Robotics in Hip and Knee Replacement

All About Orthopedics
7th Annual Conference

Creighton
UNIVERSITY

John M. Wright, MD
9/23/22

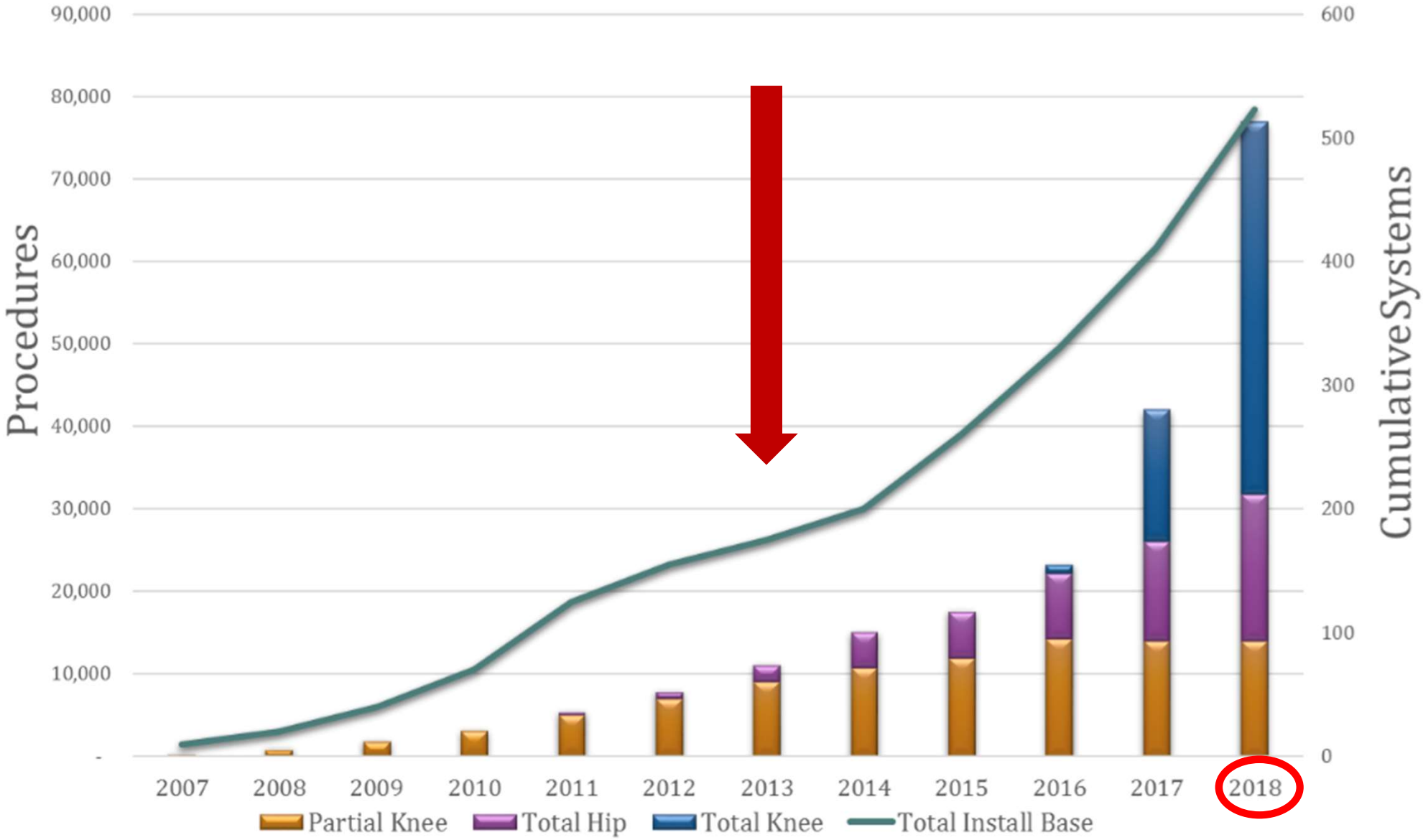
Disclosure

- I am a consultant for *Stryker, Inc*
  - *Stryker* produces and distributes hip and knee implants and associated robotic technology.
  - *I have not and will not accept any honorarium, additional payments, or reimbursements for giving this presentation.*

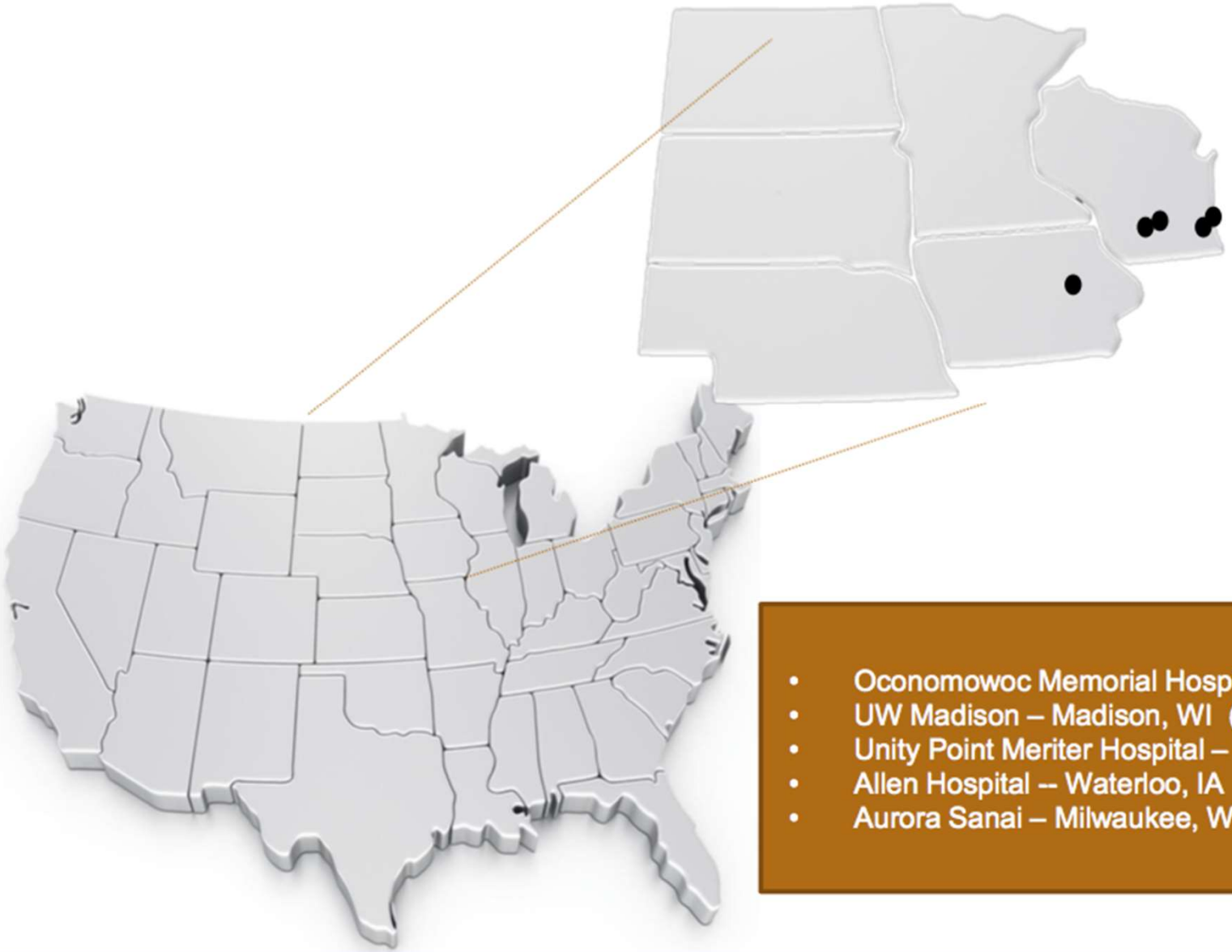
Goals

- What is this technology?
- How do we apply it to patients?
  - Hip replacement
  - Partial knee replacement
  - Total knee replacement
- How can it benefit our patients?

US Robotic Market Growth
2007-2018 (one company)

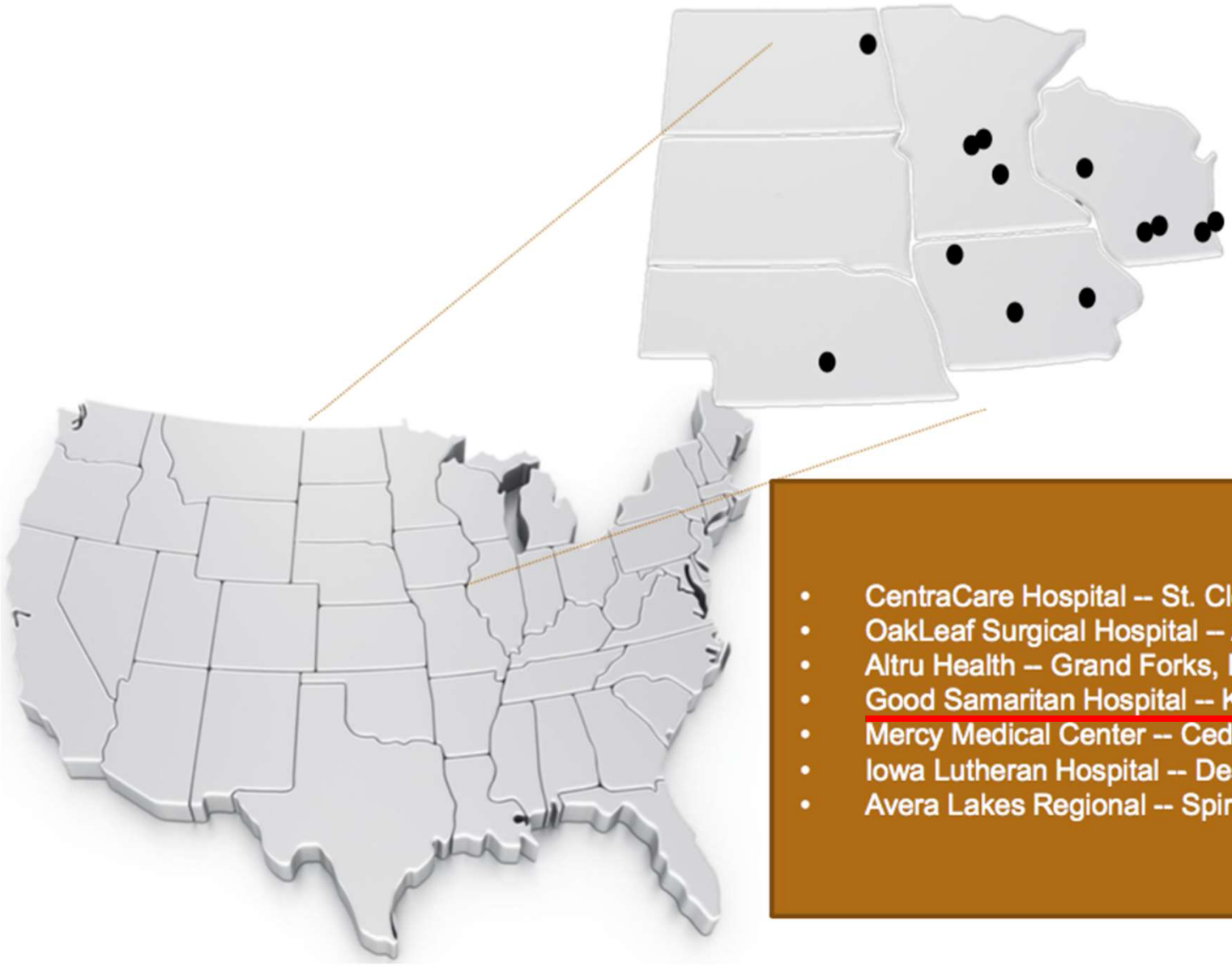


2014 5 Systems in the Midwest



- Oconomowoc Memorial Hospital – Milwaukee, WI (June 2009)
- UW Madison – Madison, WI (December 2009)
- Unity Point Meriter Hospital – Madison, WI (December 2009)
- Allen Hospital – Waterloo, IA (September 2010)
- Aurora Sanai – Milwaukee, WI (December 2012)

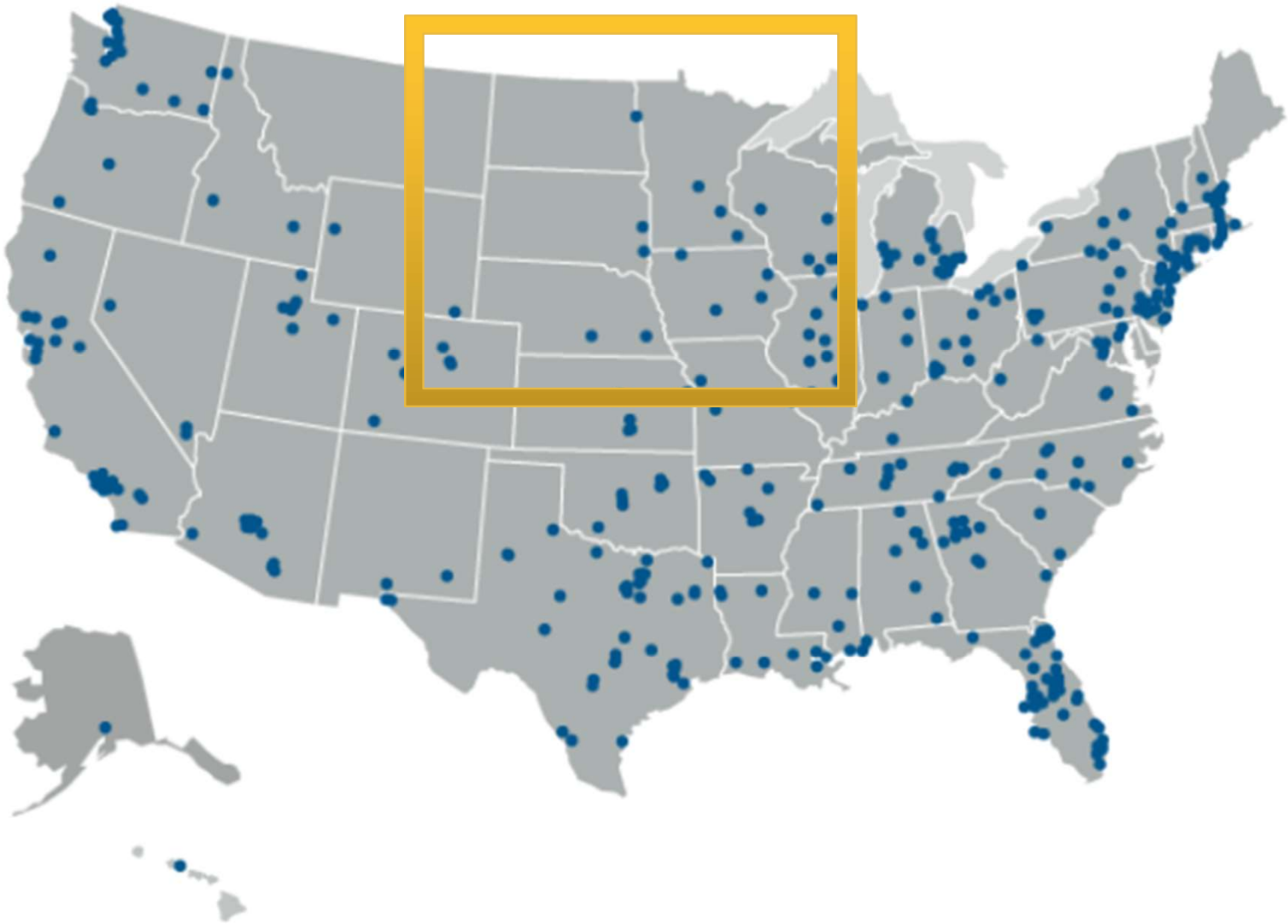
2016 13 Systems in the Midwest



- CentraCare Hospital -- St. Cloud, MN (March 2016)
- OakLeaf Surgical Hospital – Altoona, WI (March 2016)
- Altru Health – Grand Forks, ND (June 2016)
- Good Samaritan Hospital -- Kearney, NE (July 2016)
- Mercy Medical Center -- Cedar Rapids, IA (September 2016)
- Iowa Lutheran Hospital -- Des Moines, IA (September 2016)
- Avera Lakes Regional -- Spirit Lake, IA (September 2016)

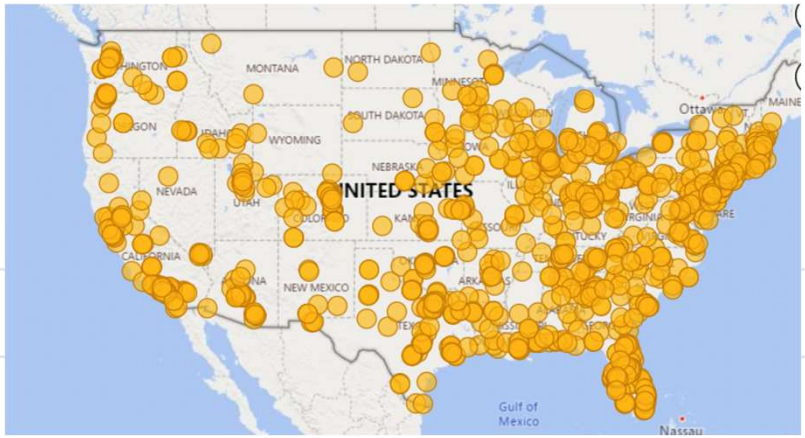
US Robotic Market Growth

2019 (one company): N=669 units



US Robotic Market Growth

2021 (one company) N=1131 units in the US



1131 total Mako Systems in the U.S.

Acquisition

Total Knee

U.S. procedures

Cumulative U.S. Systems

180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
-

1200
1000
800
600
400
200
0

2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

Mako Partial Knee
Mako Total Hip
Mako Total Knee
Total Install Base

The Major Implant Companies all now offer robotic tech.

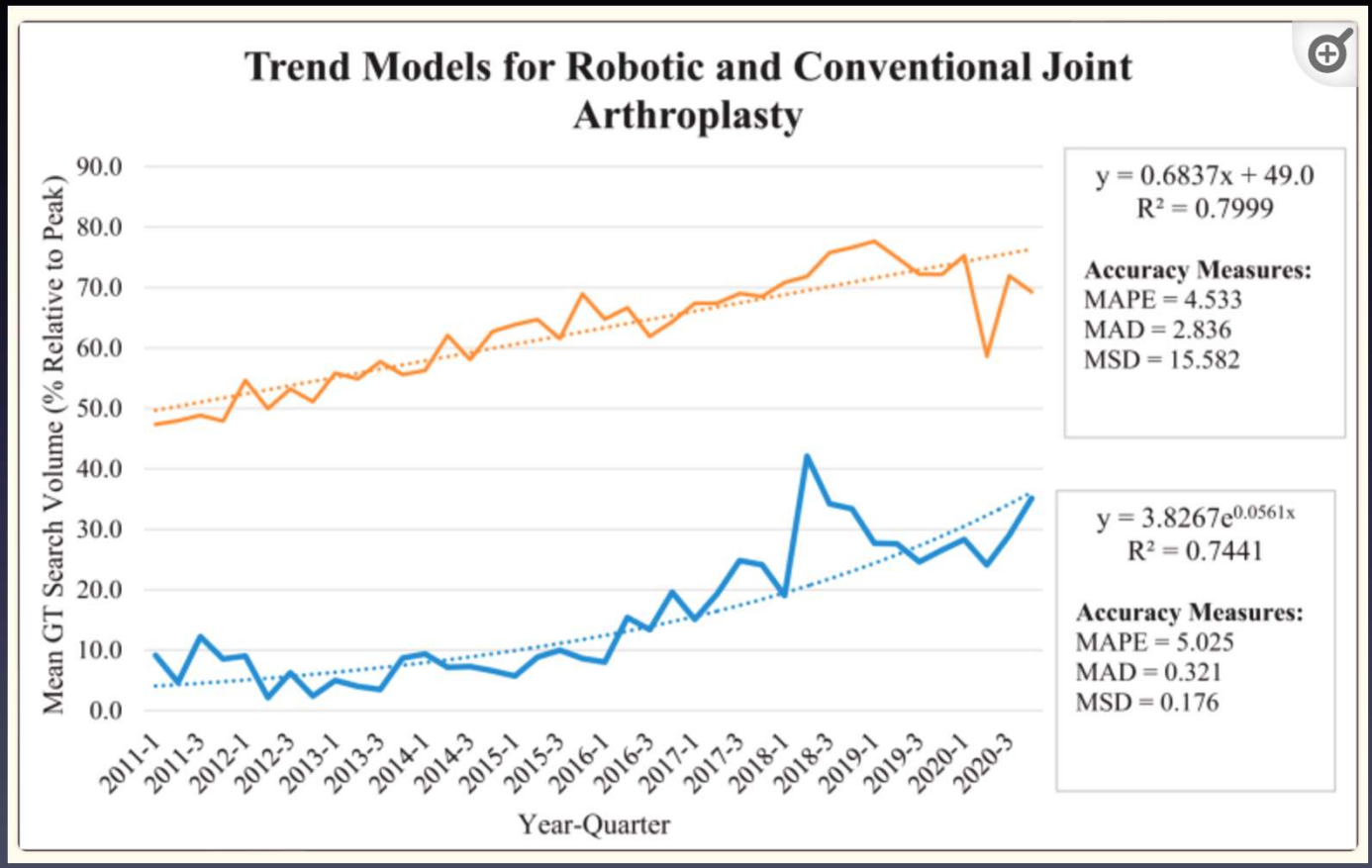
Company:	**Stryker** ***(Mako)***	**Corin** ***(OMNIbotics)***	**Smith&N** ***(Navio)***	**Zimmer** ***(Rosa)***	**Depuy** ***(Velys)***
Date launched & indications:	PKA: 2006 THA: 2011 TKA: 2016	TKA: 2011	PKA: 2013 TKA: 2017	TKA: 2019 PKA: 2021 THA: 2021	TKA: 2021

TKA = Total Knee
PKA = Partial Knee
THA = Total Hip

Arthroplast Today. 2022 Jun; 15: 13–18.
Published online 2022 Mar 24. doi: 10.1016/j.artd.2022.02.015
PMCID: PMC8961076
PMID: 35360676

Patient Interest in Robotic Total Joint Arthroplasty Is Exponential: A 10-Year Google Trends Analysis

Joseph C. Brinkman, MD,[a,*] Zachary K. Christopher, MD,[a] M. Lane Moore, BS,[b] Jordan R. Pollock, BS,[b] Jack M. Haglin, MD,[a] and Joshua S. Bingham, MD[a]

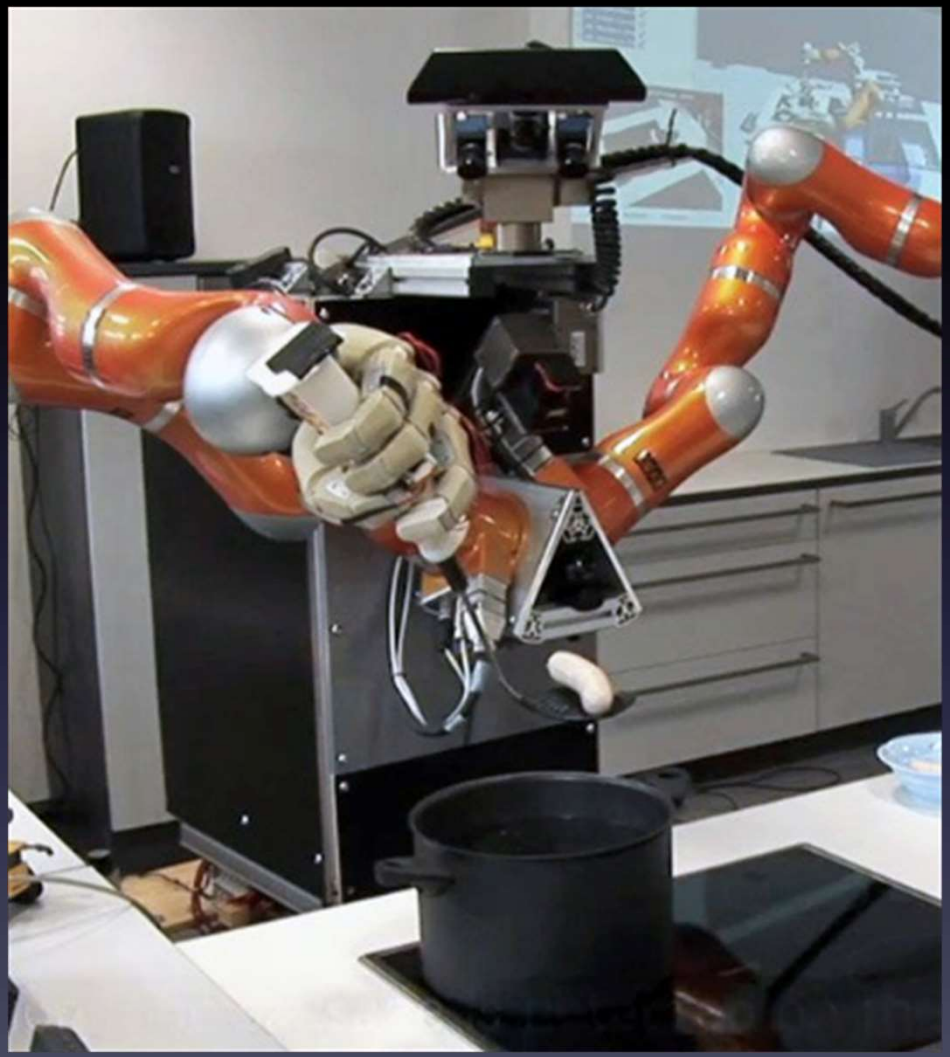


Google trends tool (2011-2021)

What is this technology?

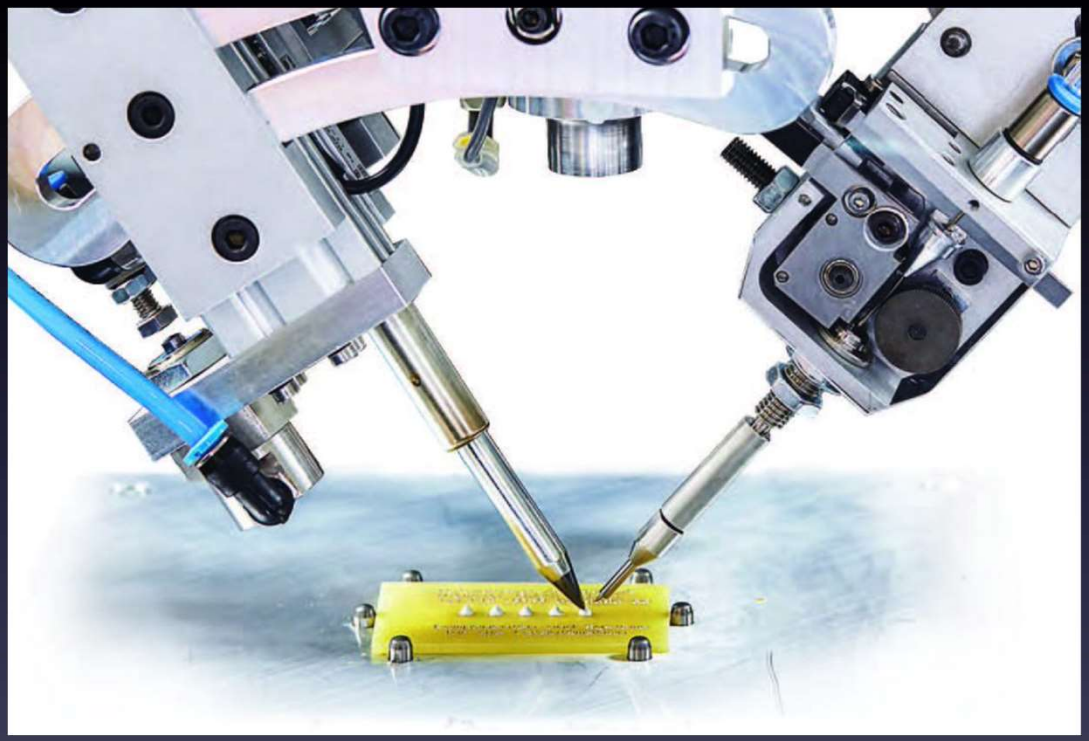
- Very sophisticated pre-operative planning tool and intra-operative alignment tool

Robot Definition:



- A machine (especially one programmable by a computer) capable of carrying out a complex series of tasks automatically.

Characteristics associated with Robots



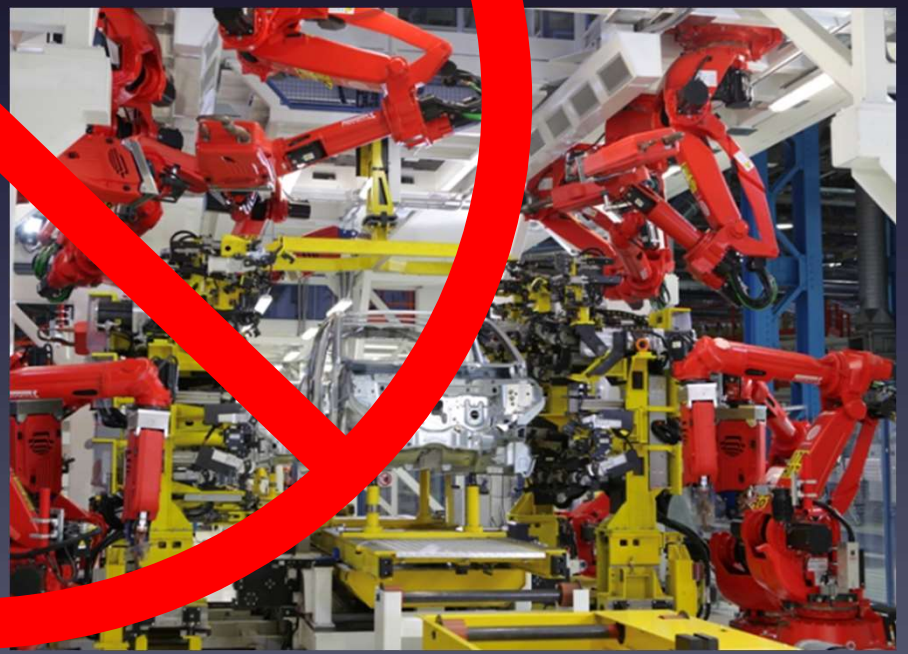
- Perform tasks with great accuracy & precision

Characteristics associated with Robots

- Execute tasks better / more reproducibly than humans

Characteristics associated with Robots

- Autonomou once programmed)
  - Perform asks ind pendently
  - Replaci g human role



Characteristics associated with Robots

- Independent decision making (once programmed)
  - Without human interaction

Characteristics associated with Robots

- Efficiency and accuracy confer cost savings.

- "No industry has ever seen robotic technology be introduced and ultimately not show an increase in production capacity, improved accuracy and precision, and lower cost."

  – *Jacofsky: J Arthroplasty 31(2016)2353-2363*

What this Robotic technology is NOT:

- Does NOT perform surgery independently
- Does NOT make decisions on its own
- Does NOT do anything to the patient without the surgeon's hand

Robotic arm assisted joint replacement with computer navigation

Robotic Arm Technology is an Alignment Tool

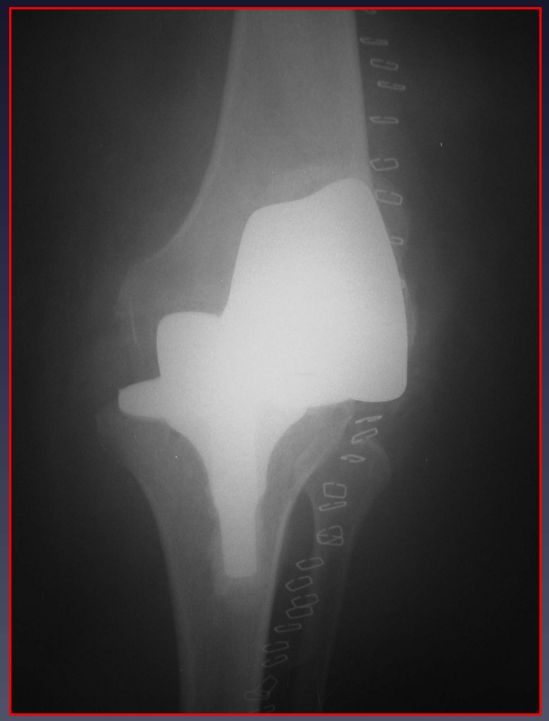
Premise #1:

Alignment Matters

- Appropriate alignment of hip and knee implants:
  - Improves function
  - Decreases complications
  - Optimizes durability

Knee Component Malalignment

- Accelerated wear
- Component loosening
- Pain
- Instability
- Stiffness



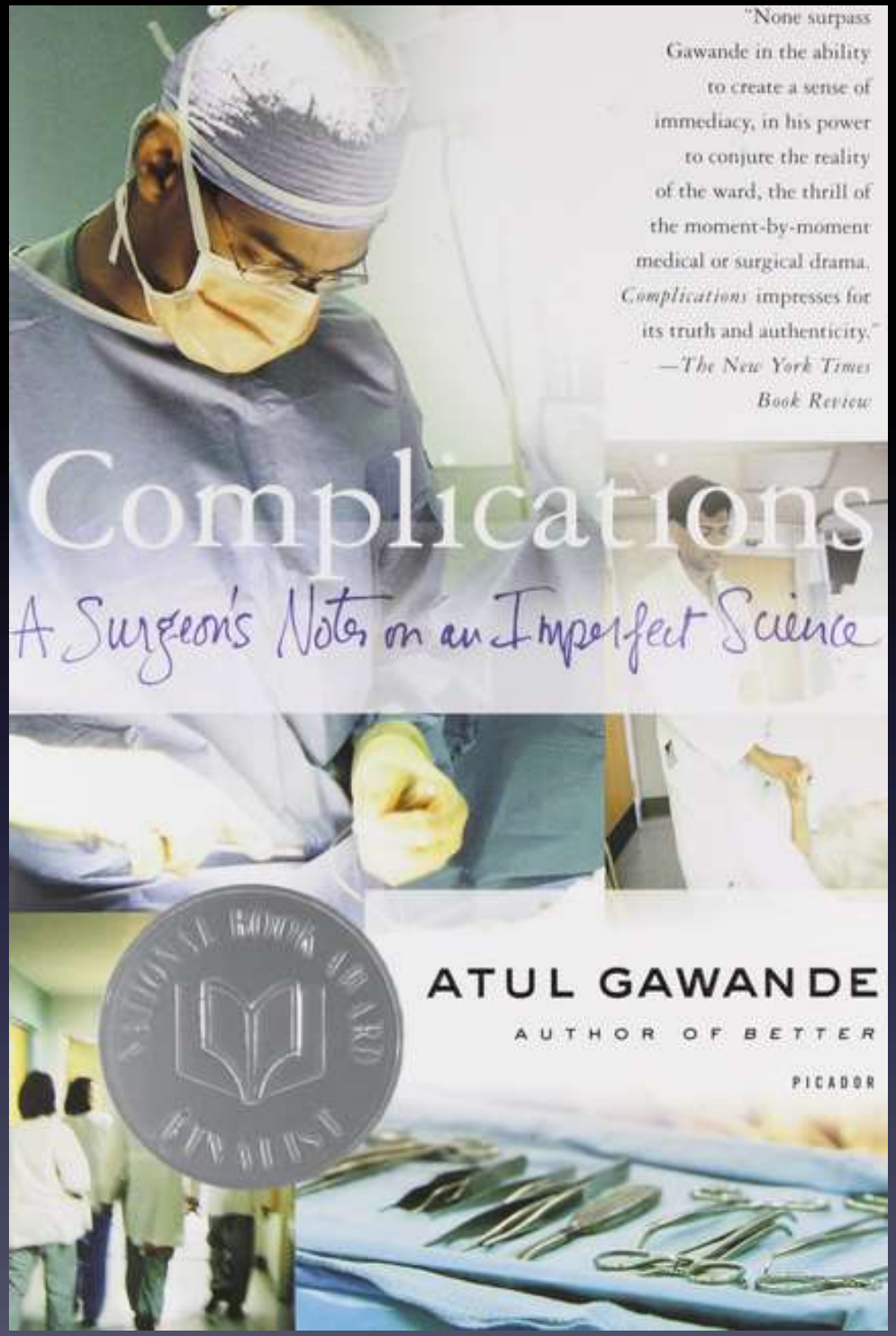
Hip Component Malalignment

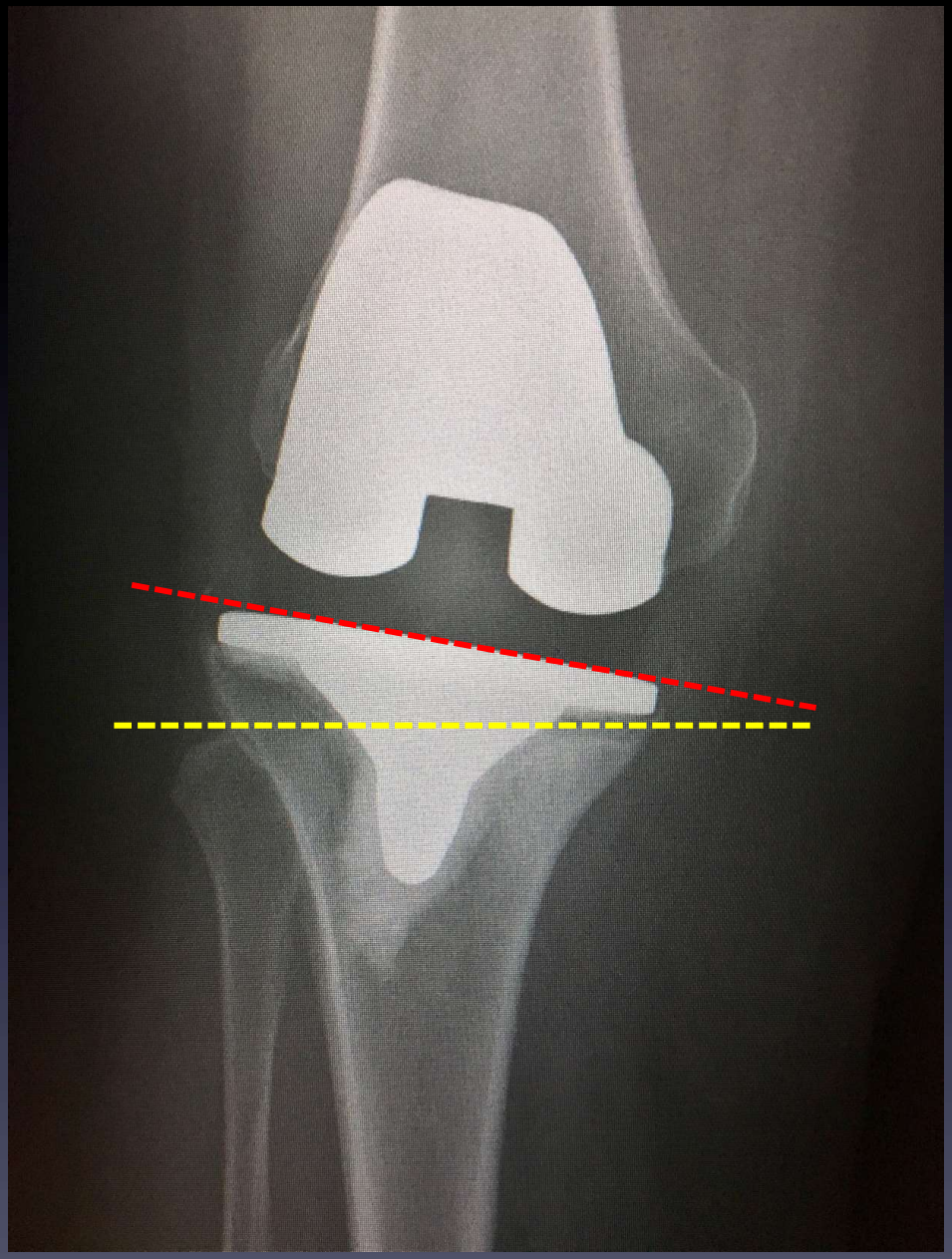
- Dislocation
- Accelerated wear
- Component loosening
- Pain
- Leg length discrepancy

Premise #2:

Humans are fallible

“”It may be in the nature of surgery itself to want to come to grips with the uncertainties of practical medicine. Surgery has become as high tech as medicine gets, but the best surgeons retain a deep recognition of the limitations of both science and human skill.”





What reasonable surgeon (*or patient*) would not want technology that allowed more precise pre-op planning and more precise execution of their pre-op plan if such technology was available ?

Why Now?

- Evolution of technology

Why Now?

- Orthopaedic device industry
  - Driving quality of care
  - Better instrumentation an enticement to use their implants
  - Better alignment will confer superior outcomes of their implants

Why Now?

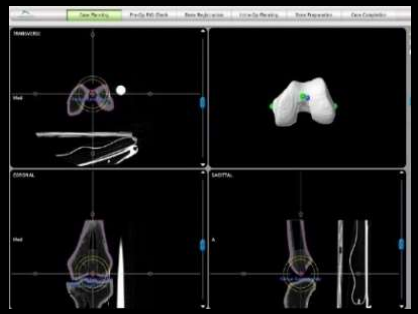
- Direct to consumer advertising

Robotic Technology in Joint Replacement

3 essential facets:

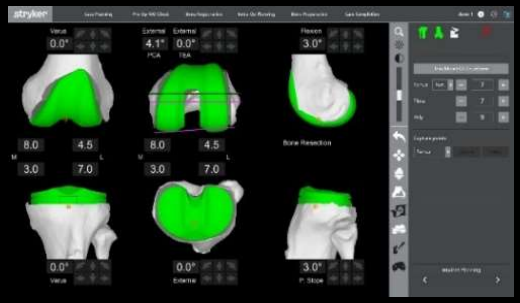
Facet #1
Pre-op, patient specific, 3-D planning

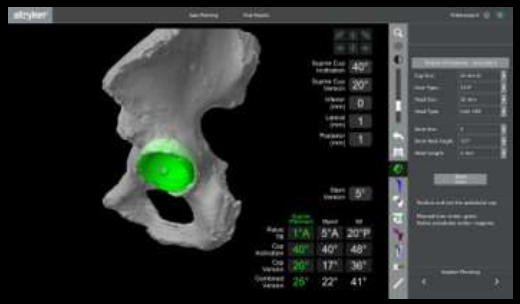
CT scan



- CT based
- 3-D template for sizing and aligning the implants
- Virtual plan

Preplanning





Facet #2
Intra-operative virtual feedback

- GPS analogy

- Adjustment of pre-op virtual plan according to intra-operative feedback

- Intra-Operative patient specific customization

Facet #3
Precise bone preparation

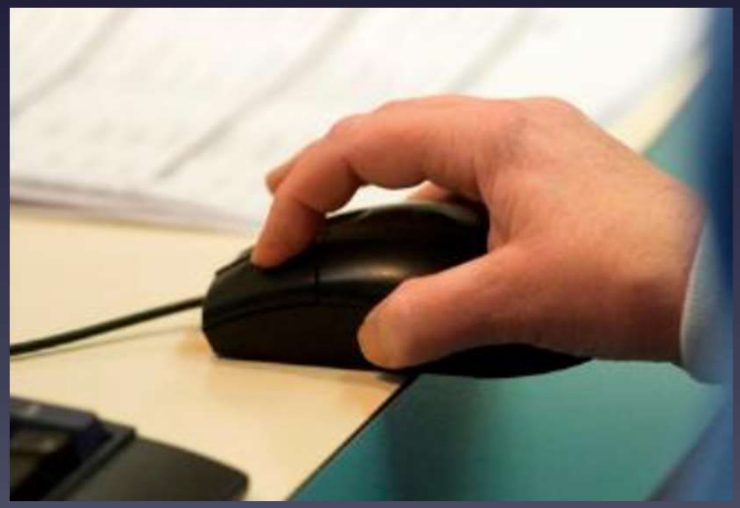
- Precise bone preparation (execution of the virtual plan) with the guidance of a haptic robotic arm.

Haptics

- Science of physical interaction between humans and computers

Haptic Device

- A device that involves physical contact between the computer and the user through an input/output device that senses body movements
  - *joystic*
  - *mouse*
  - *virtual reality glove*

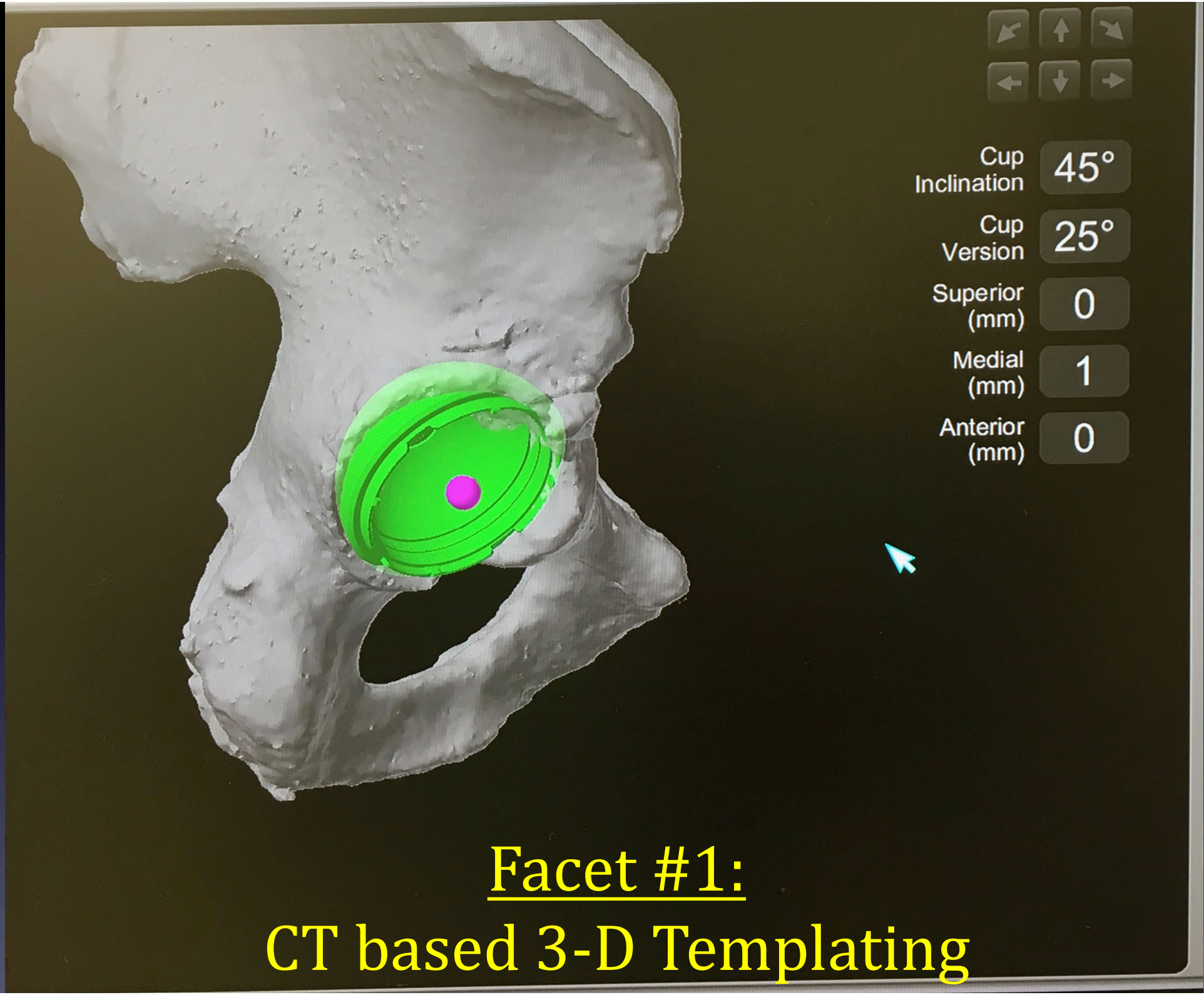


Robotic arm is a haptic tool

- Controls the surgeon's bone preparation tools
  - According to the surgeon's pre-op virtual plan
  - Surgeon no longer dependent upon cutting blocks, jigs, and manual techniques.
  - Haptic boundaries protect the patient

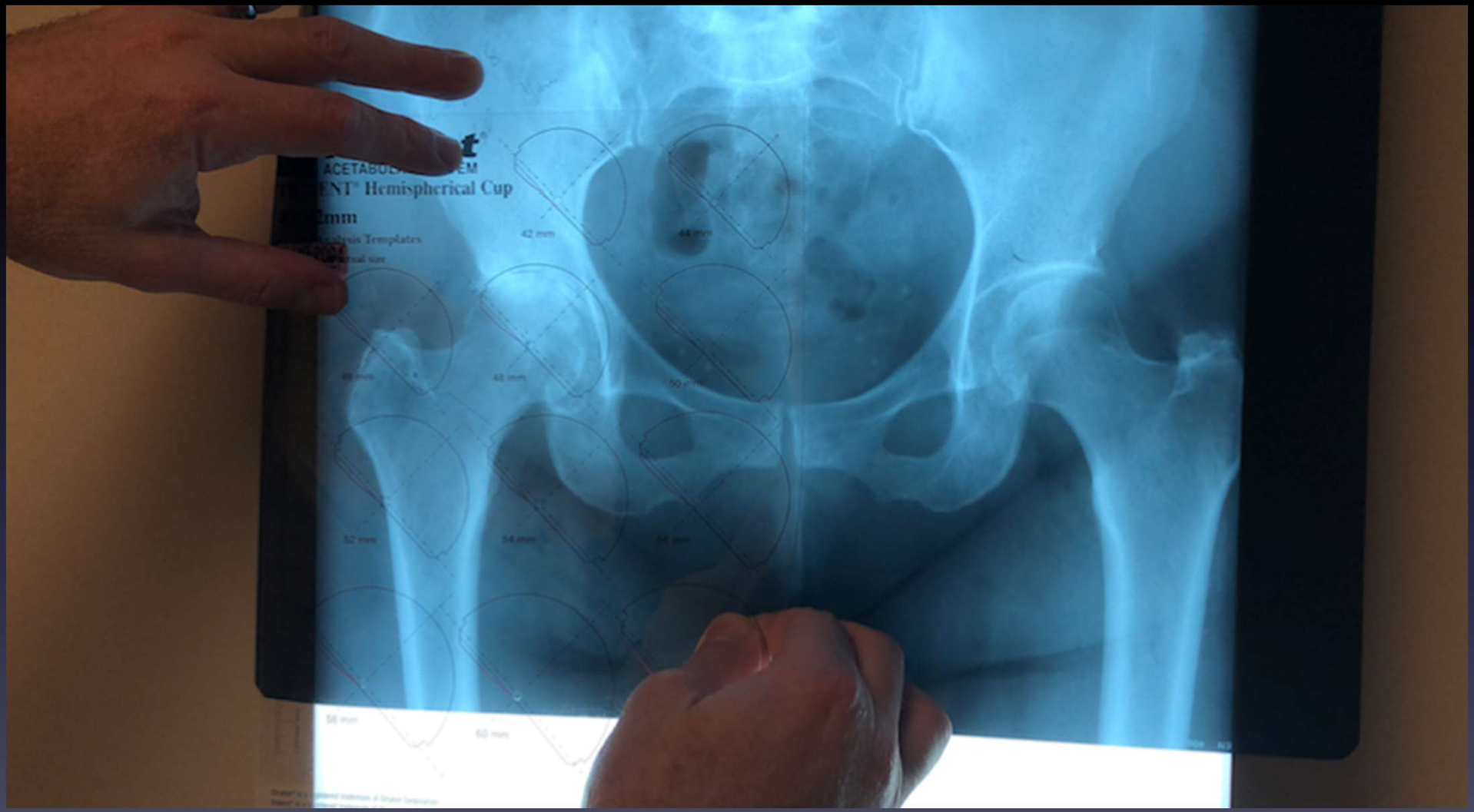
Robotic Arm Assisted Surgery

Hip Replacement Application

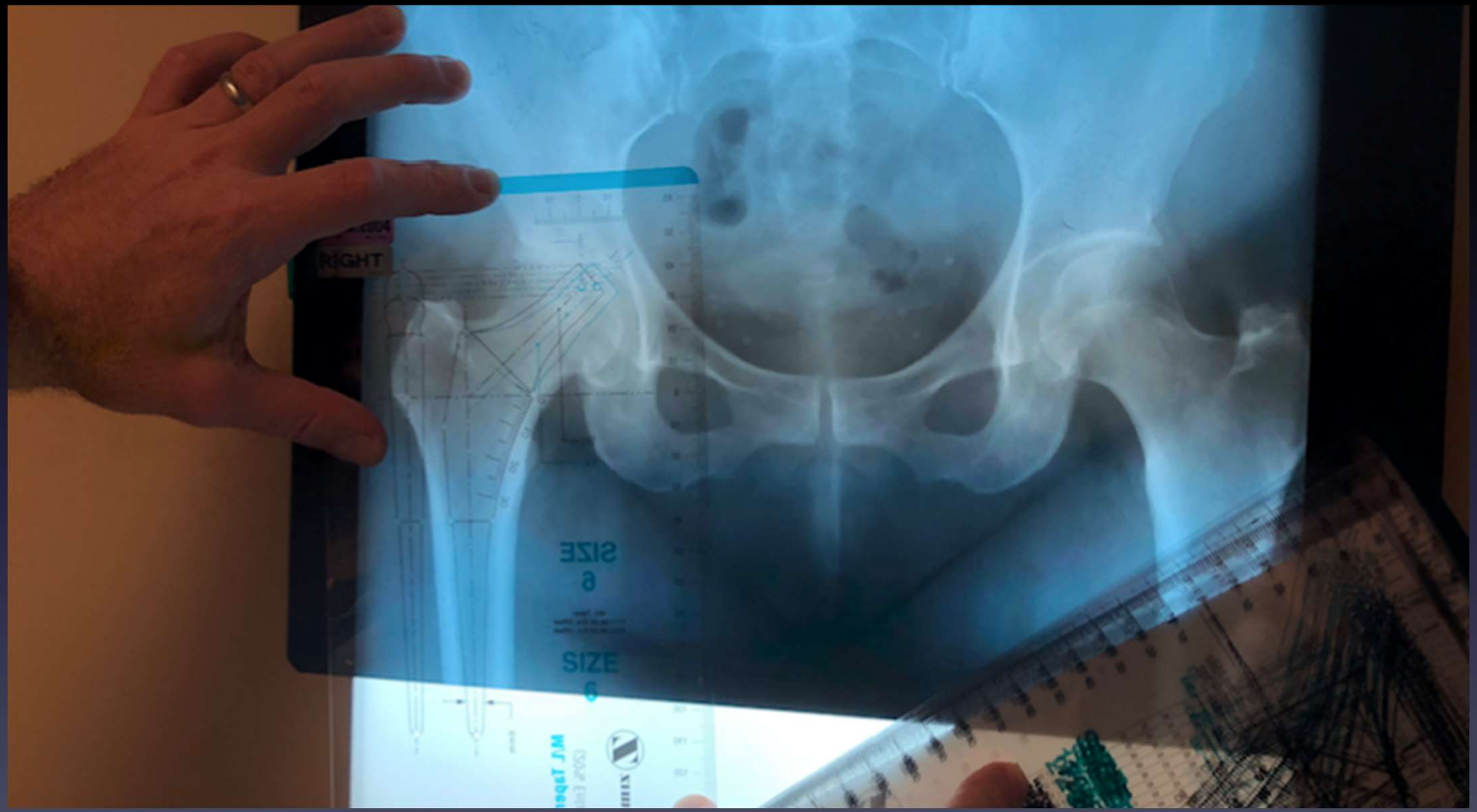


Facet #1:
CT based 3-D Templating

Traditional 2-D Manual Templating

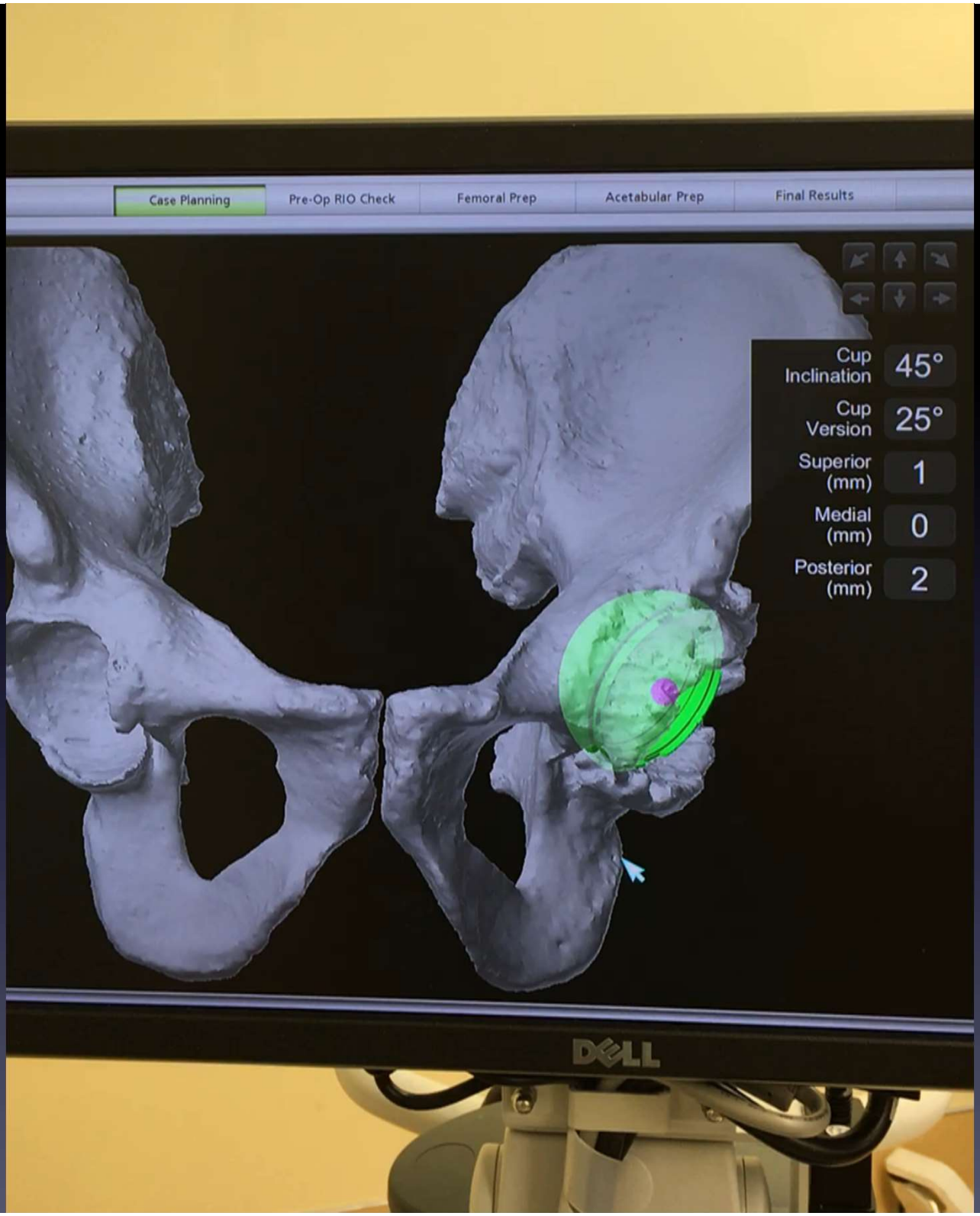


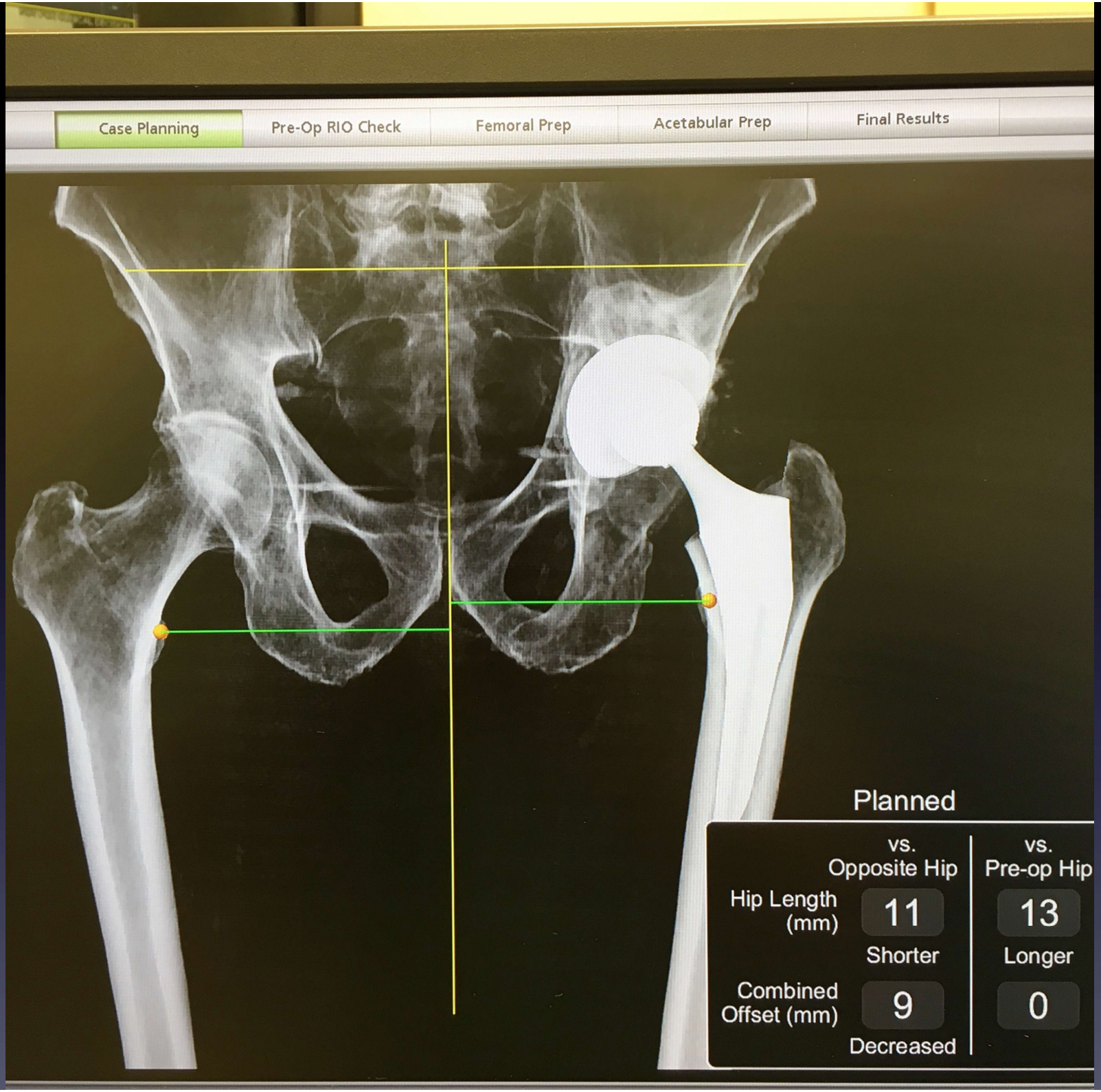
Traditional 2-D Manual Templating

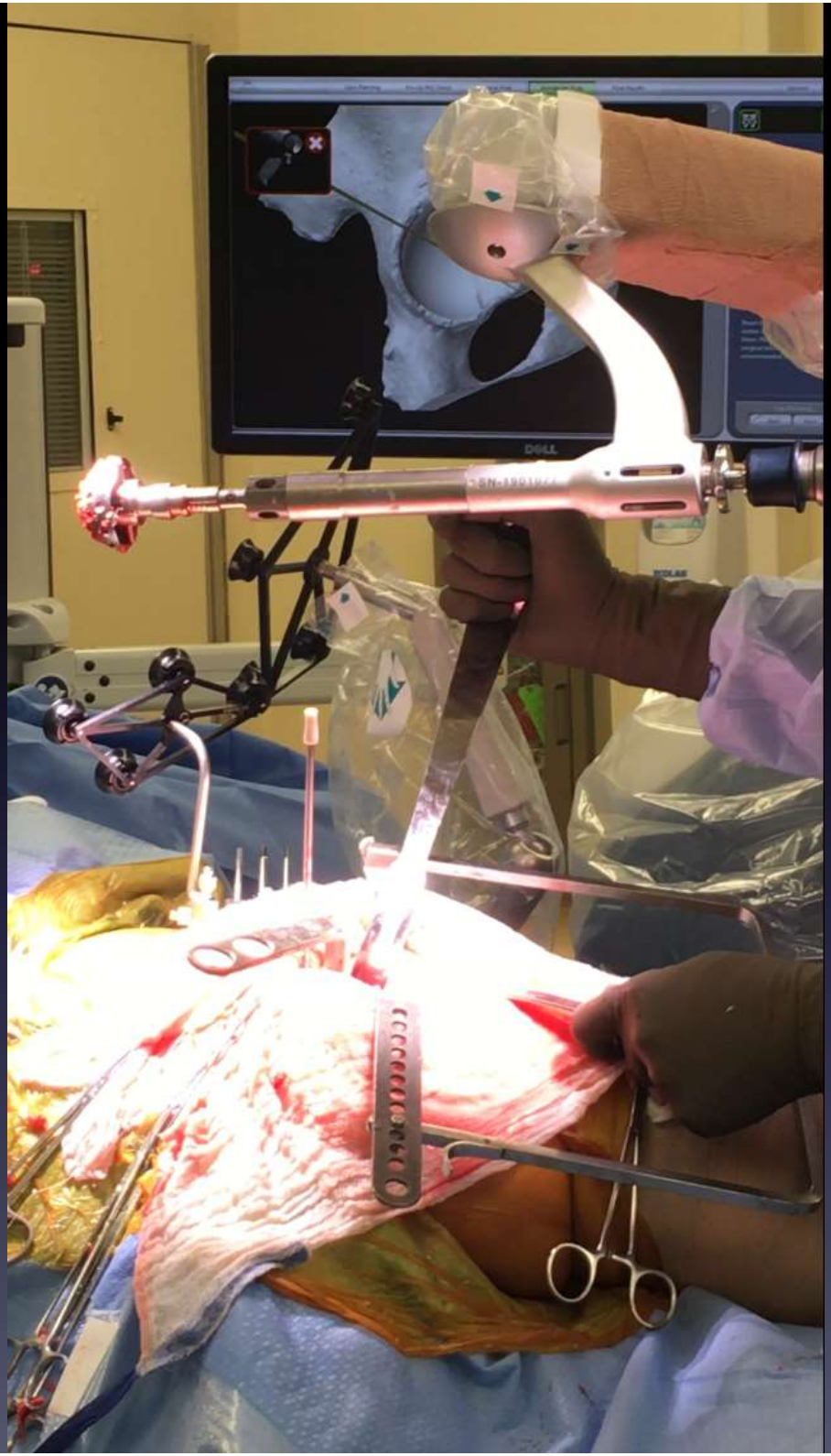


Traditional 2-D Digital Templating

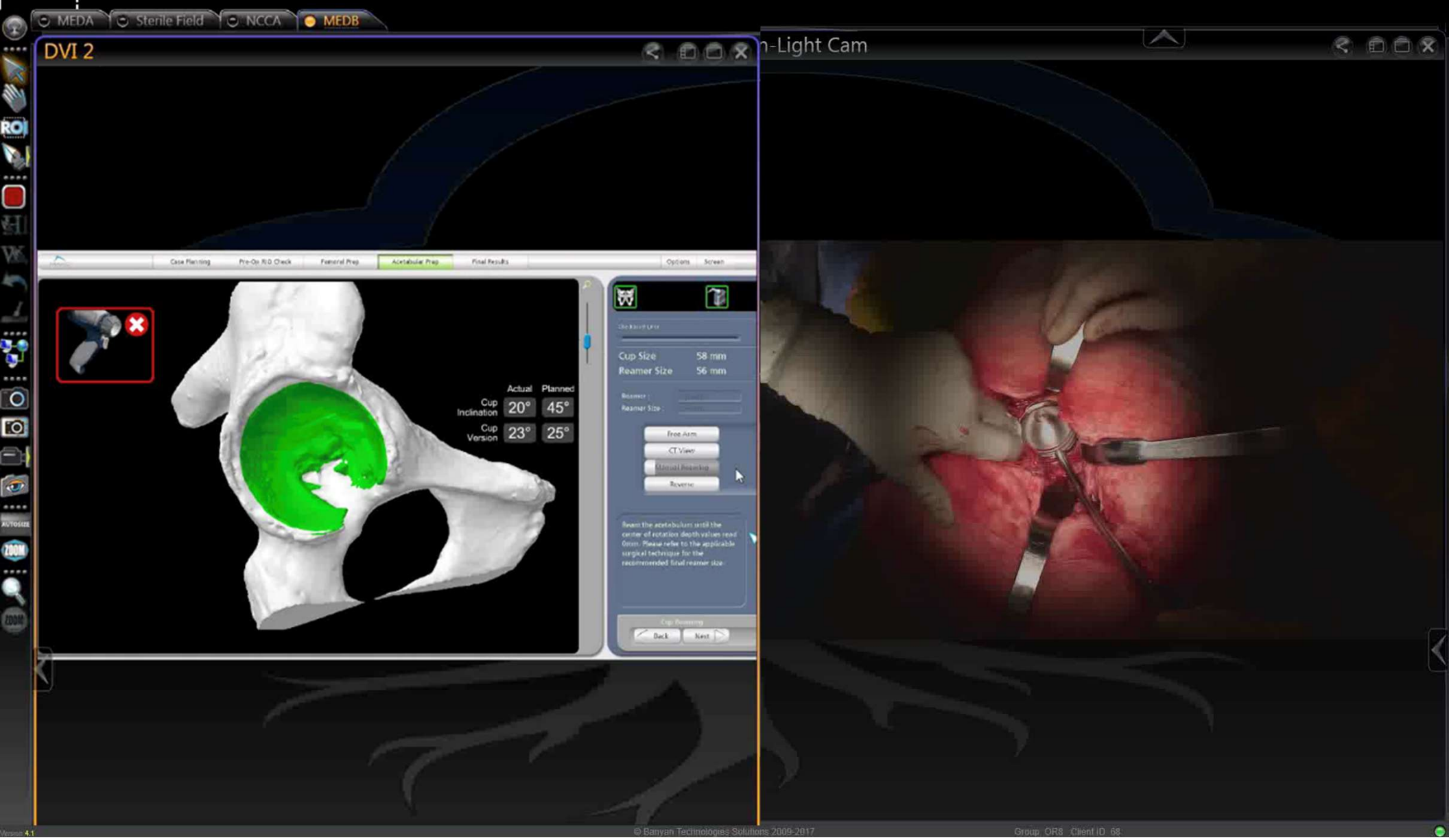
CT based 3-D Templating



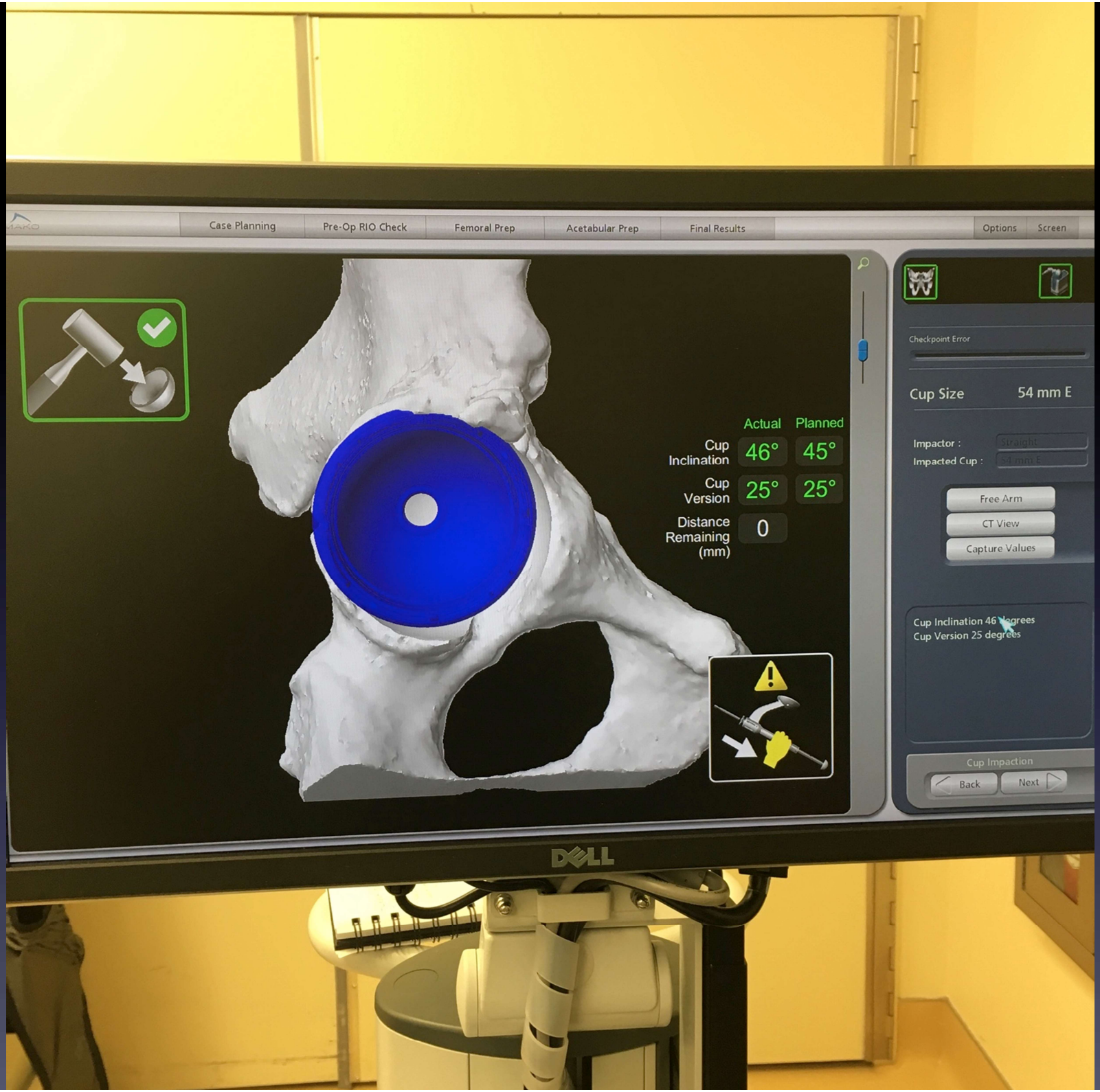

Case Planning
Pre-Op RIO Check
Femoral Prep
Acetabular Prep
Final Results
Planned
vs. Opposite Hip
vs. Pre-op Hip
Hip Length (mm)
11
Shorter
13
Longer
Combined Offset (mm)
9
Decreased
0

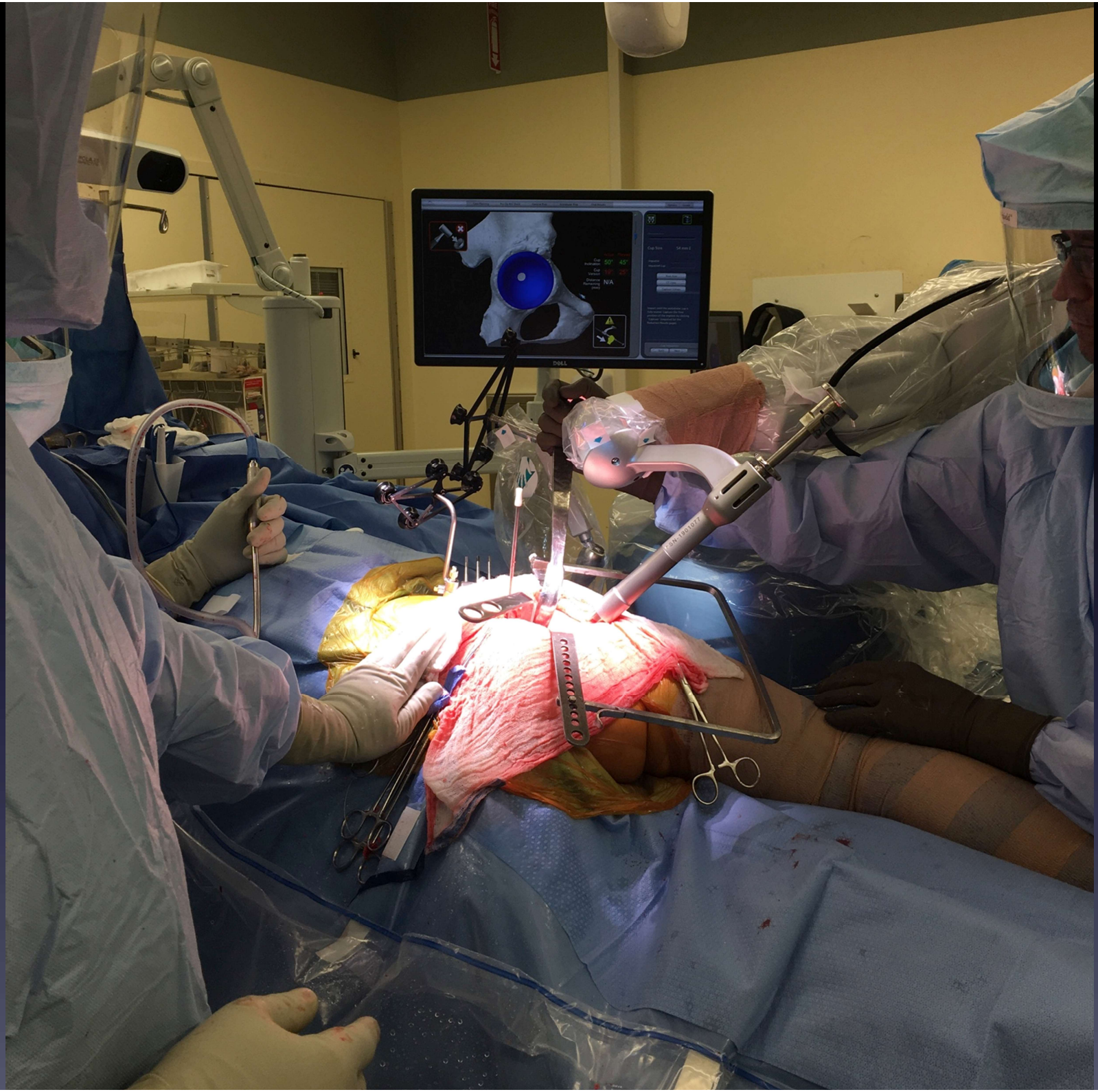


Surgeon still is controlling the arm under direct visualization



Acetabular Component Insertion


Case Planning
Pre-Op RIO Check
Femoral Prep
Acetabular Prep
Final Results
Options
Screen
Actual
Planned
Cup Inclination
46°
45°
Cup Version
25°
25°
Distance Remaining (mm)
0
Checkpoint Error
Cup Size
54 mm E
Impactor :
Straight
Impacted Cup :
54 mm E
Free Arm
CT View
Capture Values
Cup Inclination 46 degrees
Cup Version 25 degrees
Cup Impaction
Back
Next
DELL



Compared to Manual Methods

- Greater **precision to plan** compared to manual procedures[19]
- **Less** bone and soft tissue damage compared to manual procedures[5]
- More **accurate component positioning** to plan when compared to manual procedures[20]
- Greater **bone preservation** in robotic procedures[4,8]

Robotic Guided Cup Placement More Accurate

Clin Orthop Relat Res
DOI 10.1007/s11999-013-3253-7

Clinical Orthopaedics and Related Research®
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CLINICAL RESEARCH

Comparison of Robotic-assisted and Conventional Acetabular Cup Placement in THA: A Matched-pair Controlled Study

Benjamin G. Domb MD, Youssef F. El Bitar MD, Adam Y. Sadik BS, Christine E. Stake MA, Itamar B. Botser MD

Received: 23 May 2013 / Accepted: 15 August 2013
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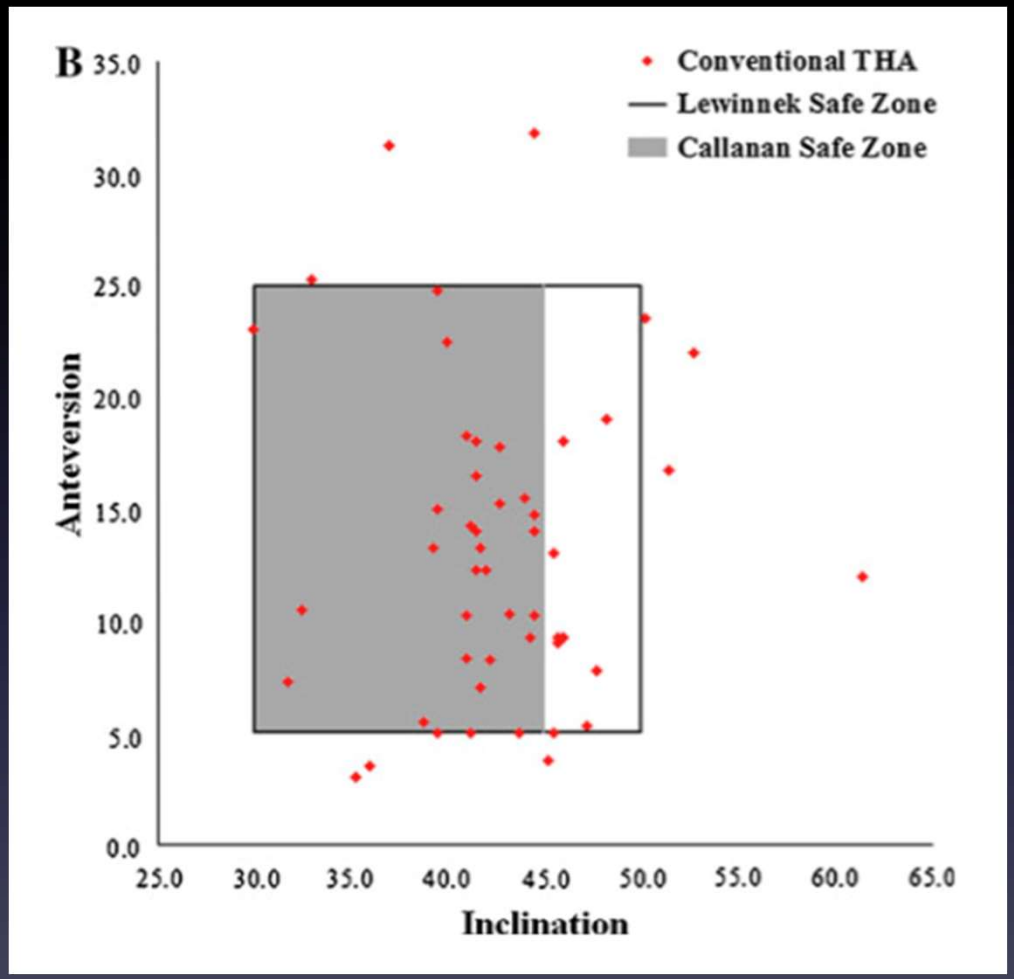
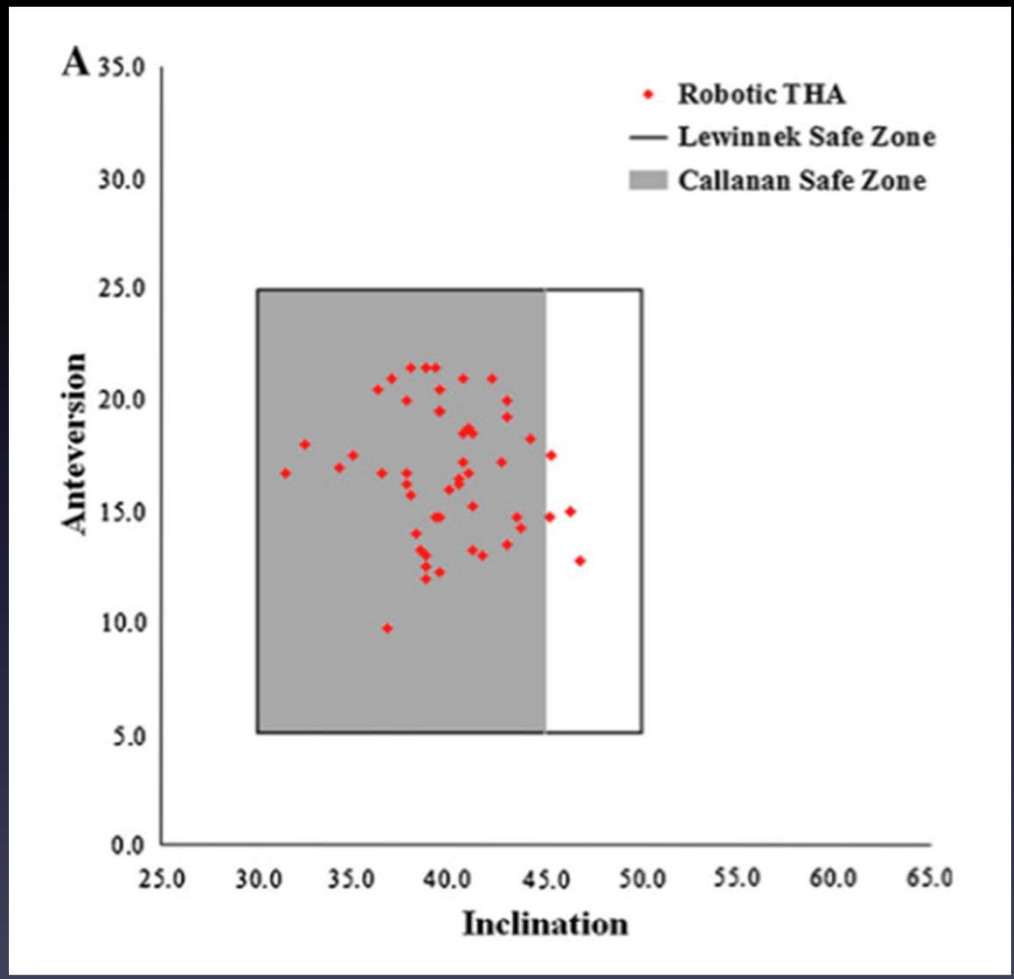
Conventional



Robotic



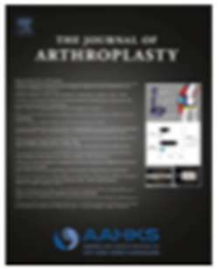
- Robotic guided cup placement more accurate than conventional or fluoroscopic guidance

The Journal of Arthroplasty 32 (2017) 125–130

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org



Primary Arthroplasty

Adoption of Robotic vs Fluoroscopic Guidance in Total Hip Arthroplasty: Is Acetabular Positioning Improved in the Learning Curve?

Eli Kamara, MD [a], Jonathon Robinson, MD [b], Marcel A. Bas, MD [a], Jose A. Rodriguez, MD [a], Matthew S. Hepinstall, MD [a,*]

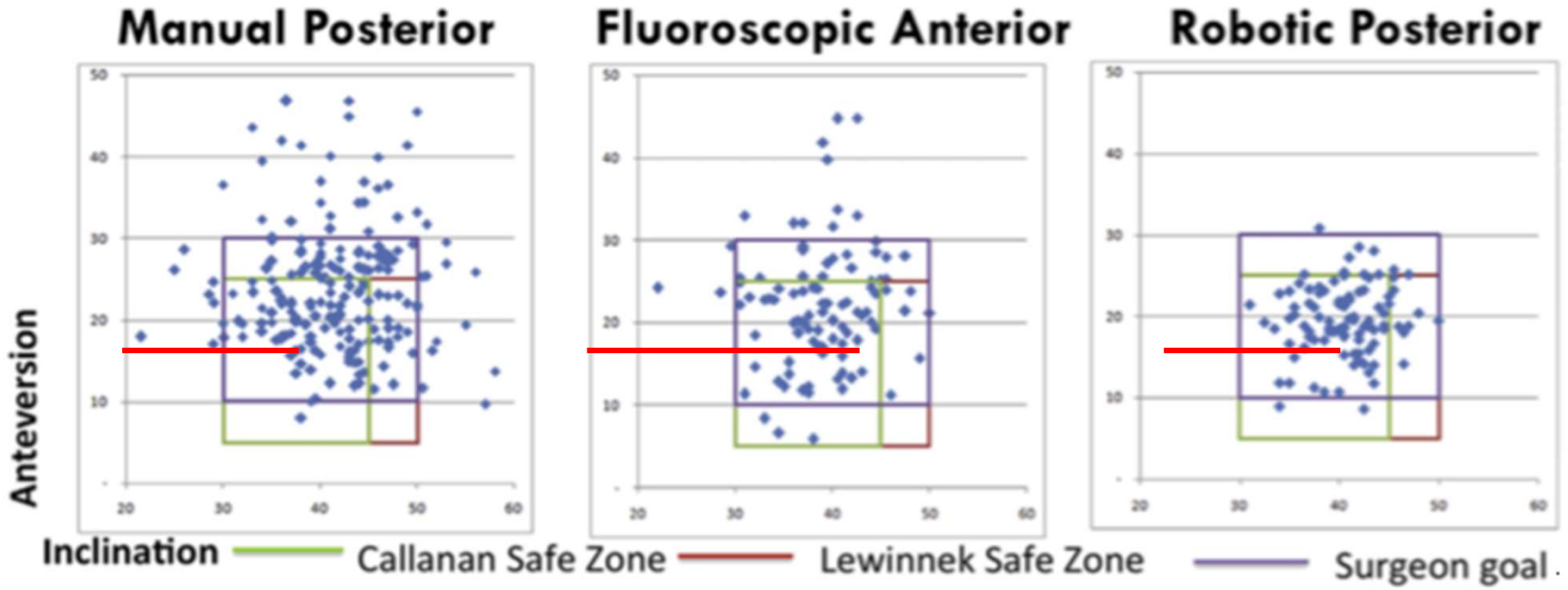


Fig. 1. Outcomes. Lewinnek safe zone inclination 30°-50°, anteversion 5°-25°; Callanan safe zone inclination 30°-45°, anteversion 5°-25°; surgeon goal inclination 30°-50°, anteversion 10°-30°.

Significant and immediate improvement during the surgeon's learning curve *(1st 100)*

Precision of acetabular cup placement in robotic integrated total hip arthroplasty

Primary investigators

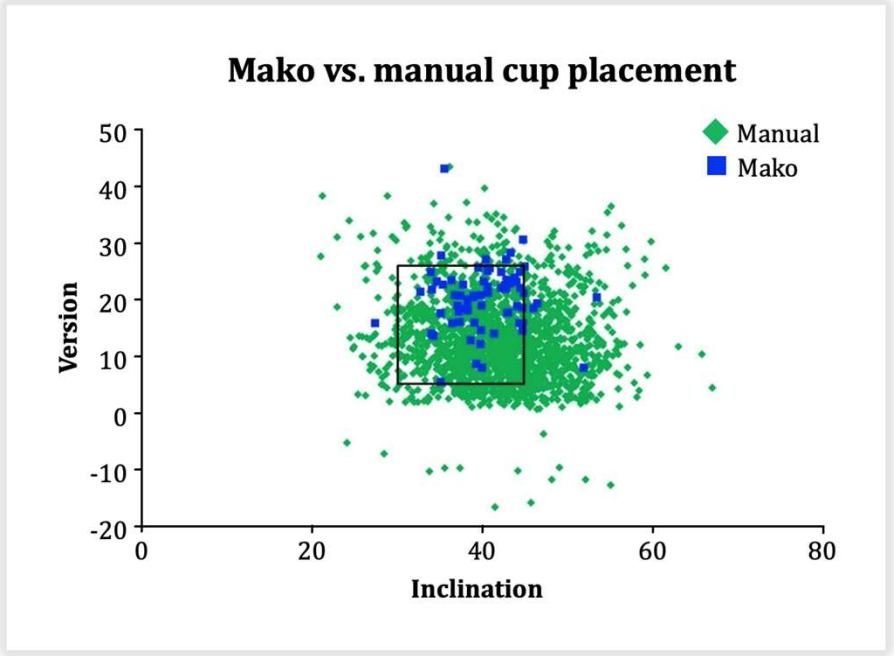
Henrik Malchau, M.D., Douglas E. Padgett, M.D., Jon Dounchis, M.D., Richard Illgen, M.D., Robert C. Marchand, M.D.[20]

Methodology

- 120 (110 were evaluated) robotic-arm assisted THA (RATHA) cases from 4 institutions' postoperative A/P pelvis and lateral X-rays were evaluated using Martell Hip Analysis software for cup positioning

Results

- Based on Mako data (3D), 96% of RATHA cases were inside the Callanan safe zone (30˚- 45˚ inclination and 5˚- 25˚ version)
- The 95% predictive interval was ± 3.5 for inclination and ± 3.6 for version using the intraoperative recorded position of the cup by the robotic-arm



Outcomes after primary total hip arthroplasty: manual compared with robotic-assisted techniques

Primary investigator

Richard Illgen, M.D.[2]

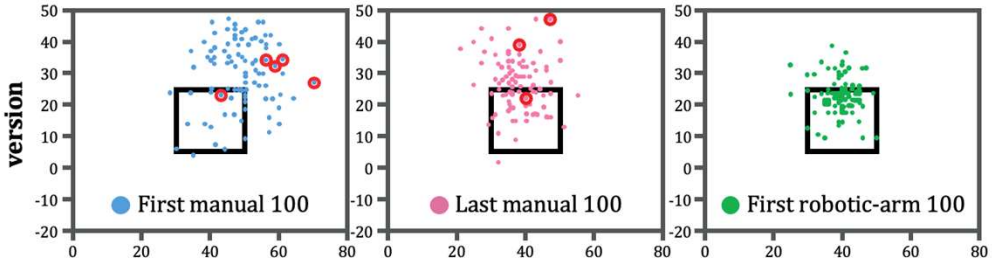
Methodology

- First 100 consecutive manual THA (MTHA) cases (2000)
- Last 100 consecutive MTHA cases (2011)
- First 100 consecutive robotic-arm assisted THA (RATHA) cases (2012)
- Radiographic and clinical outcomes assessment

Results

- RATHA demonstrated significantly higher modified Harris Hip Score and UCLA activity level compared with MTHA at a minimum 1-year follow-up
- Estimated blood loss was reduced in the RATHA patients
- RATHA improved both acetabular abduction and anteversion accuracy and achieved reduced early dislocation rates and improved rates of limb length discrepancy compared with MTHA

First manual 100	Last manual 100	First robotic-arm 100
31% in target zone	45% in target zone	76% in target zone
5% dislocation (4/5 anterior)	3% dislocation (2/3 anterior)	0% dislocation
3% fractured liners	0% fractured liners	0% fractured liners



26% of robotic arm assisted cases were planned outside the Lewinnek safe zone

Robotic-arm assisted total hip arthroplasty results in small acetabular cup size in relation to the femoral head size: a matched-pair controlled study

Primary investigator

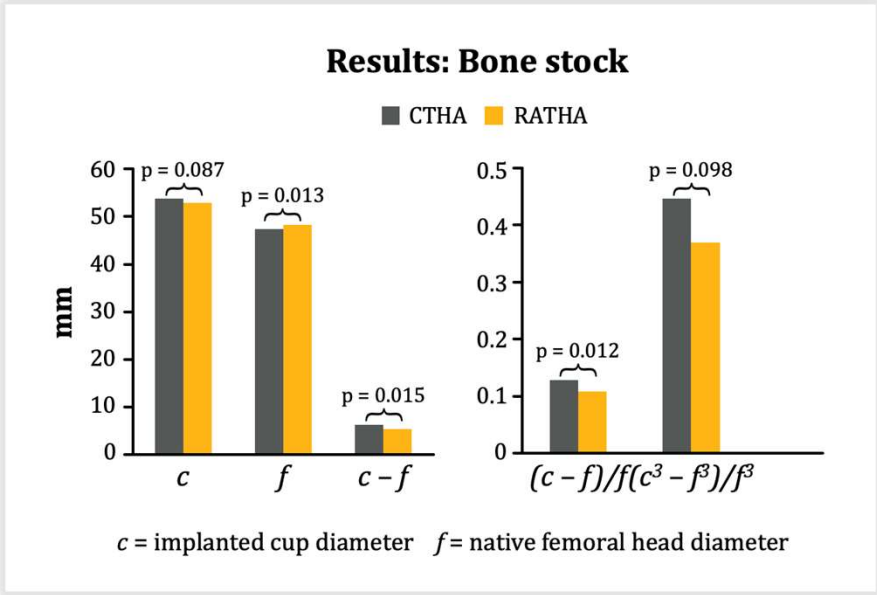
Carlos Suarez-Ahedo, M.D., Benjamin Domb, M.D.[4]

Methodology

- 114 patients
  - 57 conventional THAs (CTHA)
  - 57 robotic-arm assisted THAs (RATHA)
- Matched for femoral head size
- Acetabular cup diameter and the native femoral head diameter were used to infer the relative amount of bone stock removed

Results

- Indicated greater preservation of bone stock using RATHA compared to CTHA
- RATHA allowed for the use of smaller acetabular cups in relation to the patient's femoral head size, compared to CTHA



Robotic assisted total hip arthroplasty: A 90-day episode of care cost analysis

Primary investigator

Carlos Lavernia, M.D.[53]

Methodology

- Retrospective review of Optum Insight database between October 1, 2015 and October 1, 2018
- Propensity score matching: 938 RATHAs and 4,670 MTHAs
- Compared: 90-day EOC cost, index cost, LOS, post-index rehab utilization and costs

Post-index costs by cohort

	RATHA		MTHA		Difference	% Difference	P-value
	Mean	SD	Mean	SD			
Acute inpatient	$19,132	$14,266	$17,413	$15,232	$1,718	10%	0.282
Inpatient rehab	$11,490	$8,659	$14,674	$7,183	-$3,184	-22%	0.0470[a]
Outpatient	$1,179	$2,006	$1,111	$1,520	$68	6%	0.1473
ER	$715	$837	$786	$845	-$71	-9%	0.8201
SNF	$9,184	$6,820	$10,408	$10,159	-$1,224	-12%	0.0598
HHA	$3,352	$2,325	$3,496	$1,891	-$144	-4%	0.0133[a]
All post-index costs	$6,907	$9,710	$7,854	$11,732	-$948	-12%	0.0004[b]

[a]P<0.05 [b]P<0.001

Results

- RATHA less likely to have post-index IPR (0.64% vs. 2.68%; p<0.0001)
- RATHA less likely to have SNF admissions (20.79% vs. 24.99%; p=0.0041)
- RATHA used fewer days in post-index inpatient and SNF care (7.15 vs. 7.91; p=0.8029 and 17.98 vs. 19.64; p=0.5080, respectively)
- RATHA used fewer HHA visits (14.06 vs. 15.00; p=0.0006)
- RATHA had lower costs for IPR, SNF and HHA compared to MTHA
- Overall, RATHA patients had 12% ($948) lower average post-index costs compared to MTHA patients (p=0.0004)
- **Total 90-day EOC costs for RATHA patients were found to be $785 less than those of MTHA patients ($19,734 vs. $20,519, p=0.0095)**

Robotic-arm assisted total hip arthroplasty is more cost-effective than manual total hip arthroplasty: a Markov model analysis

Primary investigators

David Maldonado, M.D., Cammille Go, B.S., Cynthia Kyin, B.A., Philip Rosinsky, M.D., Jacob Shapira, M.D., Ajay Lall, M.D., M.S., Benjamin Domb, M.D. [54]

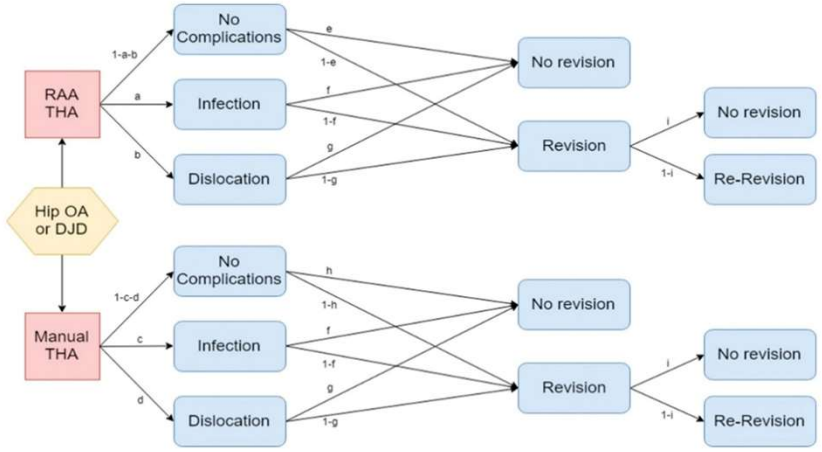
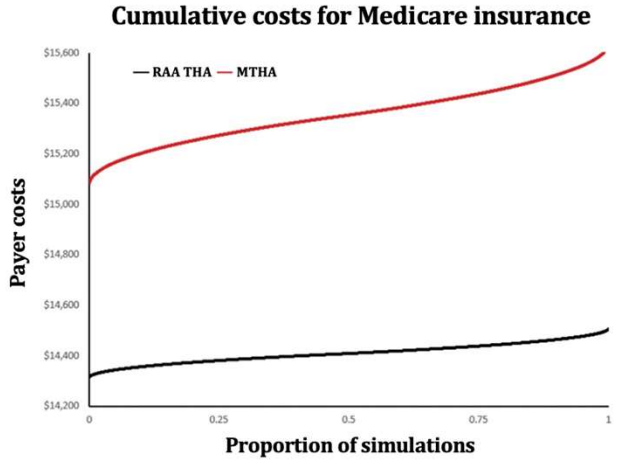


Chart showing the Markov model. Health state diagram. The yellow hexagon represents the diagnosis, red squares represent the interventions, and blue rectangles are the potential transition states. Letters represent the potential transition probabilities. DJD = degenerative joint disease, OA = osteoarthritis, RAA = robotic arm-assisted, THA = total hip arthroplasty



Graph showing the cumulative costs for Medicare. The values are derived from 100,000 simulations using a probabilistic sensitivity analysis. $ = 2019 U.S. dollars, MTHA = manual total hip arthroplasty, RAA = robotic arm-assisted, THA = total hip arthroplasty

Conclusions

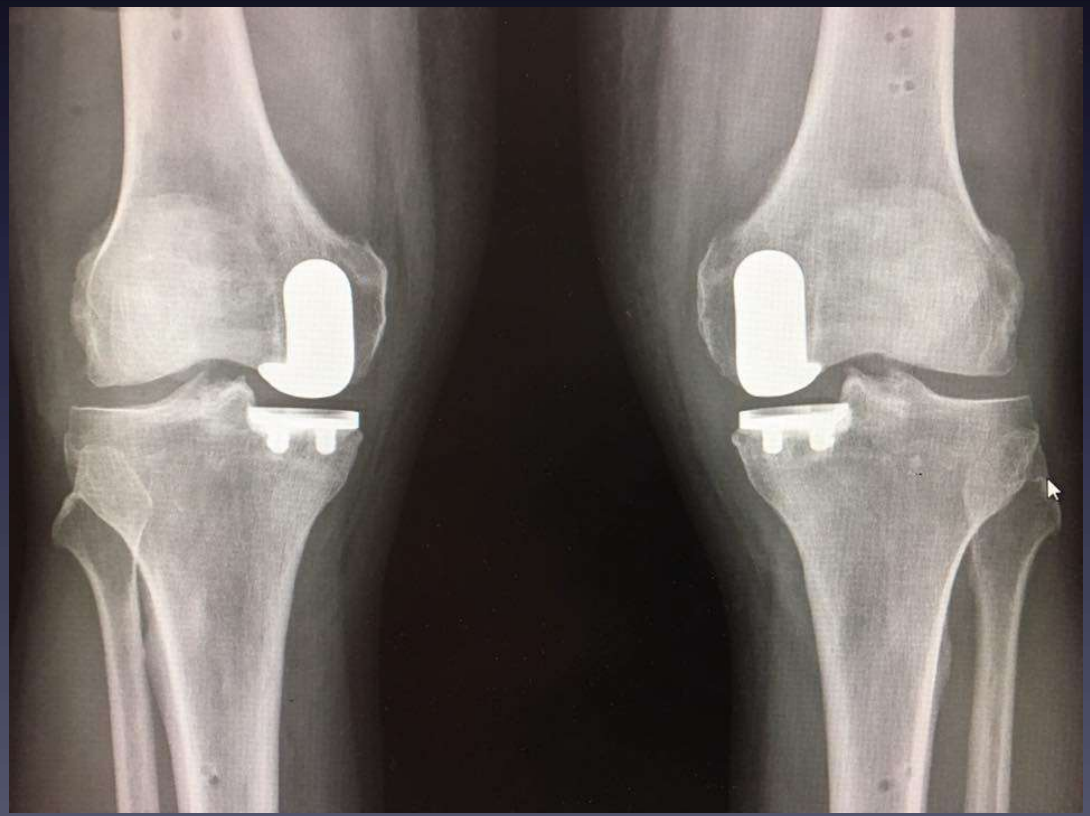
- In the Medicare and private payer scenarios, RATHA demonstrated reduced cost compared to conventional MTHA. Direct medical costs from a payer perspective were considered.

Robotic Arm Assisted Surgery

Partial Knee Replacement Application

Partial knee replacement

- First application for robotic arm technology in joint replacement



Advantages of unicompartmental knee replacement

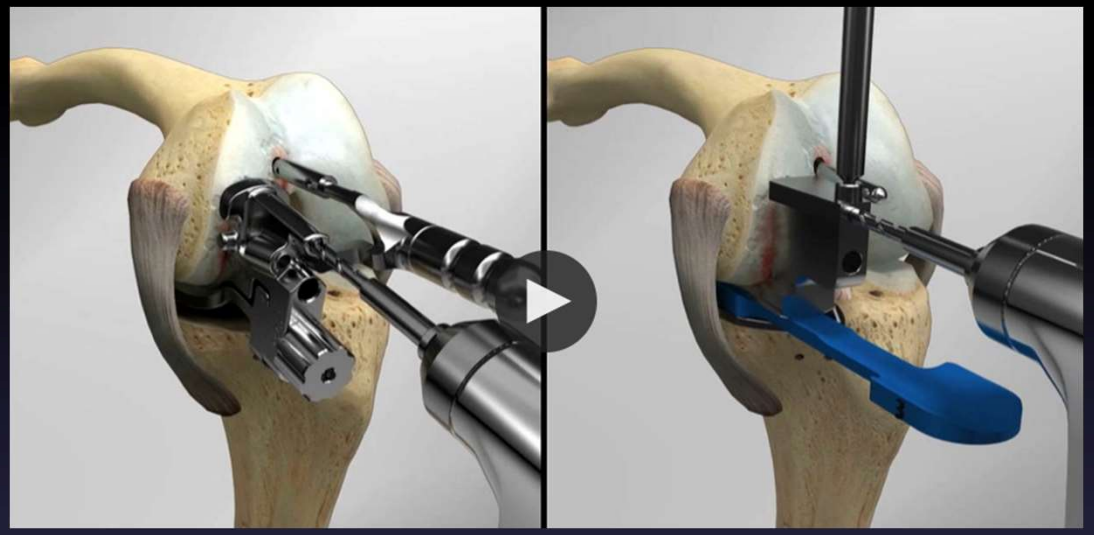
- Less "invasive"
- Bone conserving
- Less pain
- Quicker recovery
- Better ROM
- A more "normal" knee

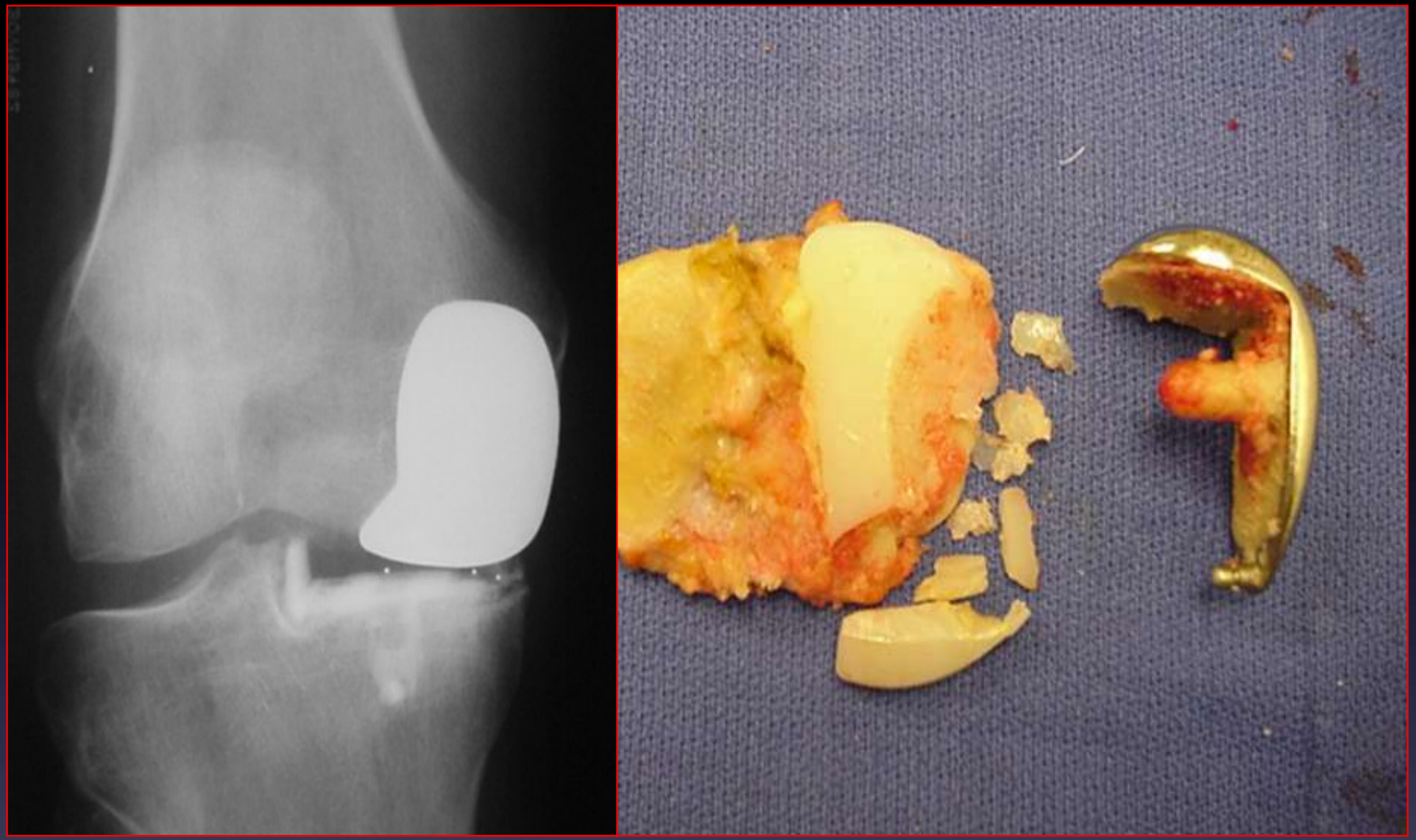
Disadvantages of unicompartmental knee replacement

- More technically demanding
- Less frequently performed
- Often combined with abridged exposure
- Higher early revision rates vs TKA *(historically)*

Baseline Status Quo
(prior to computer navigation & robotics)

- Visual landmarks
- Manual jigs



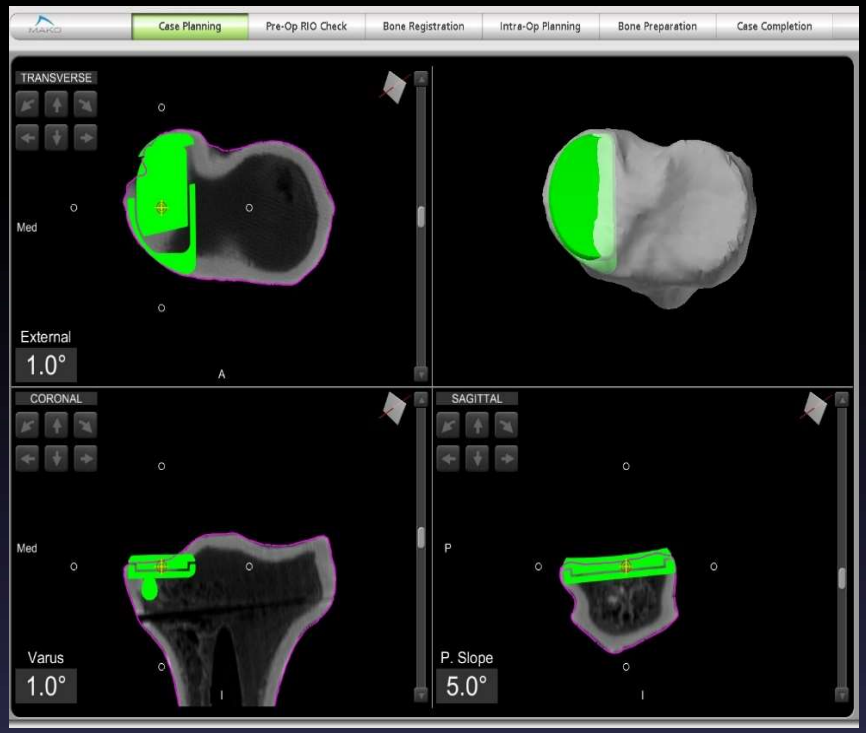


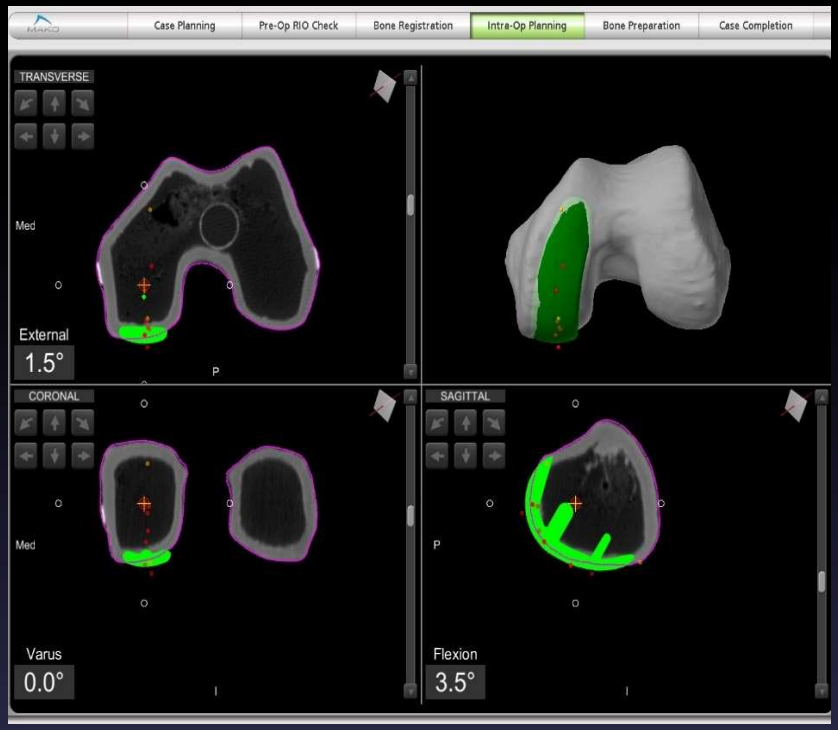
Success and durability of UKA are highly dependent on establishing appropriate alignment

120 mm

If robotic technology could provide more precise bone preparation and more accurate component sizing and alignment, then UKA outcomes would be more consistently successful.

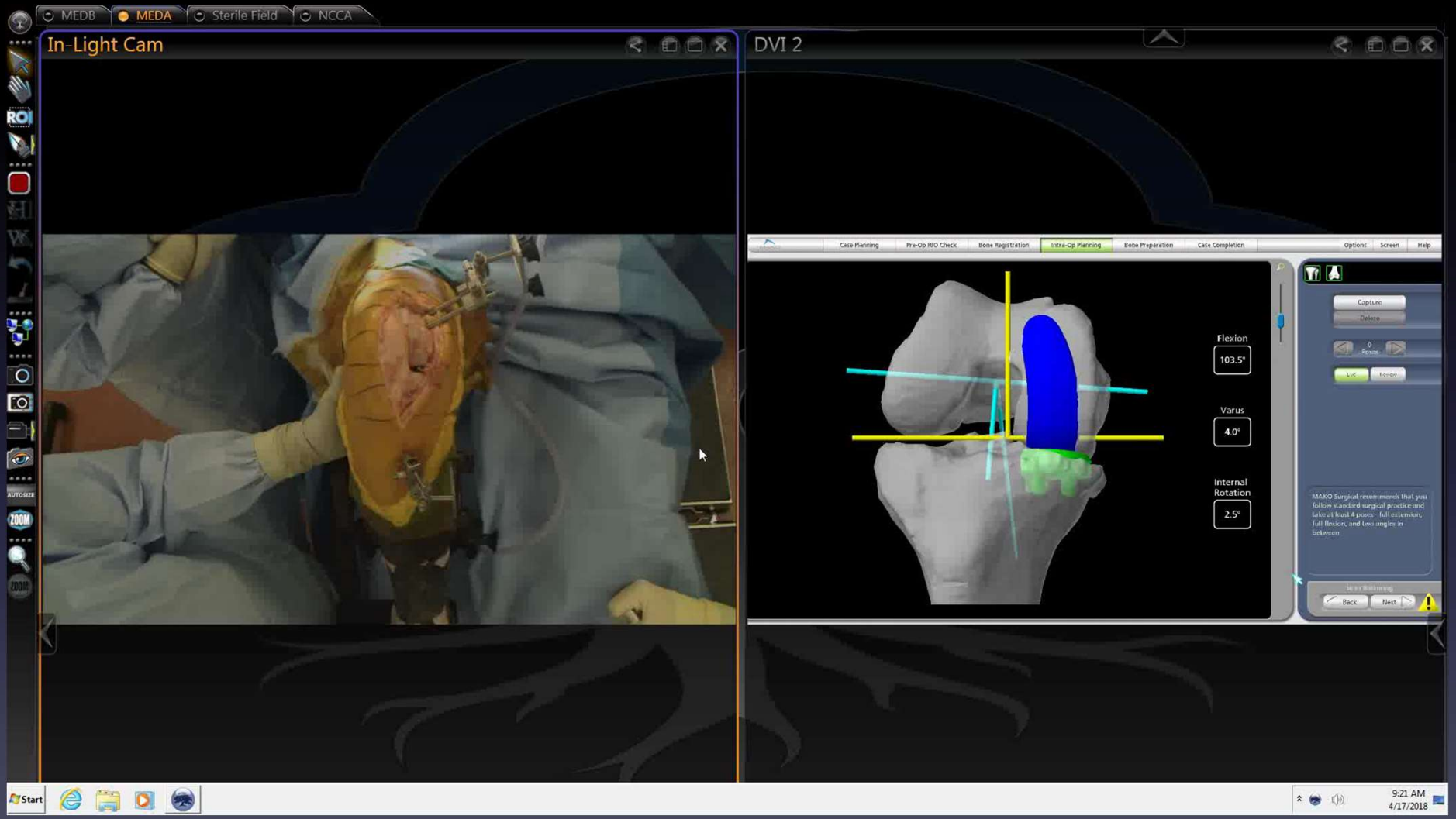
CT Based Planning



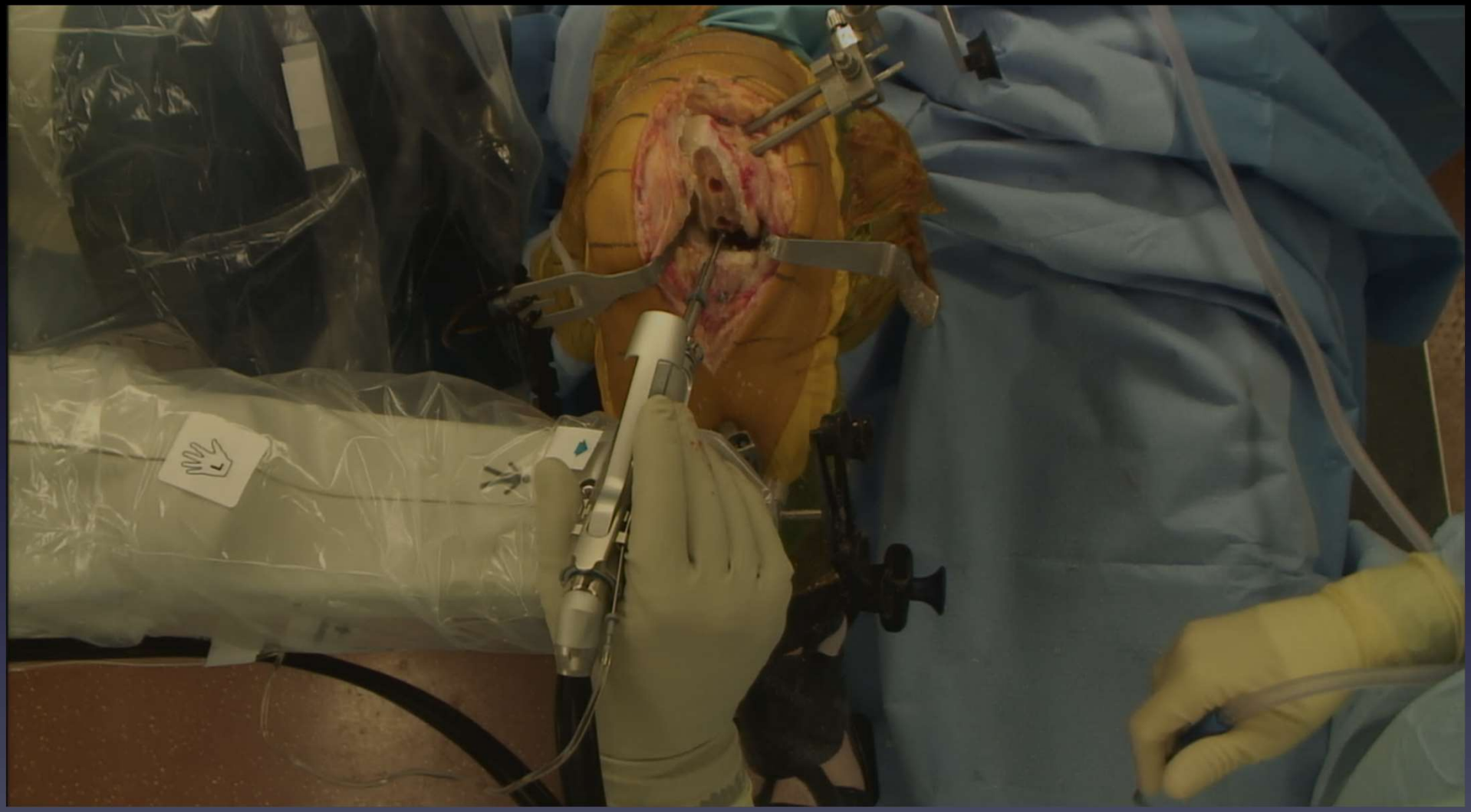


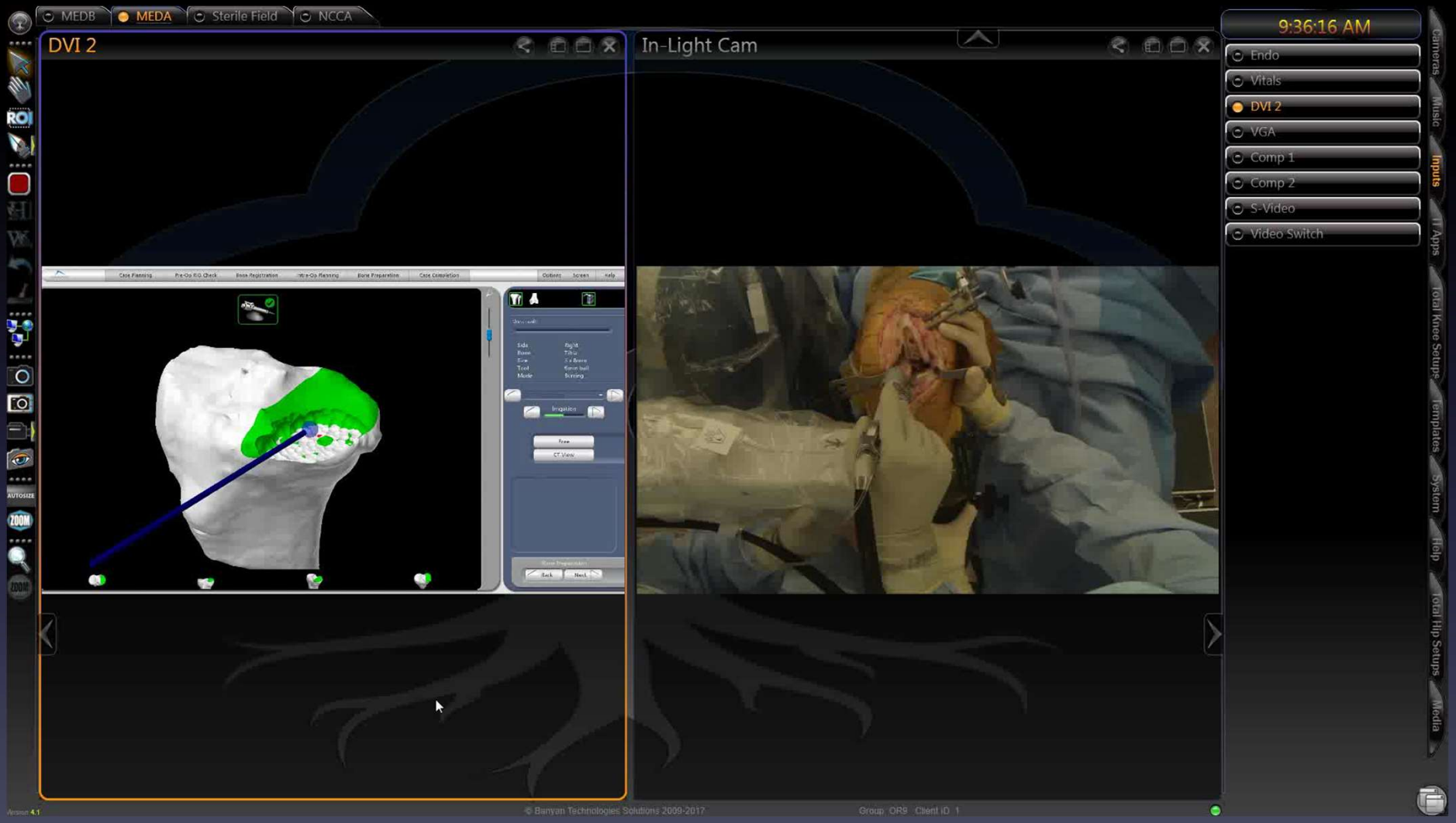
- 3D model of the pt's anatomy is created from CT data.
- Surgeon sizes and aligns the implant virtually.

Dynamic Joint Balancing



Haptic Guided Bone Preparation

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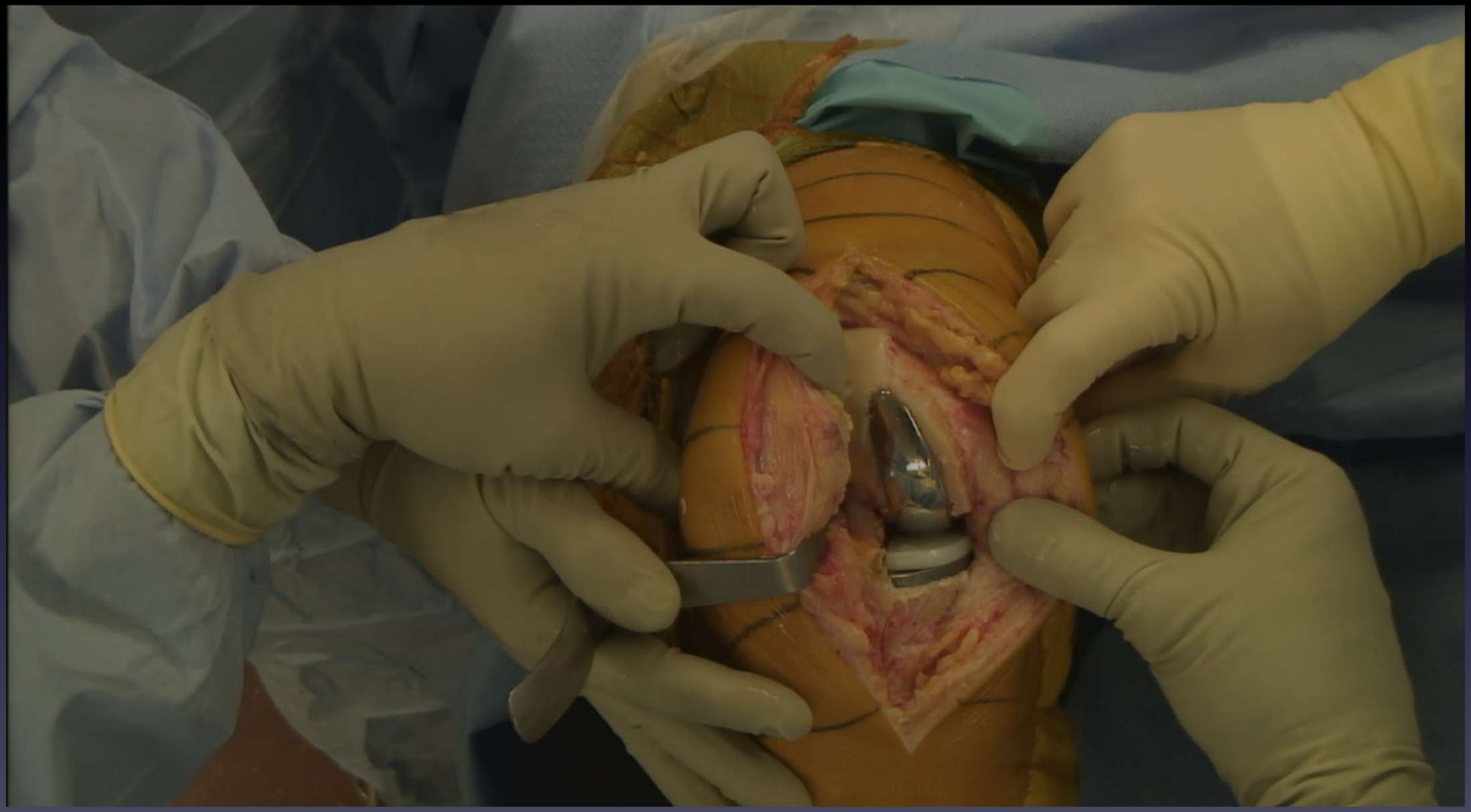

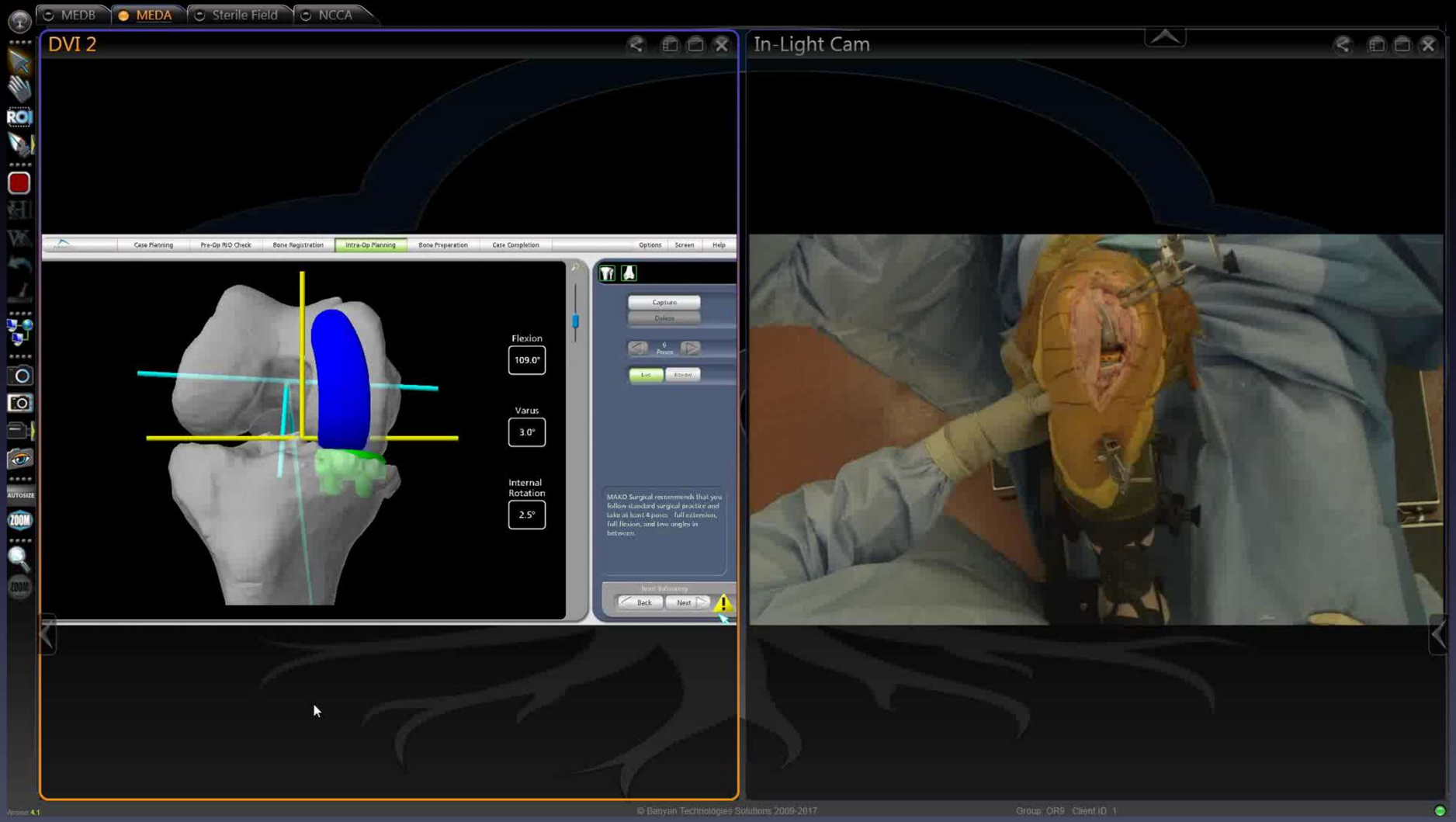
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Flexion
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Varus
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Internal Rotation
2.5°
Capture
Delete
6 Poses
Live
Review
MAKO Surgical recommends that you follow standard surgical practice and take at least 4 poses - full extension, full flexion, and two angles in between.
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Group OR9 Client ID 1

Improved Accuracy

Primary investigators

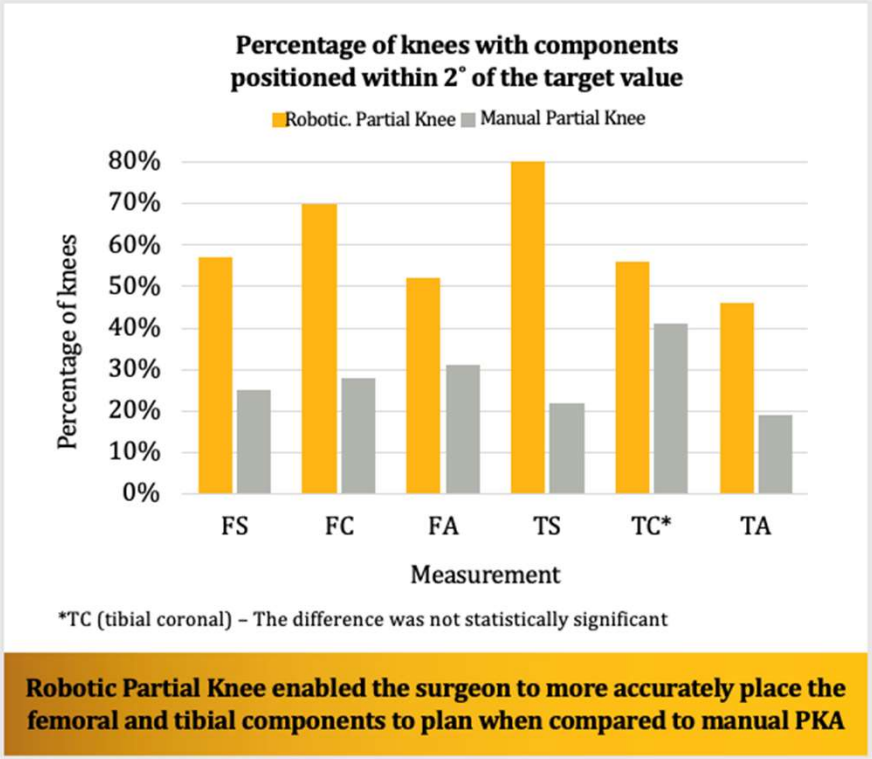
Stuart Bell, MBChB, MRCP, FRCS, Mark Blyth, MBChB, FRCS [1]

Methodology

- Initial results of 139 patients from the prospective, single center, level I, blinded, randomized controlled trial between Robotic Partial Knee and manually implanted Biomet Oxford
- Postoperative CT protocol was performed at 3 months to assess accuracy of planned vs. achieved component positioning in axial, coronal and sagittal planes for both femur and tibia

Results

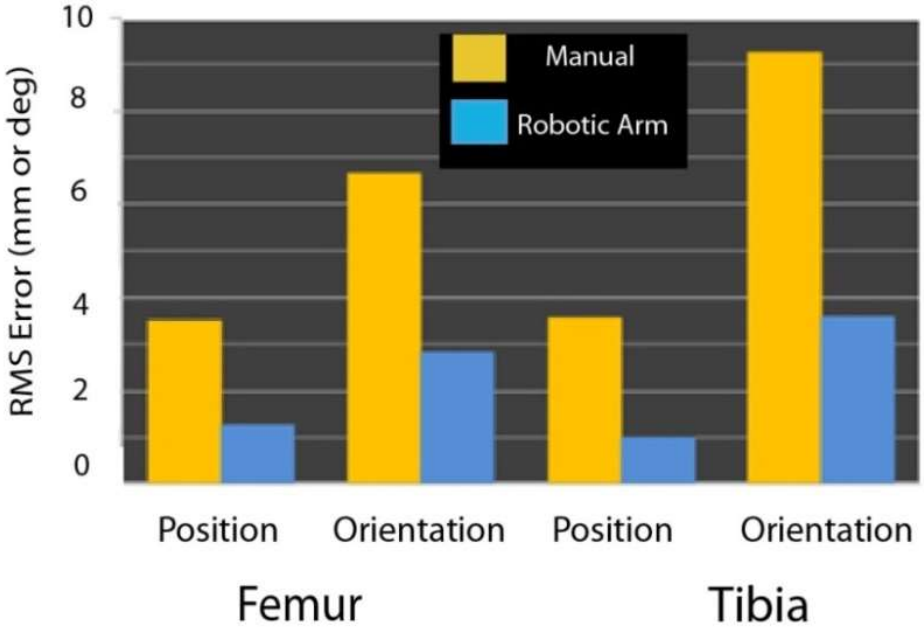
- Robotic Partial Knee showed more accurate delivery of the surgical plan in all alignment measures compared to the current manual standard
- Proportion of patients with component implantation within 2° of target was significantly greater ($p<0.05$) in Robotic Partial Knee cases compared with the manual cohort for five out of the six parameters (femoral sagittal, femoral coronal, femoral axial, tibial sagittal and tibial axial)



*TC (tibial coronal) – The difference was not statistically significant

Robotic Partial Knee enabled the surgeon to more accurately place the femoral and tibial components to plan when compared to manual PKA

Robotic guided UKA Provides More Accurate And Reproducible Implant Placement Than Conventional UKA Techniques



- **Conclusion:**
- Robotic arm assisted PKA leads to:
  - 2-3 times ***more accurate implant placement*** than manual UKA[1,2,3,4,5]
  - At least 3 times ***more reproducible implant placement*** than manual UKA[1,2,3,4,5]
  - Fewer outliers than manual UKA[6]

1. Citak M, Suero EM, Citak M, Dunbar NJ, Branch SH, Conditt MA, Banks SA, Pearle AD. Unicompartmental knee arthroplasty: Is robotic technology more accurate than conventional technique? *The Knee.* December 2012. [Epub ahead of print].
2. Dunbar NJ, Roche MW, Park BH, Branch SH, Conditt MA, Banks SA. Accuracy of dynamic tactile-guided unicompartmental knee arthroplasty. *J Arthroplasty.* 2012;27(5):803-808.e1.
3. Lonner JH. Robotic arm-assisted unicompartmental arthroplasty. In, Lotke PA, Lonner JH, eds. Master techniques in orthopedic surgery: Knee arthroplasty. Lippincott Williams & Wilkins. 2008.
4. Lonner JH. Robotic arm-assisted unicompartmental arthroplasty. *Seminars in Arthroplasty*. 2009;20(1):15-22.
5. Pearle AD, O'Loughlin PF, Kendoff DO. Robot-assisted unicompartmental knee arthroplasty. *J Arthroplasty.* 2010; 25(2):230-237.
6. Sinha RK. Outcomes of robotically assisted unicompartmental arthroplasty. *Am J Orthop*. 2009;38(2 suppl):20-22.

Less Pain

Primary investigators

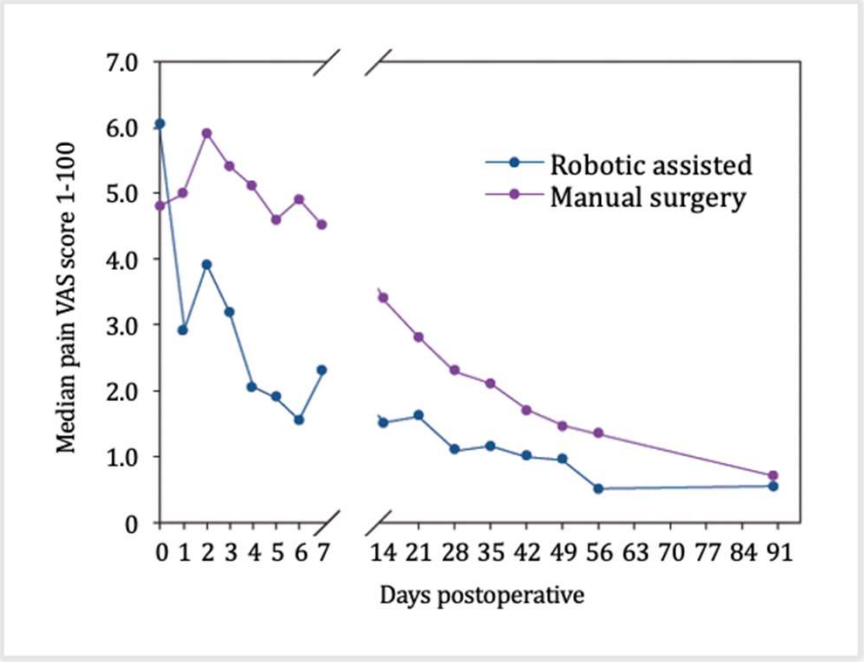
Mark Blyth, MBChB, FRCS[30]

Methodology

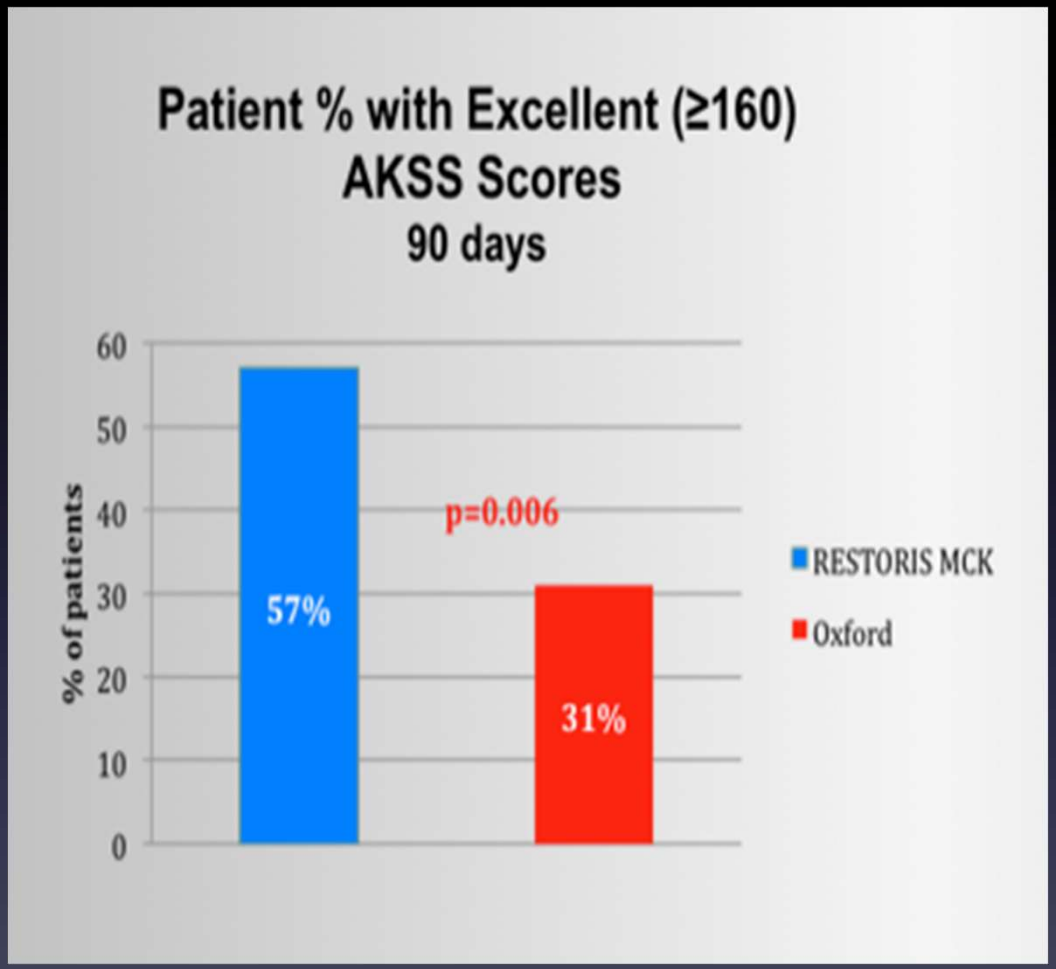
- Initial results of 139 patients from the prospective, single center, level I, blinded, randomized controlled trial between Robotic Partial Knee and Biomet Oxford
- Visual analog scale was collected for Robotic Partial Knee and manual surgery at 90 days postoperative
- American Knee Society Scores were evaluated at 90 days postoperative

Results

- Robotic Partial Knee patients reported **55.4% lower postoperative pain** compared to manual patients from day one to week eight (p=0.04)
- Robotic Partial Knee patients had better AKSS scores compared to manual patients at 3 months postoperative
- Key factors associated with achieving excellent clinical outcomes were a **preoperative activity level >5 on the UCLA activity score** and use of robotic-arm assisted surgery



Robotic UKA Demonstrates Improved Function Versus Manual UKA[1]



Conclusion:

Robotic partial knee patients showed improved function at 3 month follow-up based on AKSS

1. Jones B, Blyth M, MacLean A, Anthony I, Rowe P. Accuracy of UKA implant positioning and early clinical outcomes in a RCT comparing robotic assisted and manual surgery. CAOS International Conference, June 13-15, 2013, Orlando, Florida.

Improved Function

Primary investigators

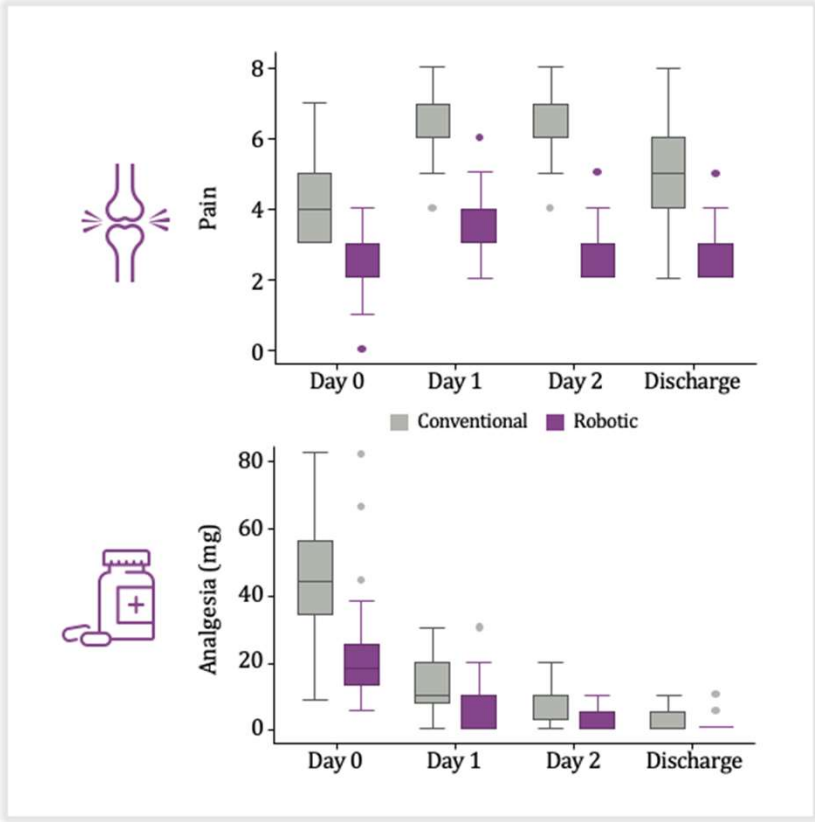
Babar Kayani, M.D., Prof. Fares Haddad[32]

Methodology

- Single-surgeon, medial PKA
- 73 consecutive conventional jig-based PKAs
- 73 consecutive Robotic Partial Knees
- Standardized postoperative inpatient rehabilitation program
- Collected: postoperative inpatient functional outcomes and time to hospital discharge

Results

- Compared to conventional PKA, the Robotic Partial Knee group demonstrated:
  - **Reduced postoperative pain (p<0.001)**
  - **Decreased analgesia requirements (p<0.001)**
  - Shorter time to straight leg raise (p<0.001)
  - Decreased number of PT sessions (5 vs. 9, p<0.001)
  - Improved max knee flexion at discharge (p<0.001)
  - Reduced mean time to hospital discharge 29 hours



Improved Outcomes

Primary investigators

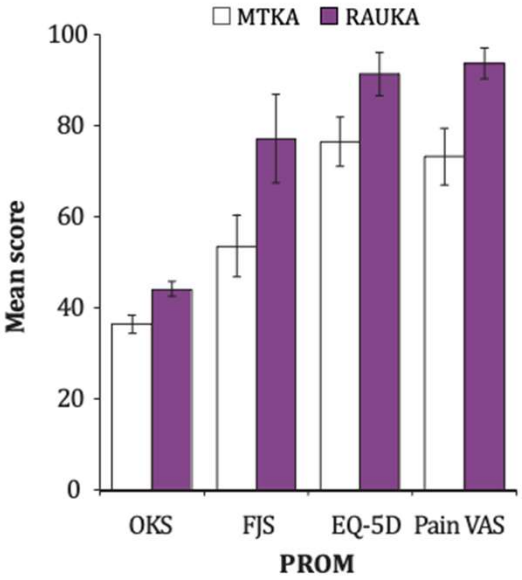
Nick Clement, PhD, FRCS Ed, Allison Bell, BSc, MSCP, Philip Simpson, FRCS, Gavin Macpherson, FRCS, James Patton, FRCS, David Hamilton, PhD[39]

Methodology

- 30 robotic-assisted UKAs compared with 90 propensity-matched manual TKAs
- Oxford Knee Score (OKS), EuroQol five-dimension questionnaire (EQ-5D), Forgotten Joint Score (FJS), patient satisfaction, Length of stay (LOS) compared at 6 months

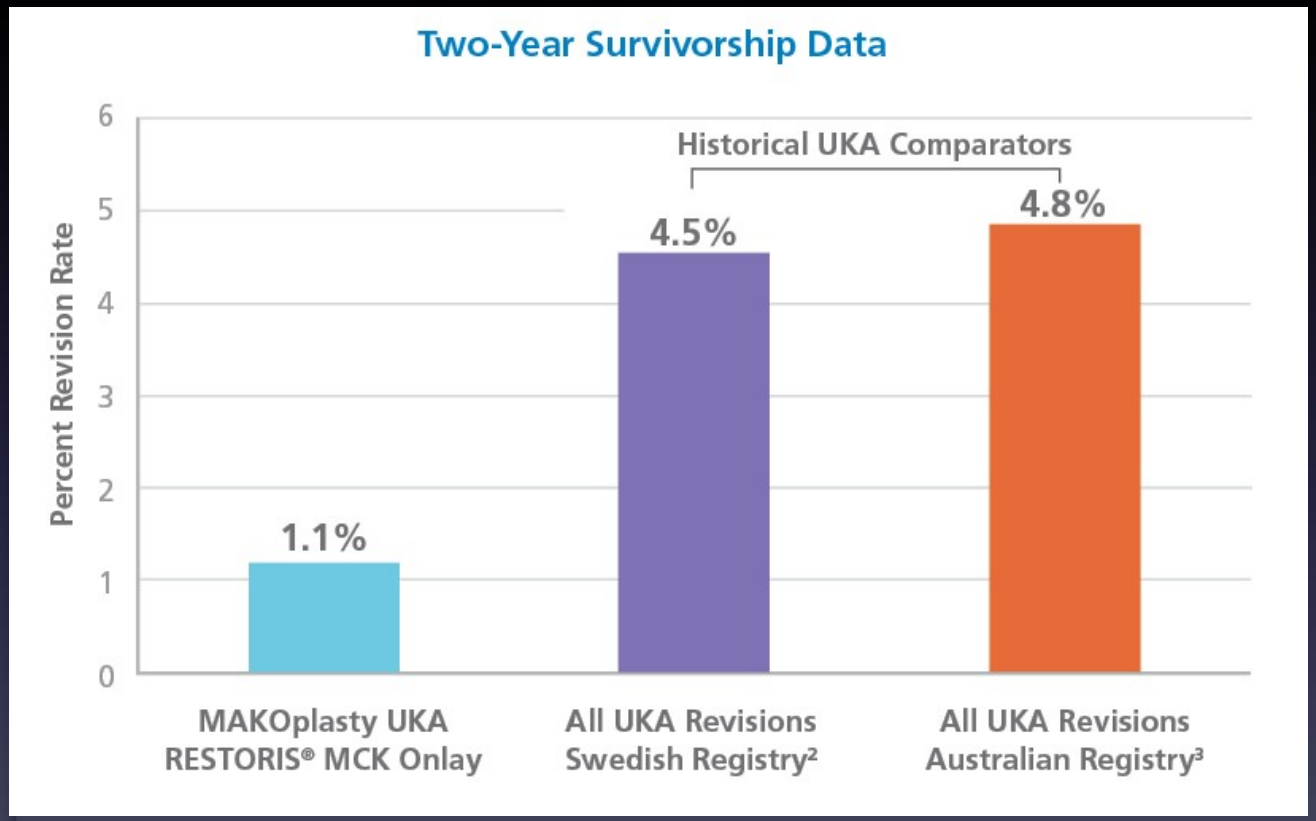
Results

- In the RAUKA group, compared to the MTKA group:
  - **OKS was significantly greater** (difference in mean 7.7, $p < 0.001$)
  - **EQ-5D was significantly greater** (difference in mean 0.148, $p = 0.002$)
  - **FJS was significantly greater** (difference in mean 24.2, $p < 0.001$)
  - **LOS was significantly ($p < 0.001$) shorter** (median two days, interquartile range (IQR) 1 to 3) compared to (median four days, IQR 3 to 5)
  - **Postoperative pain score** was significantly better (difference in mean 20.5 <0.001)



Six-month postoperative patient-reported outcome measures (PROMs) for the robotic-assisted unicompartmental knee arthroplasty and manual total knee arthroplasty groups. Error bars represent 95% confidence intervals.

Robotic UKA Has Lower Revision Rate Than Manual UKA



Conclusion:

- 1.1% Revision Rate at 2 Years Compared to Manual UKA Procedures

Coon T, Roche M, Pearle A, Dounchis J, Borus T, Buechel Jr F. Two year survivorship of robotically guided unicompartmental knee arthroplasty. ISTA 26th Annual Congress, October 16-19, 2013, Palm Beach, FL.

Improved Survivorship

- Robotic Partial Knee 5-year revision rate similar to conventional primary total knee and far superior to manual PKA[18,24,36]

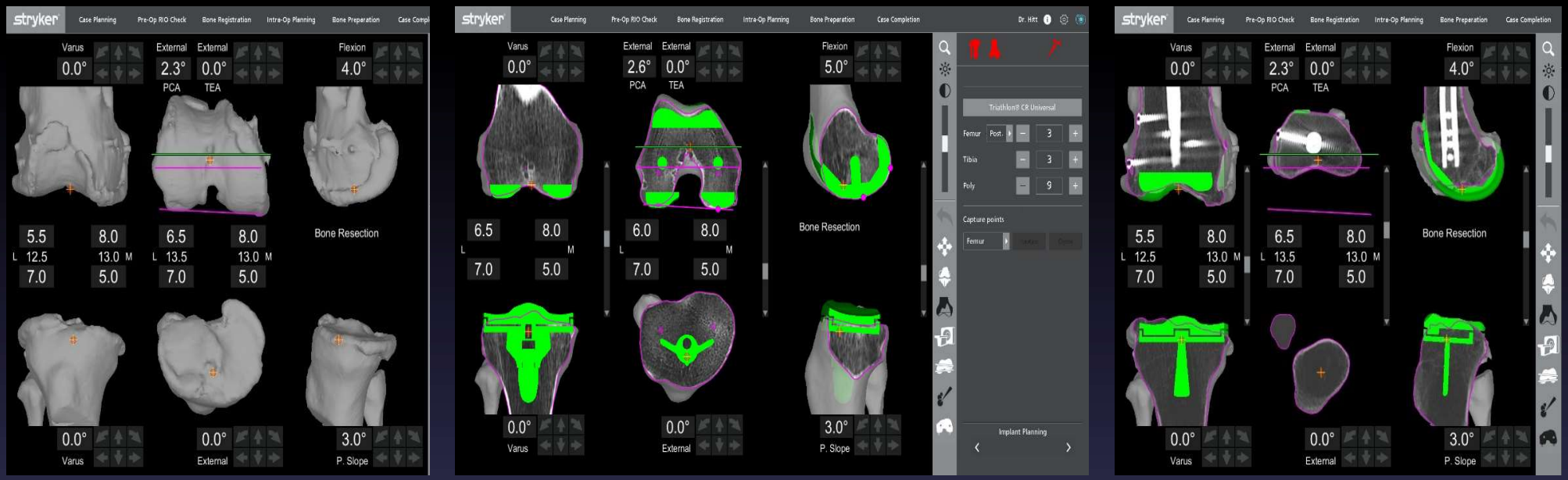
- 384 patients (432 knees) with a mean follow-up of 5.7 years (5.0-7.7), 97% survivorship[18]

- 98% survivorship at 10-year follow-up[31]

Robotic Arm Assisted Surgery

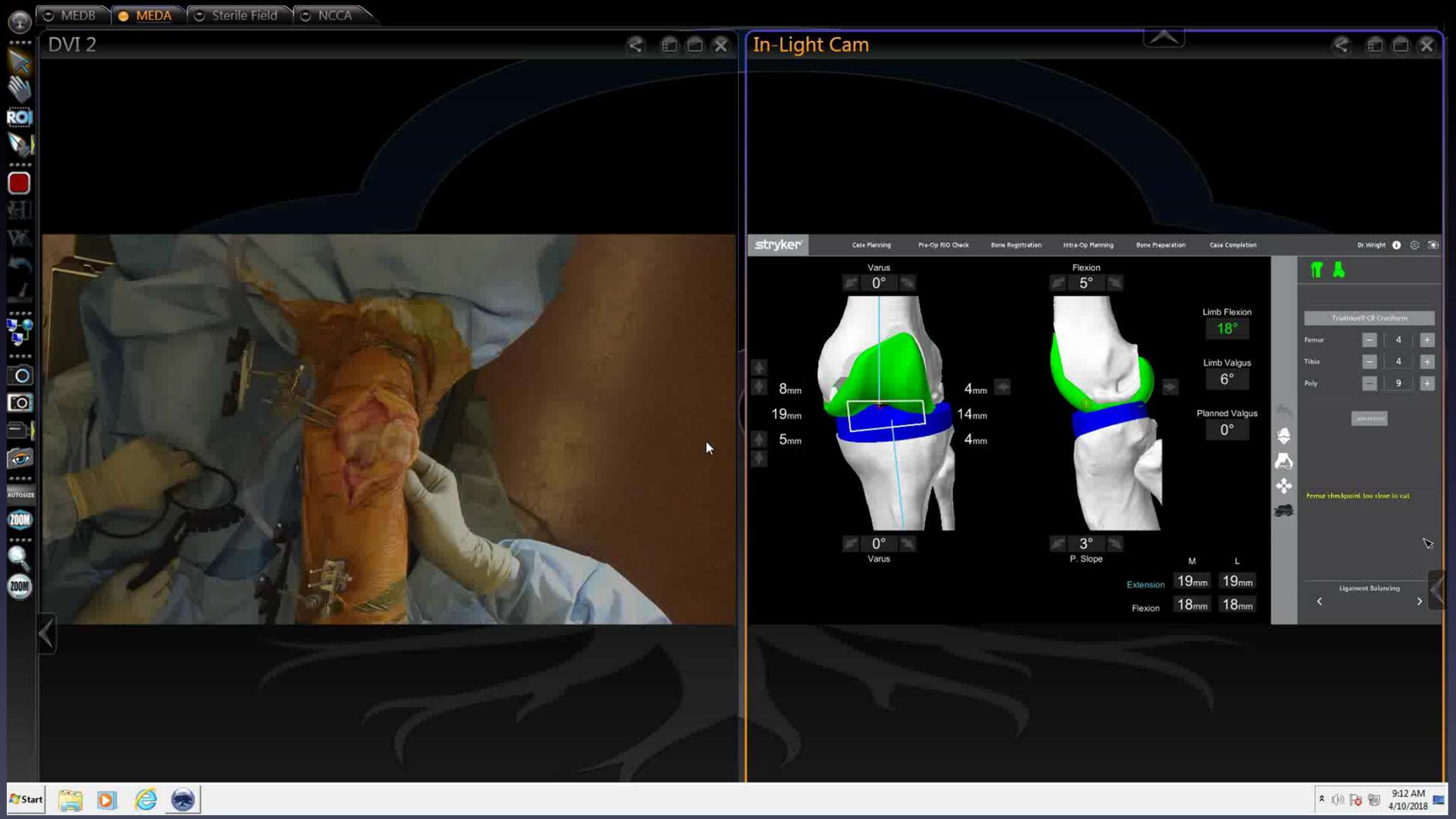
Total Knee Replacement Application

CT based planning

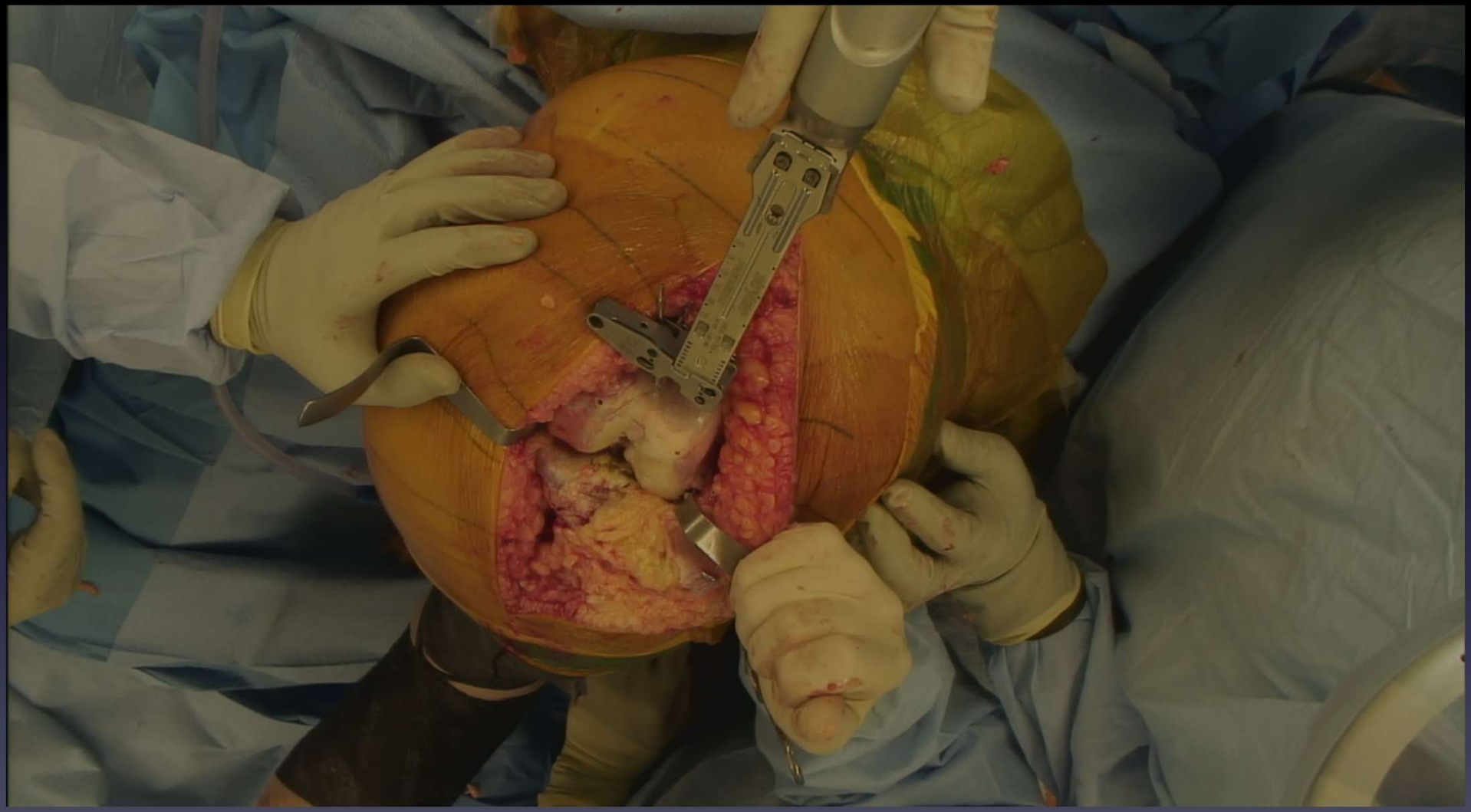


- 3D model of the pt's anatomy is created from CT data.
- Surgeon sizes and aligns the implant virtually.

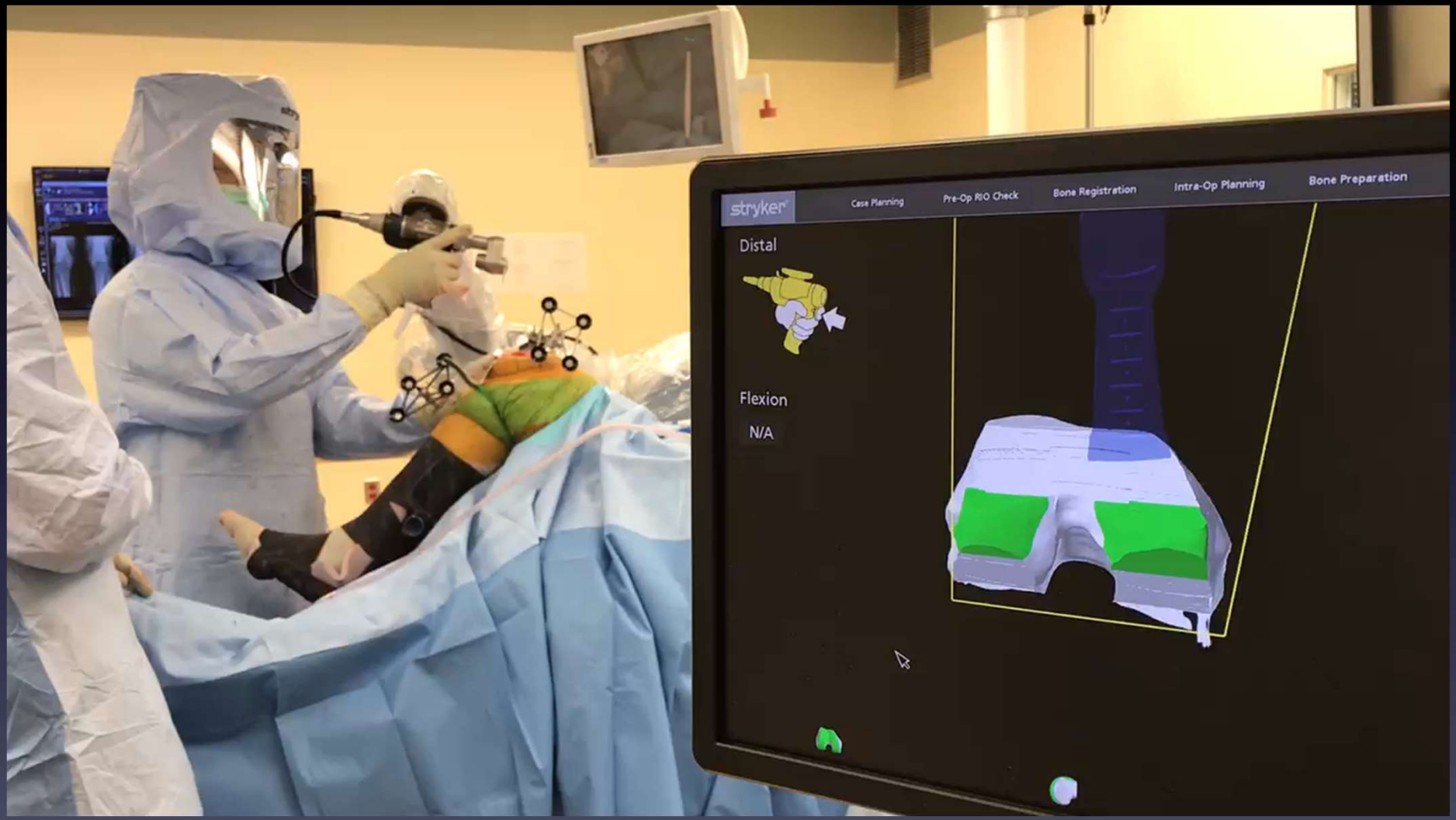
Dynamic Joint Balancing

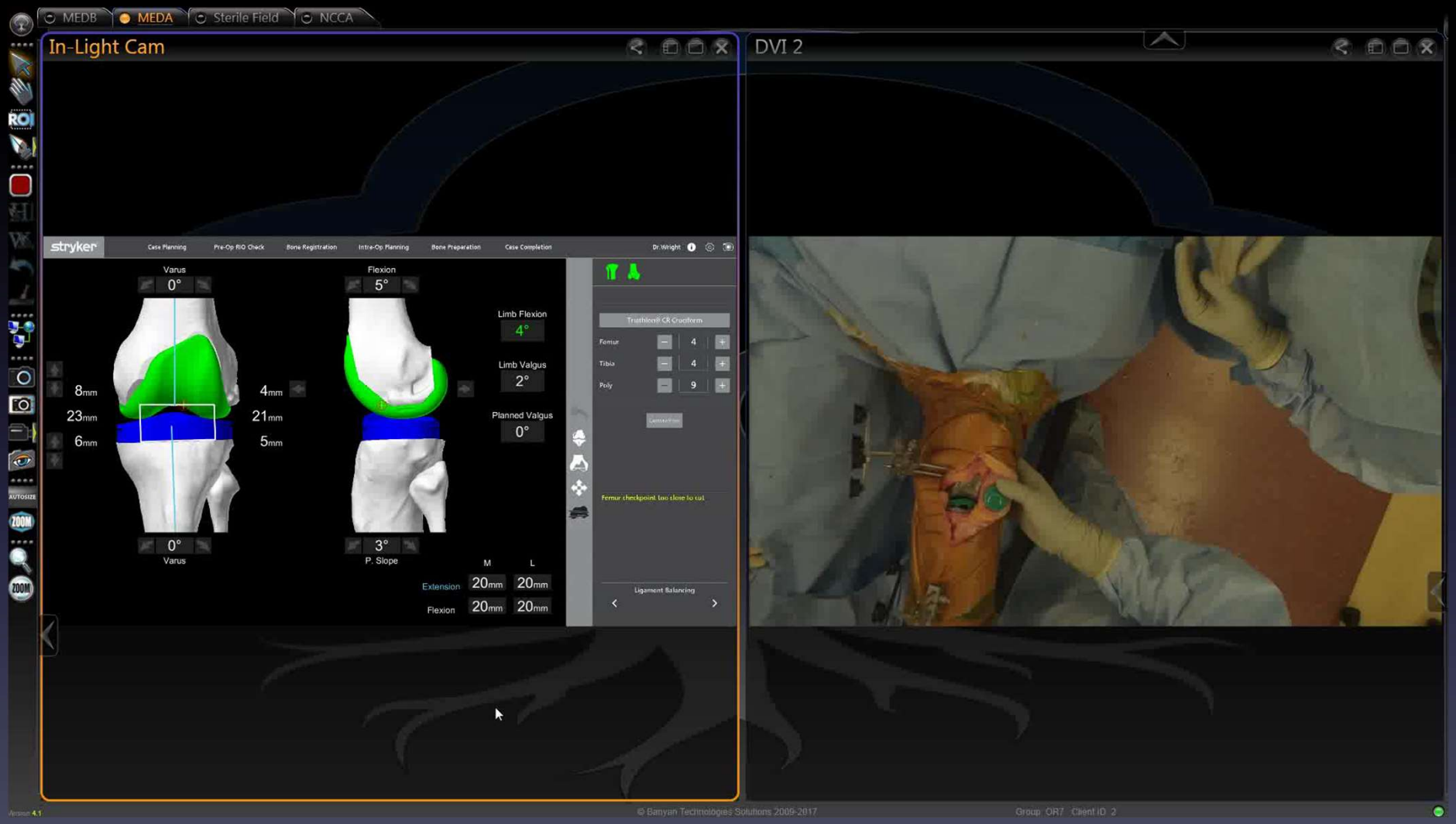


Manual cutting guides



Haptic Guided Bone Preparation

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Poly
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Ligament Balancing
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Group OR7 Client ID 2

Improved component placement accuracy (versus manual)

Primary investigators

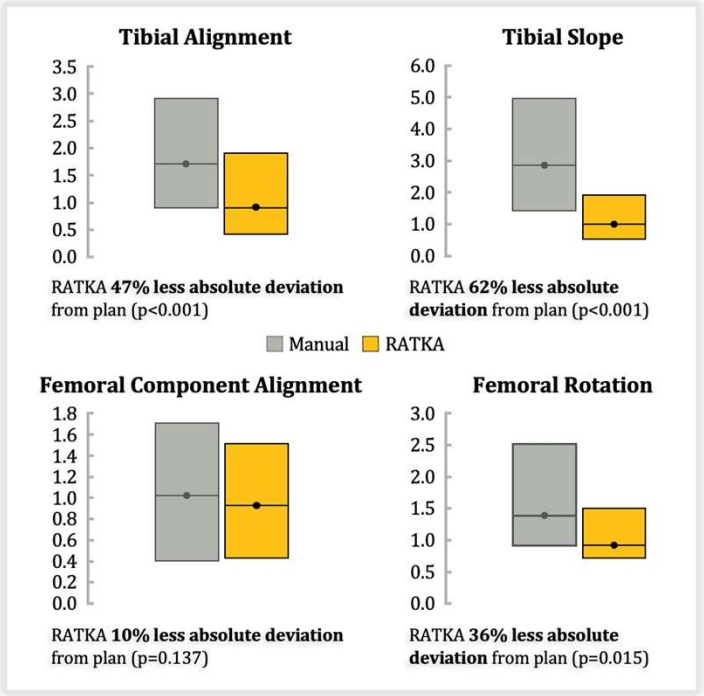
Michael Mont, M.D., Antonia Chen, M.D., Fabio Orozco, M.D., William Hozack, M.D., Ormonde Mahoney, M.D. [42]

Methodology

- Multi-surgeon, four centers and seven surgeons
- 144 robotic-arm assisted TKAs (RATKA) compared to 86 manual TKAs (MTKA)
- Groups had comparative demographics and preoperative disease state, function and health status

Results

- Improved precision and accuracy to plan of implant positioning for RATKA vs. MTKA
  - **Tibial alignment**: RATKA (1.3˚ ± 0.9˚), MTKA (2.3˚ ± 1.7˚), (p<0.001)
  - **Tibial slope**: RATKA (1.4˚ ± 1.1˚), MTKA (3.2˚ ± 2.9˚), (p<0.001)
  - **Femoral alignment**: RATKA (1.0˚ ± 0.9˚), MTKA (1.2˚ ± 1.0˚), (p=0.137)
  - **Femoral rotation alignment**: RATKA (1.1˚ ± 0.9˚), MTKA (1.9˚ ± 1.4˚), (p=0.015)



Improved Accuracy

J Arthroplasty. 2014 Dec;29(12):2373-7. doi: 10.1016/j.arth.2013.12.010. Epub 2013 Dec 14.

Robot-assisted total knee arthroplasty accurately restores the joint line and mechanical axis. A prospective randomised study.

Liow MH[1], Xia Z[1], Wong MK[1], Tay KJ[1], Yeo SJ[1], Chin PL[1].

J Knee Surg. 2019 Mar;32(3):239-250. doi: 10.1055/s-0038-1641729. Epub 2018 May 1.

Robotic-Arm Assisted Total Knee Arthroplasty Demonstrated Greater Accuracy and Precision to Plan Compared with Manual Techniques.

Hampp EL[1], Chughtai M[2], Scholl LY[1], Sodhi N[3], Bhowmik-Stoker M[1], Jacofsky DJ[4], Mont MA[3].

Decreased postoperative pain and opioid use

Primary investigators

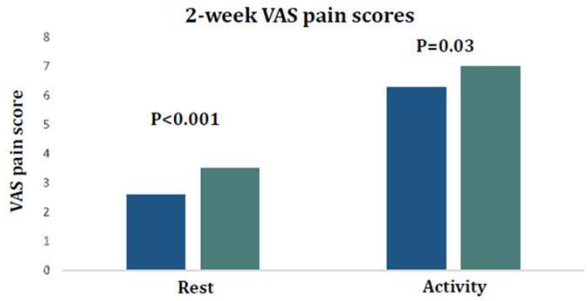
Samrath Bhimani, M.D., Rohat Bhimani, B.A., Austin Smith, M.D., Christian Eccles, M.D., Langan Smith, B.S., Arthur Malkani, M.D. [10]

Methodology

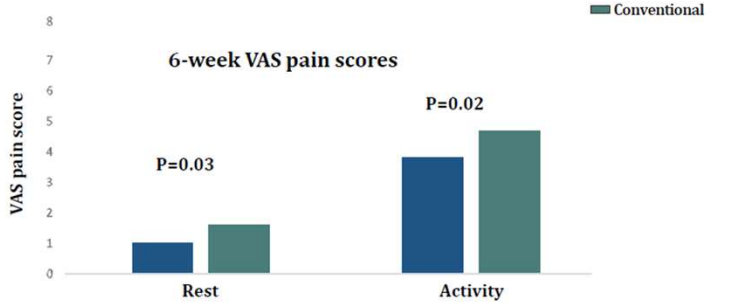
- Prospective cohort study comparing 140 Robotic Total Knee patients to 127 patients who underwent conventional manual TKA (MTKA)
- Two and six-week follow up visual analogue scores (VAS) for pain at rest and with activity, postoperative opiate usage, and length of stay (LOS) between the RATKA and MTKA groups were compared

Results

- At the six-week interval, the RATKA group required **3.2 mg less morphine equivalents** per day relative to the conventional group ($p < 0.001$), and a significantly greater number of patients in the RATKA group were **free of opioid use** compared to the conventional TKA group (70.7% vs. 57.0% ($p = 0.02$))
- Patients in the RATKA group had a **shorter LOS; 1.9 days versus 2.3 days ($p < 0.001$)**
- Patients in the RATKA group had a **greater percentage of patients discharged on postoperative day one; 41.3% vs 20.5% ($p < 0.001$)**



RATKA demonstrated decreased VAS pain scores at two weeks postoperatively compared to conventional TKA



RATKA also demonstrated decreased VAS pain scores at six weeks postoperatively compared to conventional TKA

Soft Tissue Protection

Surg Technol Int. 2017 Jul 25;30:441-446.

Robotic-Arm Assisted Total Knee Arthroplasty Demonstrated Soft Tissue Protection.

Khlopas A[1], Chughtai M[1], Hampp EL[2], Scholl LY[2], Prieto M[3], Chang TC[3], Abbasi A[3], Bhowmik-Stoker M[2], Otto J[3], Jacofsky DJ[4], Mont MA[1].

Decreased Stiffness

Primary investigators

Arthur Malkani, M.D., Martin Roche, M.D., et al.[44]

Methodology

- 188 consecutive RATKA at 5 centers paired to 188 MTKAs
- All patients followed similar postoperative rehabilitation starting on postoperative day 1
- All patients were followed for minimum of 2 years

Results

- RATKA patients had a 4.5-fold decrease in MUA rate

Table 1
Rates of MUA after robotic-assisted TKA versus manual TKA

	RATKA (n=188)	MTKA (n=188)	p-value
Number of MUAs (%)	2 (1.06)	9 (4.79)	0.032

Abbreviations: TKA=total knee arthroplasty, MUA=manipulation under anesthesia

RATKA patients had a 4.5-fold decrease in MUA rate

Improved Early Function
&
Earlier Hospital Discharge

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

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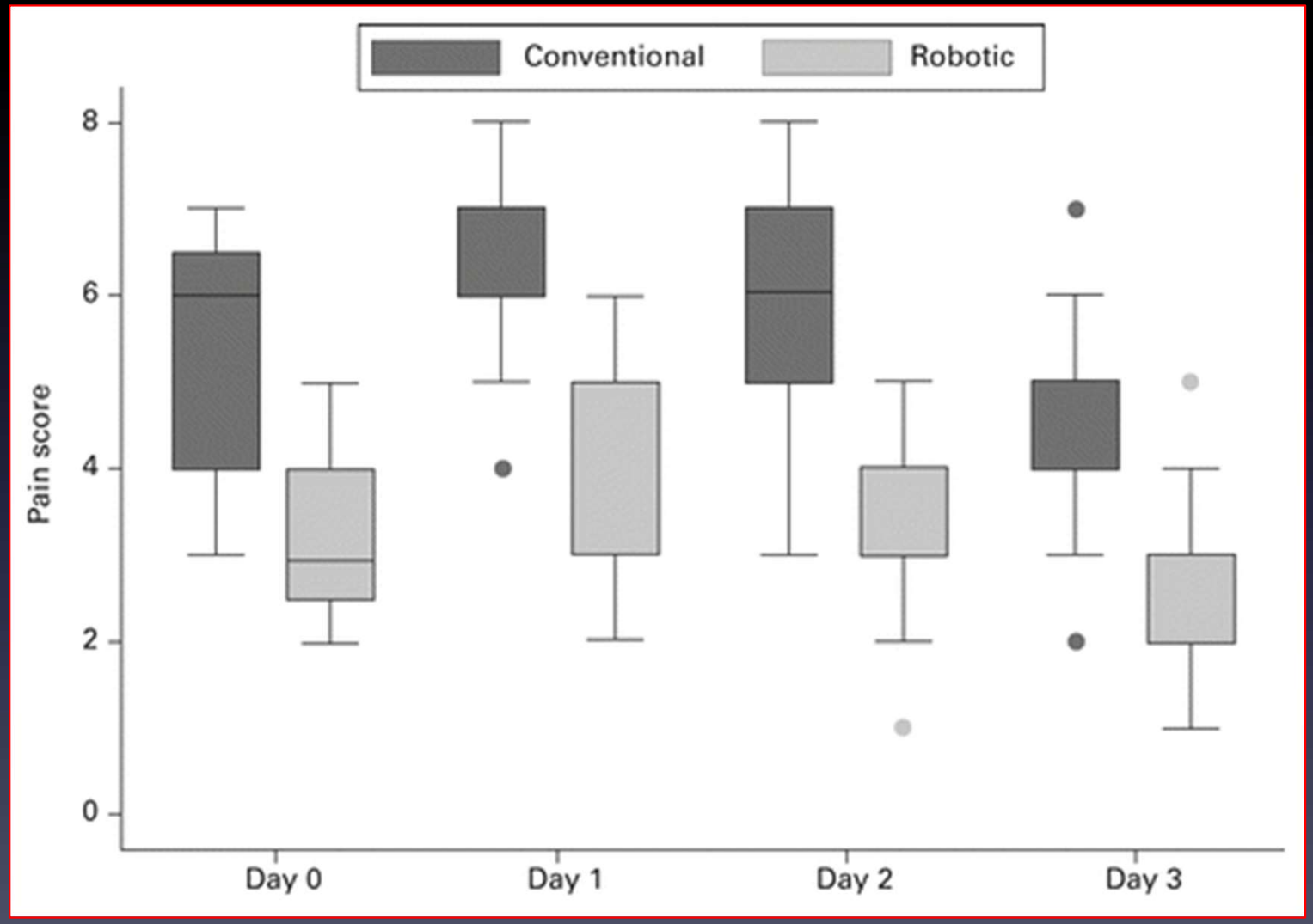
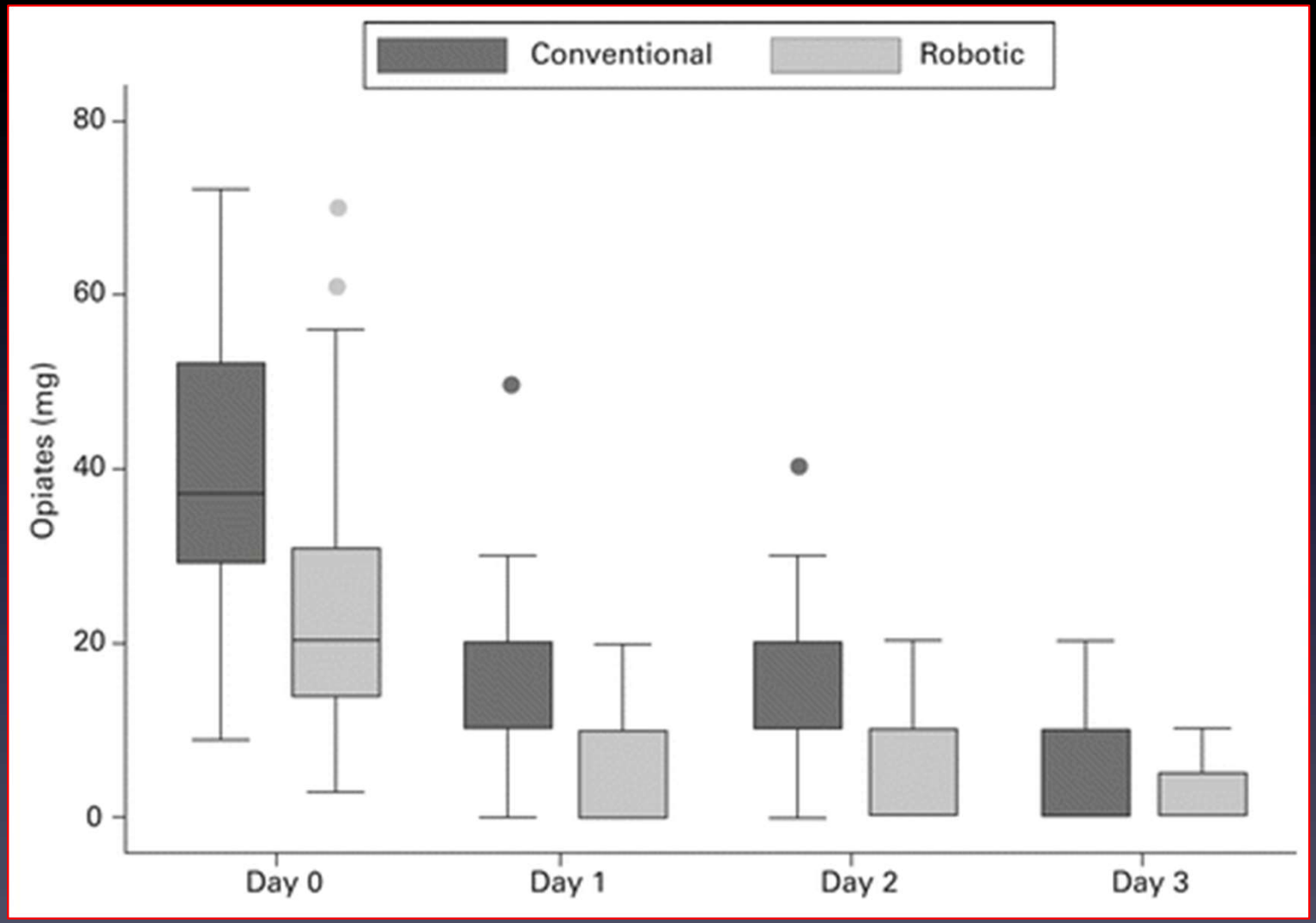
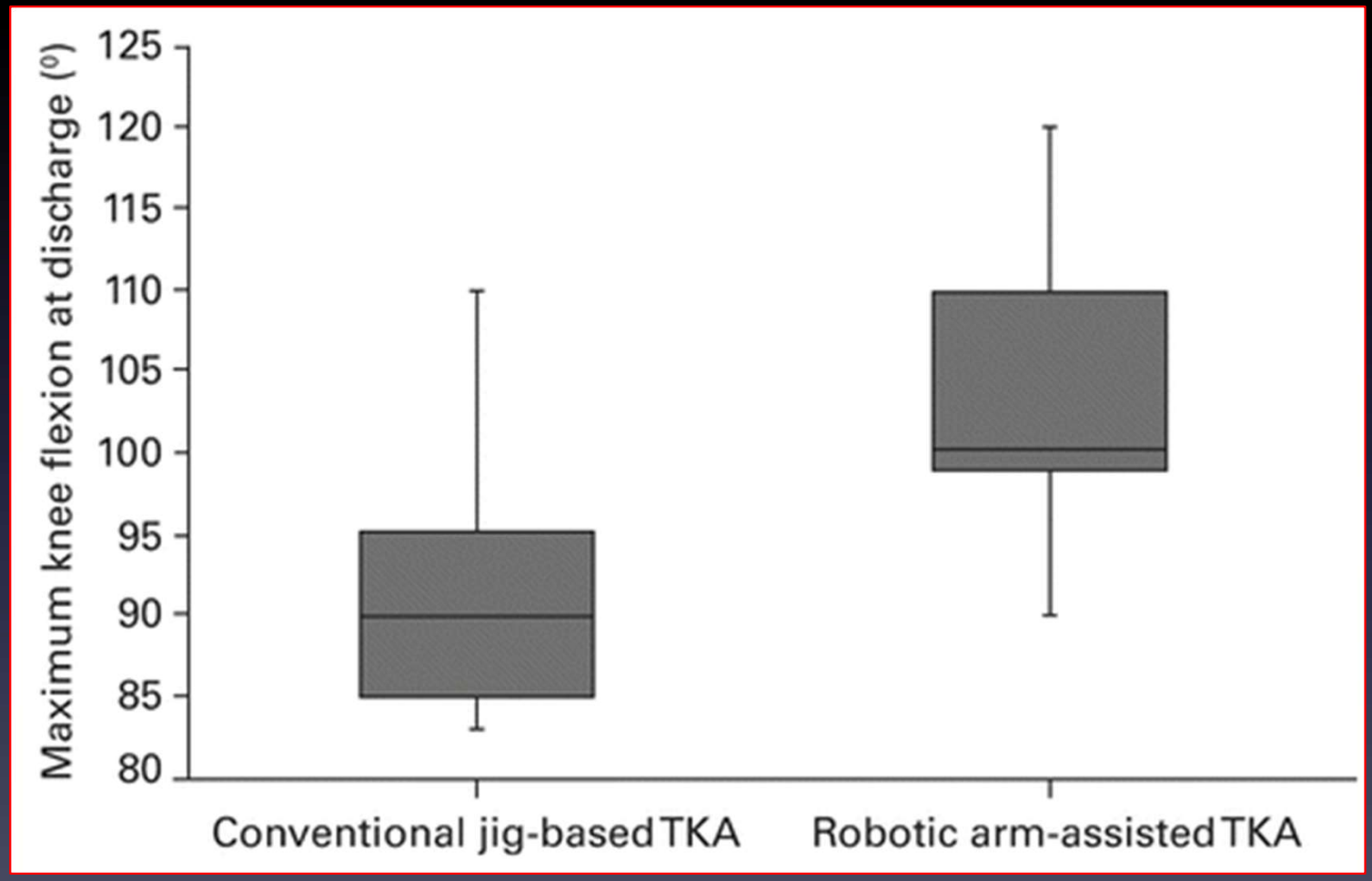
Decreased Pain Scores



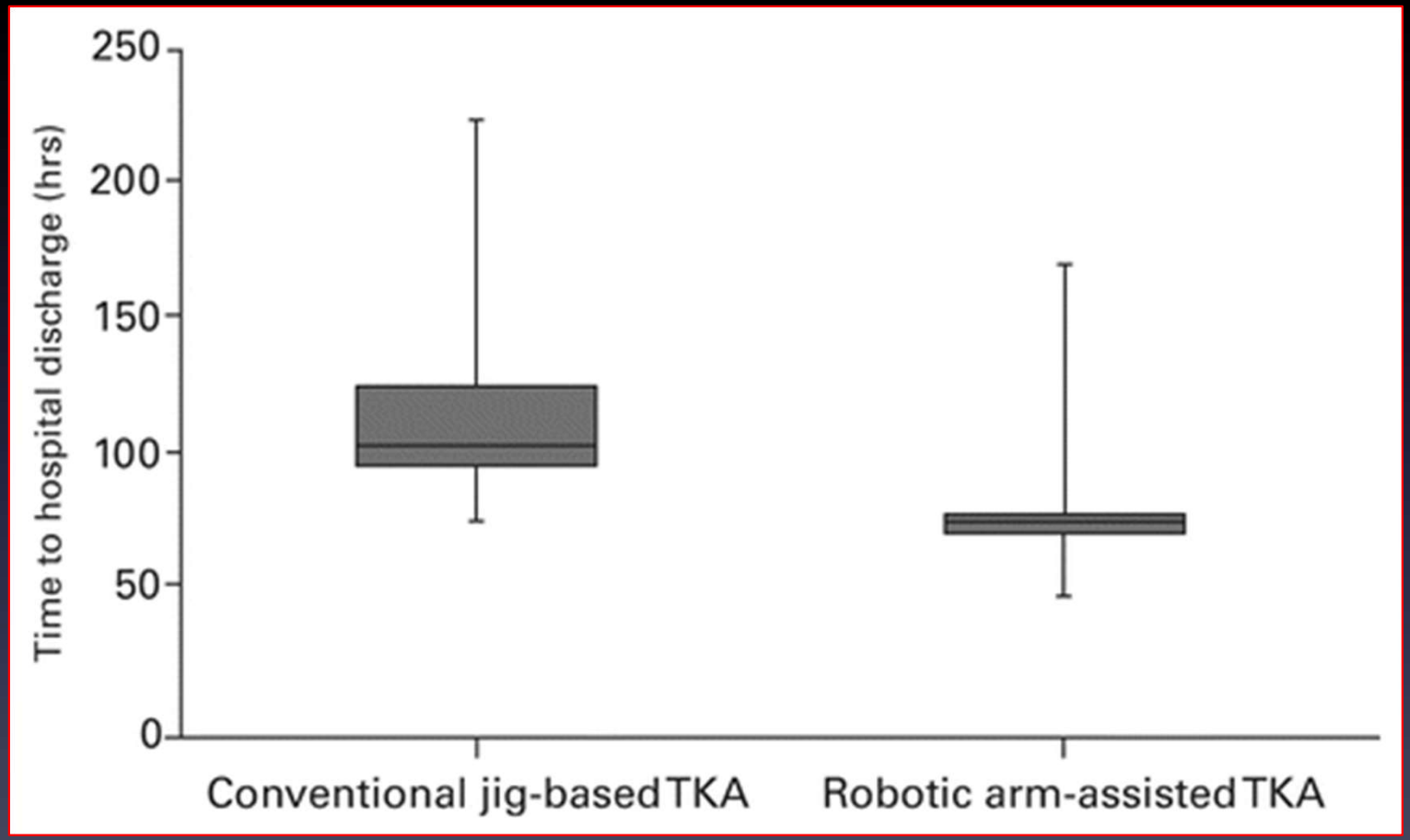
Decreased Opiate Consumption



Improved range of Motion



Earlier Hospital Discharge



Decreased 90 day episode of care cost

Primary investigators

Michael Mont, M.D., David J. Jacofsky, M.D.[12]

Methodology

- Retrospective review of U.S. Medicare database between January 2016 and March 2017
- Propensity score matching: 519 RATKAs and 2,595 MTKAs
- Compared: 90-day episode-of-care (EOC) cost, index costs, discharge disposition, LOS and readmission rates

Results

- Results are specific to a U.S.-based population
- RATKA patients had significantly lower average 90-day episode- of-care costs
- Significantly more RATKA discharged to home with care ($p<0.0001$) and less to SNF compared to MTKA ($p<0.0001$)
- LOS less by 0.7 days for RATKA ($p<0.0001$)
- RATKA 90-day readmission reduction 33% ($p<0.05$)

Table 2. Index facility costs and post 90-day costs by expense category‡

	RATKA	MTKA	Difference	p-value
Index facility costs				
– Index Costs	US $12,384	US $13,034	US -$640	0.0001†
Post 90-day costs by setting				
– Inpatient	US $12,075	US $13,267	US -$1,192	0.4904
– Outpatient	US $699	US $839	US -$141	0.0019†
– Emergency room	US $614	US $736	US -$122	0.1600
– Skilled nursing facility	US $7,201	US $7,947	US -$746	0.0230†
– Home health	US $3,045	US $3,536	US -$491	<0.0001†
Total post-90 days	US $5,234	US $6,978	US -$1,744	<0.0001†
Total EOC costs (Index + 90-day post-index)	US $18,568	US $20,960	US -$2,391	<0.0001†

†Indicates statistically significant p-values.

This table only includes data for those who have costs in the expense category of interest

EOC: Episode of care; MTKA: Manual assisted total knee arthroplasty; RATKA: Robotic-arm assisted total knee arthroplasty

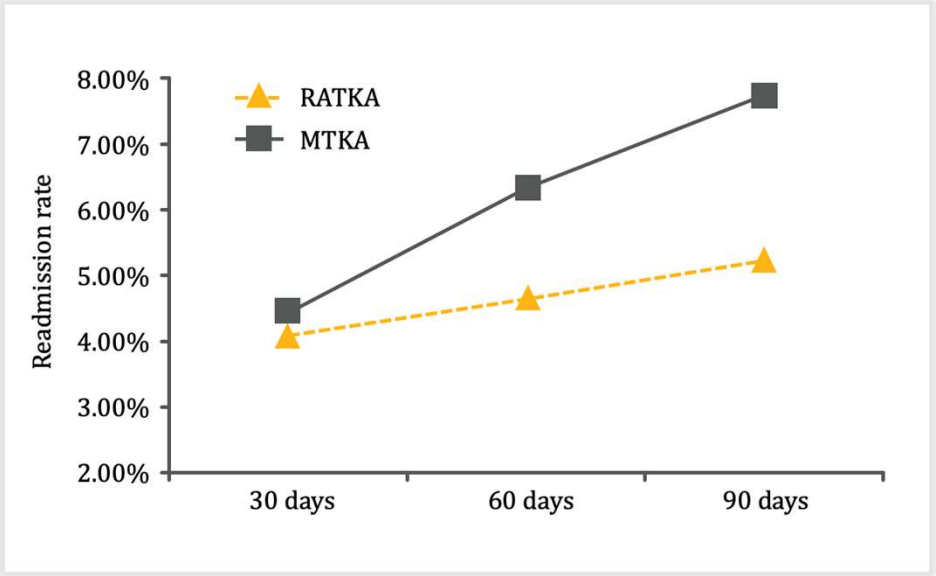
Decreased healthcare utilization and payer cost at 30, 60, & 90 days

Primary investigators

Michael Mont M.D., Christina Cool, MPH, et al. [13]

Results

- RATKA patients had **shorter lengths of stay in SNF** at 30 days (12.04 vs. 14.19, p=0.0385) - trend continued at 60 and 90 days
- RATKA patients utilized **fewer home health visits** at 30 days (11.65 vs. 14.04, p<0.0001); this trend also continued with significance at 60 and 90 days
- 31.3% **fewer RATKA patients utilized emergency room** services at 30 days post-index
- Readmission rate as shown in the chart



90 day episode of care cost analysis

Primary investigators

Carlos Lavernia, M.D.[14]

Methodology

- Retrospective review of Optum Insight database between January 1, 2016 and December 31, 2017
- Propensity score matching: 357 RATKAs and 1,785 MTKAs
- Compared: 90-day episode-of-care (EOC) cost, index costs, discharge disposition, LOS and readmission rates

Results

- LOS less by 0.9 days for RATKA (1.8 vs. 2.72, p<0.0001)
- Post-index cost was $1,332 less per case in the RATKA arm ($6,857 vs. $8,189; p=0.0018)
- RATKA demonstrated significantly less cost for outpatient rehab ($2,272 vs. $2,494; p=0.0194) and pharmacy ($588 vs. $843; p=0.0057)
- The average 90-day EOC cost was $4,049 less per case in the RATKA arm ($28,204 vs. $32,253; p<0.0001)
- Index savings of $2,722 contributed to this finding ($21,347 vs. $24,069; p=0.0002)

Average post-90-day pay amounts for those utilizing services

	RATKA	MTKA	Difference	p-value***
Index facility payment	$2,1347	$24,069	-$2,722	0.0002*
Inpatient	$13,328	$24,289	-$10,961	0.5444
Outpatient	$1,818	$2,148	-$330	0.6113
Emergency room	$7,033	$4,179	$2,854	0.0104*
Skilled nursing facility	$6,269	$7,849	-$1,580	3341
Home health	$2,009	$2,038	-$29	0.7522
Outpatient rehab costs	$2,272	$2,494	-$222	0.0194*
Physician costs	$1,253	$1,139	$115	.2170
★ Pharmacy costs	$588	$843	-$254	0.0057*
Post costs	$6,857	$8,189	$1,332	0.0018*
Total episode payment	$28,204	$32,242	-$4,038	<0.0001

*Indicates statistical significance

**This table only includes data for those who have utilization in the above service categories

***Non-parametric test was used due to non-normality

Repeated themes:

- LOS
- Postoperative utilization
- Overall episode-of-care cost

Comparative cost analysis of robotic-assisted and jig-based manual primary total knee arthroplasty

Primary investigators

E. Cotter, M.D., J. Wang, M.D., R. Illgen, M.D.[16]

Methodology

- Retrospective comparison of RATKA vs MTKA costs to a hospital
- 139 MTKAs vs. 147 RATKAs from 4/2015 to 9/2017
- Evaluating cost and health service utilization over a 90-day episode of care

Results

- Length of stay (LOS) was reduced 25% (1.2 vs. 1.6 days, respectively, $p < 0.0001$)
- Prescribed opioids were reduced 57% (984.2 versus 2240.4 MME, respectively, $p < 0.0001$)
- Fewer patients discharged to SNF (4.1% vs. 8.6%, $p = 0.113$)
- Cost of surgery + inpatient stay was lower ($14,189.09 vs $15,586.20, $p < 0.001$), driven by lower cost for tray sterilization and reduced LOS.
- Ninety-day EOC costs were $2,090.70 lower ($15,629.94 vs. 17,720.64, respectively; $p < 0.001$).

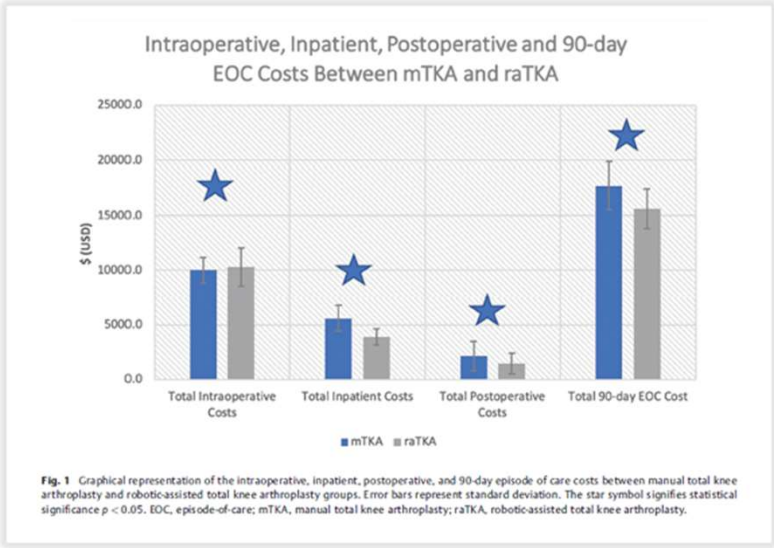
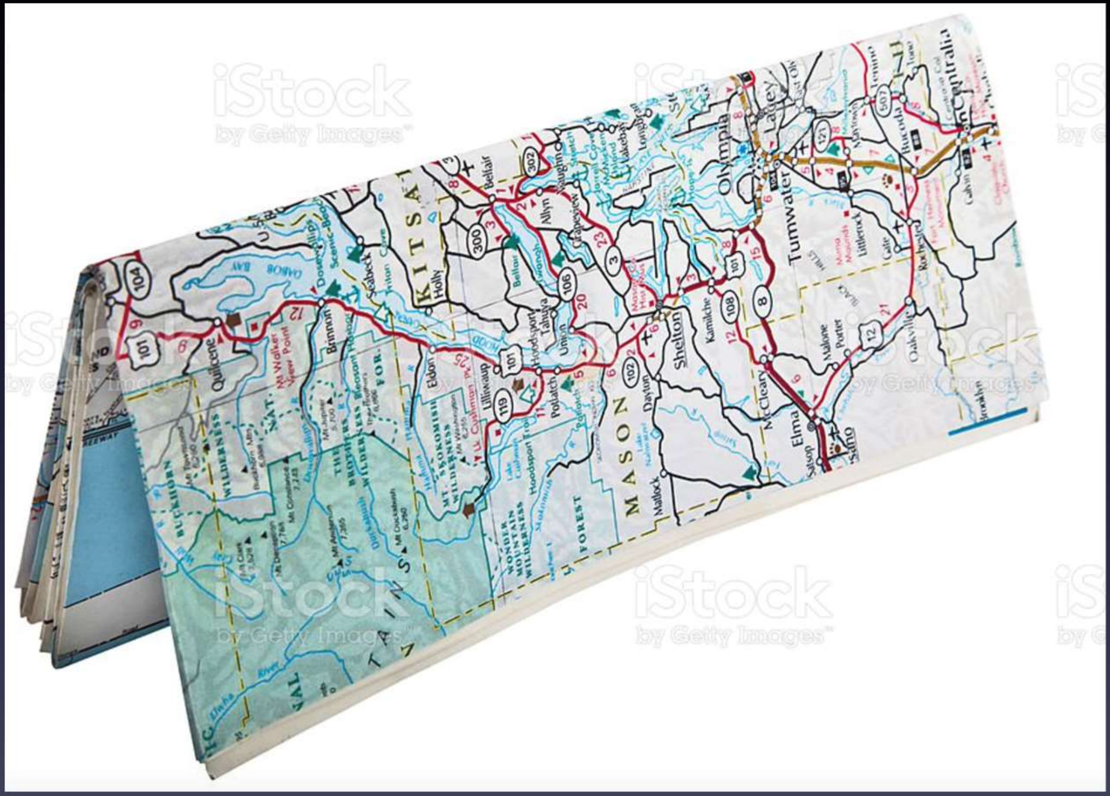
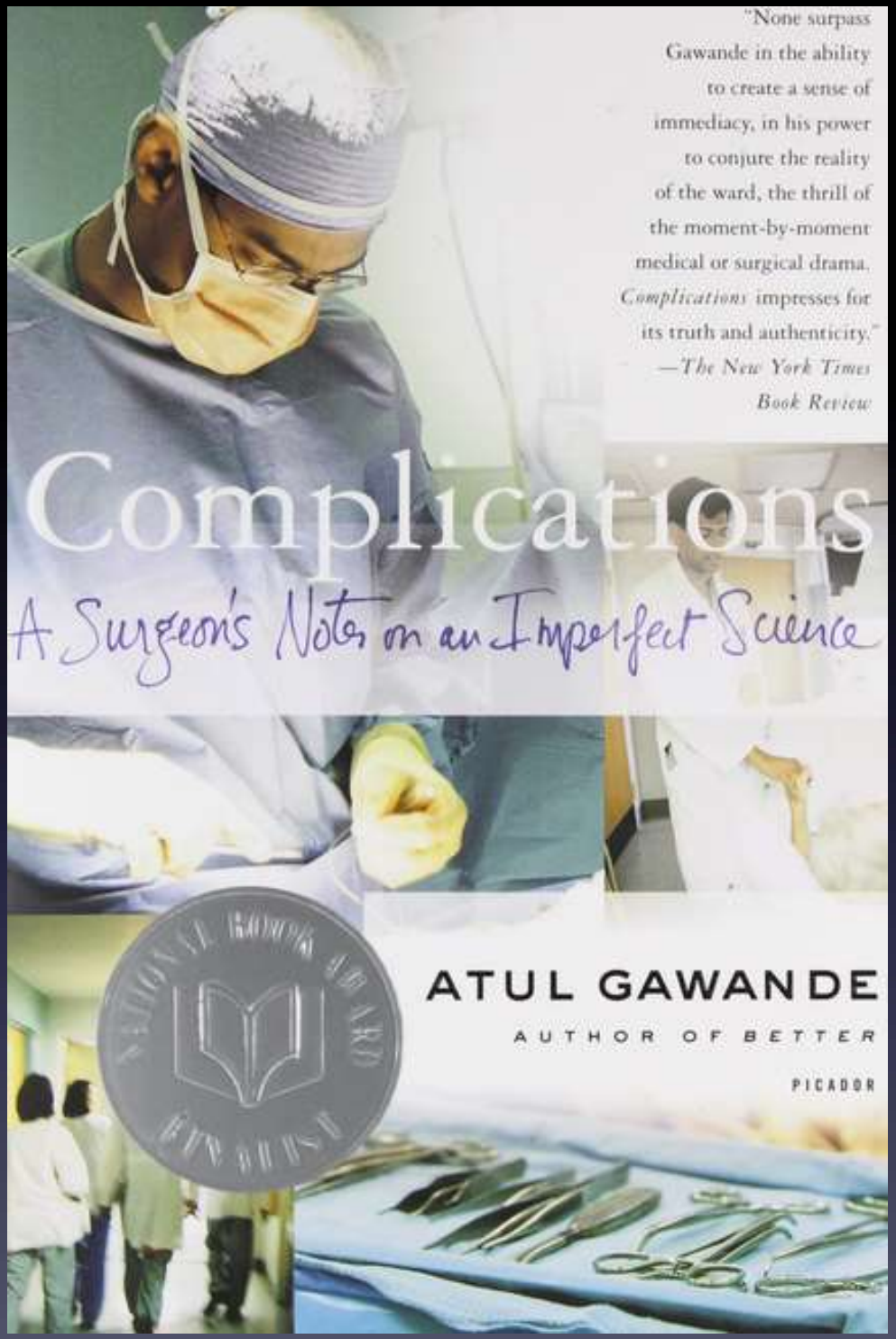


Fig. 1 Graphical representation of the intraoperative, inpatient, postoperative, and 90-day episode of care costs between manual total knee arthroplasty and robotic-assisted total knee arthroplasty groups. Error bars represent standard deviation. The star symbol signifies statistical significance $p < 0.05$. EOC, episode-of-care; mTKA, manual total knee arthroplasty; raTKA, robotic-assisted total knee arthroplasty.

Analogy:
Manual Map <u>vs</u> GPS





"To fail to adopt new techniques would mean denying patients meaningful technical advances."

Thank You

NO WHEELS HERE
NO NEW TECHNOLOGY
NO
PROTESTING AGAINST NEW TECHNOLOGY – THE EARLY DAYS

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