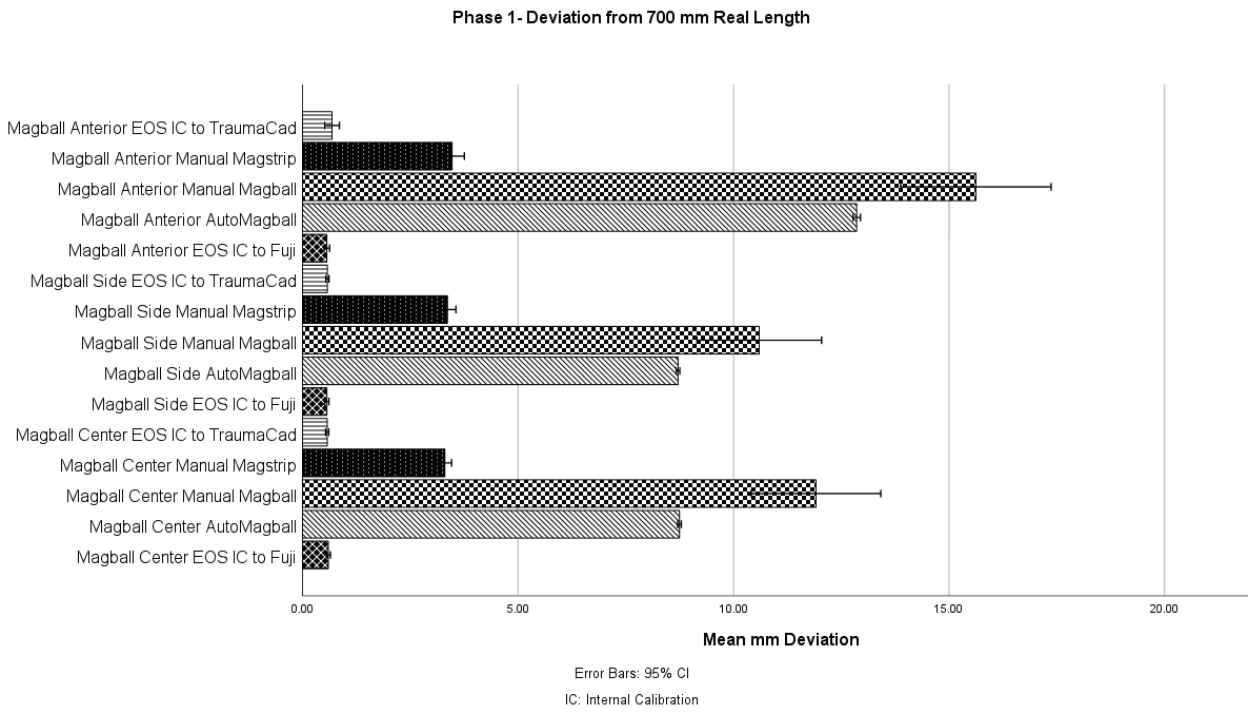


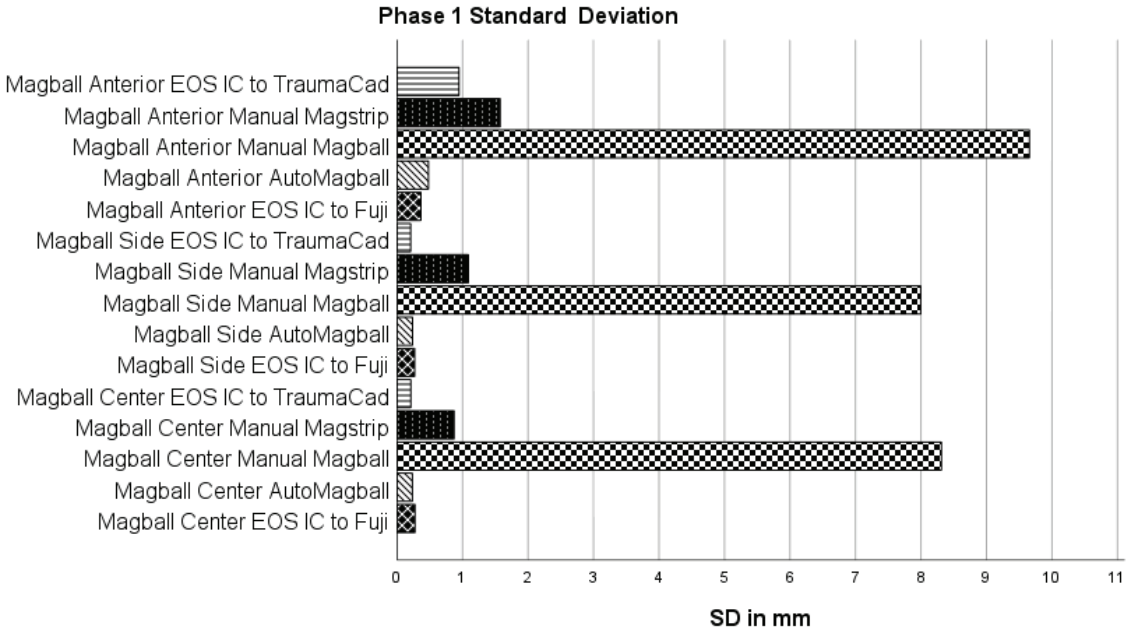
Figure 3: In Phase 2, the single shot digitally stitched teleroentgenogram were utilized. The Magball was placed in upper, middle, inferior, anterior and side positions. Here is the middle position.

Table 1

Phase 1 Measurement Results	Minimum	Maximum	Mean	Std. Deviation	Magnification Error (%)
Magball Center EOS IC to Fuji	698.5	700.06	699.40	0.28	-0.09
Magball Center AutoMagball	708	709.5	708.75	0.24	1.25
Magball Center Manual Magball	666.7	732.7	710.33	10.23	1.48
Magball Center Manual Magstrip	699.5	706.8	703.30	0.90	0.47
Magball Center EOS IC to TraumaCAD	698.7	699.8	699.43	0.21	-0.08
Magball Side EOS IC to Fuji	698.33	700.35	699.44	0.28	-0.08
Magball Side AutoMagball	707.7	709.3	708.71	0.24	1.24
Magball Side Manual Magball	684.9	735.6	710.00	8.75	1.43
Magball Side Manual Magstrip	699.5	706.8	703.36	1.12	0.48
Magball Side EOS IC to TraumaCAD	698.4	699.7	699.42	0.21	-0.08
Magball Anterior EOS IC to Fuji	697.71	700.14	699.44	0.37	-0.08
Magball Anterior AutoMagball	685.3	708.9	687.29	2.01	-1.82
Magball Anterior Manual Magball	625	726.4	695.05	17.74	-0.71
Magball Anterior Manual Magstrip	699.6	715.4	703.47	1.59	0.50
Magball Anterior EOS IC to TraumaCAD	689.3	699.8	699.31	0.95	-0.10

Magball: Magnification ball, IC: Internal Calibration, Magstrip: Magnification Strip, Fuji: Fuji PACS software, TraumaCAD: TraumaCAD software



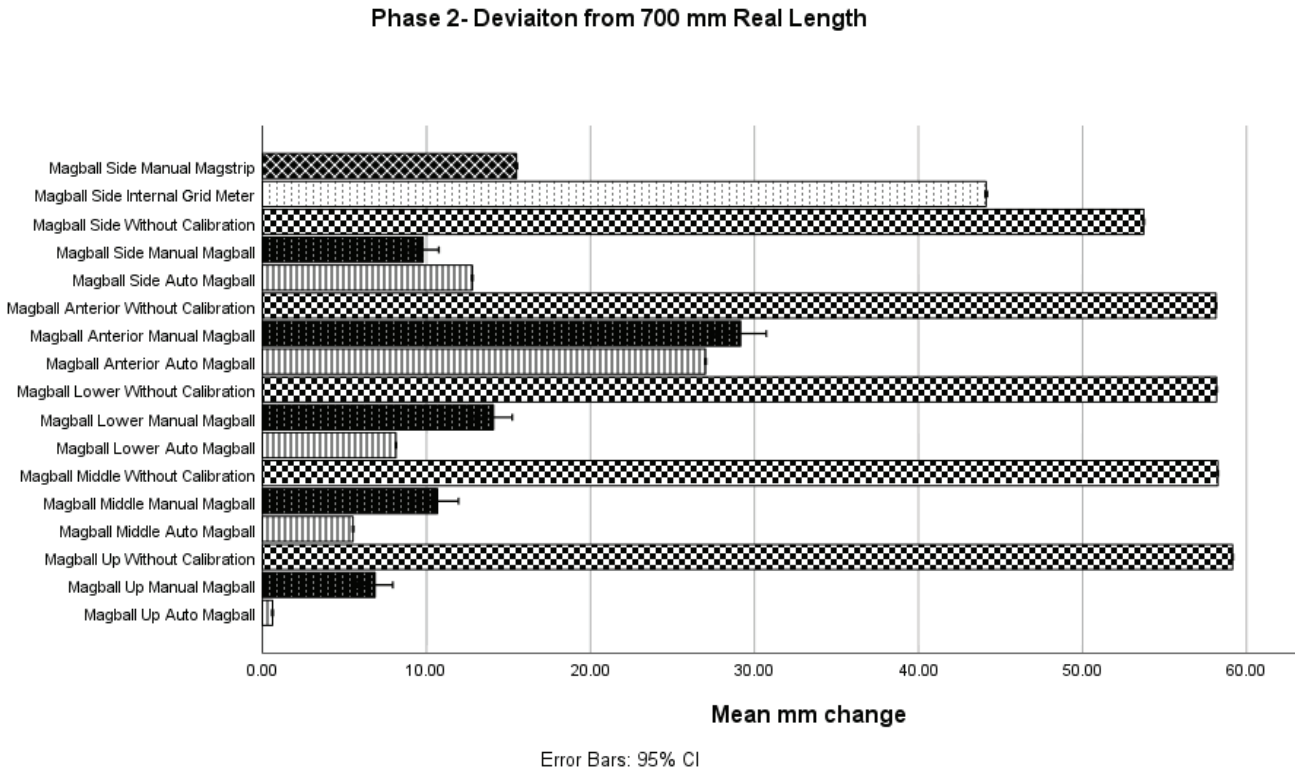


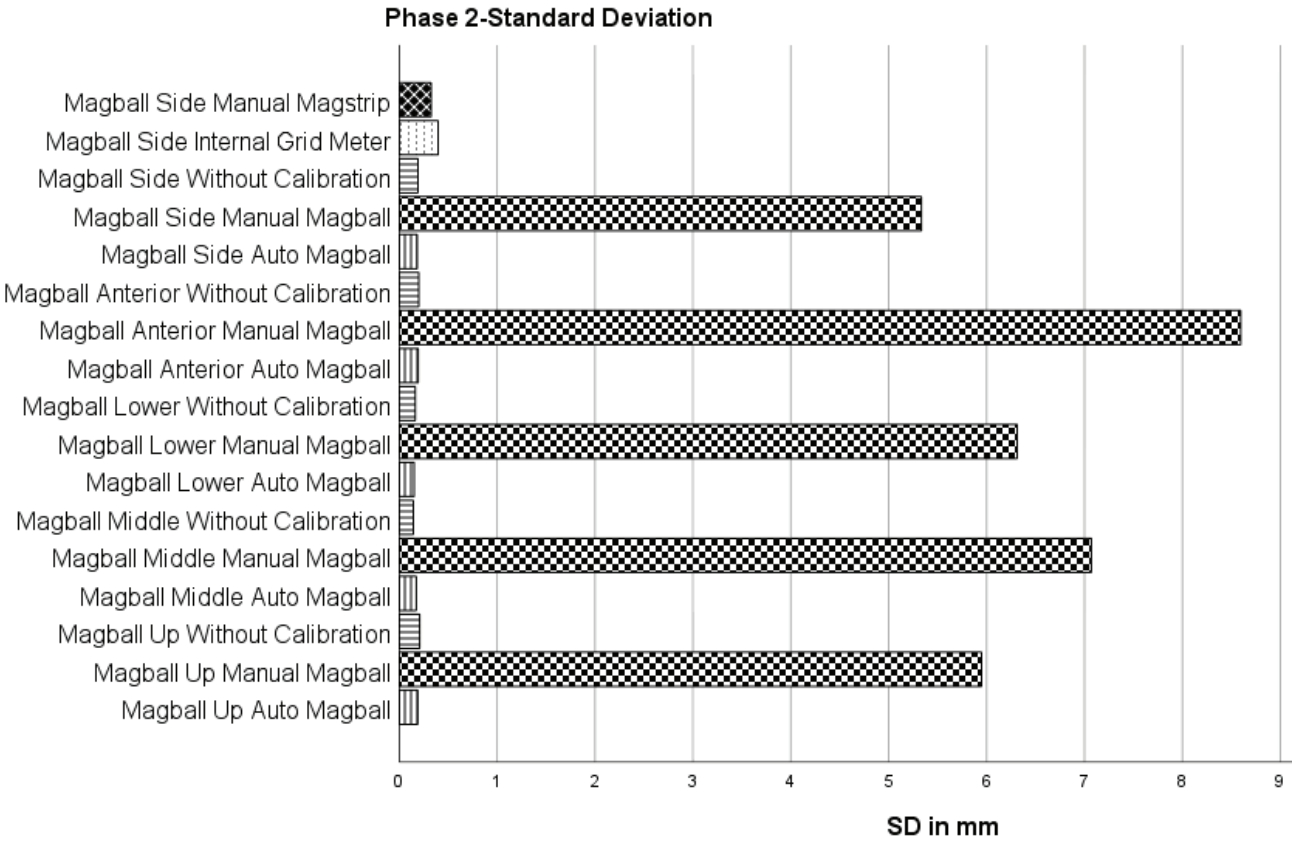
Magball: Magnification ball, IC: Internal calibration, Magstrip: Magnification strip, Fuji: Fuji PACS software, TraumaCAD: TraumaCAD software

Table 2

Phase 2 Measurement Results	Minimum	Maximum	Mean	Std. Deviation	Magnification Error (%)
Magball Up Auto Magball	698.6	699.7	699.38	0.19	-0.09
Magball Up Manual Magball	670.1	713.6	695.65	8.00	-0.62
Magball Up Without Calibration	758.3	759.5	759.15	0.21	8.45
Magball Middle Auto Magball	694	695.5	694.47	0.17	-0.79
Magball Middle Manual Magball	662.4	710.1	689.93	7.93	-1.44
Magball Middle Without Calibration	757.8	758.5	758.26	0.14	8.32
Magball Lower Auto Magball	691.4	692.4	691.85	0.15	-1.16
Magball Lower Manual Magball	669.3	701	685.92	6.35	-2.01
Magball Lower Without Calibration	757.6	758.4	758.18	0.16	8.31
Magball Anterior Auto Magball	672.3	673.7	672.98	0.20	-3.86
Magball Anterior Manual Magball	642.5	699.5	670.83	8.60	-4.17
Magball Anterior Without Calibration	757.4	758.5	758.14	0.20	8.31
Magball Side Auto Magball	712.4	713.1	712.80	0.18	1.83
Magball Side Manual Magball	691.1	727.1	709.00	6.60	1.29
Magball Side Without Calibration	753.1	754.1	753.74	0.19	7.68
Magball Side Internal Grid Meter	744	745.4	744.13	0.40	6.30
Magball Side Manual Magstrip	714.6	716.4	715.49	0.33	2.21

Magball: Magnification ball, Magstrip: Magnification strip, Auto magball: Automatic mode calibration





Magball: Magnification ball, Magstrip: Magnification strip, Automagball: Automatic mode calibration

Calibration Techniques for Daily Practice	Magnification Error	Standard Deviation
EOS Internal Calibration-Construct at side	-0.08%	0.21 mm
Orthoroentgenogram	0.26%	0.17 mm
Teleroentgenogram Construct at side - Automatic Calibration of Magball at TraumaCAD	1.83%	0.18 mm
Teleroentgenogram Construct at side - Manual Calibration of Magstrip at TraumaCAD	2.21%	0.33 mm
Teleroentgenogram Construct at side - Manual Calibration of Magball at TraumaCAD	1.29%	6.60 mm

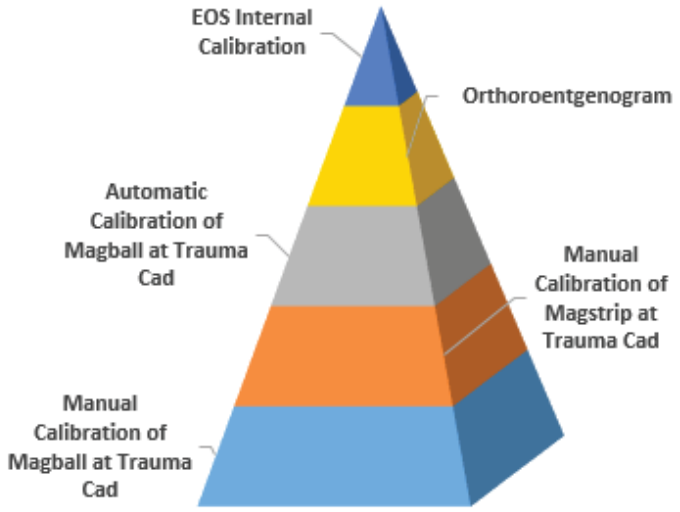


Table 1 and Graph 1: The calibration devices were utilized in clinical practice. This table shows the magnification errors and standard deviations of each calibration techniques in side position as in daily practice. The pyramid graphs were utilized to show increasing grade of calibration.