

**Limb Lengthening and Reconstruction Society:
ASAMI–North America**

Specialty Day

March 10, 2018

New Orleans, LA

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Mission Statement

The Limb Lengthening and Reconstruction Society: ASAMI–NA is devoted to the continuum study and evolution of knowledge based on the understanding of bone biology, osteogenesis regeneration and musculoskeletal applications.

Our purpose is to resolve acute and chronic musculoskeletal problems of pediatric and adult patients.

We strive to maintain the highest competency in the field of musculoskeletal deficiencies and reconstruction: limb length and extremity defects, long bone and joint deformity, limb salvage, trauma, infection and complex limb reconstruction.

As an AAOS specialty society; we are committed to the provision of educational resources, research, clinical excellence and collegial cooperation.

LLRS Welcomes New Members!

You are invited to apply for membership in LLRS.

Please go to www.llrs.org, Membership, Membership Application to join.

Membership eligibility requirements apply.

Visit

<http://www.llrs.org>

for more information about LLRS: ASAMI–North America

Please place your mobile devices on silent.

Limb Lengthening and Reconstruction Society

Saturday March 10, 2018

Morial Convention Center

Room 206

8:00 a.m.–2:30 p.m.

Great Hall B

2:30–4:45 p.m.

Continuing Education Credit

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 Musculoskeletal Infection Society. The American Academy of Orthopaedic Surgeons is accredited by the ACCME to provide continuing medical education for physicians.

The American Academy of Orthopaedic Surgeons designates this live activity for a maximum of **7.75 *AMA PRA Category 1 Credits*[™]**. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Objectives

Upon completion of this activity, physicians will be able to:

1. understand current advances in the field of limb reconstruction from South Korea;
2. recognize the options for treatment of difficult problems in adult and pediatric limb reconstruction; and
3. gain knowledge of the current controversies in the application of limb reconstruction techniques in foot and ankle surgery.

Evaluation

Please go to the link below to complete the evaluation by March 28, 2018.

<https://www.surveymonkey.com/r/LLRSSD2018>



Intramedullary Limb Lengthening Pre–Course

Thursday, July 12, 2018

San Francisco Hilton Union Square
San Francisco, CA

Registration is limited.

E–mail info@llrs.org for more information.



27th Annual Scientific Meeting

Friday & Saturday, July 13 & 14, 2018

San Francisco Hilton Union Square
San Francisco, CA

Learn more at llrs.org.

Disclosures

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Nuvasive: Paid consultant

Agenda

- 8:00–8:05 a.m. Welcome and Introduction
J. Spence Reid, MD and L. Reid Nichols, MD
- Session I** **Guest Nation: South Korea**
Moderator: J. Spence Reid, MD
- 8:05–8:20 a.m. Complications of Limb Lengthening in Achondroplasia
Mi-Hyun Song, MD, PhD
- 8:20–8:35 a.m. Skeletal Deformities Associated with Bone Tumor
Sung-Taek Jung, MD, PhD
- 8:35–8:50 a.m. Treatment of the Bone Defects with Human Embryonic Stem Cell Derived–
Mesenchymal Stem Cell – *Jung-Ryul Kim, MD, PhD*
- 8:50–9:05 a.m. Some Important Things I Have Experienced in Limb Lengthening and
Deformity Correction – *Dong-Hoon Lee, MD, PhD*
- 9:05–9:15 a.m. Discussion
- Session II** **Best Papers from LLRS 26th Annual Meeting (July 2017)**
Moderator: L. Reid Nichols, MD
- 9:15–9:25 a.m. Timing of Epiphysiodesis to Correct Leg Length Discrepancy: A
Comparison of Prediction Methods – *John G. Birch, MD*
- 9:25–9:35 a.m. Consequences Following Distal Femoral Growth Plate Violation with an
Intramedullary Implant: A Pilot Study in an Ovine Model
Derrick M. Knapik, MD
- 9:35–9:45 a.m. Use of Magnetic Growing Intramedullary Nails with an Intercalary Allograft
for Reconstruction after Tumor Resection – *Lee Zuckerman, MD*
- 9:45–9:55 a.m. Feasibility of Correcting the Mechanical Axis in Large Varus Deformities
with Medial Unicompartmental Knee Arthroplasty
S. Robert Rozbruch, MD
- 9:55–10:05 a.m. Discussion
- 10:05–10:15 a.m. Refreshment Break
- Session III** **Difficult Problems in Limb Reconstruction:
Case Presentations and Panel Discussions**
- 10:15–10:45 a.m. Trauma: Infected Tibial Nonunion in Poor Host
Case Presenter and Moderator: Joseph R. Hsu MD
Panel: *Kevin W. Louie, MD; Stephen Quinnan, MD; William Terrell, MD*
- 10:45–11:15 a.m. Pediatrics: Fibular Hemimelia
Case Presenter and Moderator: John G. Birch, MD
Panel: *John E. Heraenberg, MD; Craig A. Robbins, MD;
Mi-Hyun Song, MD, PhD*

- 11:15–11:45 a.m. Adult Reconstruction: Infected Failed TKR with Bone Loss
Case Presenter and Moderator: John K. Sontich, MD
Panel: *Kevin Tetsworth, MD; J. Tracy Watson, MD, Glenn D. Wera, MD*
- 11:45 a.m.–12:45 p.m. **Lunch on Own**
- Session IV** **Best Papers from ILLRS Meeting: Lisbon, Portugal August 2017**
Moderator: Austin T. Fragomen, MD
- 12:45–12:55 p.m. Does the Position of the Patella change during the Distraction Osteogenesis of the Femur? – *Dong-Hoon Lee, South Korea*
- 12:55–1:05 p.m. Treatment of Legg–Calve–Perthes. Comparative study between Arthrodiastasis and Intertrochanteric Osteotomy and Fixation with Plate and Screws – *Nuno Craveiro-Lopes, Portugal*
- 1:05–1:15 p.m. Management of Infected Fractures and Nonunions – Stability is the Key; Fixation Hardware is not the Enemy: A Paradigm Shift
Minoo Keki Patel, Australia
- 1:15–1:25 p.m. **Discussion**
- Session V** **Symposium: Managing Your Online Profile**
Moderators: Joseph R. Hsu, MD and Natasha O'Malley, MD
- 1:25–2:15 p.m.
- 2:15–2:30 p.m. Refreshment Break
- 2:30 p.m. **Reconvene in Great Hall B for Combined Session with AOFAS**
- 2:30–4:30p.m. **Combined Symposium: LLRS and AOFAS**
Debate: Controversies in Foot and Ankle Surgery
- 2:30–3:00 p.m. Failed TAR
Moderator: Joseph R. Hsu, MD
Douglas N. Beaman, MD; Clifford Jeng, MD
- 3:00–3:30 p.m. Post-Traumatic Ankle Arthritis in Young Patient
Moderator: Zhongmin Shi, MD
Austin T. Fragomen, MD; Justin D. Orr, MD
- 3:30–4:00 p.m. Midfoot
Moderator: Wang Xu, MD
Michael S. Pinzur, MD; W. Bret Smith, DO
- 4:00–4:30 p.m. Ankle Deformity with Osteoarthritis
Moderator: Woo Chun Lee, MD
S. Robert Rozbruch, MD; Fabian Krause, MD
- 4:30–4:45 p.m. Closing Remarks and Adjourn – *Austin T. Fragomen, MD*

Complications of Limb Lengthening in Achondroplasia



Mi Hyun Song, Hae-Ryong Song
Department of Orthopaedic Surgery
KOREA UNIVERSITY Medical Center
GURO HOSPITAL

The authors have nothing to disclose.

Dwarfism Clinic in KUMC Guro Hospital



Our research results

25 SCI(E) reports

Femoral lengthening in achondroplasia
MAGNITUDE OF LENGTHENING IN RELATION TO PATTERNS OF CALLOS, STIFFNESS OF ADJACENT JOINTS AND FRACTURE

GENERAL ORTHOPAEDICS
Comparison between upper and lower limb lengthening in patients with achondroplasia
A RETROSPECTIVE STUDY

CHILDREN'S ORTHOPAEDICS
Growth disturbance after lengthening of the lower limb and quantitative assessment of physal closure in skeletally immature patients with achondroplasia

Limb L
Bifocal Tibial Corrective Osteotomy With Lengthening in Achondroplasia
An Analysis of Results and Complications

Authors: Sandeep P. Tulsara, MS, DNB,* Hae-Ryong Song, MD, PhD,* Seok-Hyun Lee, MD,† Seung-Woo Suh, MD,* Suwanil M. Kery, MS,* and Soattemba S. Telang, MS, DNB*

Achondroplasia

- Most common skeletal dysplasia
- Incidence: one in every 30000 live birth annually
- **Rhizomelic short stature** (avg. height: 125-130 cm)



Achondroplasia

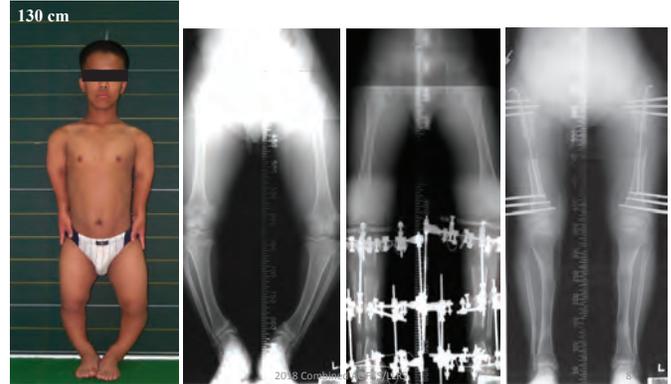
- **Genu varum**
 - ❖ Deficient endochondral ossification
 - ❖ Laxity of lateral collateral ligament
 - ❖ Differential growth rate between the tibia and fibula



Appropriate indication for lengthening

- Rhizomelic short stature and Genu varum in achondroplasia is an appropriate indication for limb lengthening, because intramembranous ossification mechanism remains intact.
 - It leads to reduction of functional impairment and improvement of the quality of life in these patients.

Case: M/20



Before lengthening



After lengthening



Complications of lengthening

- Complication rate: 14%-134%
- Untoward Events *Paley D, CORR, 1990*
 - Problems - not requiring operative intervention to resolve
 - Obstacles - requiring operative intervention but without permanent sequelae
 - Complications - intraoperative injury or anything resulting in permanent sequelae

Complications of Femoral lengthening

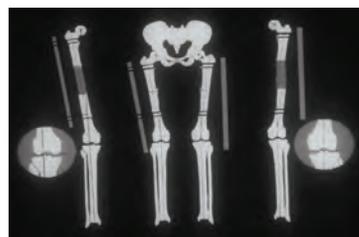
- Hip flexion contracture



Park et al, YMJ, 2015
Venkatesh, JBJS Br, 2009

Complications of Femoral lengthening

- Valgus angulation



Complications of Femoral lengthening

- Knee stiffness
- Premature consolidation
- Refracture after ex-fix removal
- Superficial pin-site infection
- Growth disturbance in a skeletal immature patient

Park et al, YMJ, 2015
Venkatesh, JBJS Br, 2009
Song et al, JBIS Br, 2012

Complications of Tibial lengthening

- Equinus deformity



Complications of Tibial lengthening

- Angular deformity
 d/t muscle imbalance or unstable frame
- Distal migration of proximal fibular segment
 d/t relative shortening of the fibula
- Premature consolidation *Park et al, YMJ, 2015*

Complications of Tibial lengthening

- Refracture after ex-fix removal
- Superficial pin-site infection
- Growth disturbance in a skeletal immature patient

Park et al, YMJ, 2015
Song et al, JBIS Br, 2012

Complications of Humeral lengthening

- Elbow jt. Flexion contracture
- Angular deformity
 d/t muscle imbalance or unstable frame
- Premature consolidation
- Refracture after ex-fix removal
- Superficial pin-site infection

Kim et al, JBIS Br, 2012

Treatment for each complication

Femoral lengthening

Complications	Treatment
Hip flexion contracture	Intramuscular recession of the rectus femoris, sartorius, and iliopsoas muscles with or without adductor longus release
Refracture after external fixator removal	External fixator reapplication with flexible intramedullary nailing with or without bone grafting (or) Plate fixation with or without bone grafting
Varus angular deformity	Repeat osteotomy for acute correction
Knee stiffness	Quadricepsplasty
Superficial pin-track infection	Oral antibiotics and local wound care

Park et al, YMJ, 2015

Treatment for each complication

Tibial lengthening

Complications	Treatment
Equinus deformity	Intramuscular gastrocnemius-soleus recession and application of the Ilizarov foot frame for gradual correction



Park et al, YMJ, 2015

Treatment for each complication

Tibial lengthening

Complications	Treatment
Genu valgum	Acute correction and insertion of additional half pins
Superficial pin-track infection	Oral antibiotics and local wound care
Distal migration of proximal fibular segment	Repeat distal fibular osteotomy and half-pin insertion
Refracture after external fixator removal	Medial closing wedge osteotomy, flexible IM rod insertion and supplemental K-wire fixation

Park et al, YMJ, 2015

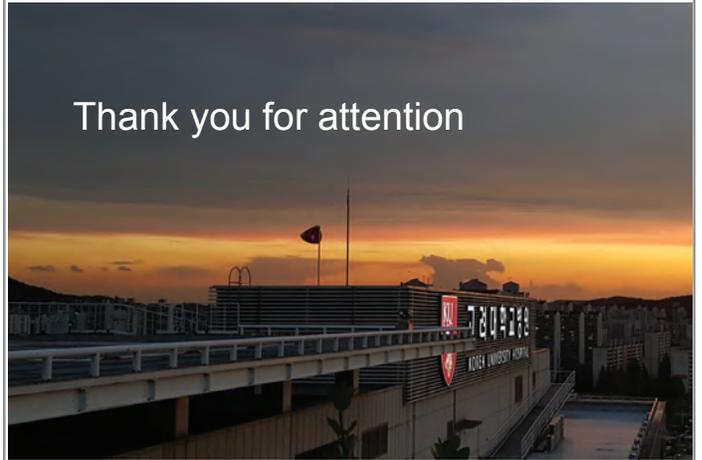
Treatment for each complication

Humeral lengthening

Complications	Treatment
Elbow jt flexion contracture	Extensive physiotherapy
Superficial pin-track infection	Oral antibiotics and local wound care
Radial nerve neurapraxia	Observation
Refracture after external fixator removal	Immobilization in a brace

Kim et al, JBJS Br, 2012

Thank you for attention



Treatment of the Bone Defects with Human Embryonic Stem Cell Derived– Mesenchymal Stem Cell

Jung–Ryul Kim, MD, PhD

Department of Orthopaedic Surgery, Chonbuk National University Medical School,
Jeonju, Republic of Korea

Mesenchymal stem cells (MSCs) are self–renewing, multipoint stromal cells that can differentiate into mesoderm–type cells for example, osteoblasts, adipocytes, and chondrocytes. MSC are being introduced into clinical trials for various musculoskeletal disorders such as large bone defects, nonunion of fractures, osteochondral defect, and rotator cuff tears. However, it is difficult to obtain sufficient numbers of MSCs needed for therapeutic applications because MSCs have the restricted ability to self–renew and develop an *in vitro* replicative senescent phenotype during *ex vivo* culture.

Human embryonic stem cells (hESCs) are a pluripotent stem cells with the capacity to proliferate unlimitedly and differentiate into any cell type. hESCs are a useful tool to study embryogenesis at the cellular level and a promising tool for cell replacement therapy by the differentiation into specialized tissues including skeletal tissues for example, bone and cartilage, thus allowing their use in skeletal tissue repair.

Recently, we have derived mesenchymal stem like cells (MSCLC) from human embryonic stem cells (hESCs) which can be differentiated into osteocytes, chondrocytes and muscle cells.

MSCLCs had some similarity to MSCs in terms of MSC–specific marker expression and morphological characteristics. MSCLCs were differentiated into osteoblasts and chondrocytes. The cells were positive for most of mesenchymal stem cell markers including CD73, CD105 and CD146, and negative for lineage markers. We observed that MSCLCs were differentiated into osteocytes with similar process to MSC differentiation in terms of the expression of osteocalcin, alkaline phosphatase and RUNX2. In addition, we confirmed the chondrogenesis by measuring expression of chondrocyte markers, AGC, SOX9, COL1A1, COL1A2, COL10. MSCLC can be derived from hESCs by inhibition of TGF– β /activating/nodal signaling and ERK signaling. We examined the *in vivo* osteogenesis of MSCLCs by injection the cells with HA–PLGA to the infected skull of Balb/c–nude mice. The application of MSCLCs with HA–PLGA scaffold completely repaired the skull bone defects. Our results provide insight into understanding the pathway for the differentiation of mesenchymal stem cells and useful therapeutic cell sources for bone regeneration.

Some Important Things I Have Experienced in Limb Lengthening and Deformity Correction

Dong Hoon Lee, MD

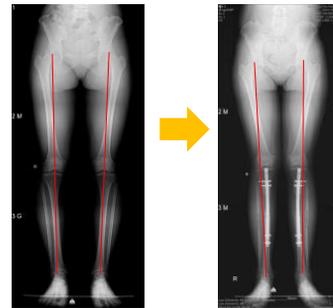
Department of Orthopedic Surgery, Severance Children's Hospital, Yonsei University, Korea



1. Distraction-resisting force is very strong
2. Lengthening and then nailing
3. Ix. Of corrective osteotomy – ‘optional’

Sometimes, distraction-resisting force is too strong than I expected .

Distraction-resisting force is very strong, it makes a considerable valgus change in LON



Clin Orthop Relat Res (2016) 474:1283–1291
 DOI 10.1007/s11999-016-4712-8

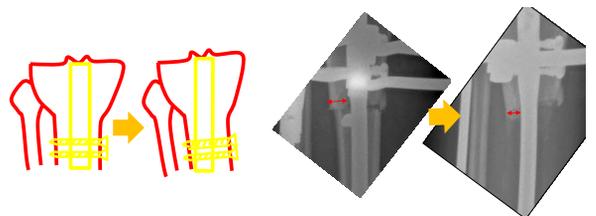
Clinical Orthopaedics and Related Research®
 (Continuation of Journal of Bone and Joint Surgery®)

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CLINICAL RESEARCH

Is there an Increase in Valgus Deviation in Tibial Distraction Using the Lengthening Over Nail Technique?

Hoon Park MD, Keun Jung Ryu MD, Hyun Woo Kim MD, PhD,
 Jin Ho Hwang MD, PhD, Joon Woo Han MD, Dong Hoon Lee MD, PhD



- Valgus change happened with lengthening, even in the proximal segment which is fixed with interlocking screws



- Valgus deviation occurred during tibial lengthening using the LON technique, and blocking screw helped minimizing the valgus change.

- Don not believe that proximal interlocking screw options against valgus changes

ETN (Synthes)



ASLS (Angular Stable Locking System)



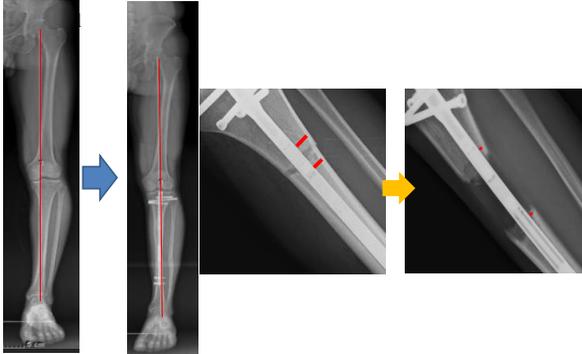
- The factors affecting the amount of valgus change
 - nail length ?

- The factors affecting the amount of valgus change
 - blocking screw

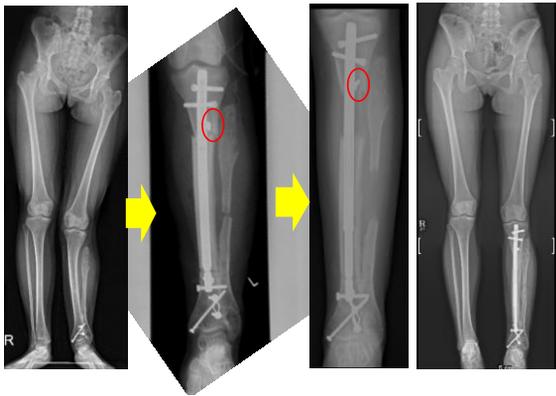
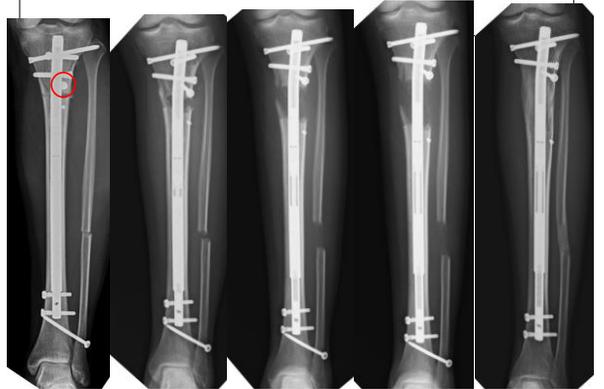
- We can use this phenomenon in proximal tibia vara

- The factors affecting the amount of valgus change
 - the shape of bone ('space')
 - discrepancy of Ø btw. the nail & marrow canal ('space')

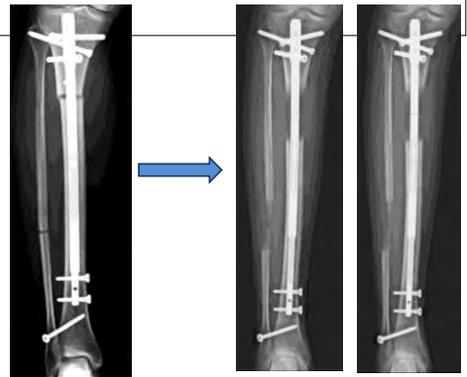
Distraction-resisting force is very strong, it makes a considerable valgus change even in LENGTHENING NAIL, or it may BEND



• Blocking screw BLOCKS valgus change

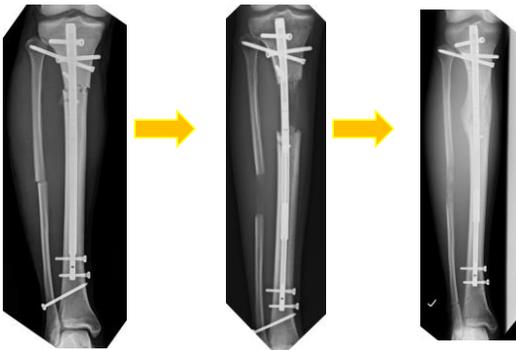


• The nail may be bent, if it is not strong enough

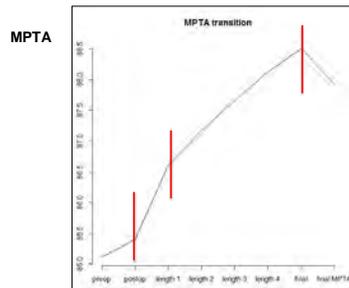


blocking screw(+), Nail bending(+)

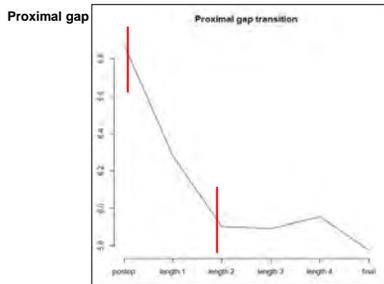
P2-8.5-245



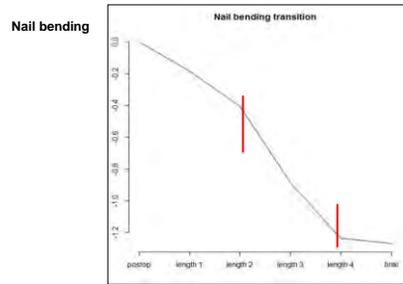
• The valgus change progress during whole lengthening phase, and maximal change happens the first 1cm distraction



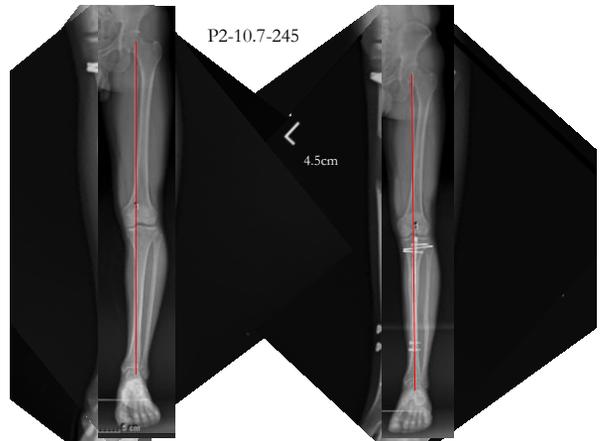
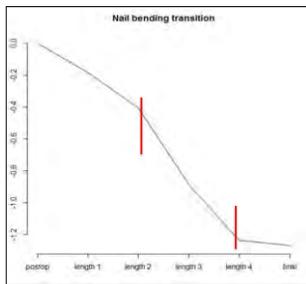
- The gap-change happens first during early 2cm lengthening



- After gap-closure, nail is bent (when it is weak)



- Most of nail-bending is recovered during consolidation phase, but sometimes it is not.

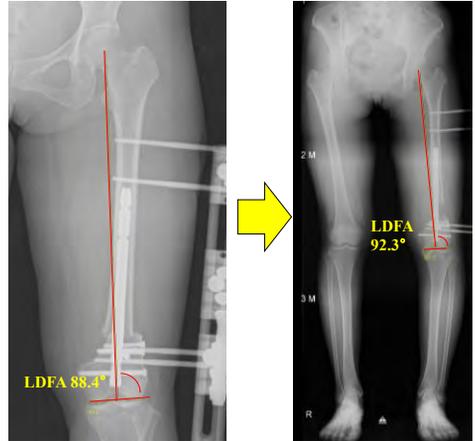
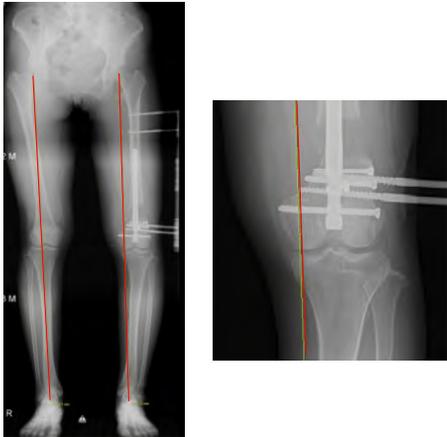
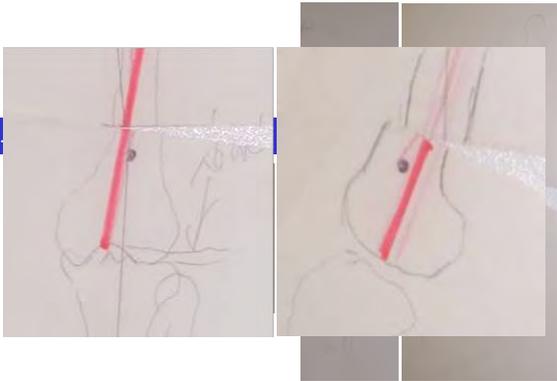


Distraction-resisting force is strong enough to break tibiofibular screws

F/41
 LLD 20 mm(Rt>Lt)
 LDFA 79° MPTA 87°
 FC 15°



1.



Limb Lengthening and Then Insertion of an Intramedullary Nail A Case-matched Comparison

S. Robert Rozbruch MD, Dawn Kleinman BA,
 Austin T. Fragomen MD, Svetlana Bizarev MD

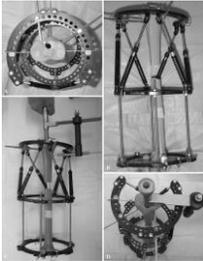


Table 3. Clinical results

Variable	LATN	Classic	p value
Followup (months)	40 (8–74)	41 (12–88)	0.9
Time in frame (weeks)	12 (3–27)	29 (14–55)	<0.001
ED to frame removal (days)	9.6 (0–35)	130 (45–278)	<0.001
EFI (months/cm)	0.5 (0.3–1.1)	1.9 (1–4)	<0.001
BHI (months/cm)	0.8 (0.4–1.3)	1.9 (1–4)	<0.001

ED = end distraction; EFI = external fixation index; BHI = bone healing index.

Strength of LATN

1. Lengthening of deformed bone; short EFI
2. Enhance bone consolidation – bone graft effect, stimulated periosteal circulation
3. Early FWB; longer, thicker nail

SR Rozbruch, CORR, 2008

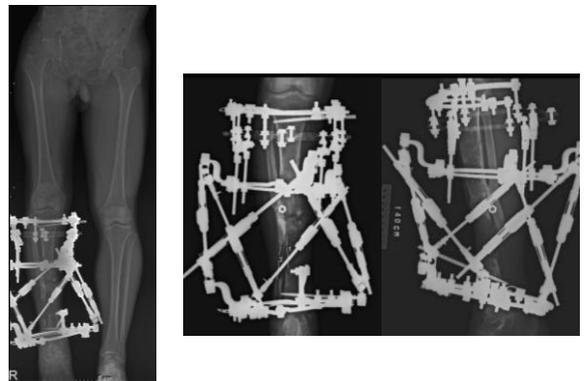


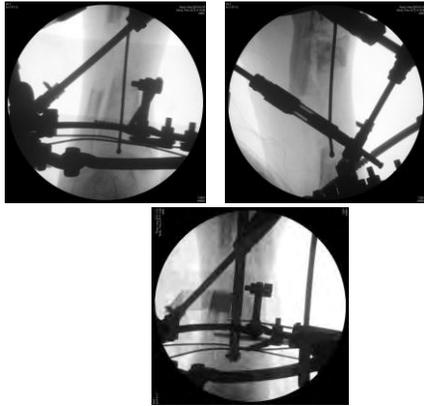
- M/50
- Trauma: 10 yrs ago
- Pain
- LLD
- Bow legs



Problems

- Tibia shortening 60mm
- Tibia vara
- Union?



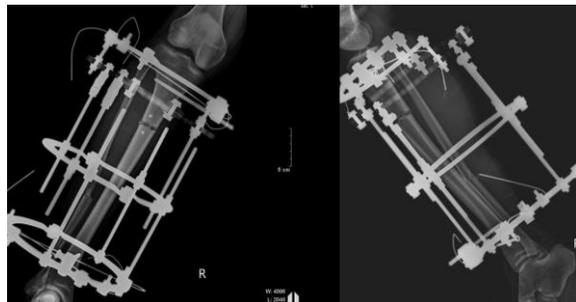


Ix of LATN

✓ lengthening of severely deformed bone

M/24

- LLD 3.5cm
- Marrow canal 7mm



EFI 28days/cm



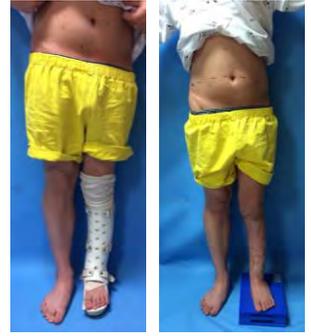
Ix of LATN

✓ narrow medullary canal

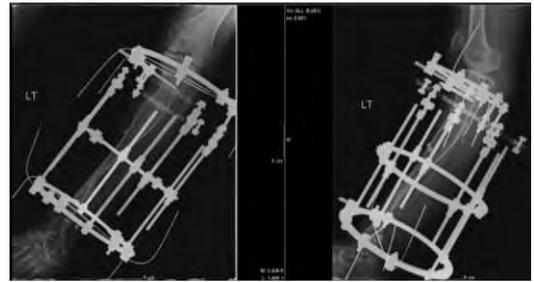


M/19

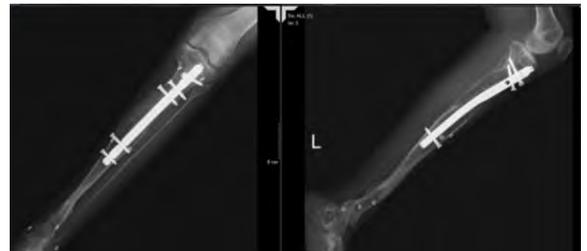
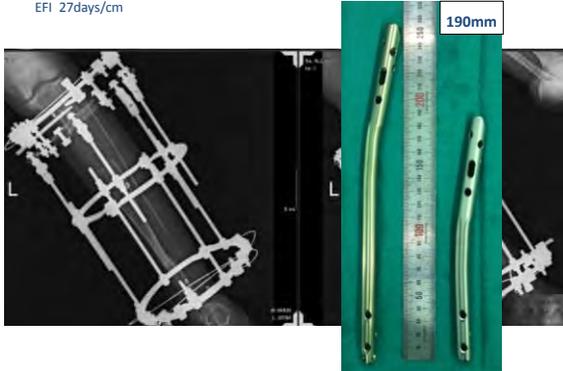
- CPT
- LLD



• Tibial shortening 75mm



EFI 27days/cm



Ix of LATN

✓ short segment

Bone regenerate in LATN

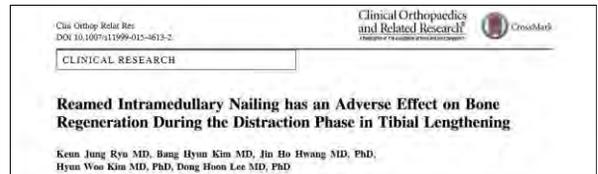
Reaming after lengthening (Dr. Rozbruch)

1. Enhancement of periosteal circulation
2. Bone graft effect

; effect of 2nd reaming

Bone regenerate in LATN

Bone formation *without reaming* during distraction phase > LON



Indication of LATN

1. Lengthening of deformed bone
2. Lengthening of bone with narrow canal
3. Lengthening of very short bone
4. Lengthening of poor bone regenerate potential

Weakness of LATN

1. Technically demanding – location of pins
2. Need for 2nd correction before nailing
3. Intramedullary nailing with long standing EF- deep infection ?



Case 1

Ix. Of correctional OT?

- M/68
- C.C: severe knee pain
- Limping gait
- Post-trauma deformity
 - Prox. tibia vara
 - Flexion contracture



- Pain
- Limping
- Slow down progression of OA
- Obtain the alignment for future-arthroplasty



Case 2

Ix. Of correctional OT?

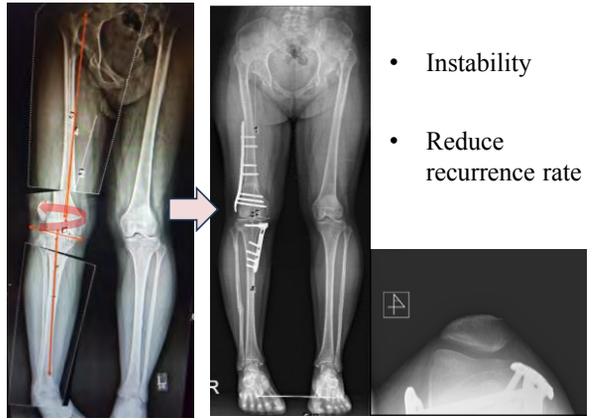
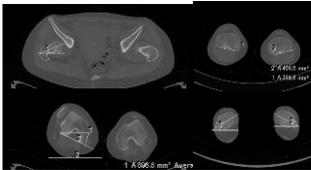
F/ 20

Recurrent dislocation, patella

Predisposing factor: DEFORMITIES

- valgus (DF valgus / PT varus)
- rotational malalignment SD

(Anteversion 47/21°, Ext tibial torsion 43/42°)



- Instability
- Reduce recurrence rate

Case 3

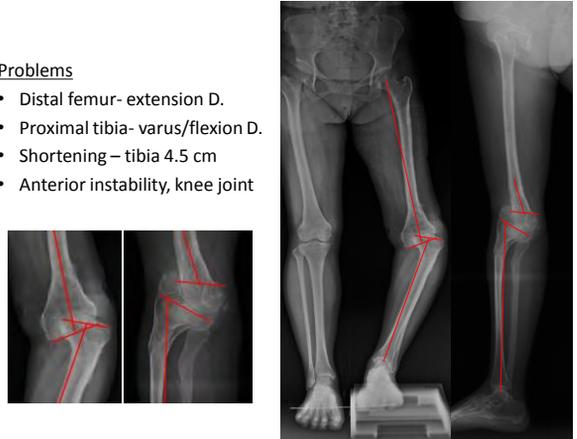
Ix. Of correctional OT?

- F/49
- C.C: severe pain
- Limping gait



Problems

- Distal femur- extension D.
- Proximal tibia- varus/flexion D.
- Shortening – tibia 4.5 cm
- Anterior instability, knee joint



- Pain
- Limping
- Slow down progression of knee instability
- Prevent knee dislocation



Case 4

Ix. Of correctional OT?

- M/33
- C.C: bow leg
- OA(+): medial compartment
- No pain



- Improve gait
- Prevent progression of OA



Case 5

Ix. Of correctional OT?

M/28

- CC; 'looks bad'
- No pain/ No osteoarthritis
- Post trauma-malunion
- Distal femoral valgus



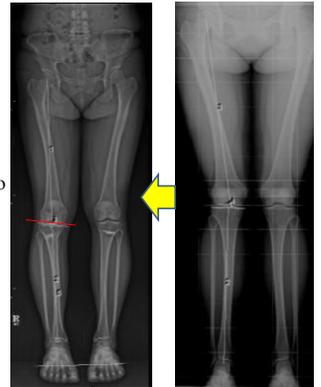
- Prevent the development of OA of the lateral compartment



Ix. Of correctional OT?

F/32

- CC; Chronic knee discomfort
- PHx; correctional OT for valgus at local clinic 2 yrs ago
- PEx; n-c
- Femorotibial angle: good
- Joint obliquity



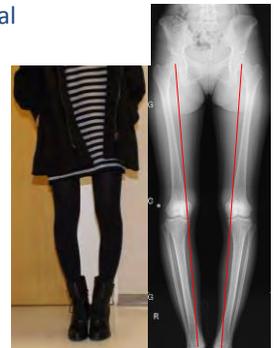
**Discomfort..
Prevent OA?**



Case 6

- Prevent the **development of** OA of the medial compartment?

- F/24
- CC. Bow legs
 - no pain/no discomfort
 - mainly cosmetic concerns
 - worried about OA in the future due to genu vara
- BMI: 22kg/m²



1. "You have higher risk of OA of the knee joint, so should get a corrective surgery ASAP"
2. "The risk for OA is slightly higher than normal alignment, so corrective surgery is recommended"
3. "We don't know if you have higher risk for OA yet, but if you want a surgery for a cosmetic reason, I do not dissuade"
4. "You don't have any risk for OA, so I will never do a surgery for you"



**Timing of Epiphysiodesis to Correct Leg Length Discrepancy:
A Comparison of Prediction Methods**

*John G. Birch, MD, FRCS(C)
Marina Makarov, MD
Taylor Jackson, BA
Connor Smith, MD
Chan-Hee Jo, Ph.D.*



Disclosures:

SCOTTISH RITE HOSPITAL
FOR CHILDREN
UT Southwestern
Medical Center

I receive royalties through TSRH for sales of a circular external fixator (TrueLok, Orthofix).

We have no other disclosures.

Detailed disclosure information is available via:

The course syllabus, or

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

Purpose of This Study:

To Compare Predicted to Actual Outcome:

- Short Leg Length
 - Long Leg Length (after Epiphysiodesis) and
 - Residual Leg Length Discrepancy
- for different prediction methods in a group of patients undergoing epiphysiodesis for leg length discrepancy at TSRH

Inclusion Criteria:

(from a database of 863 patients):

- at least three scanograms + skeletal age, at least 6 months apart (required for SLG)
- last scanogram within 3 months of surgery
 - followed to skeletal maturity
 - no complications (including prior or subsequent surgery, or overcorrection)

Study Population

77 patients met study inclusion criteria.

Male:Female: 40:37
Congenital:Acquired: 24:53
Age (range): 12+6 (11-14+6)
Surgery type:
 28 distal femur
 21 proximal tibia
 28 "pangenu"

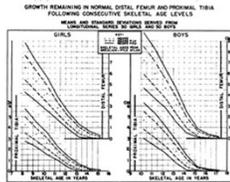
Material and Methods:

We Compared:

Green-Anderson
 White-Menelaus
 Moseley (Rotterdam) Straight-Line Graph
 Paley Multiplier Method

Analysis Methodology: Green-Anderson

- Predicted femoral and tibial growth, using the parameters of 71% (DF) and 57% (PT) contributions to total segment length, and 50th %ile values from the growth remaining charts (in 6-month intervals).



White-Menelaus Method

GROWTH ARREST FOR EQUALIZING LEG LENGTHS
 J. WARREN WHITE, M.D.
 AND
 SAM G. STUBBINS JR., M.D.
 GREENVILLE, S. C.

J. A. M. A. VOLUME 126
 Dec. 30, 1944 NUMBER 18

“Regardless of the age and size of the child, we have figured that a growth arrest procedure at the distal femoral epiphysis would retard growth at the rate of 3/8 inch a year, while at the proximal end of the tibia and fibula, it is retarded 1/4 inch.”

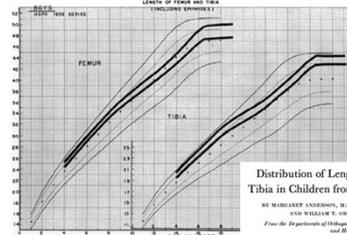
Analysis Methodology: White-Menelaus

- 3/8” / 1/4” (DF / PT) converted to metric (0.952 / 0.635 cm).
- assumed maturity as 16 (boys) and 14 (girls).
- used Green/Anderson calculations of 71% (DF) and 57% (PT) contributions to calculate segment and entire leg growth/year (2.45 cm/yr for entire leg).

A Straight-Line Graph for Leg-Length Discrepancies

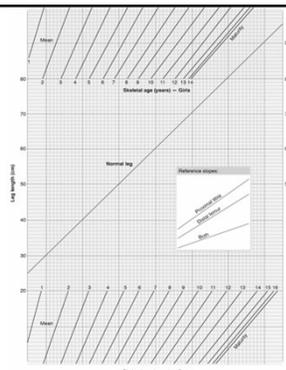
BY C. F. MOSELEY, M.D., C.M., F.R.C.S.(C)*, HAMILTON, ONTARIO, CANADA
 From the Shriners Hospitals for Crippled Children, Montreal

JBJS 59(A) 1977



Moseley SLG

- Incorporates growth inhibition, %ile height.
- Requires three scanograms/bone age, at least 6 months apart.

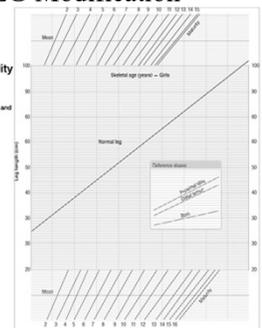


Rotterdam SLG Modification

(AOS, 1997)
 The straight line graph in limb length inequality
 A new design based on 162 Dutch children

Arnoothen Beumer*, Harold H. Lemp*, Bert A. Swainstra*, Ad F. M. Depoortere* and Paul D. H. Mulder*

- Taller, more modern population
- Equal to or better than Moseley >80% of time



Multiplier Method for Predicting Limb-Length Discrepancy*

BY DROR PALEY, MD, FRCSC(Orth), ANIL BHAVE, FRCR, JOHN E. HURZENBERG, MD, FRCSC(Orth), AND J. RICHARD BOWEN, MD

Investigation performed at the Maryland Center for Limb Lengthening and Reconstruction, Baltimore, Maryland

JBJS 82(A) 2000

Used the Green-Anderson 1964 data to create “multipliers” (femur, tibia, total leg +/- 2 SD’s)

Age (years)	Boys	Girls
1	3.24	2.97
2	2.59	2.39
3	2.23	2.05
4	2.00	1.83
5	1.82	1.66
6	1.67	1.51
7	1.57	1.43
8	1.47	1.33
9	1.38	1.26
10	1.31	1.19
11	1.24	1.13
12	1.18	1.07
13	1.13	1.03
14	1.08	1.0
15	1.04	1.0
16	1.01	1.0
17	1.0	1.0

Analysis Methodology: Multiplier Method

- We used published multiplier tables and formulae to calculate the long leg length, short leg length, and leg length inequality at maturity.
- We used the 50%ile multiplier to calculate epiphysiodesis effect on long leg.
- For congenital etiology, we used the immediate preoperative bone lengths; for developmental etiology, we used the initial and immediate preoperative bone lengths.

RADIOGRAPHIC ATLAS OF SKELETAL DEVELOPMENT OF THE HAND AND WRIST

WILLIAM WALTER GREULICH
Professor of Anatomy, Stanford University School of Medicine

S. KELLY PYLE
Assistant Director, Department of Orthopedic Surgery, Stanford University School of Medicine

STANFORD UNIVERSITY PRESS, STANFORD, CALIFORNIA

WE used both chronological and skeletal ages (Greulich and Pyle Atlas) for each method.

Results:

61/231 (26%) individual Skeletal Age readings varied > 1 year from Chronological Age

19/77 (25%) patients’ Skeletal Age averaged >1 year different from Chronological Age (3 readings)

Results:

Leg length prediction errors (predicted vs. actual, in cm.) using Skeletal Age (SA; Rotterdam and Green-Anderson) or Chronological Age (CA; White-Menelaus and Multiplier)

	Rotterdam SLG SA	Green-Anderson SA	White-Menelaus CA	Paley Multiplier CA	P-value p<0.05
Short leg (cm)	1.8 ± 1.2	2.1 ± 1.8	2.7 ± 1.8	3.2 ± 2.5	0.002
Long leg (cm)	1.2 ± 1.1	1.3 ± 1.3	1.7 ± 1.4	2.0 ± 1.8	0.014
LLD (cm)	1.0 ± 0.7	1.0 ± 0.8	1.2 ± 0.9	1.4 ± 1.3	0.318

(P value based on Friedman’s test)

Comparison of Prediction Errors, Using Skeletal Age (SA) instead of Chronological Age (CA)

Method	Variable	CA	SA	P-value p<0.05
White-Menelaus	Short leg (cm)	2.73 ± 1.79	2.06 ± 1.42	0.009
	Long leg (cm)	1.67 ± 1.37	1.33 ± 1.24	0.044
	LLD (cm)	1.21 ± 0.9	0.89 ± 0.63	0.002
Paley Multiplier	Short leg (cm)	3.24 ± 2.49	2.48 ± 2.04	0.013
	Long Leg (cm)	2.02 ± 1.8	1.73 ± 1.48	0.147
	LLD (cm)	1.39 ± 1.25	1.14 ± 0.9	0.156

(P value based on Wilcoxon signed-ranks test)

Results (Using SA for All Methods):

Leg Length Prediction Errors Using Skeletal Age For Each Method					
	Rotterdam SLG	Green-Anderson	White-Menelaus	Paley Multiplier	P-value p≤0.05
	SA	SA	SA	SA	
Short leg (cm)	1.8 ± 1.2	2.1 ± 1.8	2.1 ± 1.4	2.5 ± 2.0	0.008
Long leg (cm)	1.2 ± 1.1	1.3 ± 1.3	1.3 ± 1.2	1.7 ± 1.5	0.002
LLD (cm)	1.0 ± 0.7	1.0 ± 0.8	0.9 ± 0.6	1.1 ± 0.9	0.764

(P value based on Friedman's test)

Results (Using SA for All Methods):

Leg Length Prediction Errors Using Skeletal Age For Each Method PLUS Growth Inhibition Factor					
	Rotterdam SLG	Green-Anderson	White-Menelaus	Paley Multiplier	P-value p≤0.05
	SA	SA	SA	SA	
Short leg (cm)	1.8 ± 1.2	2.1 ± 1.7	1.8 ± 1.4	2.5 ± 2.0	0.012
Long leg (cm)	1.2 ± 1.1	1.3 ± 1.3	1.3 ± 1.2	1.7 ± 1.5	0.002
LLD (cm)	1.0 ± 0.7	0.9 ± 0.8	0.7 ± 0.5	1.1 ± 0.9	0.000

(P value based on Friedman's test)

Summary:

- White-Menelaus method was statistically the best in predicting leg length discrepancy at maturity (but all clinically comparable).
- 25% of our patients had chronological age vary from skeletal age by more than 1 year.
- Use of skeletal age significantly improved accuracy of all methods.

Summary:

- White-Menelaus (using Skeletal Age) and Rotterdam SLG were the most accurate predictors of short and long leg lengths at maturity in this study population.
- Multiplier method had greatest standard deviations in predictions.

Recommendations:

Use Skeletal Age (Greulich and Pyle, or better yet, modified Sauvegrain methods).

Be cautious in using multiplier method to determine timing of epiphysiodesis.

Be aware of variable growth inhibition rates, irrespective of prediction method.

Thank You!

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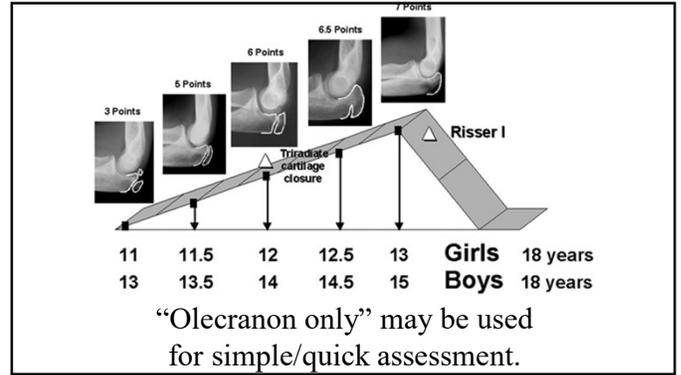
J Child Orthop (2008) 2:407–415
 DOI 10.1007/s11832-008-0119-8

CURRENT CONCEPT REVIEW

Lower-limb growth: how predictable are predictions?

Paula M. Kelly · Alain Diméglio

- Multiplier Method to estimate LLD at maturity.
- Sauvegrain “olecranon only” to estimate SA.
- Use Diméglio’s variation of White-Menelaus: From the onset of puberty (SA 11 in girls, SA 13 in boys), there are 5 cm. growth remaining: 3 in the DF, and 2 in the PT.



Derrick Knapik, MD

Title: Consequences Following Distal Femoral Growth Plate Violation with An Intramedullary Implant: A Pilot Study in a Ovine Model

Purpose

Retrograde femoral nailing is a useful technique in skeletally mature patients with applications towards acute osteotomy, lengthening over a nail, and internal lengthening nailing. These options are traditionally limited in skeletally immature patients due to concerns of violating the distal femoral physis. The resilience of the distal femoral physis to a smooth metallic implant is poorly understood. This ovine study was designed to better understand the tolerance of the immature distal femoral physis to retrograde nailing.

Method

A total of 18 sheep underwent placement of a retrograde, intramedullary implant at 3-months of age through an open distal femoral growth plate. The cross-sectional area of the distal femoral physis was measured pre-operatively and implants were selected that violated 3% to 8% of the cross sectional area of the growth plate at 1% intervals (n=3 sheep at each interval). Growth across the distal femoral growth plate was examined radiographically at 4 weeks, 8 weeks and following euthanasia 10-weeks following surgery. Following euthanasia, both the operative and non-operative contralateral femurs were removed and dissected to compare differences in femoral maximal lengths using digital calipers.

Results

Radiographic measurements of growth across the distal femoral physis demonstrated that growth continued in all specimens at 4 weeks, 8 weeks and 10 weeks post-operatively. When compared to control specimens grossly, only operative specimens with 8% of cross-sectional physeal violation demonstrated significant growth arrest when compared to control limbs.

Conclusion

Distal femoral growth continues across the physis when 3% to 7% of the cross-sectional area of the physis is violated using a retrograde intramedullary implant. Specimens with 8% of growth violation demonstrated significant growth arrest. These findings suggest that retrograde femoral nailing may be a viable option in the treatment of pediatric distal femur shaft fractures in resource poor countries where other options are limited.

Use of Magnetic Growing Intramedullary Nails with Intercalary Allograft Reconstruction After Tumor Resection

Lee Zuckerman, M.D.

Purpose:

Reconstruction after excision of tumors has remained challenging. Intercalary allograft reconstruction has remained an option, but is not without complication. Osteosynthesis techniques have included plate fixation, nail fixation, or combined techniques. Non-union occurs more frequently in those fixed with intramedullary nails alone. A novel technique of using magnetic growing intramedullary nails to compress across the entire allograft is presented. This technique also provides the opportunity to lengthen the bone at a later date using the same implant. The purpose of this study is to evaluate union rates and complications using this technique.

Methods:

A retrospective review of 8 patients with 15 osteotomy sites on 5 femurs and 3 humeri was performed. The average age was 35 (9–71) with an average follow-up of 18 months (8–34). Diagnoses included two pleomorphic sarcomas, three osteosarcomas, one metastatic endometrial stromal sarcoma, and two metastatic renal cell carcinomas. Fourteen osteotomy sites were primary resections and one site was a chronic non-union previously treated with a carbon fiber nail. Five patients received neoadjuvant and adjuvant chemotherapy, and three patients received only adjuvant chemotherapy. One patient received neoadjuvant radiation. An intercalary allograft with a magnetic growing intramedullary nail was placed. No autograft was used. The average allograft length was 17 cm (6.5–29). The nails were compressed intraoperatively. Radiographs were evaluated monthly to determine union rates and time to union.

Results:

Thirteen out of 15 sites demonstrated evidence of healing with the only non-union sites occurring in the patient who had neoadjuvant radiation. Complications included one fracture through the allograft after a fall and one screw that backed out and required removal. Three patients underwent a second compression in order to obtain a union. Two patients underwent a successful lengthening after union had occurred.

Conclusions:

In this series, there were two non-union sites in one patient. Two patients were able to be successfully lengthened in order to correct a limb-length discrepancy. Musculoskeletal tumors requiring large bony resection typically has a high rate of non-union when intramedullary nails are used with intercalary allograft. Our technique using magnetic growing intramedullary nails to compress the osteotomy sites has had positive preliminary results with an acceptable complication rate.

Abstract AAOS 2018

Feasibility of Correcting Mechanical Axis in Large Varus Deformities with Unicompartmental Knee Arthroplasty

Introduction: Due to disappointing historical outcomes of unicompartmental knee arthroplasty (UKA), Kozinn and Scott proposed strict selection criteria, including preoperative varus alignment of $\leq 15^\circ$, to improve the outcomes of UKA. The rationale is that it is less feasible to restore mechanical axis angle (MAA) to neutral or close to neutral in patients who not fulfill these criteria. A consequence of excessive residual varus alignment is increased compartment forces by overloading medially, which can ultimately lead to UKA failure from polyethylene wear or aseptic loosening. No studies to date, however, have assessed the feasibility of correcting large preoperative varus deformities with UKA surgery. Therefore, it would be important to develop radiographic predictors of deformity correction with UKA, especially since several studies showed better outcomes in patients with postoperative MAA $\leq 7^\circ$ of varus.^{4,10,11} The study goals were therefore to (1) assess to what extent patients with large varus deformities ($\geq 7^\circ$) could be corrected, and (2) determine radiographic parameters to predict adequate correction.

Methods: A total of 499 medial UKA patients were identified from a prospective surgical database between November 2008 and November 2013, of which 245 were excluded for preoperative MAA $< 7^\circ$, 44 for lack of preoperative and/or postoperative HKA radiographs, 9 for ipsilateral THA or TAA, and 1 for a history of lower extremity fractures. All patients underwent a robotic-assisted medial UKA, during which the medial collateral ligament was carefully preserved. Of all patients with a large preoperative varus deformity ($\geq 7^\circ$), the mechanical axis angle (MAA), mechanical-lateral-distal-femoral-angle (mLDFA), medial-proximal-tibial-angle (MPTA), and joint-line-convergence-angle (JLCA) were determined on hip-knee-ankle radiographs (Figure 1). It was assessed what number of patients were corrected to optimal ($\leq 4^\circ$) and acceptable (5° – 7°) alignment, and if the feasibility of this correction could be predicted using an estimated MAA (eMAA, preoperative MAA–JLCA) using regression analyses.

Results: A total of 200 consecutive medial UKA patients were included, with a mean age of 64.7 years (SD 10.1, range 43.3 – 86.6), mean BMI of 30.4 kg/m² (SD 5.9, range 18.6 – 52.9), and of which 124 patients (62%) were male. Mean preoperative MAA was 10° of varus (range 7°–18°), mean JLCA was 5° (1°–12°), mean postoperative MAA was 4° of varus (–3°– 8°), and mean correction was 6° (1°–14°). Postoperative optimal alignment was achieved in 62% and acceptable alignment in 36% of the patients; however, differences were noticed between alignment groups (Figure 2). The eMAA was a significant predictor for optimal postoperative alignment, when corrected for age and gender ($p < 0.001$). The odds of achieving an optimal postoperative MAA, when the eMAA is $\leq 4^\circ$, was 3.62 higher in comparison to an eMAA $> 4^\circ$ of

varus ($p < 0.001$) when correcting for age and gender. In patients with $eMAA > 4^\circ$, extra-articular tibial deformities were more frequent (70%) compared to patients with an $eMAA \leq 4^\circ$ (31%, $p < 0.001$).

Conclusion: Patients with large preoperative varus deformities ($\geq 7^\circ$) could be considered candidates for medial UKA, as 98% can be corrected to optimal or acceptable alignment. Furthermore, it was noted that the feasibility of achieving optimal alignment could be predicted using the eMAA, based on preoperative MAA and JLCA. When the eMAA exceed 4° of varus, extra-articular deformities could be assessed preoperatively.

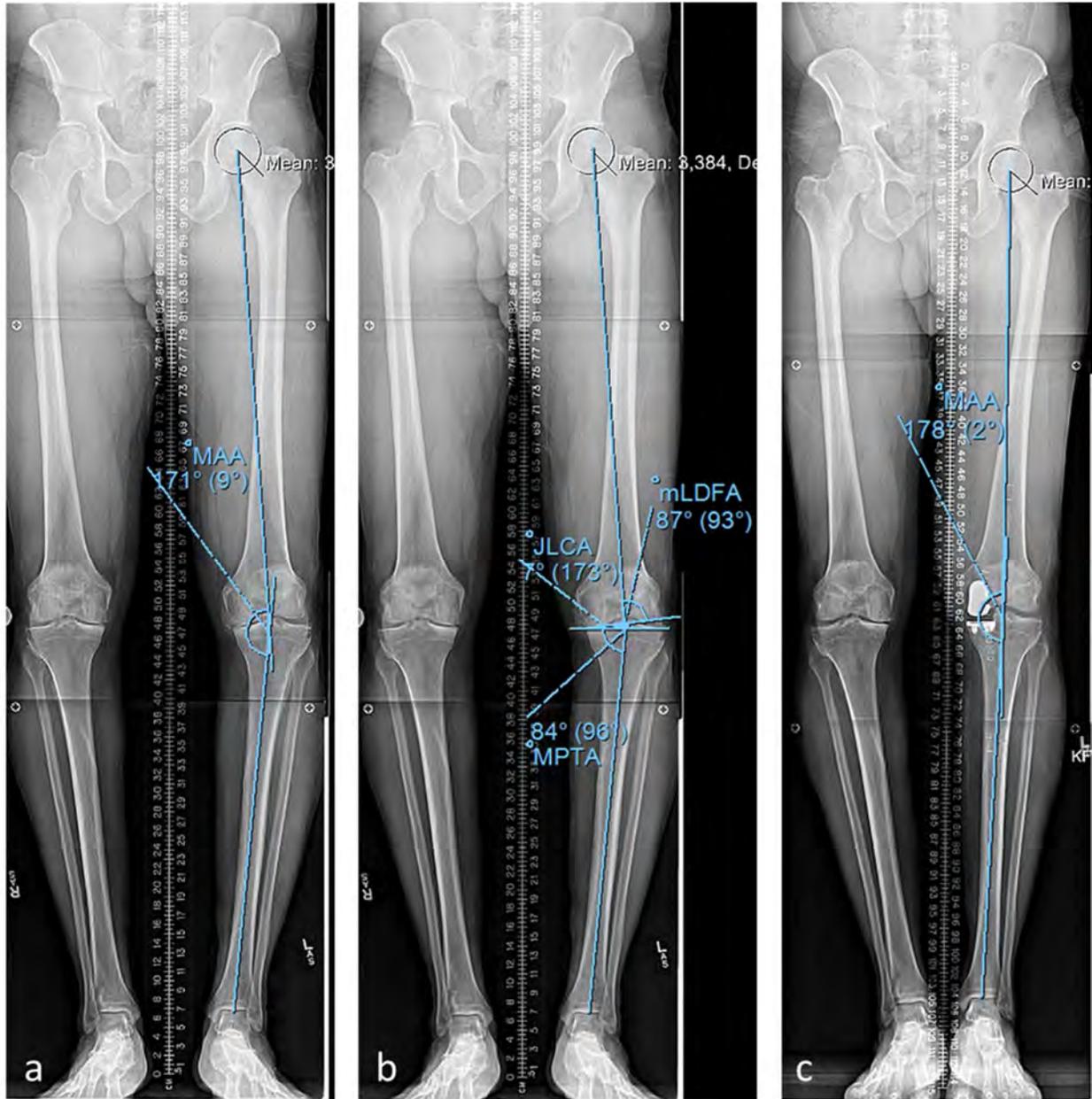


Figure 1

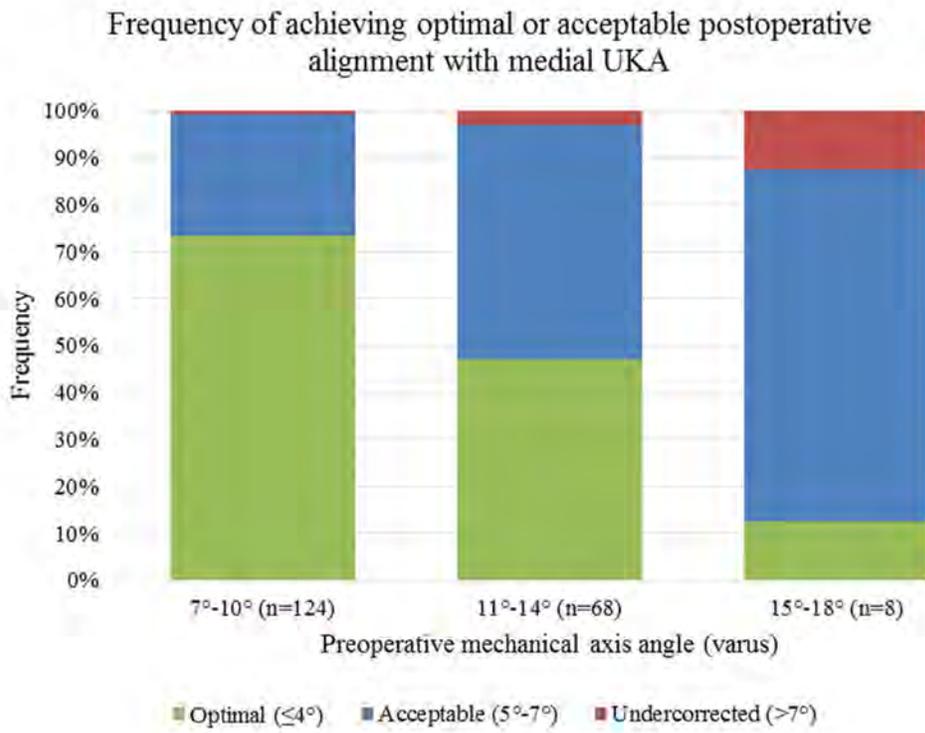


Figure 2

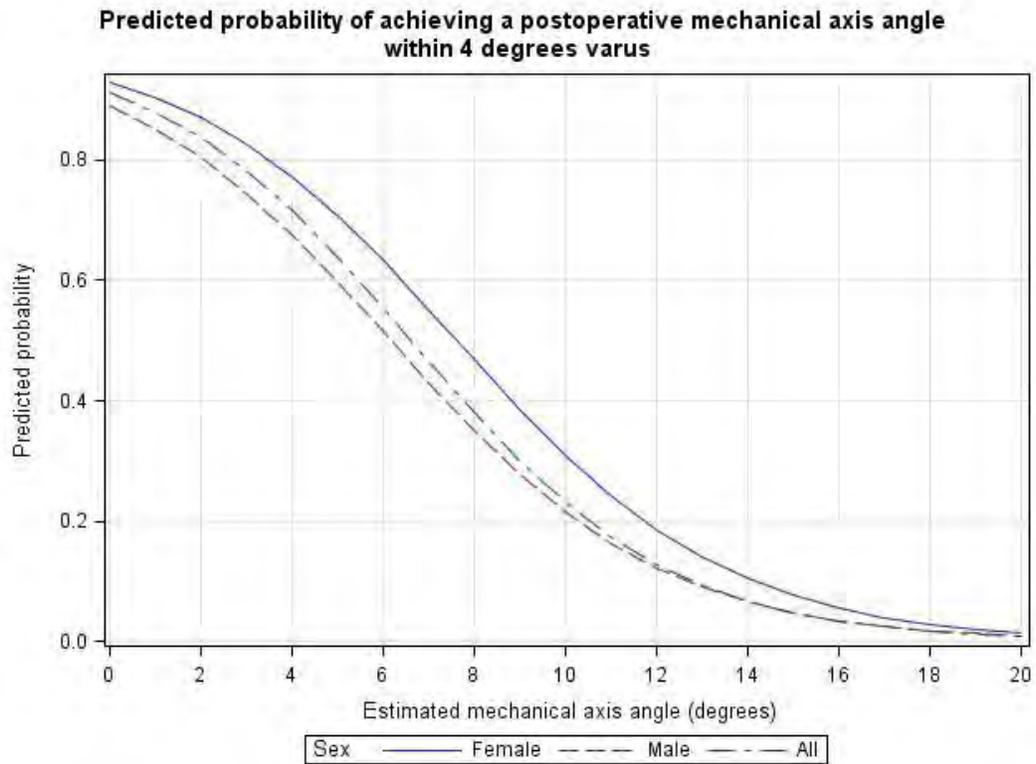


Figure 3



Primary Arthroplasty

Predicting the Feasibility of Correcting Mechanical Axis in Large Varus Deformities With Unicompartmental Knee Arthroplasty



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ABSTRACT

Background: Due to disappointing historical outcomes of unicompartmental knee arthroplasty (UKA), Kozinn and Scott proposed strict selection criteria, including preoperative varus alignment of $\leq 15^\circ$, to improve the outcomes of UKA. No studies to date, however, have assessed the feasibility of correcting large preoperative varus deformities with UKA surgery. The study goals were therefore to (1) assess to what extent patients with large varus deformities could be corrected and (2) determine radiographic parameters to predict sufficient correction.

Methods: In 200 consecutive robotic-arm assisted medial UKA patients with large preoperative varus deformities ($\geq 7^\circ$), the mechanical axis angle (MAA) and joint line convergence angle (JLCA) were measured on hip-knee-ankle radiographs. It was assessed what number of patients were corrected to optimal ($\leq 4^\circ$) and acceptable (5° – 7°) alignment, and whether the feasibility of this correction could be predicted using an estimated MAA (eMAA, preoperative MAA–JLCA) using regression analyses.

Results: Mean preoperative MAA was 10° of varus (range, 7° – 18°), JLCA was 5° (1° – 12°), postoperative MAA was 4° of varus (-3° to 8°), and correction was 6° (1° – 14°). Postoperative optimal alignment was achieved in 62% and acceptable alignment in 36%. The eMAA was a significant predictor for optimal postoperative alignment, when corrected for age and gender ($P < .001$).

Conclusion: Patients with large preoperative varus deformities (7° – 18°) could be considered candidates for medial UKA, as 98% was corrected to optimal or acceptable alignment, although cautious approach is needed in deformities $> 15^\circ$. Furthermore, it was noted that the feasibility of achieving optimal alignment could be predicted using the preoperative MAA, JLCA, and age.

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Unicompartmental knee arthroplasty (UKA) has proven to be an effective treatment for isolated medial compartment knee osteoarthritis in appropriate selected patients [1]. Historically, however, outcomes of UKA were disappointing and, as a result, Kozinn and Scott [2] proposed strict selection criteria in their landmark paper in 1989. One of the criteria was that

medial UKA should only be performed in patients with a preoperative varus deformity of 15° or less that is correctable to neutral [2]. This is based on the rationale that it is less feasible to restore the mechanical axis angle (MAA) to neutral or close to neutral in patients who have not fulfilled these criteria. A consequence of excessive residual varus alignment is increased compartment forces by overloading medially, which can ultimately lead to UKA failure from polyethylene wear or aseptic loosening [3–9].

It would be important to develop radiographic predictors of deformity correction after UKA, especially because several studies have shown that better outcomes were found in patients with a postoperative MAA of $\leq 7^\circ$ of varus [4,10,11]. More specifically, recent studies showed that postoperative varus alignment between 1° and 4° was associated with the most

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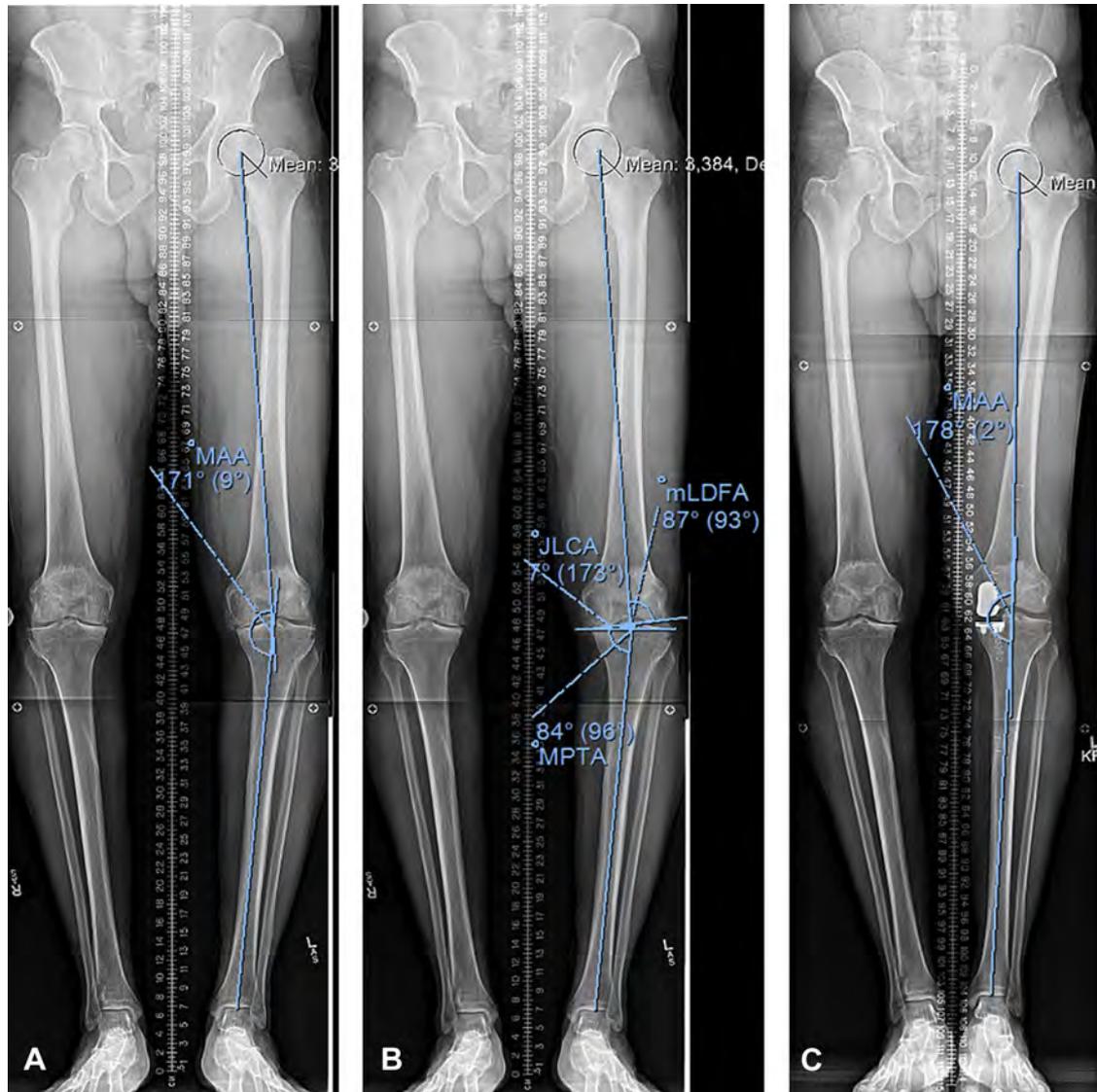


Fig. 1. Example of the radiographic assessment of the (a) preoperative mechanical axis angle (MAA), (b) mechanical lateral distal femoral angle (mLDFA), medial proximal tibial angle (MPTA), joint line convergence angle (JLCA), and (c) the postoperative MAA. These hip-knee-ankle radiographs show a preoperative MAA of 9° of varus, mLDFA of 87°, MPTA of 84°, JLCA of 7°, displaying an eMAA of 2°, which matches the postoperative MAA of 2° of varus.

optimal functional outcomes after medial UKA [6,12]. The correctability of the preoperative MAA depends on multiple factors, including the existence of femoral deformity, tibial plateau depression, and joint line convergence due to lateral collateral ligament laxity and medial compartment cartilage loss [13]. In current literature, however, there is a discrepancy to which extent large varus deformities are correctable with medial UKA surgery. Some authors suggested that most patients with a preoperative MAA of $\geq 10^\circ$ of varus could not be corrected to neutral, indicating that patients with large preoperative varus deformities might be at risk of undercorrection [14,15]. Therefore, it could be argued that medial UKA might not be the ideal treatment option for patients with large varus deformities. On the other hand, in patients with isolated medial compartment knee osteoarthritis, the varus alignment originates mostly from a progressing intra-articular deformity [16–18]. There are, however, patients with preexistent varus alignment, even before the added degenerative intra-articular deformity. A concern may be that after correction of the

articular deformity with UKA, varus alignment would still remain [19]. Chatellard et al showed that correcting the joint line obliquity through medial UKA improves the postoperative MAA and outcomes. Moreover, others emphasized that medial UKA restores the contralateral joint space width and improves joint congruence in patients with a mean preoperative varus deformity of 9° [18,20]. This implies that varus deformities can be corrected by restoring joint line obliquity during medial UKA [18,20].

Therefore, a study was performed assessing the predictive role of several radiographic deformity measurements on the postoperative mechanical axis following medial UKA in patients with large preoperative varus deformities ($\geq 7^\circ$). The purpose of this study was 2-fold; first, determine to what extent patients with large varus deformities undergoing robotic-assisted medial UKA were correctable. Second, evaluate the predictive value of an estimated MAA (eMAA) based on the preoperative radiographic deformity measurements, in particular the preoperative MAA and joint line obliquity.

Materials and Methods

Study Design and Patient Selection

After institutional review board approval, an electronic registry search was performed using a prospective database which contains over 800 medial onlay UKAs, all performed by the senior author (ADP). Surgical inclusion criteria consisted of isolated medial osteoarthritis as primary indication, intact cruciate ligaments, passively correctable varus deformity, and less than 10° fixed flexion deformity. Surgical exclusion criterion was inflammatory arthritis. Study inclusion criteria were patients with a preoperative MAA of $\geq 7^\circ$ of varus who had preoperative and postoperative hip-knee-ankle (HKA) radiographs. Exclusion criteria consisted of ipsilateral total hip arthroplasty (THA) or total ankle arthroplasty (TAA), or a history of lower extremity fracture. The goal was to include 200 consecutive patients who matched these criteria, as this was considered a representative group. A total of 499 patients were screened between November 2008 and November 2013, of which 245 were excluded for preoperative MAA $< 7^\circ$, 44 for lack of preoperative and/or postoperative HKA radiographs, 9 for ipsilateral THA or TAA, and 1 for a history of lower extremity fractures.

The postoperative alignment was categorized as optimal ($\leq 4^\circ$ of varus), acceptable (5° – 7° of varus), and undercorrected ($> 7^\circ$ of varus), which is commonly used in recent literature [4,6,10–12].

Implant and Surgical Technique

All surgeries were performed by one surgeon (ADP) and carried out using a robotic-arm assisted surgical platform (MAKO System, Stryker, Mahwah, NJ), as described previously [21,22]. All patients received a cemented fixed-bearing RESTORIS MCK Medial Onlay implant (Stryker, Mahwah, NJ). The surgical goal was to establish a relative undercorrection within the range of 1° – 7° of varus, in order to avoid degenerative progression on the lateral compartment [11,18]. The surgeon considered a final lower limb alignment of 1° – 4° to be optimal, but accepted a navigated final alignment between 5° and 7° if further correction was not possible without release of the medial collateral ligament (MCL). The MCL was carefully protected and there were no cases where an MCL release or a piecrusting of the MCL was performed.

Radiological Assessment

Radiographic evaluation was performed in a Picture Archiving and Communication System (PACS, Sectra Imtec AB, version 16, Linköping, Sweden). HKA standing radiographs were obtained as standard workup preoperatively and 6 weeks postoperatively. Patients were instructed to stand straight with both knees fully extended and evenly distribute their body weight between both limbs. The patellas were aligned with the direction of the X-ray beam. The X-ray beam was centered at the distal pole of the patella, aligning the image parallel to the tibial joint line in the frontal plane. In each HKA radiograph, the source-to-image distance was standardized to 122 cm by a standard 256 0.25-mm AISI 316 stainless steel calibration sphere (Calibration Unit; Sectra) to account for any magnification effects [23].

The radiographic assessment was performed by one assessor (LJK) according to the validated methods used by Paley et al [13,16,24,25]. Using Ortho Toolbox (PACS feature), the MAA, mechanical lateral distal femoral angle (mLDFA), medial proximal tibial angle (MPTA), and joint line convergence angle (JLCA) were determined for each patient [16,17,26]. The MAA is defined as the

Table 1
Demographic Characteristics.

	Mean \pm SD (Range)
Age (y)	64.7 \pm 10.1 (43.4–86.6)
BMI	30.4 \pm 5.9 (18.6–52.9)
Gender ratio	124 men:76 women

SD, standard deviation; BMI, body mass index.

angle between the femoral mechanical axis (center of hip to intercondylar notch of knee) and the tibial mechanical axis (center of tibial spines to center of the distal tibia). The mLDFA is the lateral angle formed between the femoral mechanical axis and the knee joint line of the femur in the frontal plane. Defining the MPTA, the proximal medial angle formed between the tibial mechanical axis and the knee joint line of the tibia in the frontal plane. The angle formed between femoral and tibial joint orientation lines is called the JLCA [13,26]. In case of medial osteoarthritis, there is medial JLCA convergence often due to medial cartilage loss [13,17]. Postoperatively, only the MAA was determined, because the joint orientation lines were indistinctive by use of the polyethylene insert. Marx et al [24] showed good to excellent intraobserver and interobserver reliability of lower extremity alignment measurements using a corresponding method (0.97 and 0.96, respectively). The correction was defined as the change in MAA, comparing the preoperative MAA relative to the postoperative MAA. All measured angles are displayed in Figure 1.

Statistical Analysis

All analyses were conducted using SPSS version 24 (SPSS Inc, Armonk, NY) and SAS version 9.3 (SAS Inc, Cary, NC). Descriptive analyses were reported using means and standard deviations (SD) for continuous variables and frequencies with percentages for discrete variables. With regard to the first research question, it was assessed to what extent patients were corrected to an optimal MAA ($\leq 4^\circ$ of varus) and acceptable MAA (5° – 7° of varus), which was based on the aforementioned recent literature [4,6,10,12]. Furthermore, a subgroup analysis was performed based on the preoperative MAA to describe the distribution of postoperative alignment and JLCA. For the second research question regarding the feasibility of achieving this optimal postoperative alignment, an eMAA was calculated by subtracting the JLCA from the preoperative MAA (preoperative MAA–JLCA). The predictive value of the eMAA was tested by means of a correlation analysis and chi-square test. The role of extra-articular deformities in achieving optimal postoperative alignment was assessed using MPTA and mLDFA. Finally, a multivariable logistic regression model was fitted to examine the feasibility of achieving an optimal MAA ($\leq 4^\circ$ of varus), based on the eMAA and corrected for patient-related factors (age, gender, body mass index). A *P* value $< .05$ was considered statistically significant.

Table 2
Preoperative and Postoperative Angle Measurements According to the Method of Paley et al.

	Mean \pm SD	Minimum	Maximum
Preoperative			
Mechanical axis angle (varus)	10° \pm 2.3°	7°	18°
Mechanical lateral distal femur angle	89° \pm 1.9°	85°	95°
Medial proximal tibial angle	84° \pm 6.1°	78°	91°
Joint line convergence angle	5° \pm 1.8°	1°	12°
Postoperative			
Mechanical axis angle (varus)	4° \pm 2.1°	–3°	8°
Correction	6° \pm 2.5°	1°	14°

SD, standard deviation.

Table 3

Descriptive Characteristics of the Distribution of Postoperative MAA in the Specific Groups Based on the Preoperative MAA.

Preoperative MAA	Mean Age (y)	Postoperative MAA		
		Optimal: $\leq 4^\circ$ (N = 124)	Acceptable: 5° – 7° (N = 72)	Undercorrection: $\geq 7^\circ$ (N = 4)
7° – 10° (N = 124)	63.8 (SD 10.1)	91 (73%)	32 (26%)	1 (1%)
11° – 14° (N = 68)	66.8 (SD 10.1)	32 (47%)	34 (50%)	2 (3%)
15° – 18° (N = 8)	64.6 (SD 10.2)	1 (13%)	6 (74%)	1 (13%)

MAA, mechanical axis angle (varus); SD, standard deviation.

Results

A total of 200 consecutive medial UKA patients were included, with a mean age of 64.7 years (SD, 10.1; range, 43.3–86.6), mean body mass index of 30.4 kg/m^2 (SD, 5.9; range, 18.6–52.9), and of which 124 patients (62%) were male (Table 1). The mean preoperative varus deformity was 10° (SD, 2.3; range, 7° – 18°), mL DFA was 89° (SD, 1.9; range, 85° – 95°), MPTA was 84° (SD, 6.1; range, 78° – 91°), and JLCA was 5° (SD, 1.8; range, 1° – 12°). Mean correction following medial UKA was 6° (SD, 2.5; range, 1° – 14°) in this cohort of patients with a preoperative MAA $\geq 7^\circ$ (Table 2).

Reviewing all 200 patients, it was noted that 62% reached an optimal MAA postoperatively, 36% an acceptable MAA, and only 4 patients (2%) had undercorrection ($>7^\circ$ of varus). In patients with a preoperative MAA of 7° – 10° of varus, the deformity was corrected to an optimal alignment range in 73%, acceptable range in 26%, and undercorrected in 1%. In patients with a preoperative MAA of 11° – 14° of varus, the deformity was in 47% corrected to optimal postoperative MAA, and in 50% to acceptable alignment. Of the patients with a preoperative MAA of 15° – 18° , optimal MAA was achieved in 13%, acceptable in 74%, and undercorrection in 13% (Table 3 and Fig. 2).

The dispersion of JLCA within the subgroups is shown in Table 4. Of all patients with a preoperative varus deformity of 7° – 10° , 47% had a medial JLCA of 1° – 4° and 50% had a medial JLCA of 5° – 8° . When the MAA increased to ranges of 11° – 14° and 15° – 18° , it was noted that most patients had a medial JLCA of 5° – 8° (74% and 75%, respectively).

A significant positive correlation was noted between the eMAA (preoperative MAA–JLCA) and the postoperative MAA (0.467 , $P < .001$). Furthermore, in the univariate analysis, a significantly higher percentage of patients achieved optimal alignment in the eMAA $\leq 4^\circ$ group (78%) when compared to the eMAA $>4^\circ$ group (50%; $P < .001$). The odds of achieving postoperative MAA $\leq 4^\circ$ was 3.4, which indicates that it is more likely to achieve optimal alignment when the eMAA is $\leq 4^\circ$ compared to eMAA $>4^\circ$ (Table 5).

The role of extra-articular deformities in estimating optimal postoperative alignment was assessed using independent *t*-tests (Table 6). With regard to tibial deformities, patients with an eMAA $\leq 4^\circ$ had a mean MPTA of 85.5° (range, 81° – 91°), whereas patients with an eMAA $>4^\circ$ had a mean MPTA of 83.3° (range, 78° – 89° ; $P < .001$). Using the normal values of Paley et al, it was noted that patients with an eMAA $>4^\circ$ had an abnormal MPTA ($<85^\circ$) more frequently compared to patients with eMAA $\leq 4^\circ$ (70% vs 31%, $P < .001$). Regarding femoral deformities, patients with eMAA $\leq 4^\circ$

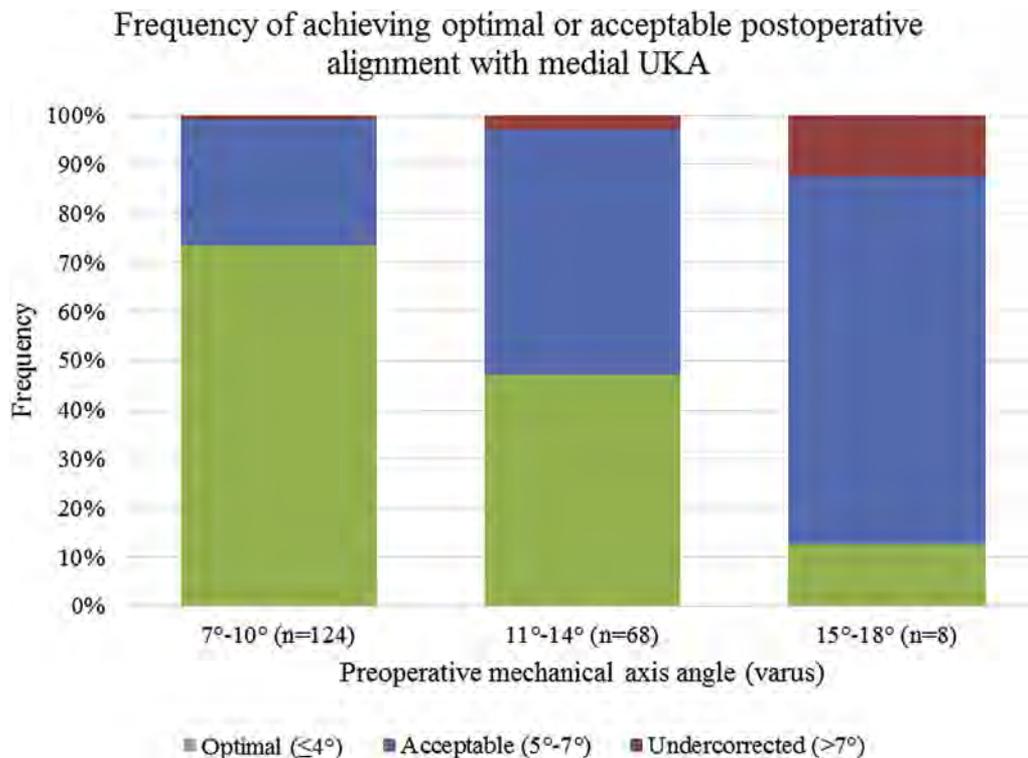


Fig. 2. Frequency of achieving optimal and acceptable postoperative varus alignment stratified by the preoperative MAA.

Table 4
Descriptive Characteristics of the Dispersion of the JLCA in the Specific Groups Based on the Preoperative MAA.

Preoperative MAA	JLCA		
	1°–4° (N = 74)	5°–8° (N = 118)	9°–12° (N = 8)
7°–10° (N = 124)	60 (48%)	62 (50%)	2 (2%)
11°–14° (N = 68)	14 (20%)	50 (74%)	4 (6%)
15°–18° (N = 8)	0 (0%)	6 (75%)	2 (25%)

MAA, mechanical axis angle (varus); JLCA, joint line convergence angle.

had a mean mLDFA of 88.5° (range, 85°–95°) compared to a mean mLDFA of 90.0° (range, 86°–94°) in the eMAA >4° group (*P* < .001). An abnormal mLDFA was noted in 8% of the patients with an eMAA ≤4° and in 35% of the patients with an eMAA >4° (*P* < .001).

Using a logistic regression model, the correctability of large varus deformities to a postoperative MAA ≤4° was assessed by using the eMAA ≤4°, age, and gender. The odds of achieving an optimal postoperative MAA, when the eMAA is ≤4°, was 3.62 higher in comparison to an eMAA >4° of varus (*P* < .001) when correcting for age and gender. Similarly, age as the continuous variable of age was noted to be a significant predictor (odds ratio, 0.97; *P* = .026), indicating that the chance of achieving optimal alignment decreases with 3% with every year a patient gets older (Table 7).

As shown in Figure 3, the predicted probability of achieving postoperative varus alignment within 4° decreases when the eMAA increases. When the eMAA exceeds 6.5° of varus, the likelihood of achieving optimal alignment is less than 50% (predicted probability 0.5).

Discussion

The purposes of this study were to (1) determine to what extent patients with large varus deformities were correctable to optimal (≤4°) or acceptable alignment (5°–7°) and (2) evaluate the feasibility of optimal postoperative alignment based on the eMAA in medial UKA patients. The main findings of this study were that optimal or acceptable postoperative alignment was achieved in 98% (62% and 36%, respectively) of the patients with preoperative varus deformity of ≥7° undergoing robotic-assisted medial UKA using a technique where the MCL is carefully preserved. Secondly, the eMAA was found to be a significant predictor to evaluate the feasibility of achieving optimal postoperative alignment (≤4°).

In our cohort, 62% of the patients were corrected to optimal alignment (≤4°), and in an additional 36% acceptable alignment (5°–7°) was achieved. Based on several studies, the surgical goal in medial UKA surgery is to achieve minor varus alignment postoperative and not exceed 7° of varus [10,18,27,28]. Avoiding severe undercorrection is recommended to prevent medial compartment overload, which is associated with accelerated polyethylene wear as was shown in the subgroup analysis of Hernigou and Deschamps

Table 5
Predicted Probability of Achieving a Postoperative MAA Within 4° of Varus Based on the eMAA.

	Postoperative MAA		Chi-Square	Odds Ratio
	≤4°	>4°		
eMAA ≤4°	66 (78%)	19 (22%)	<i>P</i> < .001	3.4
eMAA >4°	58 (50%)	57 (50%)		

Estimated MAA: preoperative MAA–JLCA. MAA, mechanical axis angle (varus); eMAA, estimated MAA; JLCA, joint line convergence angle.

Table 6
Role of Extra-Articular Deformities in Estimating Optimal Postoperative Varus Alignment Using Medial Proximal Tibial Angle and Mechanical Lateral Distal Femur Angle.

	Medial Proximal Tibial Angle (MPTA)				
	Mean ± SD	Minimum	Maximum	<i>P</i> Value	Abnormal (<85°)
eMAA ≤4°	85.5° ± 1.9°	81°	91°	<.001	31%
eMAA >4°	83.3° ± 2.0°	78°	89°		70%
	Mechanical Lateral Distal Femoral Angle (mLDFA)				
	Mean ± SD	Minimum	Maximum	<i>P</i> Value	Abnormal (>90°)
eMAA ≤4°	88.5° ± 1.8°	85°	95°	<.001	8%
eMAA >4°	90.0° ± 1.8°	86°	94°		35%

Estimated MAA: preoperative MAA–JLCA. MAA, mechanical axis angle (varus); eMAA, estimated MAA; SD, standard deviation; JLCA, joint line convergence angle.

and several other studies [4,5,9,10]. Furthermore, many authors noticed that overloading the medial compartment increases the risk of aseptic loosening [4,10,18,29]. In the absence of malalignment, almost 70% of the load across the knee passes through the medial compartment [5,17,30]. When a varus deformity increases from 4° to 6°, the load through the medial compartment approaches 90% [30]. With the presumption that undercorrection increases the risk of early polyethylene wear and aseptic loosening, many authors have, therefore, advocated to aim for minor residual varus alignment postoperatively in medial UKA patients [6,7,10,18]. Furthermore, Vasso et al and Zuiderbaan et al noted significantly higher patient-reported outcome scores (International Knee Society and Western Ontario and McMaster Universities Osteoarthritis Index, respectively) in patients with a postoperative varus alignment ≤4° [6,12]. Taking these studies into account, it could be argued that minor varus alignment (≤4°) after medial UKA is optimal.

Subsequently, across the different subgroups it has been shown that in the vast majority of patients, optimal or acceptable alignment was achieved after robotic-assisted medial UKA. However, the frequencies of achieving optimal and acceptable alignment differed between the subgroups of 7°–10°, 11°–14°, and 15°–18° (73% and 26%, 47% and 50%, and 13% and 74%, respectively). Our results were different from those of Kreitz et al [14], as they suggested that only 7.7% of their patients with a preoperative MAA of ≥10° of varus could reach neutral or beyond based on valgus stress radiographs. Furthermore, Berger et al [31] showed that in 17% of their patients (mean preoperative MAA of 8° of varus), the surgical goal (≤5° of varus) could not be achieved. However, 2 dissimilarities should be addressed: their surgical goal was slightly different, and the use of conventional methods instead of robot assistance. Robot-assisted surgery concerning medial UKA has been proven to be more accurate and less variable when compared to computer navigation or conventional UKA [6,21,32]. Studies showed that postoperative MAA was consistent within 1°–2° of preplanned position using

Table 7
Predictive Model to Assess the Likelihood of Achieving an MAA Within 4° of Varus Corrected for Gender and Age Using a Logistic Regression Model.

	Postoperative MAA ≤4°		
	Odds Ratio	95% CI	<i>P</i> Value
Female gender	1.79	0.94–3.38	.075
Age	0.97	0.94–0.998	.026
eMAA ≤4°	3.62	1.90–6.90	<.001

Estimated MAA: preoperative MAA–JLCA. MAA, mechanical axis angle (varus); eMAA, estimated MAA; CI, confidence interval; JLCA, joint line convergence angle.

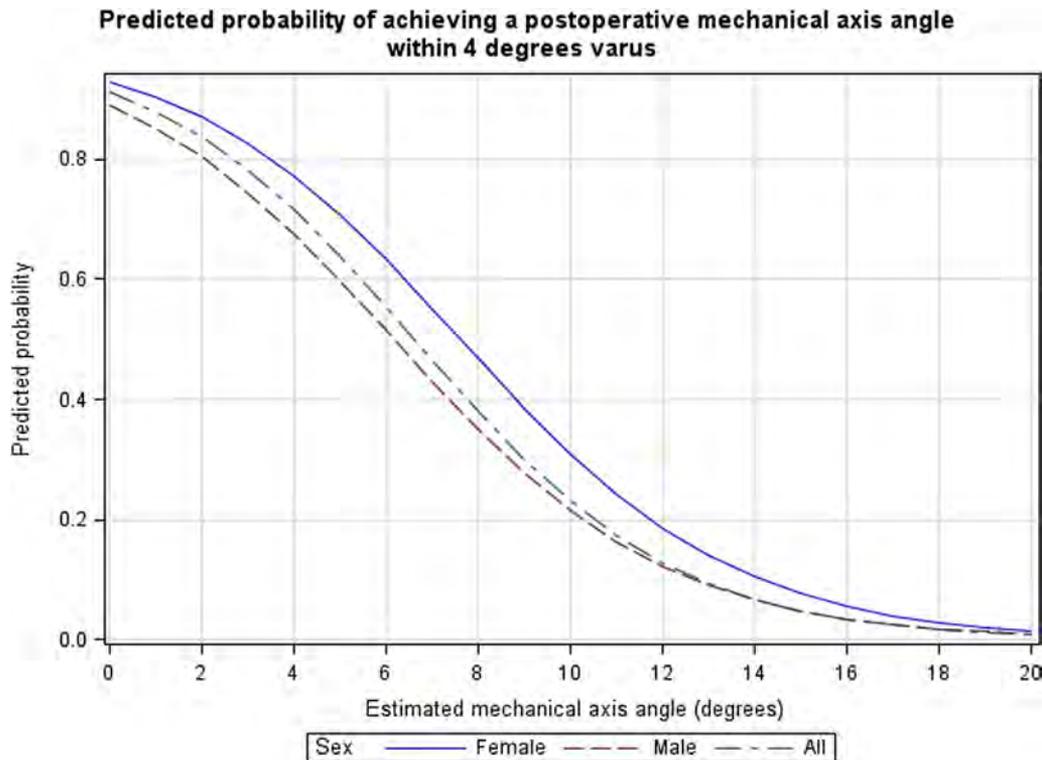


Fig. 3. Predicted probability of achieving optimal postoperative alignment with medial UKA, when correcting for age and gender using a logistic regression model.

robot assistance, a similar degree of accuracy was only achieved in 40% of conventional UKA [21,32]. Furthermore, robot-assisted surgery allows tight control, as well as improvement, of the lower leg alignment intraoperatively [33]. Therefore, the use of robot assistance might contribute favorably to the feasibility of achieving optimal or acceptable alignment during medial UKA. This study shows that 98% of the patients with large varus preoperative deformities ($\geq 7^\circ$) were corrected within optimal or acceptable range using robot-assisted surgery.

We hypothesized that the lower limb realignment after medial UKA is driven primarily by the correction of the joint line deformity (as measured the medial JLCA) in these patients. This was based on the rationale that medial UKA restores the joint height and improves joint congruence, as was shown by Chateillard et al and Khamaisy et al [18,20]. By restoring the joint space height and congruence within the knee joint, the joint obliquity returns to neutral or close to it [13,18,20]. Using this theory, the degree of correctability of the MAA in medial UKA patients could be estimated based on the preoperative MAA and JLCA. Consequently, the eMAA (preoperative MAA–JLCA) was compared with the achieved postoperative MAA to test its predictive value. A significant correlation was found between the eMAA and the achieved postoperative MAA (0.467, $P < .001$). Indeed, 78% of the patients with an eMAA of $\leq 4^\circ$ of varus achieved optimal postoperative alignment. Our results suggest that calculating an eMAA preoperatively is useful to predict the feasibility of achieving optimal postoperative alignment. When correcting for age and gender, the chance of achieving optimal postoperative alignment was 3.6 times greater when the eMAA was within similar range. Furthermore, it was noted that for every year a patient gets older, the likelihood of achieving optimal postoperative alignment decreases with 3%. This could be explained by a less compliance in the soft-tissue envelop resulting in a stiffer, less predictable correction in these knees

[1,34]. Therefore, difficulty might be encountered when correcting varus deformities in the elderly.

As shown in Table 6, extra-articular deformities were more frequent in patients with an eMAA $>4^\circ$ compared to the eMAA $\leq 4^\circ$ ($P < .001$). More specifically, the mean MPTA was within normal range in the eMAA $\leq 4^\circ$ group, whereas the mean MPTA was outside normal range in the eMAA $>4^\circ$ group according to Paley et al [26,35]. In our cohort, especially more tibial deformities were observed in the eMAA $>4^\circ$ group compared to the eMAA $\leq 4^\circ$ group (70% and 31%, respectively). This indicates that in patients with an eMAA $>4^\circ$, the presence of extra-articular deformities using the MPTA and mL DFA should be evaluated. Moreover, when combining these findings with the significantly lower predicted probability of achieving optimal postoperative alignment (Fig. 3), other treatments, such as high tibial osteotomy and distal femoral osteotomy, may be considered in this subgroup of patients [36–39].

This study has several limitations. Firstly, there were only 8 patients included with a preoperative MAA $>15^\circ$; therefore, cautious interpretation of the results of this group is necessary. Furthermore, stress views were not obtained in this study. The stress views are an established means of evaluating the flexibility of a varus deformity. However, stress views may be difficult to obtain, are operator dependent, and are non-weight-bearing. It remains unclear whether stress views are predictive of lower leg alignment correction after UKA; future studies may be directed at incorporating stress view data into realignment prediction after medial UKA. Another limitation was the use of Ortho Toolbox which permitted calibration of each HKA radiograph, but measured angles using rounded numbers. Measurements could not be taken using decimals; consequently, a standard measurement error of 0.5° has to be taken into account when interpreting the results. This method was chosen as several studies showed high reliability, and more importantly, high accuracy of this method [15,24,40,41]. Finally, the registration data concerning the intraoperative correctability and

ligament tension recorded by the robotic system was not saved and therefore could not be compared to the eMAA and postoperative MAA. The role of soft-tissue balancing in correcting the mechanical axis with UKA could be assessed in future studies, as a previous TKA study already suggested an extrinsic contribution to the bony deformity, such as a tight soft-tissue envelope, in patients with a varus deformity $>10^\circ$ [42].

In conclusion, in this study it was noted that patients with a preoperative varus deformity between 7° and 18° could be considered candidates for medial UKA as 98% was restored to either optimal (62%) or acceptable (36%) postoperative alignment. However, a cautious approach is needed in patients with a deformity exceeding 15° of varus. Furthermore, the eMAA was a significant predictor for optimal postoperative alignment with medial UKA, when correcting for age and gender. Future studies are necessary to assess the functional outcomes and revision rates in medial UKA patients with large preoperative varus deformities.

Acknowledgments

We would like to thank the Biostatistics Department, in particular Brenda Chang, for their assistance in the statistical analysis of this study.

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Difficult Problems in Limb Reconstruction: Case Presentations and Panel Discussions

Trauma: Infected Tibial Nonunion in Poor Host

Case Presenter and Moderator: Joseph R. Hsu, MD
Panel: Kevin W. Louie, MD; Stephen Quinnan, MD; William Terrell, MD

Pediatrics: Fibular Hemimelia

Case Presenter and Moderator: John G. Birch, MD
Panel: John E. Herzenberg, MD; Craig A. Robbins, MD; Mi-Hyun Song, MD, PhD

Adult Reconstruction: Infected Failed TKR with Bone Loss

Case Presenter and Moderator: John K. Sontich, MD
Panel: Kevin Tetsworth, MD; J. Tracy Watson, MD; Glenn D. Wera, MD

Best Papers from ILLRS Meeting: *Lisbon, Portugal August 2017*

Moderator: Austin T. Fragomen, MD

Does the Position of the Patella Change during Distraction Osteogenesis of the Femur ?

Dong Hoon Lee, MD.

Severance Children's Hospital College of Medicine, Yonsei University, Korea



Iliotibial band in femoral lengthening

- Iliotibial band(ITB)
 - One of the **strongest distraction-resisting structures** against the femoral lengthening
 - Inhibit rehabilitation during femoral lengthening

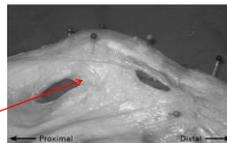
(Elias 2006)



Iliotibial band in femoral lengthening

superficial oblique retinaculum

- Iliotibial band(ITB) – “Another point”
- joins the patella through the superficial oblique retinaculum and the deep transverse fiber



Deep transverse fiber

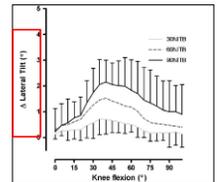
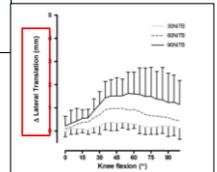
(Eduardo LVS, Arthroscopy, 2007)
(AM Merican JBJS BR, 2008)



- 9 FRESH FROZEN CADAVER



- ITB tension ↑
- patellar translate & tilt laterally
- suggest the increased lateral cartilage pressure



Question

- Does the position of the patella change during the femoral lengthening?
- What are contributory factors?

Material

- Retrospectively investigated
- Jan 2011 ~ Jan 2016, 99 segments underwent femoral lengthening with lengthening nails
- Inclusion Criteria
 - Complete physical examination (Including Ober test, Ely test)
 - Complete radiologic evaluation
 - Minimum 1 year follow-up

Material

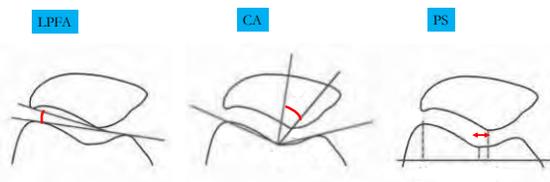
- Exclusion Criteria
 - Lengthening with external fixators
 - Lengthening due to neuromuscular disease
 - Previous surgery on the same segment
 - Simultaneous additional surgery on the same segment
 - Incomplete radiologic evaluation
- **40 femoral lengthening were included** in the study

Evaluation

- Before surgery
 - Physical examination included **ROM of knee, Ober test, popliteal angle, and Ely test**
 - Radiologic evaluations : **femoro-tibial angle, merchant view**
 - CT scan : **rotational alignment**
- After surgery
 - Routine radiologic evaluation : **femoro-tibial angle, merchant view**
- FU
 - every 1-2 week during lengthening period
 - once a month during consolidation period

Radiologic Evaluation

- To check the position of the patella; Merchant view
 - **Lateral patellofemoral angle (LPFA), Congruency angle(CA), Patella shift (PS)**



(William RB, PATELLOFEMORAL PAIN)

Radiologic Evaluation

- CT; Femoral Anteversion, Tibial Torsion



@ to find the contributory factors...

- **Patient-related factors**
 - Age, BMI
 - Physical Examination; Knee ROM, **Ober test**, Ely test, popliteal angle
 - Preop. alignment; FT angle, LPFA, Congruency Angle, Patella shift, femoral anteversion, tibial rotation
- **Distraction-related factors**
 - Final length gain, the rate of distraction, healing index

Statistics

- Linear Mixed Model
 - the position of patella change with time
- Multiple Linear Regression Model
 - variables associated with change of patella position
- SPSS version 23

Demographic Data

Total 40 segments(20 pts)	
Demographic variables	
Age	25.3 (Range, 17 ~ 40)
Sex (Male : Female)	17 : 3
Preoperative height (cm)	165.7 ± 12.7
BMI (kg/m ²)	22.6 ± 3.1
Duration of followup (months)	97 ± 14
Preop. Femoral anteversion	28.5 ± 11.3
Preop. Tibial torsion	28.2 ± 6.6
Preop. Femoro-tibial Angle	Valgus 2.64 ± 2.58

Distraction-related data

Total 40 segments(20 pts)	
Variables	
Final length gain (mm)	58 ± 15
Rate of distraction (mm/day)	1 ± 0.2
Healing index (month/cm)	0.68 ± 0.1

Case 1

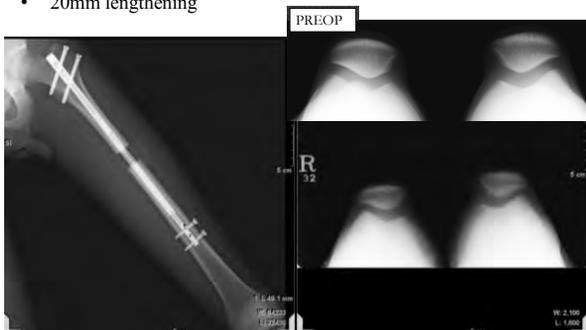
- M/18
- bilateral femoral lengthening
- Nail; PRECICE 2®
- Ober test (+/+)
- Popliteal angle(0/0), Ely test (-/-)
- X-ray; varus alignment / normal patella position
- CT; normal rotation



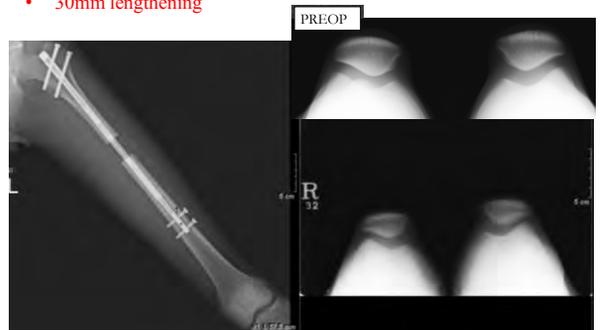
- 12mm lengthening (1mm/day)



- 20mm lengthening



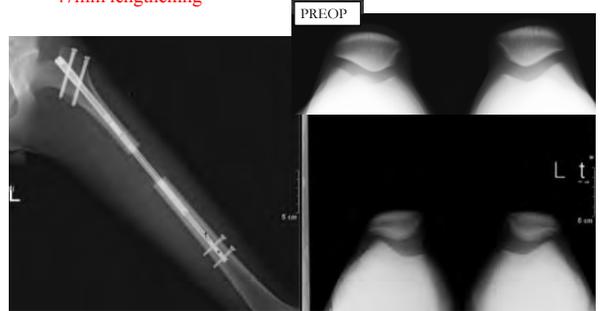
- 30mm lengthening



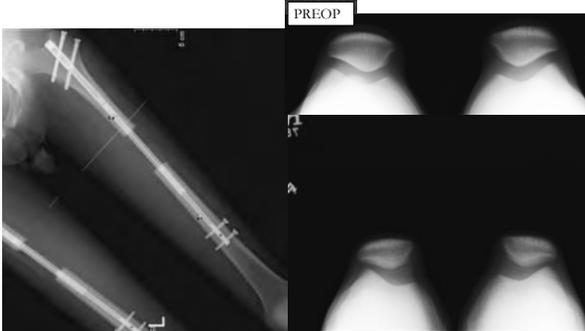
- 40mm lengthening



- 47mm lengthening



- 53mm lengthening, (po#2mo- End of lengthening phase)



- Po # 3mo, consolidation phase



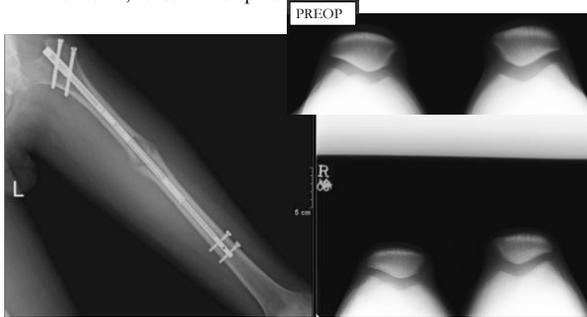
- Po # 4mo, consolidation phase



- Po # 5mo, consolidation phase



- Po # 6mo, consolidation phase

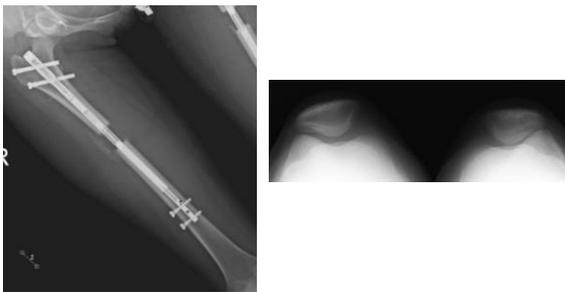


Case 2

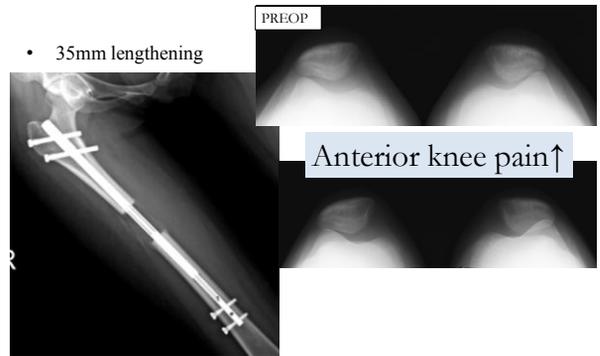
- F/25
- bilateral femoral lengthening
- Nail; PRECICE 2®
- Ober test (-/-)
- Popliteal angle(0/0), Ely test (-/-)
- X-ray ; LPFA -6/ -6.5°, CA 14° lat./ 15° lat,
patella shift -2.2/-1.8 mm lat



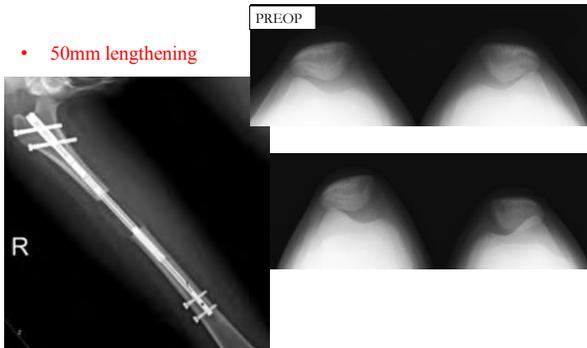
- 20mm lengthening (1mm/day)



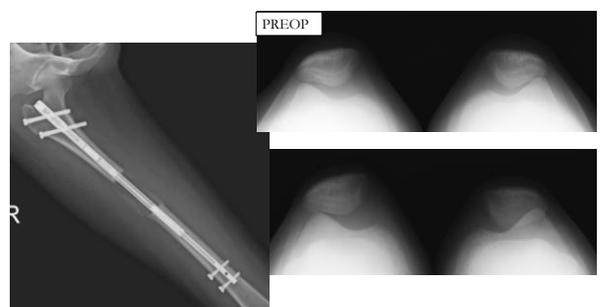
- 35mm lengthening



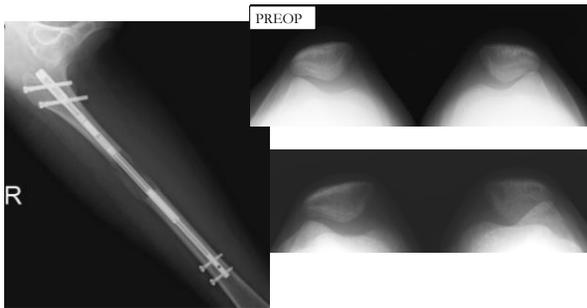
- 50mm lengthening



- Po # 2mo, (End of lengthening phase)



• Po # 3mo, consolidation phase



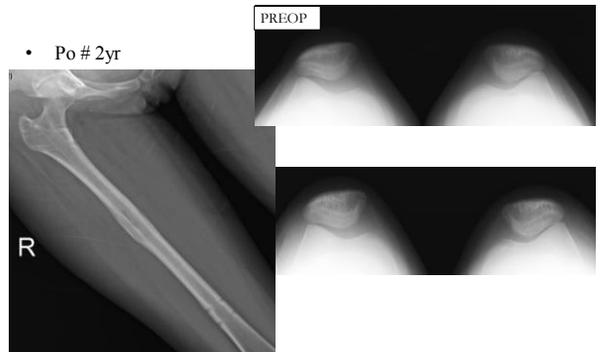
• Po # 6mo



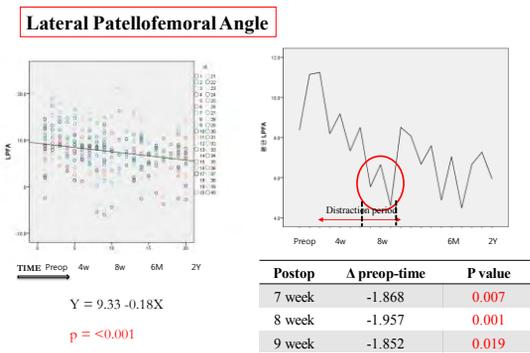
• Po # 1yr



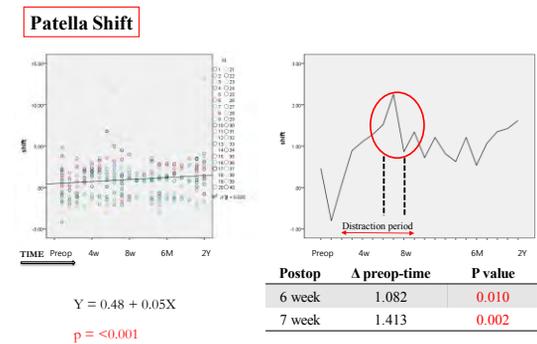
• Po # 2yr



Results – LPFA changed significantly during distraction phase

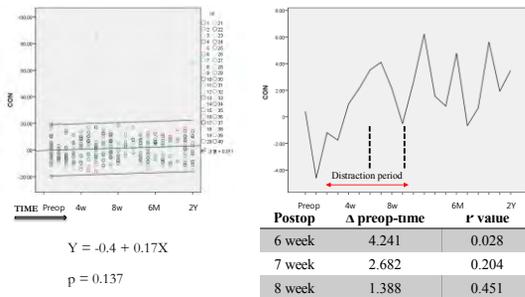


Results – PATELLA SHIFT changed significantly during distraction phase



Results – CA showed the tendency, but not significantly

Congruency Angle



Results – factor analysis **LPFA**

Variables	exp (B)	p value
Age	0.147	0.352
BMI (kg/m ²)	0.148	0.954
Preop. Femoral anteversion	-0.018	0.938
Preop. Tibial torsion	0.136	0.170
Preop. Femoro-tibial Angle	0.162	0.477
Preop. LPFA	-0.399	< 0.001
Preop. CA	-4.780	0.455
Preop. Shift	-4.162	0.791
Ober test	-4.780	0.002
Ely test	-4.162	0.151
Final length gain	-0.332	0.925
Rate of distraction	-4.530	0.658
Healing index	-2.162	0.895

Results – Multipel Linear Regression **Patella Shift**

Variables	exp (B)	p value
Age	-0.063	0.281
BMI (kg/m ²)	-0.310	0.005
Preop. Femoral anteversion	-0.022	0.557
Preop. Tibial torsion	0.026	0.564
Preop. Femoro-tibial Angle	-0.200	0.095
Preop. LPFA	0.42	0.583
Preop. CA	-4.780	0.977
Preop. Shift	-4.162	0.039
Ober test	0.293	0.656
Ely test	1.638	0.234
Final length gain	-3.434	0.984
Rate of distraction	-4.998	0.695
Healing index	-4.438	0.765

Results – Multipel Linear Regression **Congruency Angle**

Variables	exp (B)	p value
Age	-0.172	0.483
BMI (kg/m ²)	-0.967	1.546
Preop. Femoral anteversion	-0.155	0.320
Preop. Tibial torsion	0.208	0.278
Preop. Femoro-tibial Angle	-0.544	0.086
Preop. LPFA	4.937	0.086
Preop. CA	-4.780	0.196
Preop. Shift	-4.162	0.116
Ober test	1.207	0.663
Ely test	6.694	0.249
Final length gain	-3.332	0.845
Rate of distraction	-2.750	0.878
Healing index	-3.433	0.985

Conclusion

- Patella tend to move laterally during the lengthening phase of the femoral lengthening, esp, from postop. 6-8wks (35-50mm lengthening)
- This may suggest increased pressure on the patello-femoral joint during femoral lengthening
- Ober test(+), ↑ preop. patella tilt or patella shift, and large BMI could be suggested as predisposing factors

Conclusion

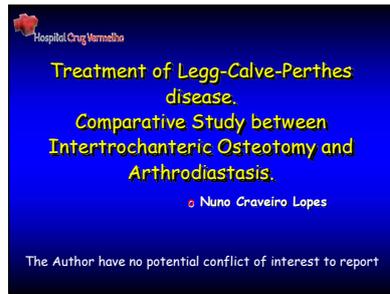
- Need to consider preventive release of soft tissues to avoid over-pressure on the patello-femoral joint
- The higher level-studies are necessary
 - to confirm this phenomenon
 - to validate the predisposing factors
 - to establish the indication, efficacy and safety of the preventive soft tissue procedures



THANK YOU FOR YOUR ATTENTION !



Slide 1



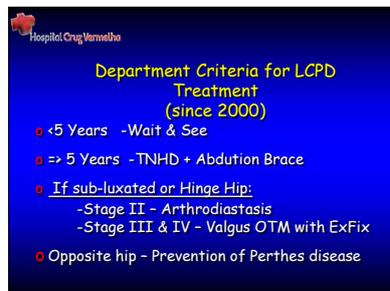
Slide 2



Thank you mister chairman... Dear Colleagues

This study was carried out in these two hospitals, one public, Garcia de Orta hospital in Almada and a private one, Portuguese Red Cross hospital in Lisbon.

Slide 3



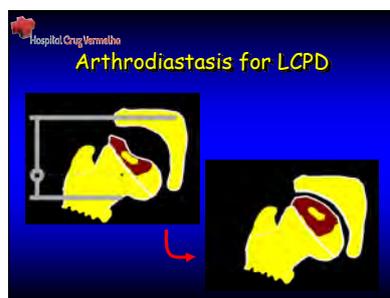
We have modify our treatment protocol for Perthes disease after the year two thousand. It includes for patient five years old and above, a early transphiseal neck-head drilling and protection with an abduction brace. If a sub-luxation and collapse occurs during the evolution with a hinge hip fenomenon, at the late fragmentation stage we proced to a hip arthrodiastasis with a Ilizarov frame. If patient is seen at late reconstruction stage or sequelar stage, presenting an extruded colapsed head with Trendelemburg gait and shortening, we use a valgus osteotomy done also with a Ilizarov frame. We are also doing the prevention of Perthes disease on the opposite hip, utilizing a transphiseal neck-head drilling, if signs of suspicion are noted.

Slide 4



So, on those patients that develop an femoral head collapse and extrusion, commonly called "hinge hip"...

Slide 5



Hip arthrodiastasis may represent a valuable therapeutic option by the possibility to reduce the subluxation and decompress the hip, protecting it during the fragmentation stage. Moreover, the daiastasis of the joint space, will allow the epiphysis to regain its spherical shape during the fragmentation stage due to the elastic memory of the articular cartilage and the vacuum effect of the daiastasis.

Slide 6



For arthrodiastasis we use a small non hinged frame, assembled with components of the Ilizarov apparatus, permitting a 3D positioning of the pins. This frame is simple, robust and well tolerated by the patient, avoiding the need to use tenotomies, Botox or non weight bearing, as when using a monolateral frame.

Slide 7



Comparative Study

<u>ADT Group</u>	<u>OTM Group</u>
15 patients	11 patients
2000-2011 - 11 years	1979-1989 - 10 years
Follow-up - 6.1 (2 to 13)	Follow-up - 6 (2 to 17)
Male / Fem - 12 / 2	Male / Fem - 10 / 1
Mean age - 7.3 (5 to 10)	Mean age - 7 (5 to 10)
Herring - 3B, 11C	Herring - 5B, 6C

Statistically not significant differences (p > 0.05)

In this paper, a comparative study was done between fifteen patients operated on with early transphyseal neck-head drilling and post collapse arthrodiastasis with a fixed Ilizarov frame and a group of eleven patients operated with an close wedge osteotomy and plate fixation after a period of traction in bed. Follow up, age, sex and severity of lesion was similar between the two groups.

Slide 8



General Data

	<u>ADT</u>	<u>OTM</u>
Duration of Surgery	- 28 m	- 60 m
Blood Loss	- 64 cc	- 650 cc
Gait Recovery	- 3 d	- 42 d

Statistically very significant differences (p < 0.0005)

What concerns the duration of surgery, blood loss and gait recovery after surgery, there were statistically significant differences, with much lower values on the arthrodiastasis group.

Slide 9



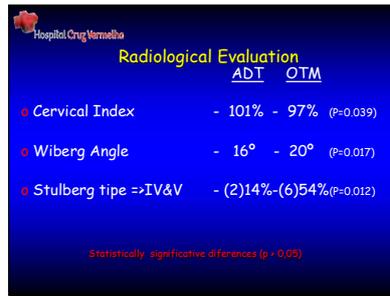
Radiological Evaluation

	<u>ADT</u>	<u>OTM</u>	
Epiphyseal Index	- 40%	- 31%	(P=0.013)
Acetabular Angle	- 12°	- 16°	(P=0.044)

Statistically significant differences (p < 0.05)

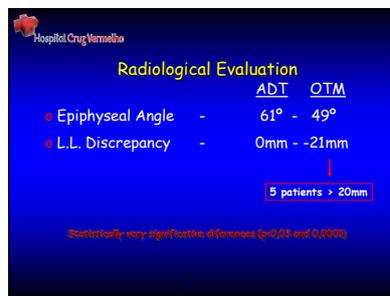
Mean values of epiphyseal index and acetabular angle had statistically significant differences, with the arthrodiastasis group showing a rounder head and a less dysplastic acetabulum.

Slide 10



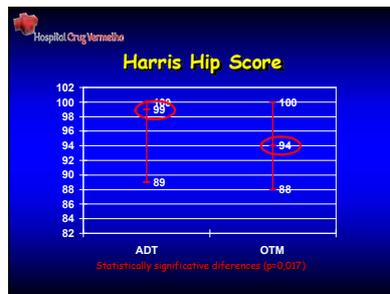
Arthrodiastasis group had also better mean values of cervical index, Wiberg angle, and Stulberg classification with less cases grade IV and V, with values statistically significatives.

Slide 11



The epiphyseal angle and leg length discrepancy, showed also values with a statistically very significant difference, with normal data for the arthrodiastasis group and tendency to varus deformity and shortening for the osteotomy group, with five patients presenting more than twenty millimetres of leg length discrepancy.

Slide 12



The evaluation of the final functional outcome by the Harris Hip Score, showed a better result for the arthrodiastasis group, with an average score of ninety nine percent and for the osteotomy group, ninety four percent, values with statistically significant differences.

Slide 13

Hospital Cruz Verdeña

Complication

ADT Group (15)		OTM Group (11)	
Superf. pin infections	- 8	Incorrect OTM	- 2
Hinge Relapse	- 2	Discrepancy + coxa vara	- 1
Reinterventions	- 1	Osteochondritis Dissecans	- 1
		Deep infection	- 1
		Hardware removal	- 11

Finally, regarding the complications of the procedures, on the arthrodiastasis group we noted some problems with superficial pin infections easily treated with local dressings and oral antibiotics, a relapse of the hinged hip in two cases, one of them needing a reintervention. The osteotomy group had two cases of incorrect osteotomy, one case of evolution to excessive varus and shortening, one osteochondritis dissecans and one deep infection needing revision. Moreover, all cases required second surgery for hardware removal.

Slide 14

Hospital Cruz Verdeña

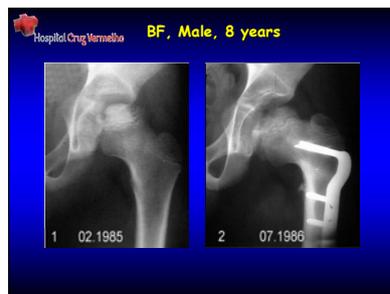
Results

	ADT (15)	OTM (11)
Stulberg I & II	11 (73.5%)	5 (45%)
Stulberg III & IV	3 (20%)	4 (36%)
Stulberg V	1 (6.5%)	2 (18%)

Statistically significant differences (p<0.019)

So, comparing the final results with Stulberg classification with a mean follow up of 6 years, arthrodiastasis showed 73.5% and osteotomy 45% of Stulberg one. This difference was statistically significant.

Slide 15



Let me show you some cases: in this case of osteotomy and plate fixation a exaggerated varus was done, resulting in leg shortening, limping gait and Trendelenburg...

Slide 16



At 5 years of follow up, the patient had varus deformity, two point five centimetres of discrepancy, Trendelenburg gait and hip pain due to a osteochondritis dissecans. Despite having a Stulberg two result, the functional outcome by the Harris Hip Score was the worst of the two series, 88%.

Slide 17



This other case where arthrodiastasis was done, one can see the degree of injury, the extrusion and hinge hip, treated by the described method.

Slide 18



One can see here the hipervascular response to the distraction procedure and the evolution of sphericity of the femoral head... over the three months that the patient had the frame applied.

Slide 19



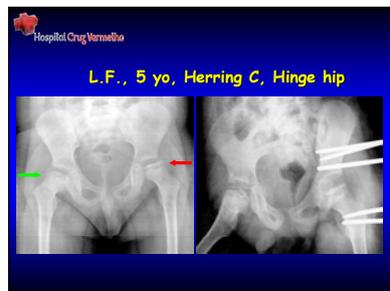
At 11 years old and 4 years of follow-up he had a good outcome, with a Stulberg II result and a Harris Hip Score of 100%.

Slide 20



As usual, patients with this procedure recovers full range of motion in 1-2 months and have no residual shortening...

Slide 21



This other patient, a five years old boy has his first episode of Perthes in the right hip when he was three years old with a good prognosis (green arrow), and now at five and half years old is having a second episode at the opposite hip (red arrow), a Herring C with hinge hip, with bad prognosis, even at this early age. A Arthrdiastasis was done and maintained during 4 months.

Slide 22



This is the aspect at two months after removal of the frame, with the characteristic osteoporosis when the patient was using the protection abduction brace.

Slide 23



And here when he was twelve years old, at seven years of follow up with a Stulberg one result and a Harris Hip Score of 100%, a excellent result.

Slide 24



And the clinical aspect of the patient.

Slide 25



This last patient is a seven years old boy that developed this herring C, extruded hinge hip. You can see at right, the Ilizarov frame on the usual position: About fifteen degrees of limb abduction.

Slide 26



This sequential X-rays, shows the possibility of reduction and the evolution of sphericity of the femoral head... over the three months period that the patient was with the frame applied.

Slide 27



Despite the great initial hip extrusion and stiffness, indicating a poor prognosis, at thirteen years of follow-up when the patient was twenty years old he had a good outcome, with a Stulberg II result and a Harris Hip Score of 100%.

Slide 28



Here you can see the clinical aspect of the patient. As usual, patients with this procedure recovers full range of motion in 1-2 months and have no residual shortening...

Slide 29



As conclusion, may I say that compared with classic osteotomy and plate fixation, arthrodiastasis led to: - Better congruency and sphericity - Less residual sequelae regarding discrepancy and varus - Better functional results according to the Harris Hip Score - Much less complications and no second surgery for hardware removal - It is a shorter surgical procedure, with no blood loss - and allows for earlier ambulation of the patient.

Slide 30



Infected fractures and nonunions - Stability is the key Fixation hardware is not the enemy – A paradigm shift



Minoo Patel, MBBS, FRACS, MS, PhD



Monash University, University of Melbourne, Epworth Hospital, Cabrini Hospital, Melbourne

AAOS, LLRS Specialty Day, New Orleans, 2018



Traditional thought

- Bones cannot heal in the presence of infection
- Hardware harbours bacterial biofilm and infection
- All hardware must come out to allow bone healing
- Infected fractures with hardware = infected arthroplasty

Traditional thought

- Bones cannot heal in the presence of infection **X**
- Hardware harbours bacterial biofilm and infection **✓**
- All hardware must come out to allow bone healing **X**
- Infected fractures with hardware = infected arthroplasty **X**

Bone, infection and metal

- Bone can heal in the presence of infection
- Stable Osteosynthesis hardware can remain in situ
- Stable new hardware can be inserted to obtain union
- Stable external fixation is not the source of infection
- Infected non-union <<≠>> infected total joint arthroplasty
- I.D. physicians have a poor concept of osteomyelitis and non-union

Studies

- Implant maintenance
- Femur infected non-unions
- Complex infected non-unions
- Humerus infected non-unions
- Tibia infected non-unions
- Knee fusion post infection
- Hybrid internal and external fixation

Protocol

- Hybrid internal and external fixation
- Internal fixation left in situ post union
- Implant maintenance

This Online First article has been peer reviewed and accepted for publication. It is subject to final revision and approval by the journal.

ORIGINAL ARTICLE

Acute Infections After Fracture Repair Management With Hardware in Place

Eric Righietto MD, David Zurawski PhD, Mark Vrabec MD

Received: 14 March 2017 / accepted: 24 October 2017
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Abstract Managing infections in fractures treated with open reduction and internal fixation is an ongoing dilemma. Little published data exist to support the current practice of treating these infections with retained hardware, irrigation, debridement, and antibiotic suppression. We evaluated the effectiveness of this approach. We identified potential subjects from a central trauma database and selected them based on chart review and specific inclusion and exclusion criteria. We divided the patients into two groups. Patients

operated between the groups by analysis of variance. Sixty-nine cases were available for analysis. Forty-seven (68%) were successful and 22 (32%) were unsuccessful. Average time to healing was 130 days. Most of the failures occurred within 120 days from the time of surgery. Smoking was a major risk factor with a 3.7 times greater likelihood of procedure being unsuccessful per month than procedure among nonsmokers. Treating infected fractures with hardware in place is less successful than widely believed.

Implant maintenance

Journal of Orthopaedic Trauma

Maintenance of Hardware After Early Postoperative Infection Following Fracture Internal Fixation

Richard A. Thompson, MD, PhD, and Michael Brown, MD, PhD, for the Fracture Fixation Consensus Committee

Background: The development of a deep seated infection in the presence of hardware after open reduction and internal fixation presents a clinical dilemma, and there is scant literature to aid in decision-making. The purpose of the present study was to summarize the prevalence of hardware when left, maintenance of hardware after the development of postoperative infection versus its removal after removal of hardware.

Methods: The present study included 122 patients from three Level I trauma centers, retrospectively identified from 2007 and 2009 registries. In total, 123 osteosynthetic implant infections were present. Osteosynthetic hardware that developed a deep-seated infection after internal fixation of acute fractures. The decision of whether to retain hardware without removal was calculated, and the parameters that predicted success or failure were evaluated.

Results: Eighty-six patients (implant infection); 73% had hardware left with antibiotic administration, irrigation of hardware, and subsequent debridement and debridement. The decision of whether to retain hardware was based on a score of 0-100 and the prevalence of a re-injury was 0-100. Lower variables were not significant for success versus failure or infection versus noninfection, including smoking, infection with Pseudomonas species, and involvement of the femur, tibia, ankle, or foot.

Conclusions: Despite infection after internal fixation of a fracture can be treated successfully with systemic antibiotics, irrigation, debridement, and irrigation of hardware and hardware retention. These results may be improved by patient selection based on certain risk factors and the specific hardware and infection involved.

Level of Evidence: Therapeutic Level II. See Instructions for Authors for a complete description of levels of evidence.

Implant maintenance

Dewar et al, Newcastle, OTA, 2016

- Better union rates
- Faster union
- With implant retention

Implant maintenance



Management

- Early – Antibiotics
- Delayed – ABs + local therapy
- Debridement, pulsed lavage
- Maintain fixation if stable
- Improve the host (C ► A)



Debridement and soft tissue coverage

- Go early! Go hard! But, go sensible!
- “All dead bone needs to be removed”
- UK NICE guidelines – early coverage (flaps), lower infection



Journal of Orthopaedic Trauma

RECONSTRUCTION OF SEGMENTAL BONE DEFECTS DUE TO CHRONIC OSTEOMYELITIS WITH USE OF AN EXTERNAL FIXATOR AND AN INTRAMEDULLARY NAIL

Richard A. Thompson, MD, PhD, and Michael Brown, MD, PhD, for the Fracture Fixation Consensus Committee

Background: Chronic osteomyelitis of an intramedullary nail is a rarely seen but potentially devastating complication of the use of an intramedullary nail. The purpose of the present study was to summarize the prevalence of hardware when left, maintenance of hardware after the development of postoperative infection versus its removal after removal of hardware.

Methods: The present study included 122 patients from three Level I trauma centers, retrospectively identified from 2007 and 2009 registries. In total, 123 osteosynthetic implant infections were present. Osteosynthetic hardware that developed a deep-seated infection after internal fixation of acute fractures. The decision of whether to retain hardware without removal was calculated, and the parameters that predicted success or failure were evaluated.

Results: The mean size of the defect was 10 cm (range, 5 to 13 cm) in the distal tibia and 7 cm (range, 3 to 10 cm) in the femur. The mean time to surgery was 110 days after diagnosis. The prevalence of infection was 0-100 and the prevalence of a re-injury was 0-100. Lower variables were not significant for success versus failure or infection versus noninfection, including smoking, infection with Pseudomonas species, and involvement of the femur, tibia, ankle, or foot.

Conclusions: Despite infection after internal fixation of a fracture can be treated successfully with systemic antibiotics, irrigation, debridement, and irrigation of hardware and hardware retention. These results may be improved by patient selection based on certain risk factors and the specific hardware and infection involved.

Level of Evidence: Therapeutic Level II. See Instructions for Authors for a complete description of levels of evidence.

Tibia and femur – bone transport

Femur

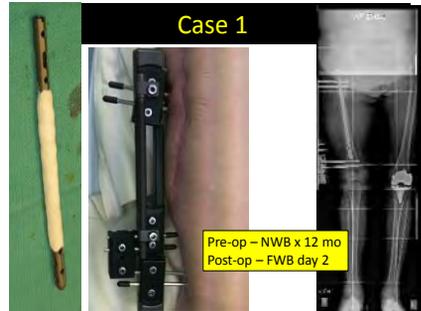
The study – 12 cases (2000-2014)

Treatment Protocol

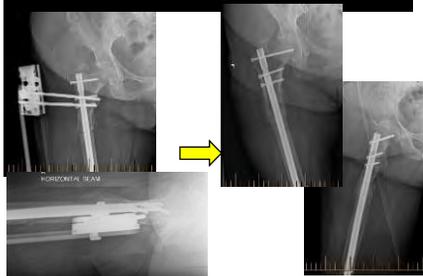
- 1) Removal of all infected and broken implants
- 2) Intramedullary reaming with distal venting, followed by intramedullary lavage.
- 3) Excision of necrotic and atrophic bone
- 4) Insertion of antibiotic cement nail (Paley & Herzenberg; Conway)
- 5) Monolateral fixator for compression
- 6) Fixator removal and distal interlocking after confirmation of union
- 7) Secondary lengthening if necessary

Case 1

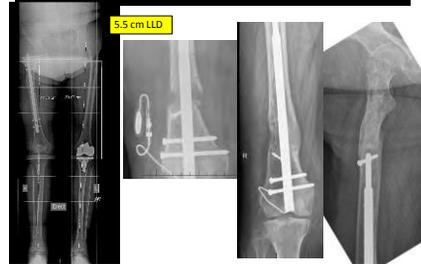
- 58 yr old lady
- Excision of bone 'tumour'
- Previous surgeries – 4
- Staph epidermidis



Case 1



Post union lengthening with Fitbone



Results

- Union – 12/12
- Time to union 18 weeks
- Surgeries prior – 3.2
- Additional surgeries post index surg – 1.4 (including fixator removal)

Results (at 12 mo)

- Knee extension: -5 degrees (range 0- -10 deg)
- Quadriceps lag: 0
- Knee flexion: 135 deg (range 150-120 deg)
- All patients off antibiotics
- **The SF-12 PCS 25.5 (pre-op) to 45.3 (12 mo.) and MCS from 29.4 to 62 (p<0.05).**

Case 2



- *36 yr old
- *175 kg
- *Type 2 Diabetes
- *Immune-suppressed
- *Endocarditis
- *Nailed for post RIA path fracture
- *MRSA + serratia + enterococcus
- *Nail cut-out prox femur
- *Discharging sinus
- *Offered hip disarticulation

Case 2



Humerus

Monash / Epworth series

- **15 non-unions – 2001-2018**
- 6 infected NU
 - diaphyseal (6)
 - atrophic (4); hypertrophic (2)
- 9 aseptic atrophic NU
 - diaphyseal (6)
 - metaphyseal (3)
- Time from index procedure - 14.1 months (12-19 mo.)
- High energy trauma – 8/14
- Average number of surgeries prior to Ilizarov recon = 3.3
- **Co-morbidities**
- Smoking – 6*
- Mental illness, non-compliance – 1*
- Osteoporosis - 2

Surgical Technique

- Remove all infected hardware
- Remove non-infected hardware only if it interferes with treatment
- Minimal soft tissue interference
- Excision of devitalised bone in atrophic non-unions
- External fixation
- Compression
- Accordion (sequential compression distraction)
- Ex Fix augmented by an intra-medullary device
- Lock the IM device at fixator removal

Infected non-union - 6 cases

- Union – 6/6
- Average time spent in frame – 4.5 mo (3.5 -5mo)
- Infection eliminated – 6/6

Results

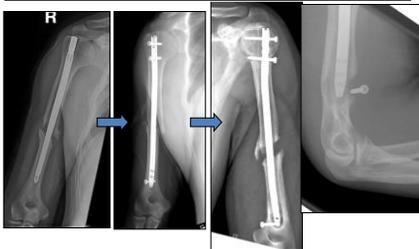
- Average DASH score
 - pre - 31
 - post - 23 (p=0.02)
- Average shoulder range
 - abduction – 171° (160-180)
 - forward elevation - 175° (160-180)
 - ER - 25° (20-35)
 - IR – S1-T10

Results

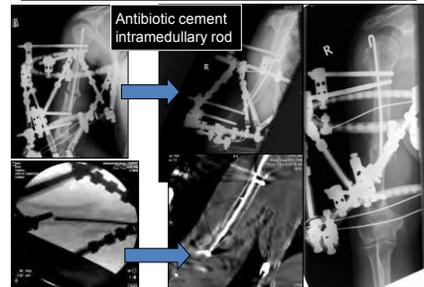
- Average elbow range
 - Flexion = 136° (150-110)
 - Extension = -18° (-40 - 0)
- Average elbow range (supracondylar)
 - Flexion = 120° (110, 130)
 - Extension = -35° (-30, -40)

Case 1: Infected Diaphyseal non-union

Smoker, Schizophrenic, loads the upper limb



Case 1: Infected diaphyseal non-union



Case 1 :Infected diaphyseal non-union



Infected NU humerus



Ankle

Journal of Limb Lengthening & Reconstruction

Official Publication for Association of Study & Application of methods of Ilizarov (ASAMI-BSI) & International Limb Lengthening & Reconstruction Society (ILLRS)

ORIGINAL ARTICLE

Year : 2015 | Volume : 1 | Issue : 1 | Page : 14-20

Fixator-assisted nailing for revision ankle fusion with deformity, bone loss and or infection

Misool K Patel¹, Rajesh V Manrambath²

¹ Monash University, Centre for Limb Reconstruction, Epworth Health Care, Melbourne, Australia

² Centre for Limb Reconstruction, Epworth Health Care, Melbourne, Australia

Ankle fusion

- 2001-2014, 24 patients, 26 non-unions
- 16 infected non-unions
- 15/16 union
- One painless non-union with ankle fusion nail in situ
- One amputation at 36 months in an immuno-compromised patient, after union
- Salvage rate – 25/26 (96.2%)

Neuropathic joint + sepsis + nonunion



EBI Biomet trauma ankle fusion nail – adjustable jig slides between the fixator and the foot



FAN ankle fusion

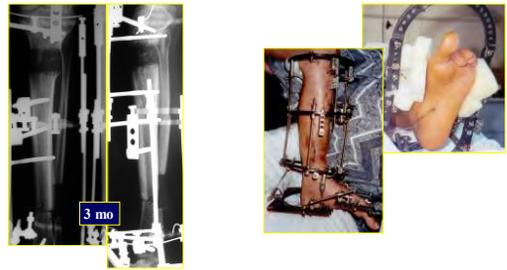
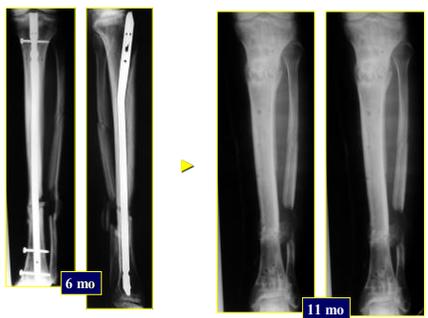


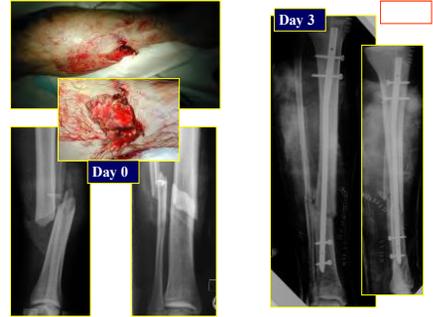
Motorised nail for ankle fusion with infection



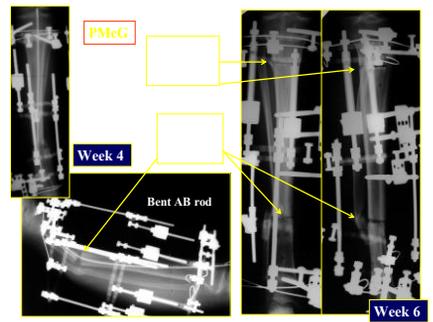
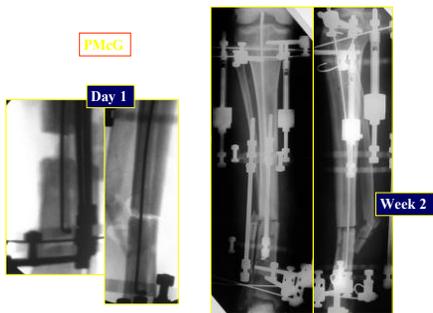
Tibia

- 16 infected non-unions
- 16 acute shortening – 1 - 4.5 cm
- Union 15/16
- Amputation – 1/16, multi organism, prior compartment syndrome, poor coverage (skin graft) – refused IM nail
- AB nail 14 (10 non-locking, 4 locked)





Delayed union ► exchange nailing ► intra-medullary pus





Infected fracture ≠ Non-union ≠ Osteomyelitis

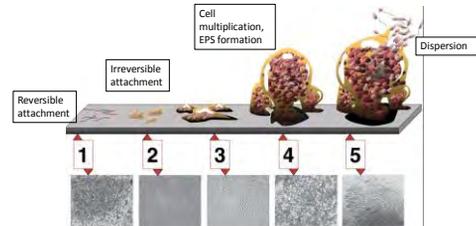
- Osteomyelitis ▶▶▶▶▶ bone infection
- Infected fracture /NU ▶▶ non-healing fracture with infection
- + plates, nails ▶▶ non-healing infected fracture + hardware
- Once healed ▶▶▶ Previously infected fracture with hardware

Williamsburg surgeon's notebook

- Treatment for non-union
- Was to irritate the fracture by pulling strands of wool through the fracture site
- 'Healing was facilitated by laudable pus'
- i.e.
- Osteomyelitis ►►► Involucrum



Bacterial Biofilm (Pseudomonas Aeruginosa)



Biofilms (slime)

- Cells adhere to each other on a surface
- Produce EPS – extra cellular polymeric substrate
- EPS – DNA, proteins, polysaccharides
- Bacteria in biofilms are physiologically distinct from 'planktonic' bacteria
- Undergo phenotypic shift

Removal of biofilm

- High concentration of antibiotics – antibiotic cement
- Mechanical removal
- Removal of metal
- High pressure irrigation
- Other local agents
- Hydrogen peroxide is not of much use
- Hyperbaric oxygen – jury is still out

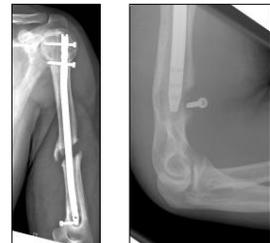
Stability! Stability! Stability!

- Is the bone stable (or healed)?
- Are the soft tissues 'stable'?
- Is the host stable?

- Implant maintenance

Stability, stability, stability

- What is worse than an infected fracture?
- An **UNSTABLE** infected fracture!



Stability, stability, stability

- Ring or monolateral fixator
- Bridge plate – Masquelet
- I.M. nail
- Fixator + nail

The changing paradigm

- We present salient findings that make for a paradigm shift in the management of infected fractures and non-unions.
- 1) **Preservation of fixation implants in infected fractures leads to better chance of union & faster union**
- In 100+ fractures with infection, union was achieved in over 93% cases by
- preserving the hardware, improving stability where necessary, improving the soft tissue conditions, antibiotics
- (*Dewer et al, University of Newcastle, OTA; JOT*)

The changing paradigm

- 2) **Removal of hardware delays fracture union** or
- leads to non-union.
- Hardware exchange may also delay fracture union.
- (*Dewer et al, University of Newcastle, OTA; JOT*)
- Infectious diseases physicians have a poor concept of bone infections.
- Infected fracture ≠ 'Osteomyelitis'
- Infected fracture implant ≠ infected total joint arthroplasty

The changing paradigm

- 4) **What about bone infection?**
- Quiescence of infection, if not cure, is achieved with union.
- Once union is achieved infection usually settles
- An infected solid bone is better than
 - infected fractured bone
 - infected non-union
 - 'sterile' non-union

The changing paradigm

- 5) We present our technique of fixator assisted and associated nailing for infected non-unions.
- 6) We also present our published results with management of infected non-unions with fusion of neuropathic ankles and femoral fractures.

Symposium: Managing Your Online Profile

Moderators: Joseph R. Hsu, MD and Natasha O'Malley, MD

Combined Symposium: LLRS and AOFAS

Debate: Controversies in Foot and Ankle Surgery

Failed TAR

Moderator: Joseph R. Hsu, MD
Douglas N. Beaman, MD
Clifford L. Jeng, MD

Post-Traumatic Ankle Arthritis in Young Patient

Moderator: Zhongmin Shi, MD
Austin T. Fragomen, MD
Justin D. Orr, MD

Midfoot

Moderator: Xu Wang, MD
Michael S. Pinzur, MD
W. Bret Smith, DO

Ankle Deformity with Osteoarthritis

Moderator: Woo Chun Lee, MD
S. Robert Rozbruch, MD
Fabian Krause, MD

Saturday, March 10, 2018

Combined AOFAS/LLRS

2:30 pm – 4:45 pm

Great Hall B

Limb Lengthening and Reconstruction Society (LLRS)

Ankle Deformity and Osteoarthritis

S. Robert Rozbruch, MD

In this debate format, I will take the position of joint preservation and osteotomy realignment for mild to moderate osteoarthritis. For severe arthritis and infection, I prefer realignment and arthrodesis. Techniques of ankle distraction, distal tibial osteotomy with circular frame and with plate and screws will be discussed. Brief review of outcomes and literature will be presented. Principles will be taught with clinical case examples.