KA update

Has the robot changed the game?

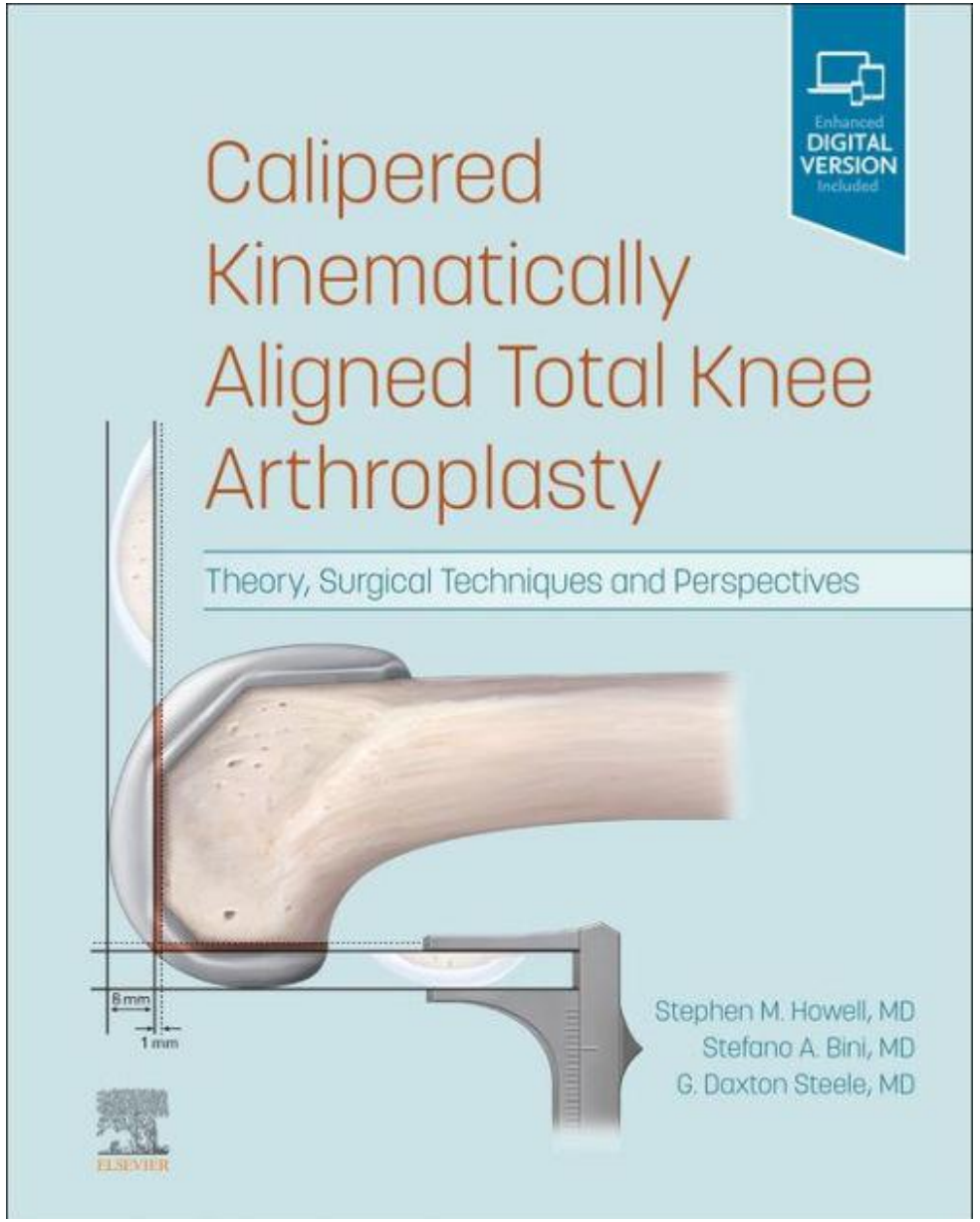
Stefano A. Bini, MD
Professor of Orthopaedics UCSF

Conflicts of Interests

- Consultant for Stryker Corporation
- Advisor
  - Sira Health
- Formerly advised
  - CloudMedx
  - InSilico Trials
  - Capture Proof
- Grant from Google ATAP division
  - Sensors, AI and Predictive Analytics for Gait
- Journal of Arthroplasty
- Arthroplasty Today
- Journal of Orthopaedic Experience and Innovation
- Founder and VP of the Personalized Arthroplasty Society
- Founder and Chair Digital Orthopaedics Conference San Francisco

New Textbook

- 20 Chapters and outstanding reading.
- Nominated for a Pulitzer Prize



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journal homepage: www.elsevier.com

Review article

What you need to know about kinematic alignment for total knee arthroplasty

Charles Rivière[a,b,c,d,*], Loic Villet[a], Dragan Jeremic[d,e], Pascal-André Vendittoli[f]

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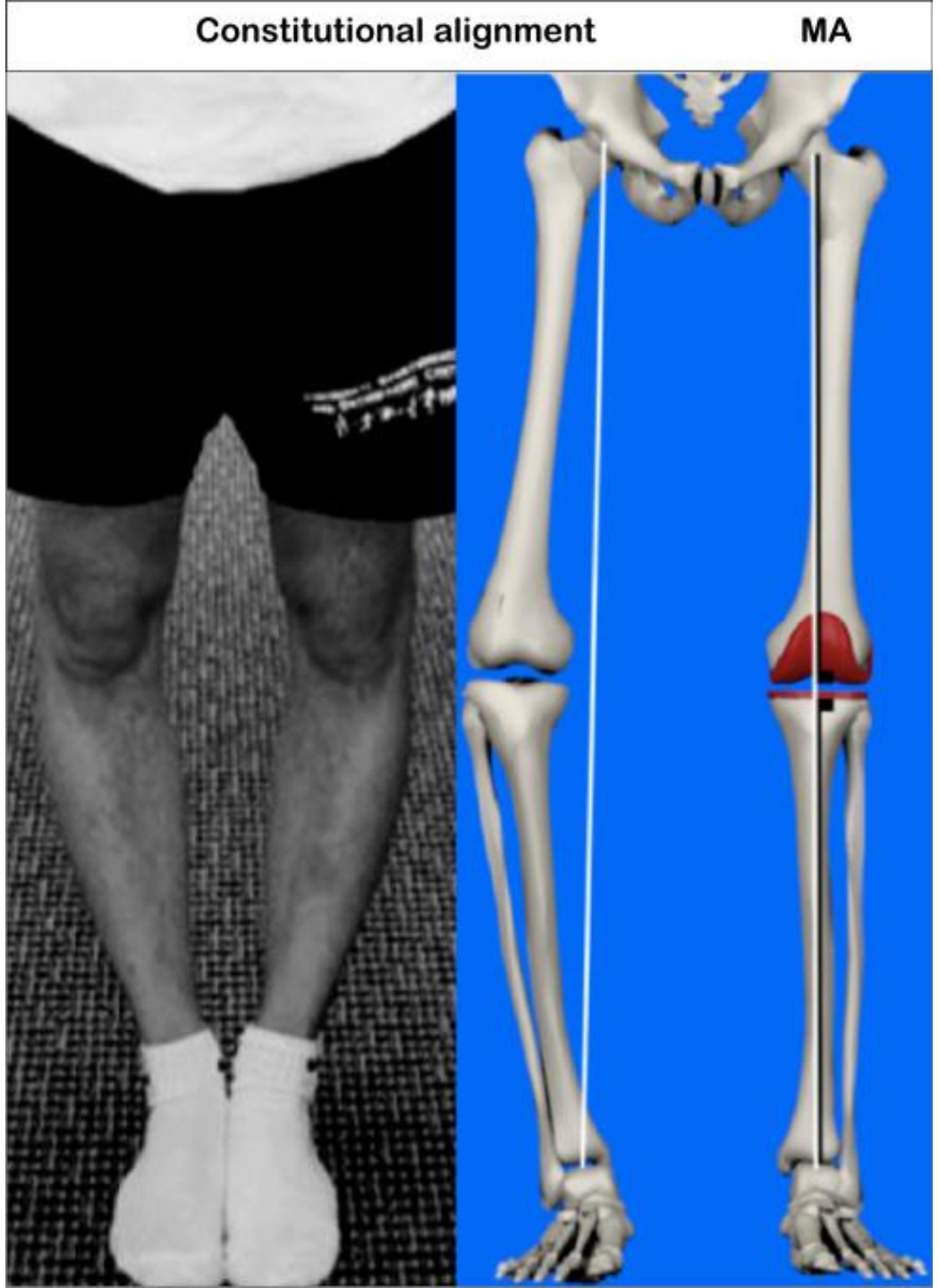
[b] *MSK Lab - Imperial College London, UK*
[c] *The Lister Hospital, Chelsea Bridge Rd, SW1W 8RH London, UK*
[d] *Personalised Arthroplasty Society, Montreal, Canada*
[e] *Clinic for Orthopedic Surgery, St. Vincenz Hospital, Brakel, Germany*
[f] *Département de chirurgie, Université de Montréal, Hôpital Maisonneuve-Rosemont, 5415, boulevard L'Assomption, H1T 2M4 Montréal, Québec, Canada*

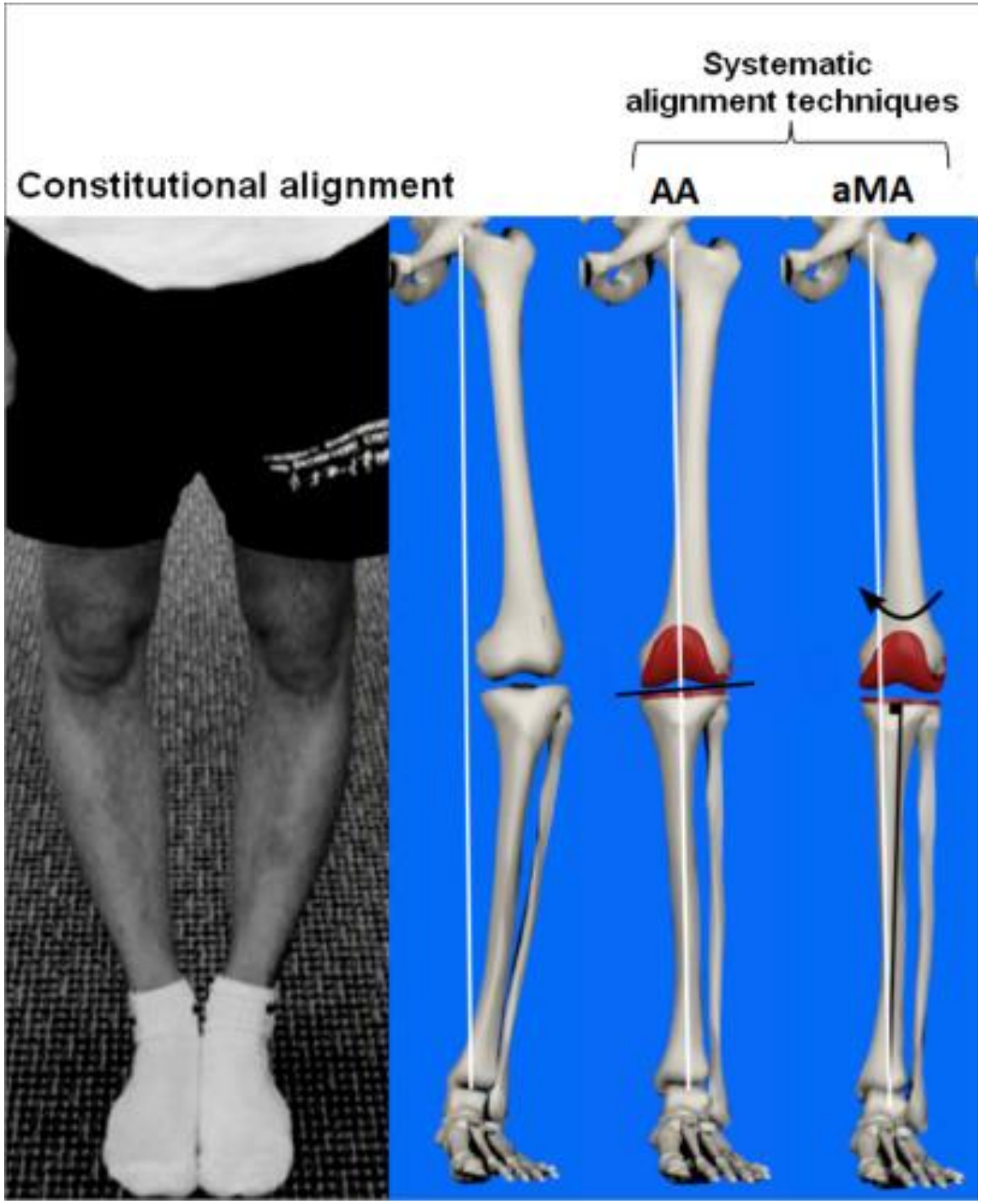
Mechanical Alignment

- Freeman Insall
- Standardized alignment, every patient
  - Both cuts orthogonal to Mechanical Axis (HKA), fixed posterior slope, ER of 3deg, ligament release to balance at 0 and 90.
- Make procedure reproducible
- Distribute loads evenly to avoid ASL



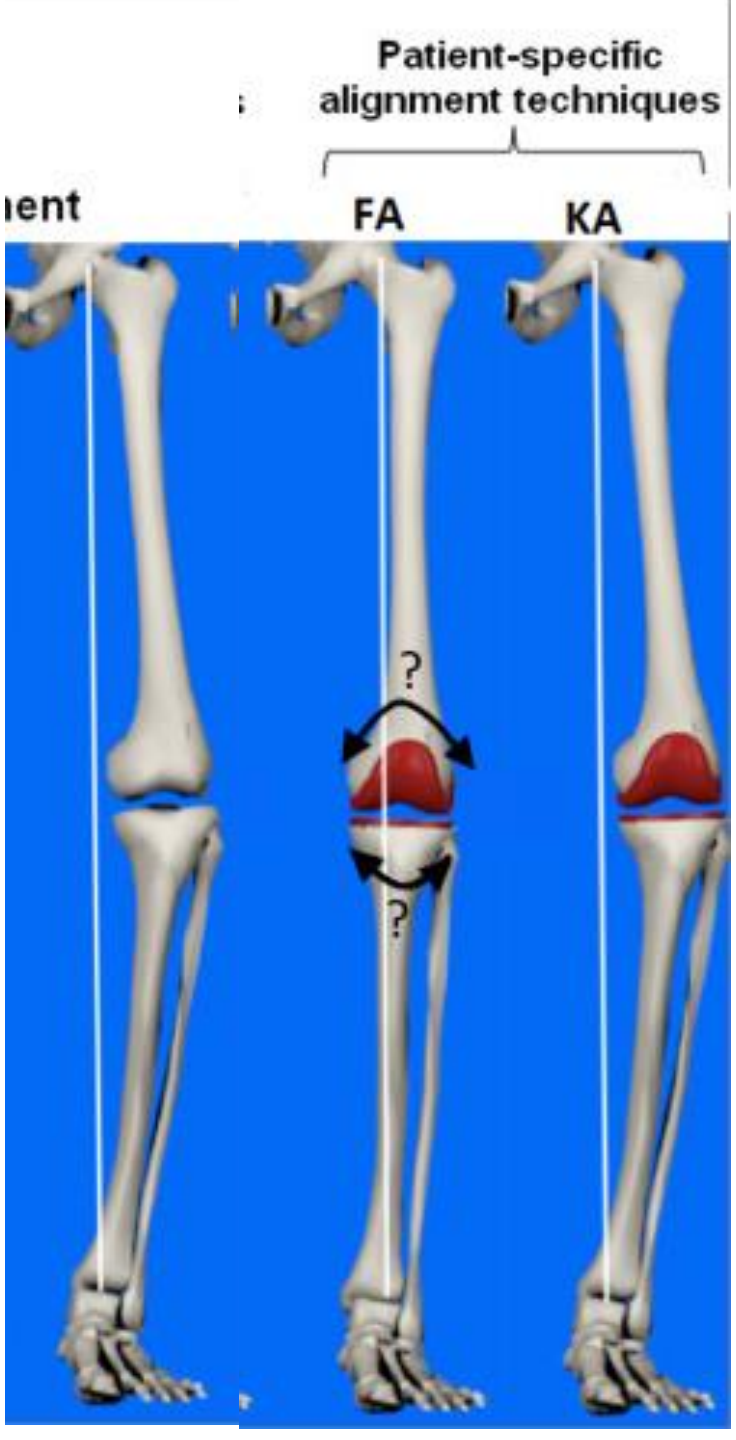
Alternatives: Systematic

- Anatomic Alignment
  - Hungerford, Krakow
  - Straight LE, Joint line at 3deg to HKA (parallel to ground when standing)
  - Asymmetric implants (S&N)
- Adjusted Mechanical
  - Bellemans
  - Constitutional Varus
  - Orthogonal tibial cut but accepts 2-3 deg of varus relative to HKA, increased valgus DFA



Alternatives: Personalized

- Kinematic Alignment
  - Howell mid 2010s
  - Restores patient anatomy to “pre-arthritic” condition with no limits
  - Native Alignment in coronal , sagittal and rotational plane, no soft tissue releases, CR
- Restricted KA (rKA)
  - Vendittoli
  - KA, but limits variation from HKA in Coronal Alignment to 3 deg
  - Adjusts all cuts accordingly



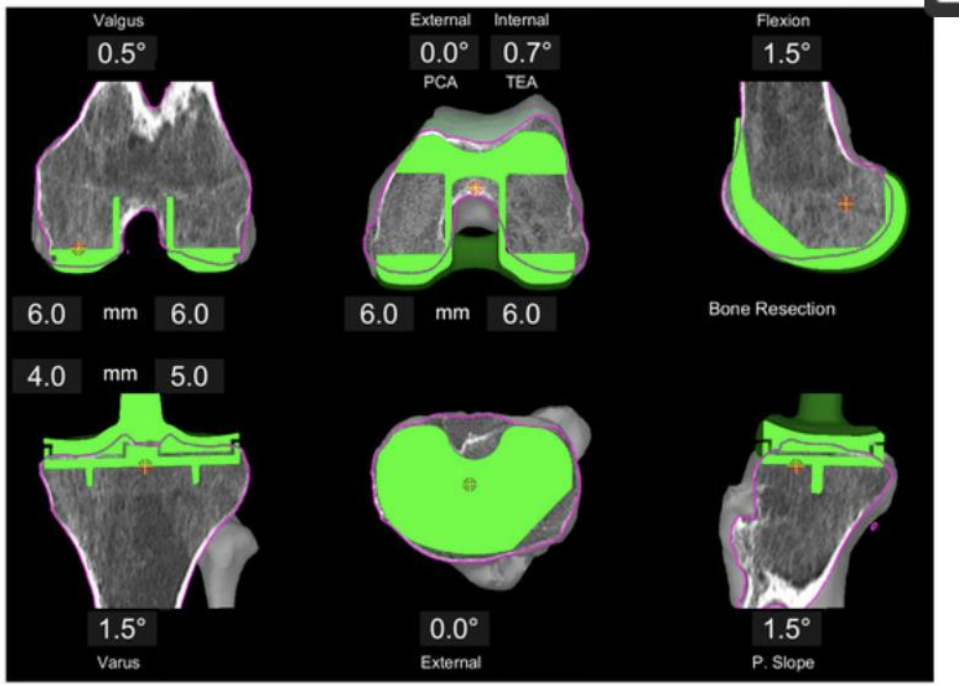
True Kinematic Alignment Is Applicable in 44% of Patients Applying Restrictive Indication Criteria—A Retrospective Analysis of 111 TKA Using Robotic Assistance

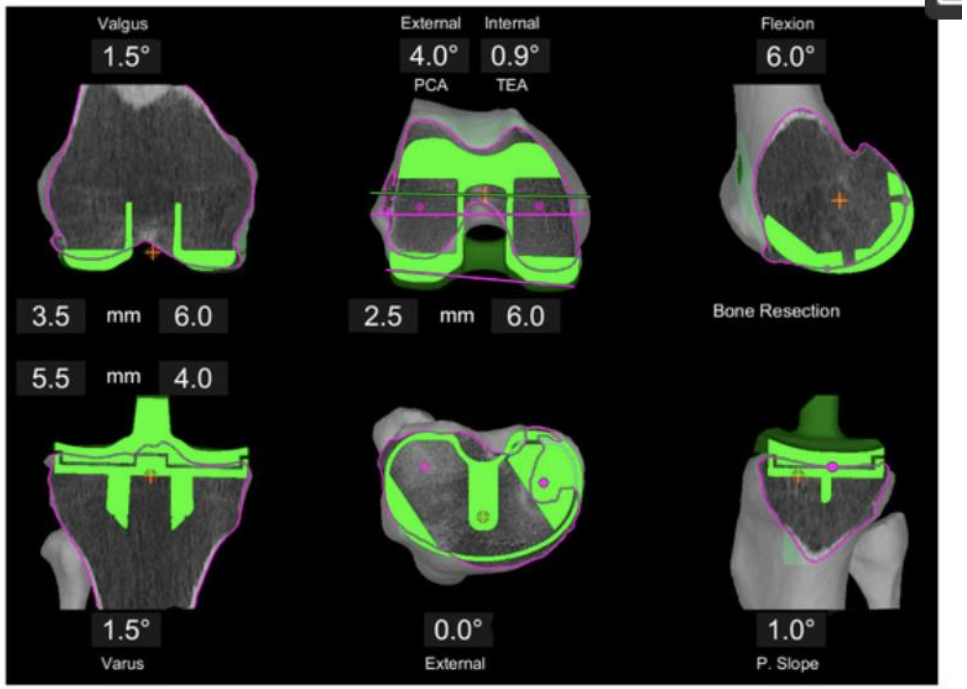
by Kim Huber [1], Bernhard Christen [1], Sarah Calliess [1,2] and Tilman Calliess [1,*]

[1] articon Spezialpraxis für Gelenkchirurgie, 3013 Berne, Switzerland

[2] Campusradiologie Bern, Engeried-Spital, 3012 Berne, Switzerland

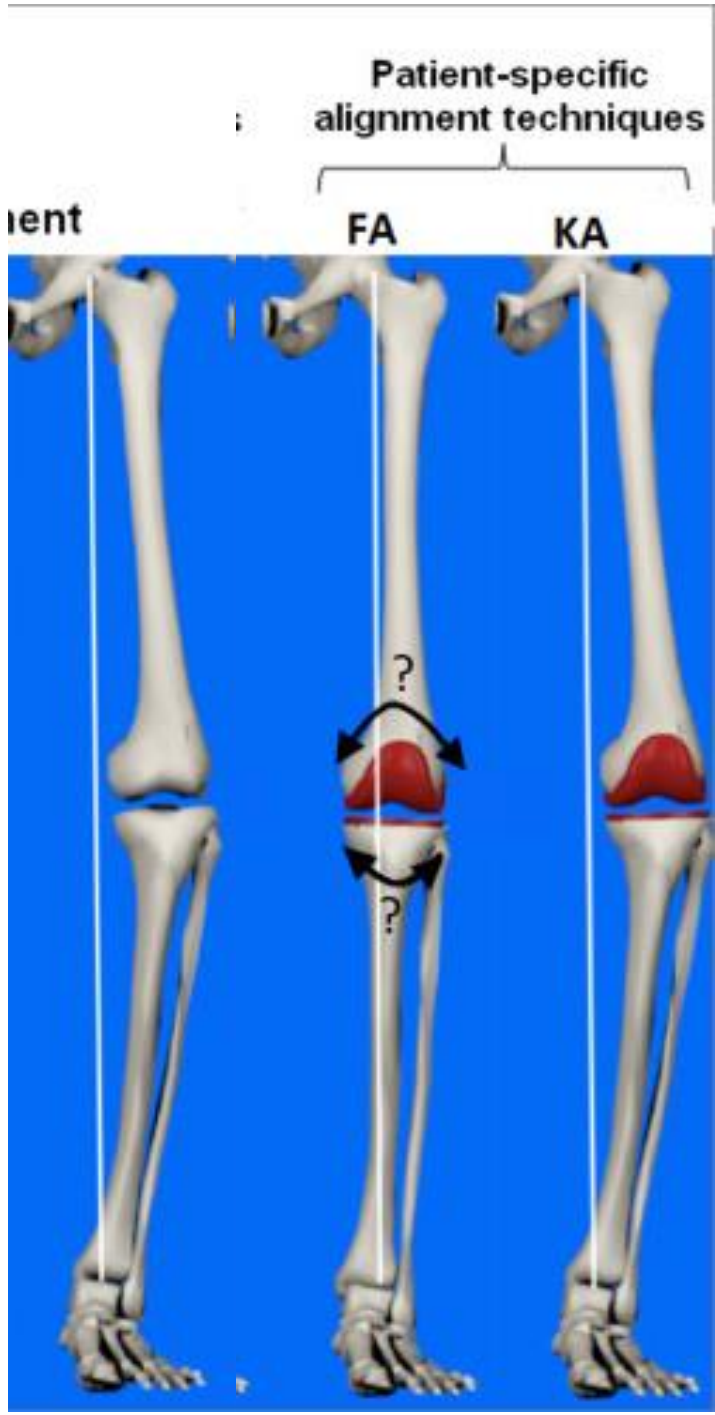
- Criteria set at > 3 degrees from the HKA in varus and 1 of valgus
- Use Robot to adjust Rotation and DFA to match their criteria
- 317 knees
- 44% of TKA could be done in KA without “compromising” the limits of rKA
- KA had better results for all outcomes than the rKA group





Alternatives: Personalized

- Functional Alignment
  - Technology enabled personalization of alignment
  - Objective is neutral alignment HKA +/- 3 degrees
  - Adjust bone cuts based using balancing data on pre-operative CT based templating
  - Minimize soft tissue releases.



Alternatives: Personalized

- Functional Alignment
  - Data Limited
- Variations on the theme
  - iKA
  - Tibia first technique
  - Restricted
- Posterior Stabilized
- Medial Stabilized
- Bi-Uni techniques

The Bone & Joint Journal, Vol. 100-B, No. 7 | Knee

Open Access |

Robotic-arm assisted total knee arthroplasty is associated with improved early functional recovery and reduced time to hospital discharge compared with conventional jig-based total knee arthroplasty

a prospective cohort study

B. Kayani, S. Konan, J. Tahmassebi, J. R. T. Pietrzak, F. S. Haddad

Published Online:28 Jun 2018https://doi.org/10.1302/0301-620X.100B7.BJJ-2017-1449.R1

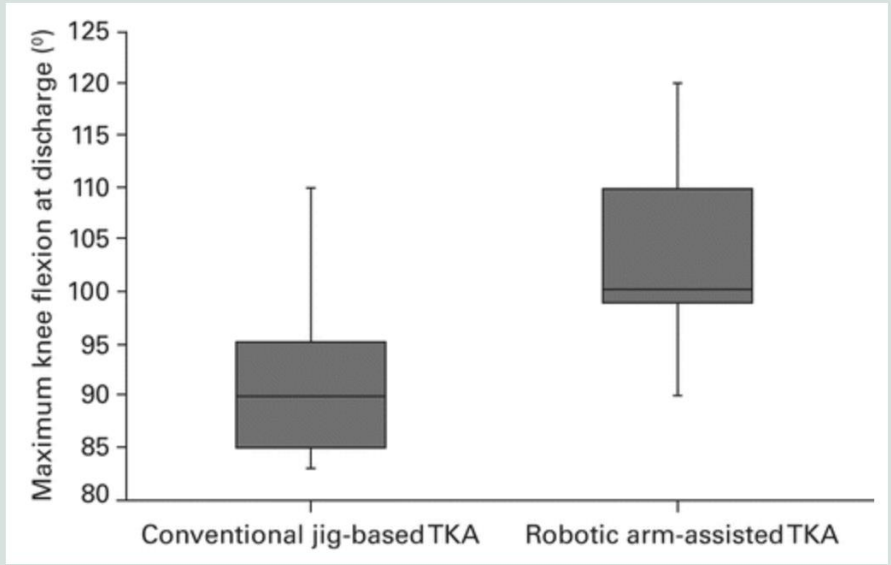


Fig. 4 Boxplot showing maximum knee flexion (°) at discharge in conventional jig-based total knee arthroplasty (TKA) *versus* robotic-arm assisted TKA.

Meta Data

- KA vs MA
- PROMs
  - 11 studies (2021)
    - 7 better outcomes
    - 4 no difference
- Biomechanics
  - 3 better
  - 1 no difference

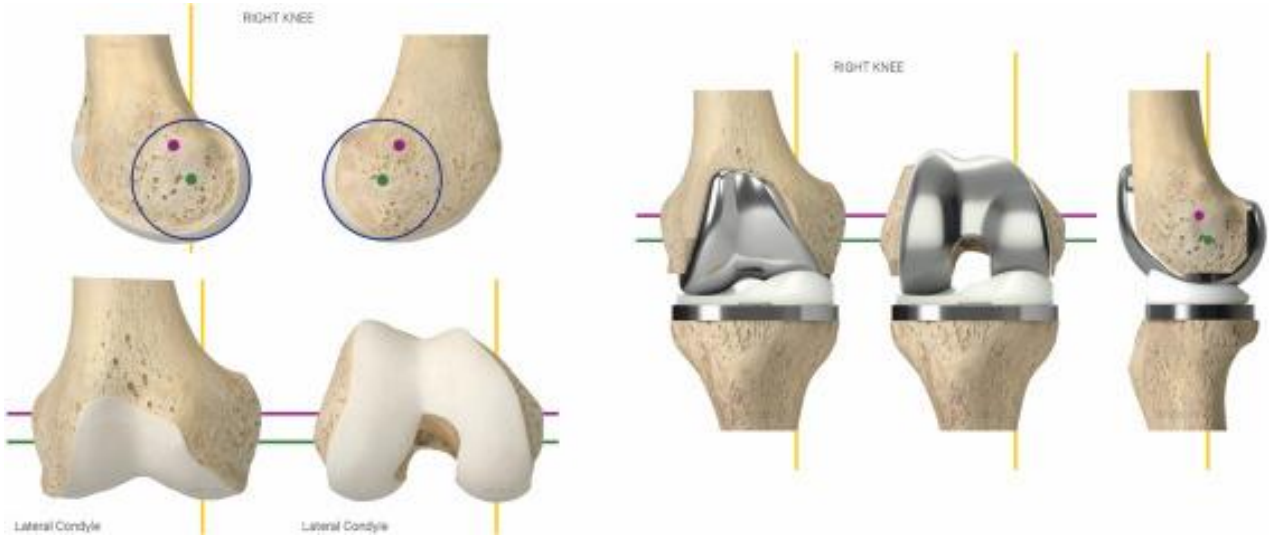


Fig. 3. The three axes that dictate knee kinematics: Cylindrical (green), patellar (purple), tibial (yellow). The tibia and patella flex and extend around the cylindrical axis (green) and patellar axis (purple), respectively. Axial rotation of the tibia around the tibial axis (yellow).

Riviere et al, OTSR 2020

Battle of the Trials

FA vs. MA and KA vs MA with the robot as the Referee

Robotic-assisted surgery and kinematic alignment in total knee arthroplasty (RASKAL study): a protocol of a national registry-nested, multicentre, 2×2 factorial randomised trial assessing clinical, intraoperative, functional, radiographic and survivorship outcomes

Samuel J MacDessi [1], Gregory C Wernecke [2], Durga Bastiras [3], Tamara Hooper [3], Emma Heath [4], Michelle Lorimer [4], Ian Harris [5] for the RASKAL Study Group

Correspondence to Dr Samuel J MacDessi; samuelmacdessi@sydneyknee.com.au

This study aims to assess the effectiveness of RAS, KA or both to improve clinical outcomes, functional measures, radiographic precision and prosthetic survivorship when compared with current gold standards of surgical care.

A prospective double-blinded randomised control trial comparing robotic arm-assisted functionally aligned total knee arthroplasty versus robotic arm-assisted mechanically aligned total knee arthroplasty

Babar Kayani, Sujith Konan, Jenni Tahmassebi, Sam Oussedik, Peter D. Moriarty & Fares S. Haddad

The objective of this study is to determine the optimal alignment technique in TKA by comparing patient satisfaction, functional outcomes, implant survivorship, complications, and cost-effectiveness in MA TKA versus FA TKA. Robotic technology will be used to execute the planned implant positioning and limb alignment with high-levels of accuracy in all study patients.

KNEE | Published: 01 October 2018

Kinematic alignment in total knee arthroplasty better reproduces normal gait than mechanical alignment

William Blakeney, Julien Clément, François Desmeules, Nicola Hagemeister, Charles Rivière & Pascal-André Vendittoli

- 18 rKA vs 18 MA vs 170 Healthy controls
- Retrospective case control study pre- and post-op gait lab, CR, Navigated
- KA
  - No significant difference to normal controls
- MA
  - Significantly different from normal controls
- Lower PROMS
  - KOOS: KA 74 vs MA 61 (p=0.034)

- < Sagital ROM (49 vs 54, p=0.02)
- < Max flex (52 vs 57, p=.002),
- <adduction angle 2.0 vs 7.5, (p=.01)
- <ER in mid stance (< 2.3 deg p=.008)

RCT KA+PSI vs MA + CAS : RSA migration

- Laende et al, BJJ 2019
- 24 KA vs 23 MA
  - Demographically similar
  - Cemented CR TKA (Triathalon)
  - 2 year follow up
- Migration <0.5 24 months both groups
- Overall change in migration from 1 – 2 years <0.2 mm
- Inducible displacements were equal

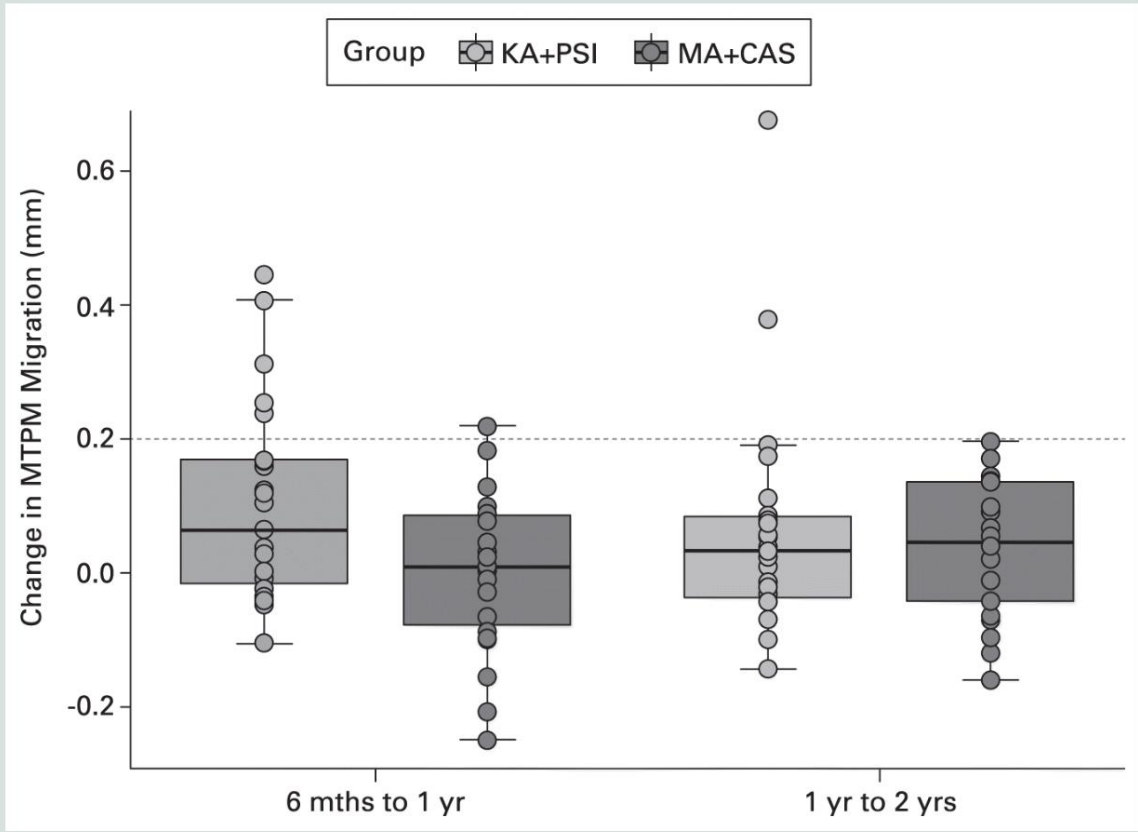


Fig. 5 Mean change in maximum total point motions (MTPM) migration from one to two years. KA+PSI, patient-specific instrumentation for kinematic alignment; MA+CAS, computer-assisted surgery targeting neutral mechanical alignment. The internal horizontal line indicates the median, boxes enclose the interquartile range, and whiskers extend a further 1.5 times the interquartile range.

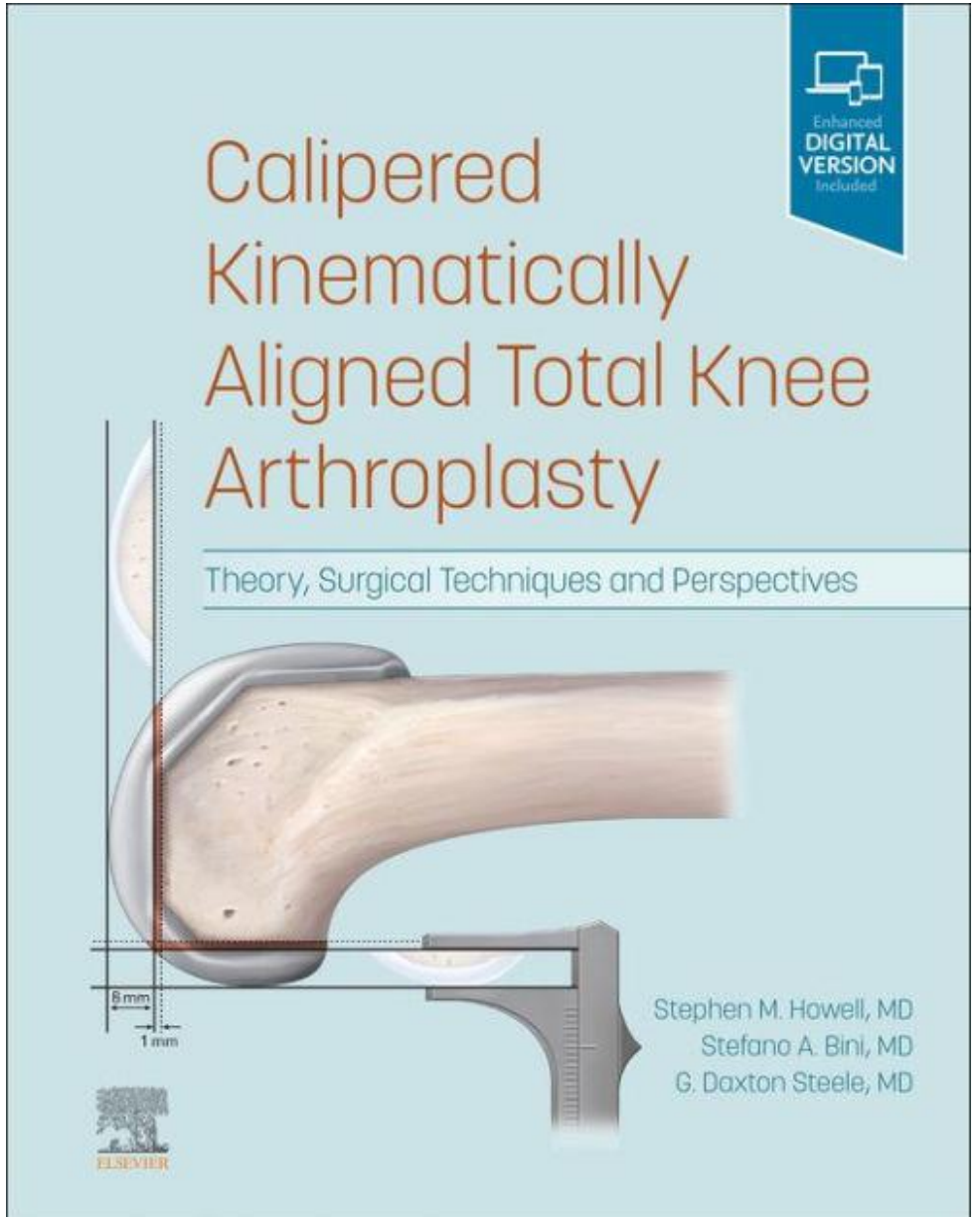
Coronal Plane: Does KA lead to Medial Compartment overload?

- Outlier (>3 deg) Intraoperative forces = to those “in range” (Shelton, BJJ 2017)
- Similar migration patterns (RSA) (Laende BJJ 2019)
- Reduced intensity and frequency of dynamic edge loading (Nedopil, Int Orthop 2017)
- Paradoxically decreased tibial cortical strain (Bini et al, 2018)
- Loosening of the tibial component 0.3% at 2-10 years (Howell, Orthop 2019)

Aseptic Loosening not a problem

- Metaanalysis
- 877 KA aligned TKA
- Weighted mean follow-up **38 months**
- **Cumulative survivorship 97.4%**

- Courtney, P. Maxwell, and Gwo-Chin Lee. "Early outcomes of kinematic alignment in primary total knee arthroplasty: a meta-analysis of the literature." *The Journal of arthroplasty* 32.6 (2017): 2028-2032.



New Textbook

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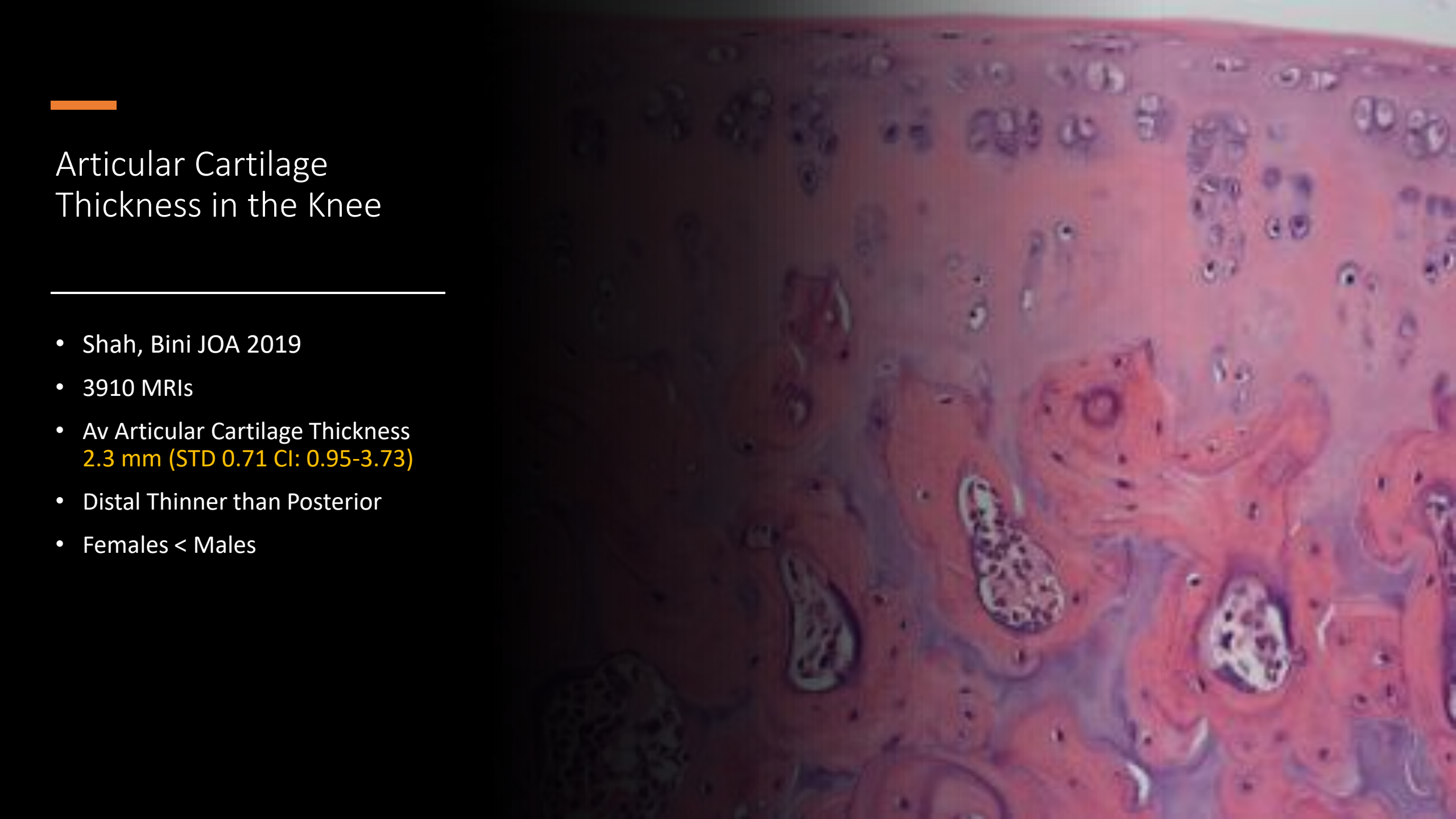
- Nominated for a Pulitzer Prize

Is The Lateral Femoral Condyle **hypoplastic**?

- Bini, Shah (submitted)
- 6829 MRIs
- Machine Learning algorithm
- 10-160 deg arc
- LFC >MFC 1-4 mm
  - Varied by Kalgren Lawrence score
  - Valgus knees greater difference than Varus (L>M)
- Submitted for publication (BJJ)

Articular Cartilage Thickness in the Knee

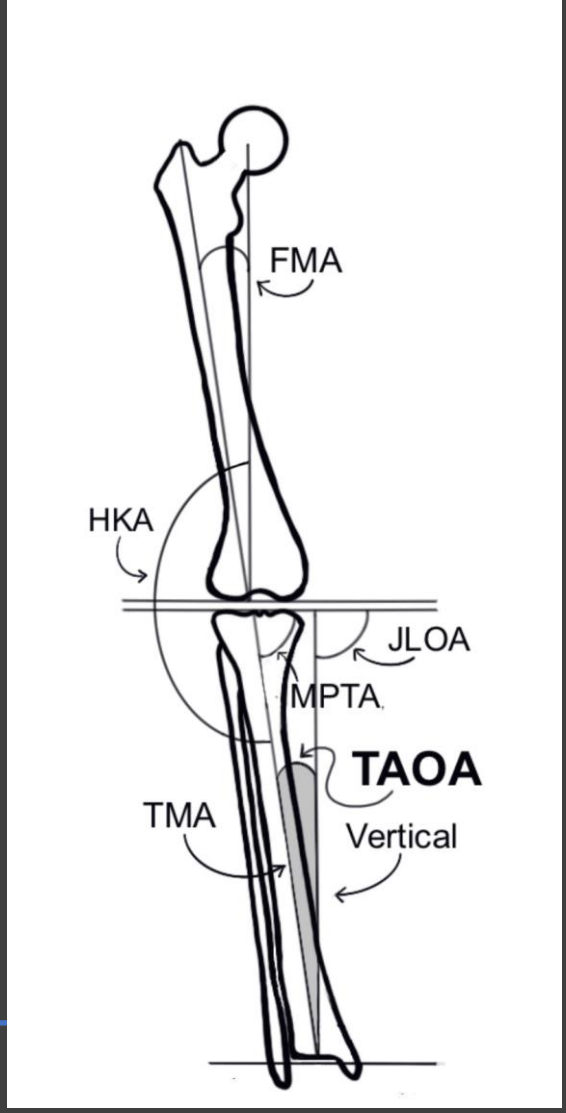
- Shah, Bini JOA 2019
- 3910 MRIs
- Av Articular Cartilage Thickness
  2.3 mm (STD 0.71 CI: 0.95-3.73)
- Distal Thinner than Posterior
- Females < Males



The native tibia is not vertical
Tibial Axis Orientation Angle (TAOA)

- 65 patients
- Standing XR (hip-ankle)
- In VARUS Knees, the **Tibial Axis Orientation Angle (TAOA)** is in 4.7 deg of varus relative to the floor

- Bini et al, Arthroplasty Today 2021



Bini, Stefano A., et al. "Tibial mechanical Axis is nonorthogonal to the floor in Varus knee alignment." *Arthroplasty today* 8 (2021): 237-242

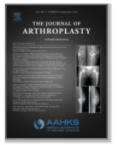
Coronal Tibial Alignment

- Does a change in tibia metaphyseal angle correlate with PROMs?
- 204 knees, high change (>3 deg) vs. low change
- 3, 12 and 24 mo PROMs (KOOS, Promise, VR12)
- Max XR flexion
- No change in PROMs or max flexion

ELSEVIER

The Journal of Arthroplasty

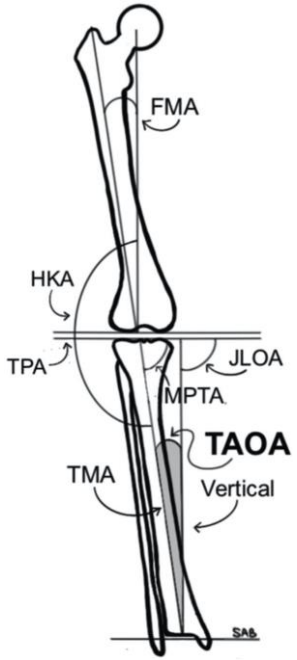
Volume 37, Issue 9, September 2022, Pages 1793-1798



Primary Knee

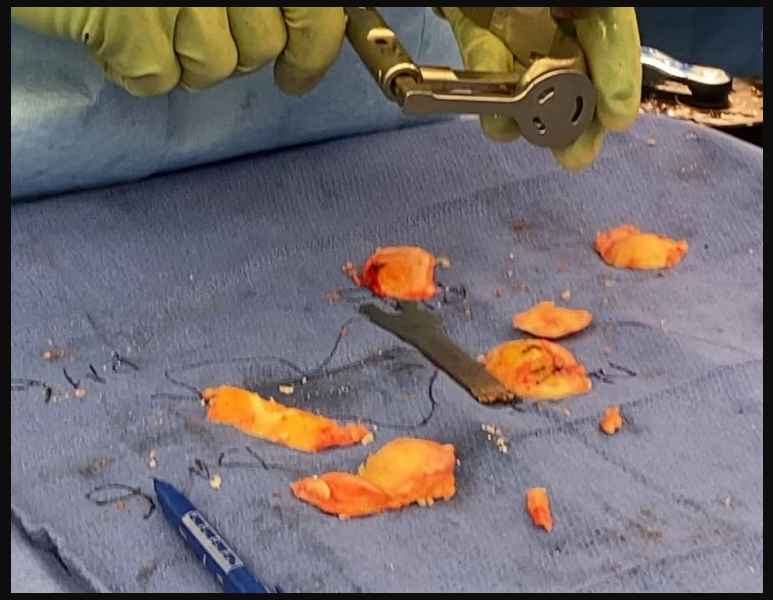
No Correlation Between Clinical Outcomes and Changes in the Tibia-Metaphyseal Angle Following Total Knee Arthroplasty: A Retrospective Study

Matthew Cherches MD, Nathan Coss, Kevin Nguyen, Ryan Halvorson MD, Sachin Allahabadi MD, Stefano Bini MD



Restoration of Extension with KA and Robot

- Elliot Sappey, Stefano Bini 2022
  - Sequential TKAs using Robotic Assisted KA (equal resections)
  - Caliper measured resection, slope and alignment data
  - 36 TKAs , >5 Fixed Flexion Cx vs. <5deg FFCx (Control)
- Results
  - Mean FFCx 11.1 deg (range: 5-25) (0.8 for control, range: 0-4)
  - At closure, <u>all patients <5 deg</u>



Journal of Personalized Medicine

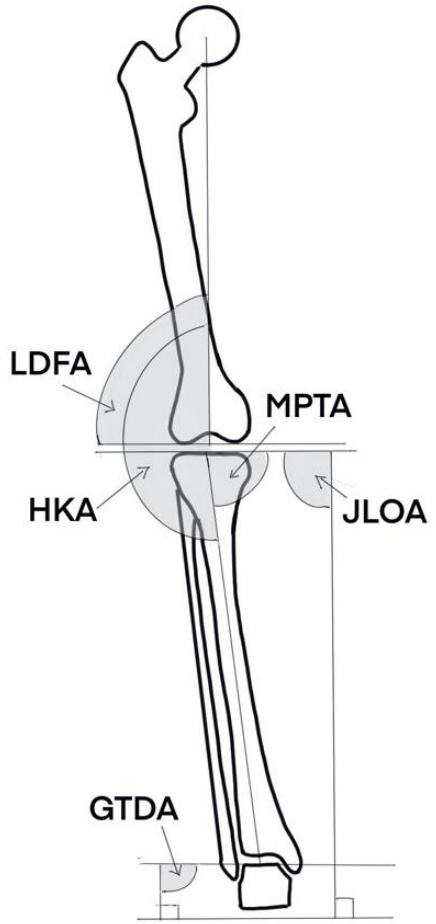
MDPI

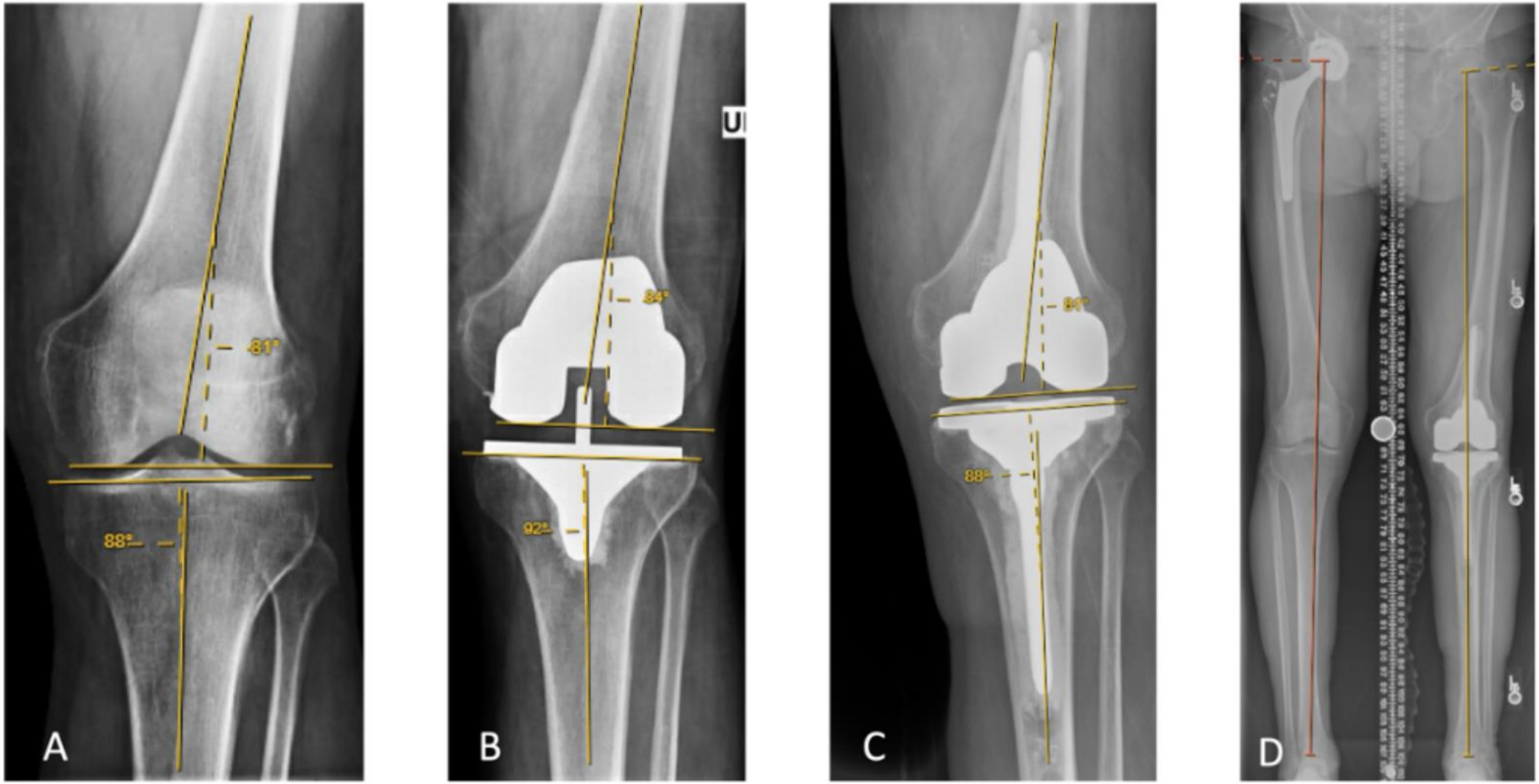
Original article

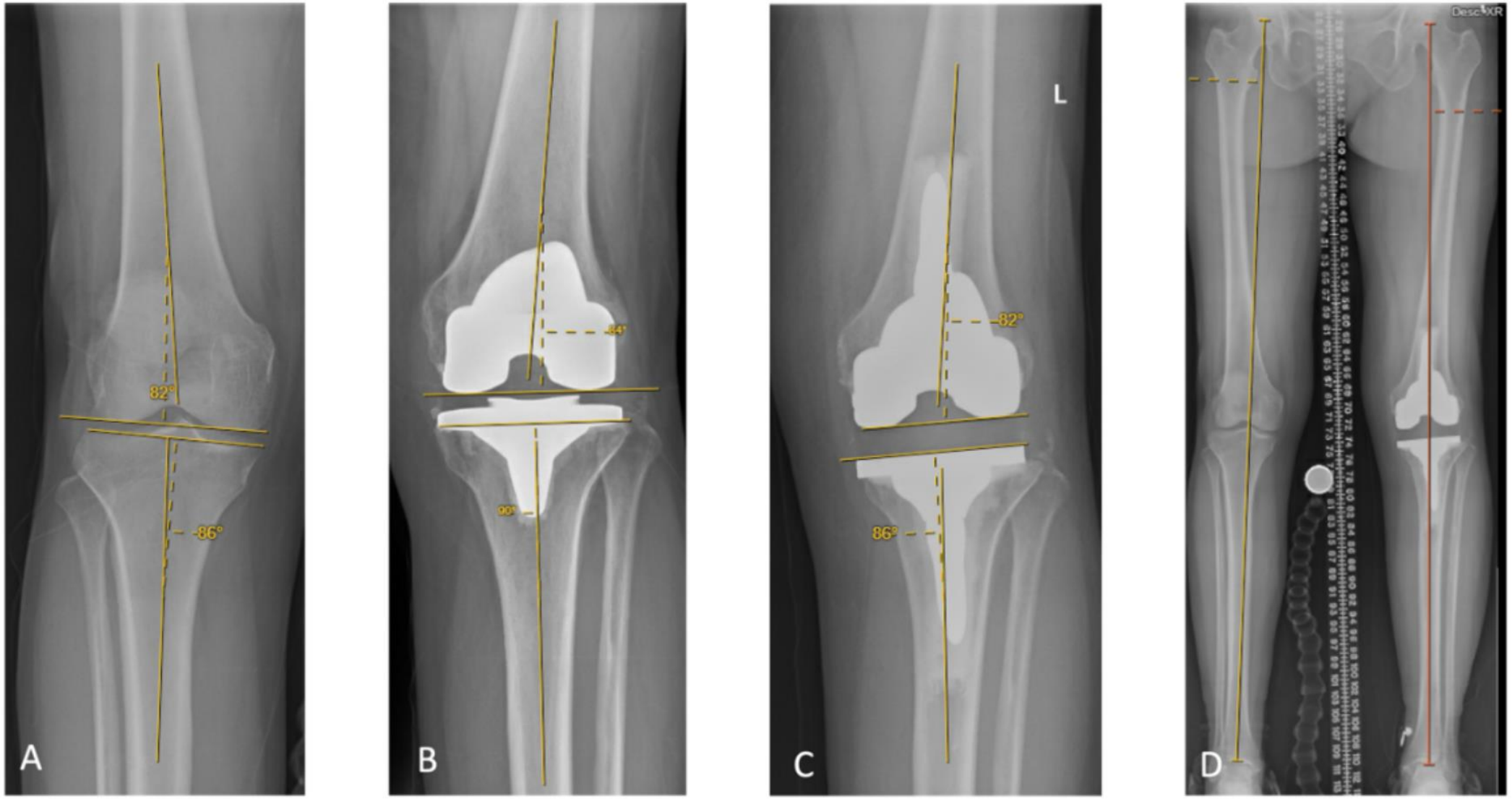
Kinematic alignment of failed mechanically aligned total knee arthroplasty restored constitutional limb alignment and improved clinical outcomes: a case report of 7 patients.

Elliot Sappey-Mariner MD, PhD [1*], Stefano A. Bini MD[1]

- Seven patients revised for stiffness (<90) or mid-flexion instability (>5 deg) after well aligned MA and significant change from constitutional limb alignment.
- KSS improved in all patients
- Mean Flexion gain was 30deg
- MFI resolved in all patients
- Limb alignment restored in all within 2 degrees.




A
81°
88°
B
84°
92°
C
81°
88°
D


82°
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A
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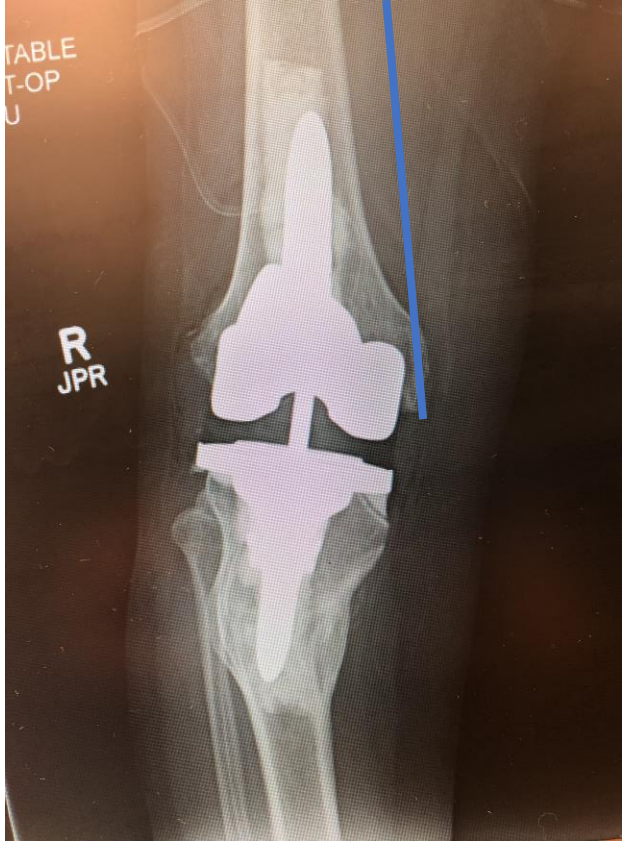
MHE





Severe post traumatic Deformity

- Very pleased: “my knee is straight again”

ROBOTS: My Experience

- 14 months experience
- OR Time is longer
  - For Meticulous KA
  - Bone resections can be +/- 1-2 mm from plan.
- Bone cuts are individually made and not linked
- MPS knowledge base is critical
- Data is addictive
- Results seem comparable to manual KA

Accuracy of Robotic TKA vs Manual

- Deckey et al, BJJ 2021
- 100% MA sequential TKAs
- Robot (96) vs Manual (103)
- All angular parameters R>M (p<.001)
- 50% fewer femoral recuts

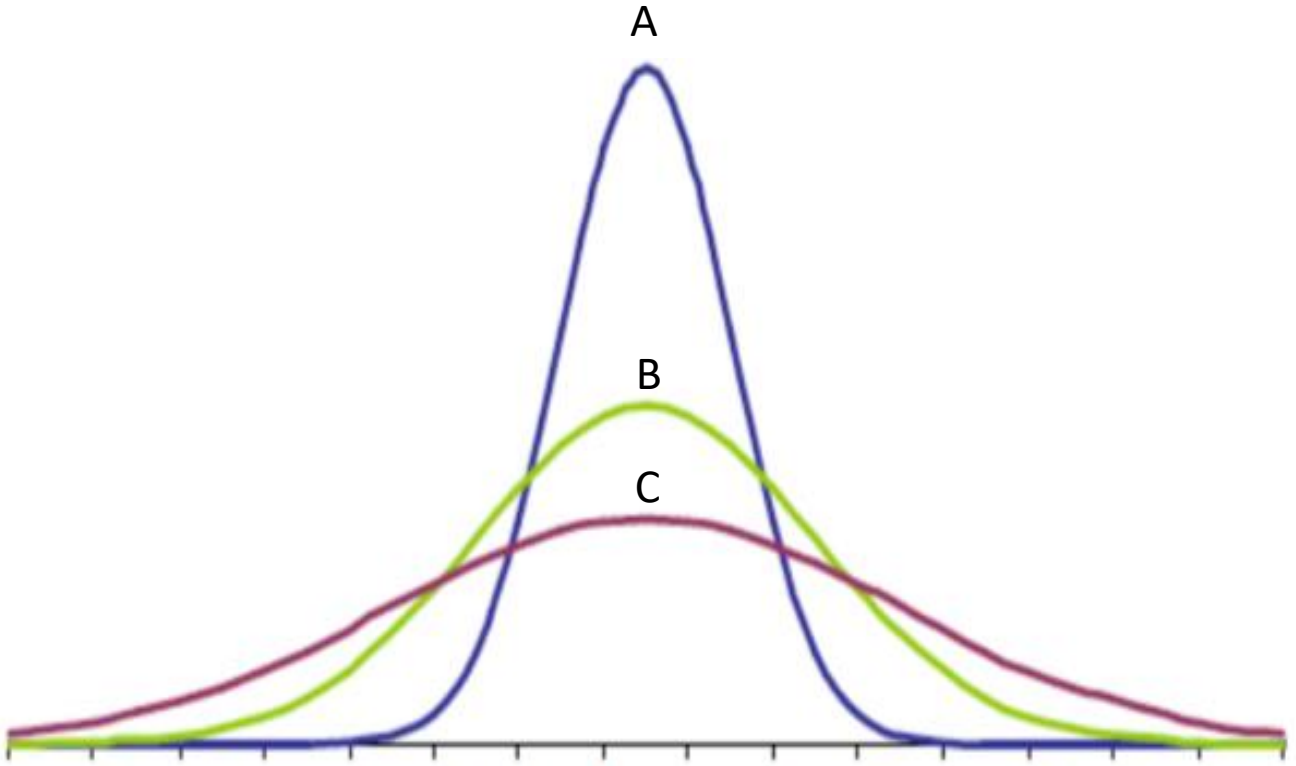
The Bone & Joint Journal, Vol. 103-B, No. 6 Supple A | The Knee Society

Robotic-assisted total knee arthroplasty improves accuracy and precision compared to conventional techniques

David G. Deckey, Christian S. Rosenow, Jens T. Verhey, Joseph C. Brinkman, Cory K. Mayfield, Henry D. Clarke, Joshua S. Bingham

Published Online:31 May 2021https://doi.org/10.1302/0301-620X.103B6.BJJ-2020-2003.R1

Why Robots?



MA vs KA using Same Knee and Robot

- Elbuluk, Jerabek et al, JOA 2022
- 100 consecutive patients KA vs 100 MA (Power Analysis : 94 patients)
  - FJS
    - **KA better** 1 and 2 years (p<.001)
  - KOOS
    - **KA Better** 6 wk (p= <0.5), 1 year (p= <0.5), 2 years (p=.09)
  - VAS
    - **KA better** 6 weeks (p= .04)
  - ROM
    - similar
  - VR12
    - similar

Table 1. Mechanical Alignment vs Kinematic Alignment: FJS.

FJS	MA	KA	*P*-Value
6 wk	57.2 ± 8.9	53.4 ± 6.4	NS
1 y	72.4 ± 5.8	88.2 ± 6.9	<.001
2 y	77.6 ± 7.1	92.0 ± 5.3	<.001

FJS, Forgotten Joint Score; MA, mechanical alignment; KA, kinematic alignment; NS, not significant.

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PROMS Arthroplasty

- Accepted Standard
- PROMs
- Widely available
  - Patient Centric
  - Widely adopted in the late 90's early 2000's
- **Is this the BEST we can do in 2022**

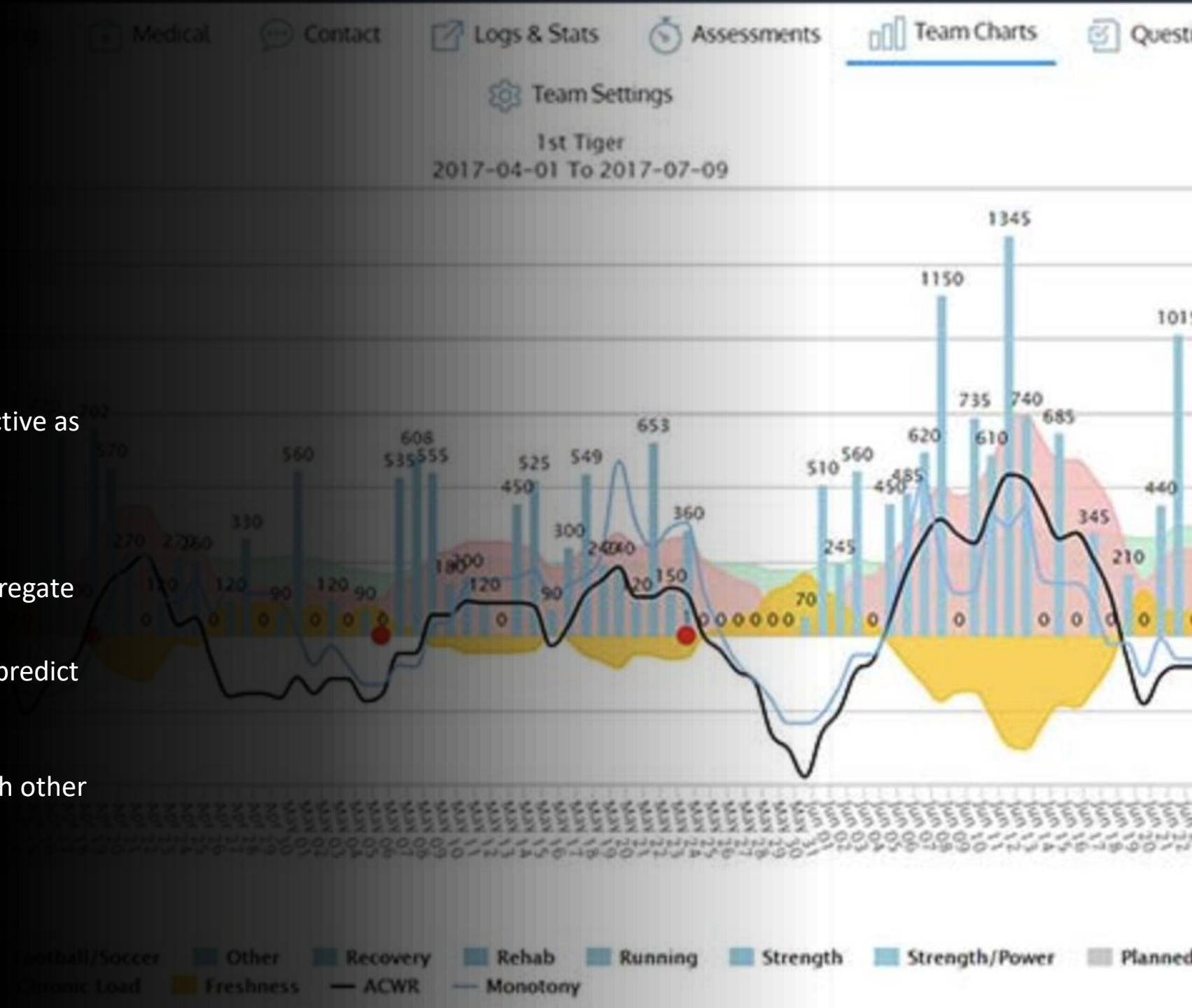
Physical Function	1. Descending stairs	0	1	2	3	4
	2. Ascending stairs	0	1	2	3	4
	3. Rising from sitting	0	1	2	3	4
	4. Standing	0	1	2	3	4
	5. Bending to floor	0	1	2	3	4
	6. Walking on flat surface	0	1	2	3	4
	7. Getting in / out of car	0	1	2	3	4
	8. Going shopping	0	1	2	3	4
	9. Putting on socks	0	1	2	3	4
	10. Lying in bed	0	1	2	3	4
	11. Taking off socks	0	1	2	3	4
	12. Rising from bed	0	1	2	3	4
	13. Getting in/out of bath	0	1	2	3	4
	14. Sitting	0	1	2	3	4
	15. Getting on/off toilet	0	1	2	3	4
	16. Heavy domestic duties	0	1	2	3	4
	17. Light domestic duties	0	1	2	3	4

Research

- UCSF experience with sensors in Arthroplasty

What we learned about sensors in Arthroplasty

- Absolute data measures are not as predictive as longitudinal data
- Sensor accuracy is not as important as its consistency
- Second by second data is better than aggregate data
- By 11 days, the activity trend lines could predict PROMs at 6 weeks
- Spot checks that compare “point in time” variables showed no correlation with each other



Continuous data monitoring + AI

- Continuous data monitoring through wearable sensor
  - Low cost
  - Easy to use
  - Low energy
  - Edge computing
  - Connected data sharing
  - Continuously learning

BMIL
Biomechanics & Musculoskeletal Imaging Lab

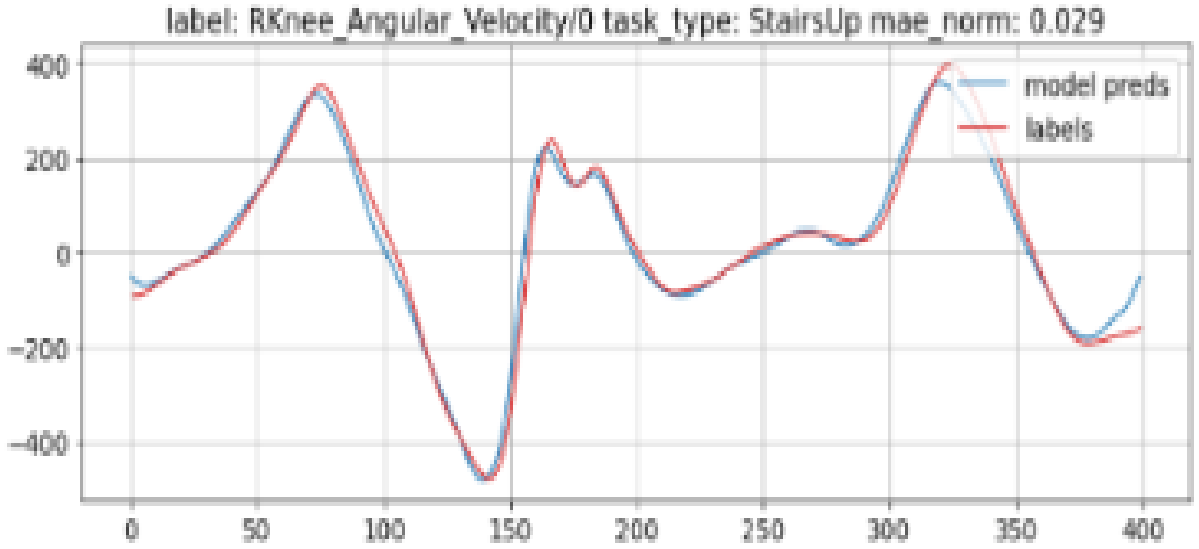
UCSF Human Performance Center

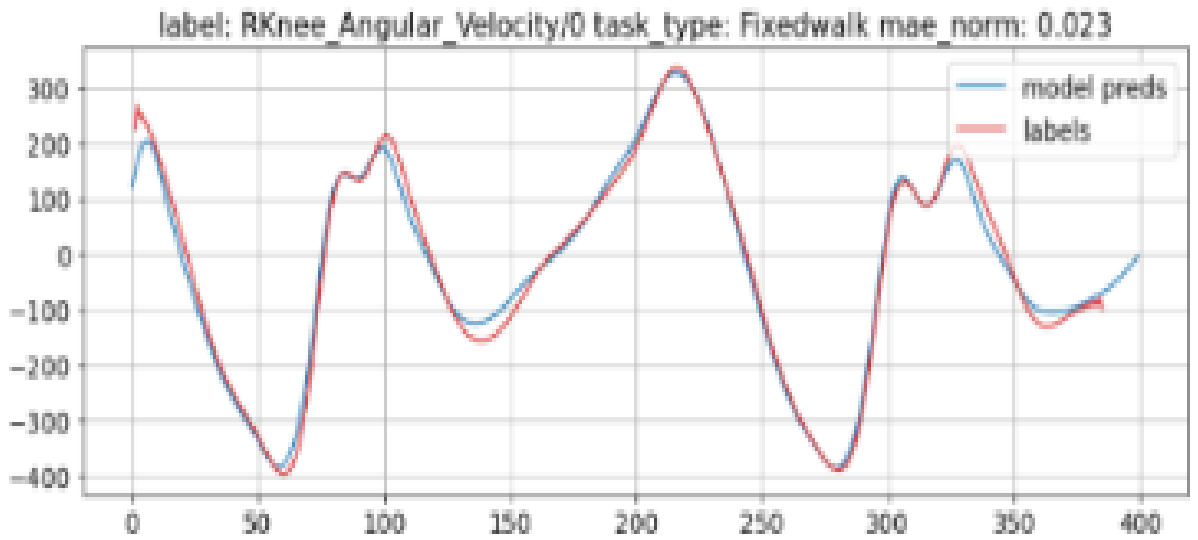
UCSF

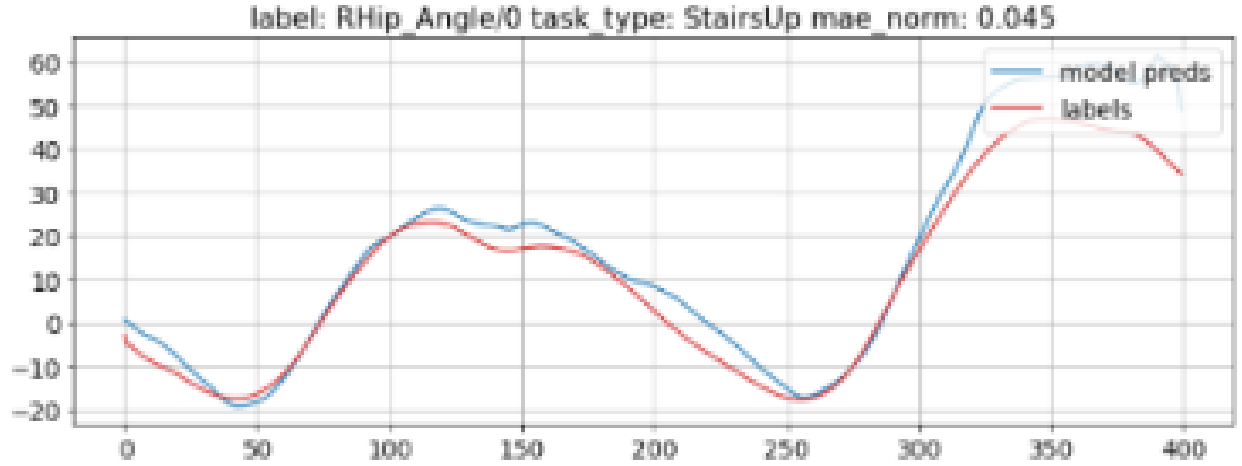
Personalized
Dynamic
Sensor Derived
Open Access
Objective Outcome
Measure
TKA

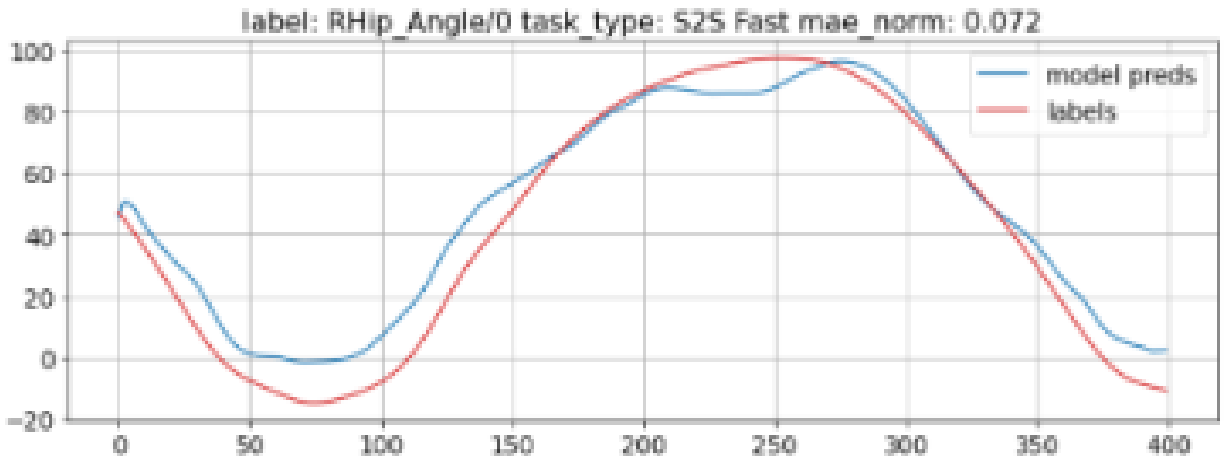
- Personalized: user specific inputs
  - add data, demographic data, SDH data, zip code, nationality, etc
  - Expand normative data set to provide a phenotypically accurate comparison
- Dynamic: variable feature selection not fixed.
  - Let the algorithm select the from the available data what is the most reliable/accurate amongst the data available at that moment
- Open Access
  - Accepts input variables obtained from any device
  - Open Data Set, Open Algorithm
  - Inexpensive sensor

UCSF
University of California
San Francisco

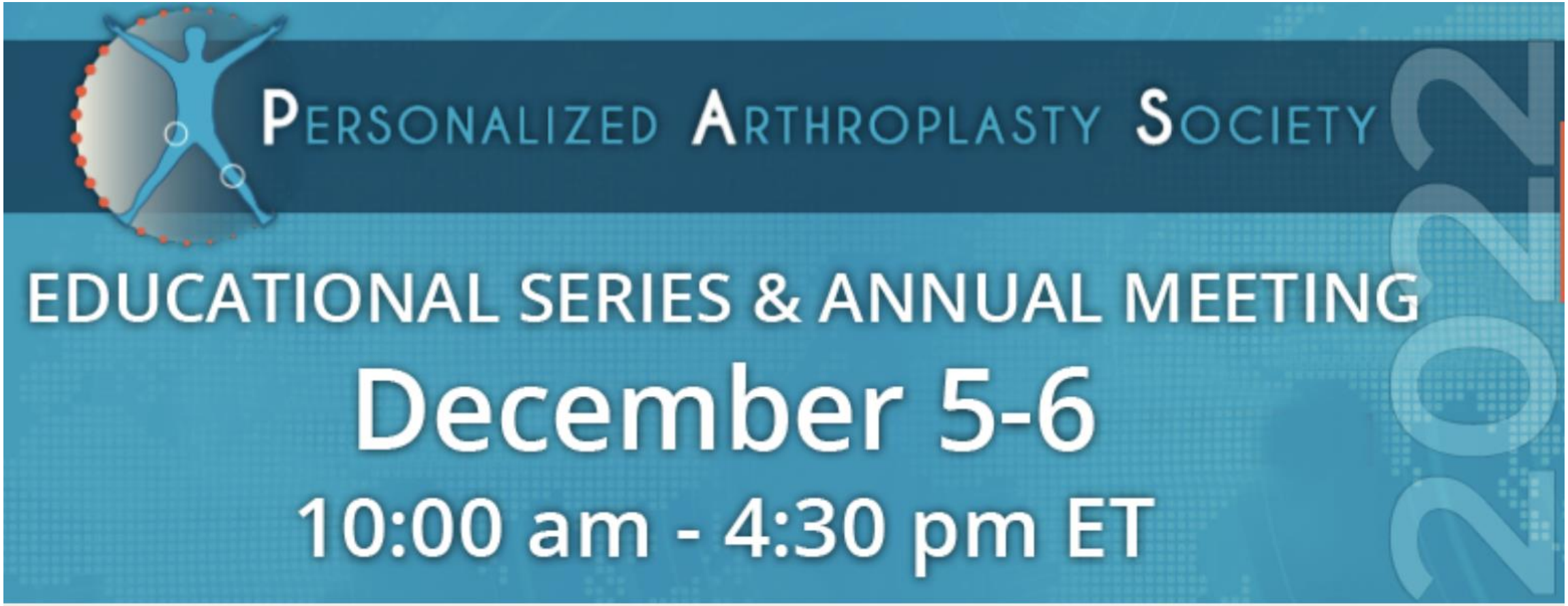








Mean absolute error <0.5



www.personalizedarthroplasty.org

Launched in May, 2020.

473 Followers on L.I., 153 member, 9 committees, 27 countries

Bottom Line

- KA and its variants are generally better than MA in most functional aspects (Especially ROM and lack of MFI)
  - But clear superiority has not been demonstrated
  - SDOM
  - Reader beware
- Most surgeons using Robotics move towards more Personalized cuts
- No increased failure rate due to mechanical loosening or wear
- IMO the coronal tibial plane has been a bit of a red herring
  - The game is going to play out with Femoral Component Rotation
  - Medial Stabilized designs on the tibia
  - Patellar/Trochlear alignment

Thank you.