

Methods Article

Design and Preliminary Evaluation of a New Dual-Styli and Angel-Wing Resection Guide in Limiting Tibial Varus-Valgus Angle and Slope Recuts in Kinematically Aligned Total Knee Arthroplasty

Alexander J. Nedopil, MD, PhD^{1,2a}, Ahmed Zabiba, BS^{3b}, Patrick Sadoghi, MD, PhD^{4c}, Stephen M. Howell, BS, MD^{5d}, Maury L. Hull, BS, MS, PhD^{2,5,6,7e}

¹ Orthopaedic Surgery, University of Würzburg, ² Institute for Orthopaedic Surgery and Research, California Northstate University, ³ School of

- a Dr. Alexander J. Nedopil is a German-born and raised orthopedic surgeon and academic specializing in total knee and hip arthroplasty, with a strong focus on kinematic alignment, biomechanics, and implant design. He is an Associate Professor of Orthopedic Surgery at the University of Würzburg (Germany) and California Northstate University, and is affiliated with UC Davis and Adventist Health/Lodi Memorial Hospital. He completed his medical degree and doctoral training in Germany, followed by postdoctoral research at UCSF, residency training at Würzburg and UC Davis, and a joint replacement fellowship at the University of British Columbia. Dr. Nedopil is board-certified in the United States and a Fellow of major international orthopedic societies. His work has resulted in over 100 peer-reviewed publications, multiple books and book chapters, and patents related to surgical instruments and methods in kinematically aligned total knee arthroplasty.

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- b Ahmed Zabiba is a medical student at the University of California, Davis School of Medicine with an interest in orthopaedic surgery and clinical research. His research interests include total knee arthroplasty, knee biomechanics, and improving patient outcomes following orthopaedic procedures. He has contributed to multiple orthopaedic research projects spanning clinical outcomes, biomechanics, and surgical innovation.

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- c Dr. Patrick Sadoghi finished his tenure track as Associate Professor for Orthopedics and Orthopedic Surgery at the Medical University of Graz in Austria, where he currently works as the Head of the Division of Knee Surgery at the Department of Orthopaedics and Trauma.

He trained at Ludwig-Maximilians University Munich, Germany, the Medical University of Graz, Austria, and attended various clinical fellowships in the United States.

He finished his PhD thesis on Platelet-Rich Plasma in collaboration with the Children's Hospital Boston and his MBA master thesis on cost-effectiveness in arthroplasty in collaboration with the School of Public Health at Harvard T.H. Chan.

He specialises in all aspects of reconstructive knee surgery with a very high clinical and academic background, combining over 350 knee arthroplasty procedures per year with renowned research in the fields of knee implant, joint preservation, and orthopedic sports medicine.

He has been granted all relevant national and several international awards and is editorial board member of the most renowned journals in his expertise such as the Journal of Arthroplasty, Arthroscopy, and KSSTA. He lives with his wife Birgit Sadoghi, a dermatologist, and his son Lorenz in Graz, Austria.

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- d Stephen Howell is a pioneer of kinematically aligned total knee arthroplasty (KA TKA) with a career spanning 44 years in both clinical practice and research. He is the founder and editor of www.kaoptimizedtka.com, a leading, free educational resource covering all aspects of kinematically aligned TKA. As an Adjunct Professor of Biomedical Engineering at the University of California, Davis, he collaborates with Distinguished Professor Maury L. Hull, Ph.D., with whom he originated the caliper-verified kinematic alignment (KA) method for TKA in 2006. He has performed over 7,000 caliper-verified kinematically aligned TKAs—the largest series with the longest follow-up reported for this technique—and he is the editor of the definitive textbook on KA TKA. His surgical techniques and documentation helped two implant companies gain FDA approval for KA instrumentation. Together with Professor Hull, he established a sustained KA research program at UC Davis, supervising 36 M.S. and 4 Ph.D. students and managing grants from the National Science Foundation, industry, and independent foundations. Earlier in his career, he contributed to advances in anterior cruciate ligament (ACL) reconstruction, meniscal transplantation, and shoulder biomechanics. Dr. Howell has authored over 255 peer-reviewed studies and holds 32 U.S. and six international patents. His Google Scholar h-index is 77, and his i10-index is 208 as of July 2026. Search his National Library of Medicine Bibliography.

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Medicine, University of California, Davis, ⁴ Division of Knee Surgery, Medical University of Graz, ⁵ Department of Biomedical Engineering, University of California, Davis, ⁶ Department of Mechanical Engineering, University of California, Davis, ⁷ Department of Orthopaedic Surgery, University of California, Davis

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Purpose

To overcome limitations using manual instruments designed for mechanical alignment to set the tibial resection plane in kinematically aligned (KA) total knee arthroplasty (TKA), this paper reports a new dual-styli and angel-wing tibial resection guide. The primary objectives were to describe the design and perform a preliminary evaluation by reporting the frequency of tibial recuts and the proportion of thinner inserts, which indicated a conservative resection thickness. A secondary objective was to determine the incidence of radiographic varus-valgus (V-V) angle and posterior tibial slope (PTS) baseplate outliers, defined as deviations greater than $\pm 3^\circ$ from preoperative values.

Methods

In this retrospective consecutive case series, 195 KA TKAs performed by two surgeons were included. The dual styli set the varus-valgus (V-V) angle by referencing the medial and lateral tibial sub-chondral bone. Orienting the angel wing in the saw slot of the tibial jig, parallel to the medial joint line, set the posterior tibial slope (PTS). A V-V angle recut occurred when the extension space was asymmetric by ≥ 2 mm. A PTS recut occurred when the anterior-posterior thickness difference in the medial tibial resection differed by ≥ 2 mm and an osteotome placed on the anterior and posterior rim was not parallel to the resected surface. Postoperative V-V angle and PTS deviations were measured radiographically.

Results

Recuts in V-V angle and PTS were not required in 93% and 95% of cases, respectively, and 91% of inserts were 10-12 mm thick. Postoperative V-V angle outliers occurred in 1 of 195 cases ($< 1\%$), and PTS outliers occurred in 1 of 195 cases ($< 1\%$) and these were two different patients.

Conclusion

Surgeons using the new dual-styli and angel-wing tibial resection guide can expect to infrequently recut the tibia and use a thinner insert. The $< 1\%$ incidence of postoperative V-V angle and PTS baseplate outliers demonstrated reliable restoration of preoperative tibial alignment in this preliminary series.

INTRODUCTION

In kinematically aligned (KA) total knee arthroplasty (TKA), the goal is to restore the limb and knee alignments to the

pre-arthritic state, which in most patients precludes the need to release the collateral, retinacular, and posterior cruciate ligaments. KA ignores the locations of the center of the femoral head and center of the ankle because setting

^e Maury L. Hull, PhD is Distinguished Professor Emeritus at the University of California Davis where he where he held appointments in the Department of Biomedical Engineering, the Department of Mechanical Engineering, and the Department of Orthopaedic Surgery. He received his BS degree in mechanical engineering from Carnegie-Mellon University in 1969 and MS and PhD degrees also in mechanical engineering from the University of California Berkeley in 1970 and 1975. Dr. Hull became a faculty member in the Department of Mechanical Engineering at the University of California Davis in 1976. Dr. Hull's research activities encompass orthopedic biomechanics with emphasis on the human knee, musculoskeletal system modeling and simulation of movement, and sports biomechanics and equipment design. He has published more than 300 papers in scientific journals and has received numerous awards including the Giovanni Borelli Award from the American Society of Biomechanics, the H. R. Lissner Medal from the Bioengineering Division of the American Society of Mechanical Engineers, and the Alumni Outstanding Achievement Award from Carnegie-Mellon University.

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components to these landmarks alters limb alignment and joint-line obliquity, creating kinematic conflict among the ligaments during knee motion that can lead to stiffness, instability, poor clinical outcome scores, and shortened implant survival (Bae et al. 2024; Eckhoff et al. 2005; Franceschetti et al. 2025; MacDessi et al. 2021).

From a surgical perspective, the initial step in KA is to restore the pre-arthritis distal and posterior femoral joint lines. For the femoral condyle(s) on which articular cartilage is unworn, this is achieved by resecting articular cartilage and bone to a depth equal to the condyle of the femoral component. For the femoral condyle on which articular cartilage is worn, the cartilage is removed down to the level of subchondral bone and the resection thickness is decreased by 2 mm (Nam et al. 2014). Hence, articular cartilage is removed to the subchondral bone generally on the medial femoral condyle in varus knees and on the lateral femoral condyle in valgus knees. To perform these resections, a femoral referencing guide that directly contacts the surfaces is used.

The next step in KA involves restoring the pre-arthritis varus-valgus (V-V) angle and posterior tibial slope (PTS). Currently, KA is performed using manual instruments designed for mechanical alignment (MA), which include a proximal tibial cutting block attached to an extramedullary rod with a fixture that clamps just above the ankle. A single stylus in the cutting block is set on the lateral articular surface to set the depth of the resection. The surgeon adjusts the V-V angle and the PTS by changing the position of the extramedullary rod at the ankle. The PTS is fine-tuned until an angel wing, inserted in the medial saw slot, is parallel to the medial tibial articular surface. This setup has two limitations relevant to KA: visual setting of the V-V angle introduces variability, and the extramedullary fixture has limited adjustment range when the native PTS is shallow or steep, which varies by up to 17° across the population (Calek et al. 2022).

This study introduces a new dual-styli and angel-wing tibial resection guide designed to simplify tibial resection by registering the subchondral bone on both the medial and lateral tibia, thereby eliminating the need for the extramedullary rod and ankle reference. The primary objectives were to describe the design and perform a preliminary evaluation by reporting the frequency of tibial recuts and the use of thinner inserts, which indicate a more conservative resection thickness. A secondary objective was to evaluate the incidence of radiographic V-V angle and PTS base-plate outliers, defined as deviations greater than $\pm 3^\circ$ from preoperative values.

METHODS

An institutional review board approved the cross-sectional study using de-identified data (IRB # Pro00073629). Each patient met the Centers for Medicare & Medicaid Services guidelines for medical necessity for TKA, had Kellgren–Lawrence Grade III–IV osteoarthritis, and received treatment regardless of the severity of varus or valgus deformity or flexion contracture.

Between December 2024 and July 2025, two surgeons performed 204 caliper-verified KA TKAs with manual instrumentation and a KA-optimized implant system (GMK SpheriKA, Medacta International, Castel San Pietro, Switzerland, www.medacta.com, accessed on October 5, 2025) (Table 1). In every case in which the dual-styli and angel-wing tibial resection guide was available, it was used, indicating consecutive patient inclusion with 195 KA TKAs included in the study. Nine cases were excluded because the dual-styli and angel-wing guide was not available due to supply chain delays during the early study period; in these cases, conventional extramedullary tibial instrumentation was used. The KA-optimized implant system consists of a tibial insert with a flat lateral articular surface, medial ball-in-socket conformity, and posterior cruciate ligament (PCL) retention (Elorza et al. 2023); a femoral component featuring spherical condyles, a trochlear groove with a lateral wall opening to 20° valgus, and a flattened medial wall (Howell, Zabiba, Nedopil, et al. 2025; Howell et al. 2026; Howell, Zabiba, Sadoghi, et al. 2025); and an anatomic tibial base-plate that orients the anteroposterior axis of the insert parallel to the flexion-extension plane of the knee (Nedopil et al. 2021).

DESCRIPTION OF THE TIBIAL RESECTION GUIDE

The components and operation of the new dual-styli and angel-wing tibial resection guide, including two tibial registration screws, two rotating and sliding styli, a connecting post, a tibial cutting jig, and an angel wing, are shown and described in Figure 1.

STEPS FOR USING THE TIBIAL RESECTION GUIDE

Using the tibial resection guide involved four key steps: 1) exposing subchondral bone, 2) placing registration screws, 3) mounting and adjusting the tibial cutting jig, and 4) pinning the jig in place. After knee exposure, the femur was resected to restore the distal and posterior joint lines to the pre-arthritis state as previously described (Nedopil et al. 2018; Scott and Horton 2025). Where cartilage wear was evident, cartilage was removed to the subchondral bone. A caliper was used to measure the thickness of the medial and lateral distal and posterior femoral resections, which were verified as correct when they were within ± 0.5 mm of the condyle thickness of the femoral component, after adjusting 1 mm for the saw blade's kerf and 2 mm for worn cartilage.

The tibia was prepared by exposing the medial side 12 mm distal to the joint line and the entire tibial articular surface. With a 10-mm curette, an anteroposterior groove was created by removing cartilage down to subchondral bone in the center of the medial and lateral tibial compartments, with one edge of the groove at the base of the tibial spine, away from areas of tibial bone wear. In the center of each groove, a registration screw was drilled into the subchondral bone. The styli magnetically lock into the registration screws, and the length and rotation of the styli were set to rest the tibial cutting jig on the anterior surface of the tibia. The jig was secured by turning the tightening knob.

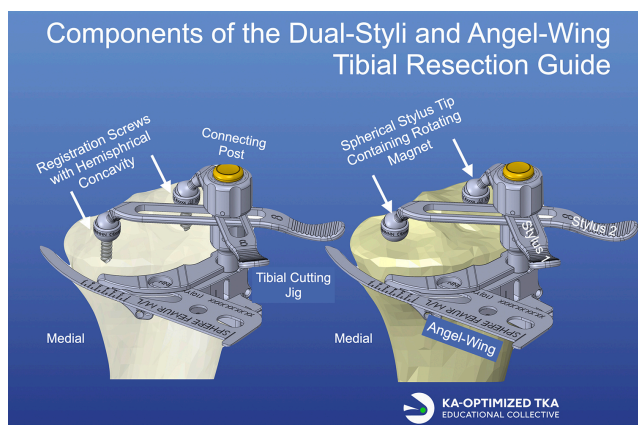


Figure 1. Pictorial of the dual-styli and angel-wing tibial resection guide showing a top-medial view of the left knee. The components include two tibial registration screws, two rotating and sliding styli, a connecting post, a tibial cutting jig, and an angel wing. Each registration screw consists of a head with a hemispherical concavity of 9 mm inner diameter and a slotted recess for driving the screw, a 12 mm shank, a 3.2 mm thread, a 2 mm core, and a self-drilling tip. Each stylus comprises a 9 mm diameter spherical tip containing a rotating magnet, attached to the stylus's slotted body by a short, narrow, angled section. The slot in the stylus allows it to be translated and rotated about the connecting post. The connecting post has a tightening knob that can switch between a free position for both styli and a locked position, and a release mechanism that allows it to engage and disengage from the lateral hole of the tibial cutting jig. The angel wing is inserted through the jig's medial side of the saw slot and serves as a reference surface, enabling the surgeon to visualize the resection plane and set it to restore the pre-arthritic slope.

The angel wing was inserted into the saw slot's medial side, and the jig angulated until it was parallel to the medial tibial slope. The jig was fixed to the tibia with three pins: two drilled in parallel with one another and one drilled at an angle to the other two. These steps set the plane of the jig to restore the pre-arthritic V-V angle and PTS and to remove 8 mm of bone from the proximal tibia. To see a demonstration of the guide's use intraoperatively, the interested reader should go to <https://www.kaoptimizedtka.com/> and view Lesson 9.

BALANCING STEP ONE: VERIFY WHETHER THE VARUS-VALGUS ANGLE OF THE TIBIAL RESECTION IS CORRECT OR REQUIRES A RECUT

As a preliminary verification check of balancing step one, a caliper was used to measure the thickness difference between the medial and lateral tibial resection at the base of the tibial spine. The second and definitive verification check was to determine whether the medial and lateral gaps were negligible and equal in extension with a spacer block during a varus-valgus stress test. When the gap in one com-

partment exceeded 1 mm as determined visually, a recut was performed by removing bone from the opposite tibial compartment using a skimmer saw cut or a recut guide to achieve a tight rectangular space.

BALANCING STEP TWO: VERIFY WHETHER THE POSTERIOR SLOPE OF THE TIBIAL RESECTION IS CORRECT OR REQUIRES A RECUT

As a preliminary check of balancing step two, a caliper was used to measure the thickness difference between the anterior and posterior rims of the medial tibial resection. The second verification check was to view the medial side of the tibial resection, place a flat object like an osteotome on the anterior and posterior rim, and determine whether the slope of the osteotome was parallel to the tibial resection plane. When the osteotome was not parallel and the thickness difference was ≥ 2 mm, a recut was performed using a recut guide by removing bone from the under-resected region.

BALANCING STEP THREE: USE AN INSERT GONIOMETER TO CHOOSE THE OPTIMAL INSERT THICKNESS WITHIN ± 1 MM

The final balancing step was to use an insert goniometer to select the optimal insert thickness. The optimal thickness was the one that restored full extension and provided the maximum tibial internal rotation without anterior lift-off of the insert at 90° of flexion. If insert lift-off was observed, then balancing step two above was repeated.

RADIOGRAPHIC MEASUREMENT TECHNIQUE FOR DETERMINING THE DEVIATION IN BASEPLATE V-V ANGLE AND POSTERIOR TIBIAL SLOPE FROM PREOPERATIVE

All radiographs were obtained according to the Knee Society radiographic evaluation system and methodology (Meneghini et al. 2015). Long-leg alignment films were not used, as the measured variables are knee-level measurements. Pre- and post-operative radiographic analysis determined the deviation of the V-V angle and PTS of the tibial baseplate from the preoperative knee. One author (AZ) measured the posterior tibial slope (PTS: posterior slope $> 0^\circ$) as the angle between a line along the posterior tibial cortex and a line parallel to the medial tibial plateau. The same author measured the anatomic medial proximal tibial angle (aMPTA; varus angle $< 90^\circ$) (Horos 4.0.1, horosproject.com, last accessed 11/05/25) as the angle between the anatomic axis and the proximal tibial joint line. The author (AZ) was blinded to surgeon identity, recut status, and all clinical details at the time of measurement. Deviation in the V-V angle was defined as post-aMPTA minus pre-aMPTA; a positive value indicated greater baseplate valgus than preoperative. Deviation in PTS was defined as post-PTS minus pre-PTS; a positive value indicated a greater baseplate slope than preoperative. Deviations $> 3^\circ$ in magnitude were considered outliers. The $\pm 3^\circ$ threshold for defining outliers was selected based on its established use

in prior arthroplasty literature as a clinically meaningful deviation from intended alignment (Bosco et al. 2025; Deckey et al. 2021). Intraobserver reliability (i.e. repeatability or precision) in each angle was determined by having one observer measure each angle in three trials on 20 patients selected randomly. The repeatability was the square root of the pooled variance. Because the deviation was determined from the difference between two independent random variables, the precision in the deviation was calculated as: deviation precision = angle repeatability $\times$ 1.414 (i.e. square root of 2). The deviation precisions were limited to 0.6° for the V-V angle and 0.7° for the PTS.

DATA ANALYSIS

Statistical software (JMP Pro, version 18.0.1, Cary, NC, <https://www.jmp.com>, accessed on January 12, 2026) was used to determine the frequencies of V-V angle and PTS tibial recuts and the distribution of insert thicknesses. The mean and standard deviation (SD) are reported for the radiographic V-V angle and PTS angular differences from preoperative values. Upper (UCL) and lower (LCL) 95% confidence limits for proportions were computed using the Wilson score interval.

RESULTS

The 62 KA TKAs performed by the surgeon with 20 years of experience and the 133 KA TKAs performed by the surgeon with 6 years of experience had similar distributions of age, sex classification, Kellgren-Lawrence osteoarthritic classification, insert thickness, and a similar mean changes in V-V angle and PTS of the baseplate relative to preoperative (Table 1).

Of the 195 KA TKAs, 181 of 195 (93%, UCL/LCL: 96%/88%) and 185 of 195 (95%, UCL/LCL: 97%/91%) of the tibial resection planes were not recut in the V-V angle and PTS, respectively (Figures 2 and 3). In 177 of 195 (91%, UCL/LCL: 94%/86%) of cases, the insert thickness ranged from 10 to 12 mm and no insert exceeded 14 mm (Figure 4). Baseplate outlier alignments more than $\pm 3^\circ$ from preoperative occurred in V-V angle in one of 195 cases (i.e., < 1%) and in PTS in 1 of 195 cases (i.e., < 1%) (Figures 5 and 6). These two outliers occurred in two different patients. Neither outlier required revision surgery during the follow-up period.

DISCUSSION

In this early clinical evaluation, the most important findings are that the new dual-styli and angel-wing tibial resection guide overcame two limitations of conventional extramedullary tibial instruments (i.e. visual setting of the V-V angle and limited adjustment range), had a low frequency of V-V angle and PTS recuts, used thinner inserts indicating a conservative tibial resection thickness, and had few outlier alignments from preoperative.

This new dual-styli and angel-wing tibial resection guide is an evolution of commonly available extramedullary tibial

resection instrumentation that clamps to the ankle and addresses two key limitations of this setup. Instead of visually setting the V-V angle based on a single stylus, which typically contacts the lateral articular surface, the two styli are connected to two registration screws drilled into the subchondral bone at the base of the lateral and medial tibial spines (Figure 1). By registering the screws drilled into the subchondral bone directly in both compartments, the uncertainty associated with visually aligning the V-V angle is eliminated. Also, by eliminating the extramedullary fixture, which interferes with the tibia and has inherent limitations of excursion when shallower or steeper tibial slope is required, the dual-styli and angel-wing resection guide extends the range of adjustment to restore the patient's prearthritic PTS.

Although the dual-styli and angel-wing resection guide eliminated the visual alignment of the V-V angle, the PTS is still set by visual alignment. However, PTS restoration with an angel wing, placed either medially as done with the dual-styli angel-wing reference guide or on top of the medial tibial articular surface, is reasonably accurate (Franceschetti et al. 2025; Nedopil et al. 2017). Evidence of this accuracy is further confirmed by the results of the present study, showing that 95% of patients did not require a tibial recut (Figure 3).

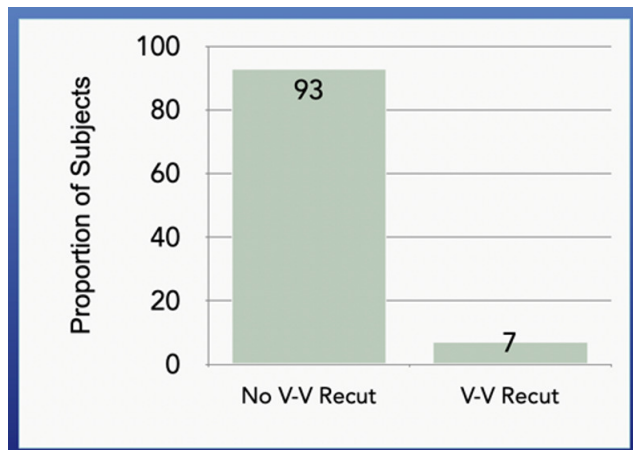
Since manual instruments are used to perform KA without relying on radiographic measurements by placing the femoral and tibial guides directly on the articular surfaces of the femur and tibia, the number of error sources are minimized. For the femur, the main source of error is the use of a fixed 2 mm adjustment for the thickness of the articular cartilage (Campi et al. 2025; Giurazza et al. 2025; Sandhar et al. 2026). For the tibia, the main sources of error associated with using the new dual-styli angel-wing resection guide for the V-V angle are the screw position choice, as well as bone wear if present under the screws. The main error source for the PTS is relying on visually aligning the angel wing parallel to the slope of the medial articular surface. However, errors from these sources had a minimal impact on tibial baseplate positioning, as the percentage of outliers exceeding 3° was < 1% for both the V-V angle (Figure 5) and the PTS (Figure 6).

Not only were the number of error sources minimized leading to a low frequency of V-V angle and PTS recuts, but also thinner inserts were used indicating conservative tibial resection thickness. Beyond indicating a conservative tibial resection, the narrow distribution of insert thicknesses (91% between 10–12 mm) also has practical implications for inventory management, particularly in ambulatory surgery centers where maintaining a broad range of insert sizes is logistically challenging.

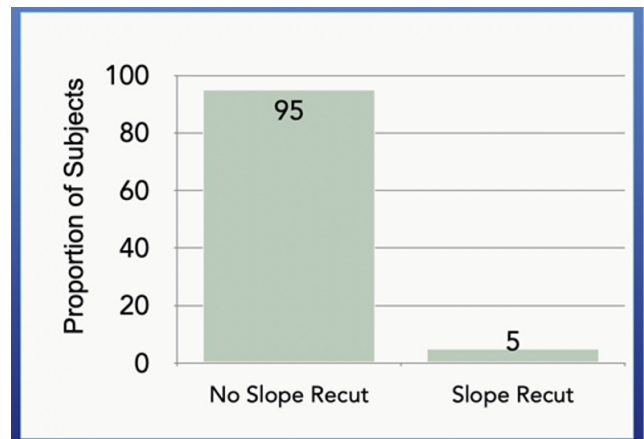
Since this was a preliminary evaluation, several future studies for a more thorough evaluation are warranted. One is that results should be compared to those of control group where extramedullary instrumentation was used. In addition to the process-based measurements herein, this comparison should include operative efficiency and patient-reported outcomes. Also, a multicenter study is needed to determine inter-surgeon variability in recuts, insert thick-

Table 1. Summary of patient demographics and postoperative changes in the V-V angle and PTS from preoperative for the two surgeons of different experience levels.

		Surgeon	
		20 years of experience	6 years of experience
Age (yrs)	Mean	72.3	68.7
	Std Dev	7.4	9.4
Female		36	80
Male		26	53
Kellgren-Lawrence Grade (1-4)			
3		11	27
4		51	105
Insert Thickness (mm)			
10		29	50
11		20	48
12		8	23
13		4	8
14		1	4
Difference in V-V angle (°) (Post-op minus Pre-op; + more valgus)	Mean	0.2	0.3
	Std Dev	1.4	1.1
Difference PTS (°) (Post-op minus Pre-op; + more posterior slope)	Mean	-0.4	-0.3
	Std Dev	1.2	1.1

**Figure 2. Column graph showing the proportion of subjects with asymmetry in gaps at extension requiring a tibial recut.**

ness distribution, and alignment outliers. Next, the present study does not provide information about the learning curve, which is the number of cases a typical surgeon needs to perform to obtain the low recut rate and distribution of insert thicknesses that indicate a conservative tibial resection thickness.

**Figure 3. Column graph showing the proportion of subjects with asymmetry in the PTS requiring a tibial recut.**

CONCLUSION

Two surgeons using the dual-styli and angel-wing tibial resection guide infrequently required recuts and infrequently used inserts thicker than 12 mm. The < 1% incidence of postoperative V-V angle and PTS baseplate outliers demonstrated reliable restoration of preoperative tibial alignment in this preliminary series.

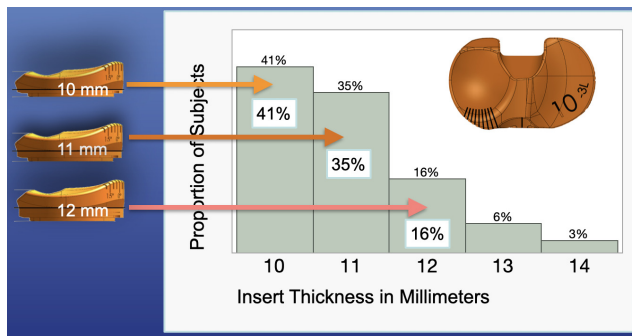


Figure 4. Column graph showing proportion of subjects with varying insert thickness. Ninety one percent of inserts were 10-12 mm thick, indicating that the initial tibial resection was conservative and that the risk of using an insert thicker than 14 mm was low.

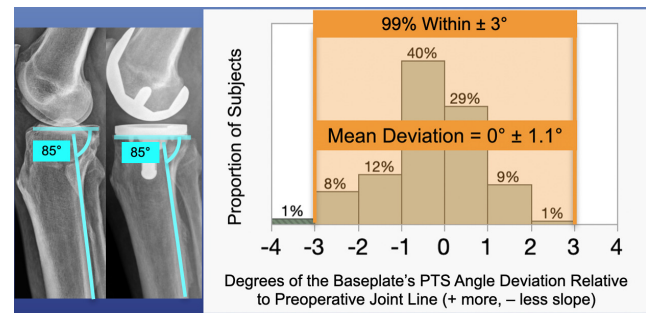


Figure 6. Column graph showing the proportion of subjects with degrees of deviation in PTS from the preoperative joint line. Ninety-nine percent of baseplates had a PTS deviation within $\pm 3^\circ$ of the pre-arthritis joint line.

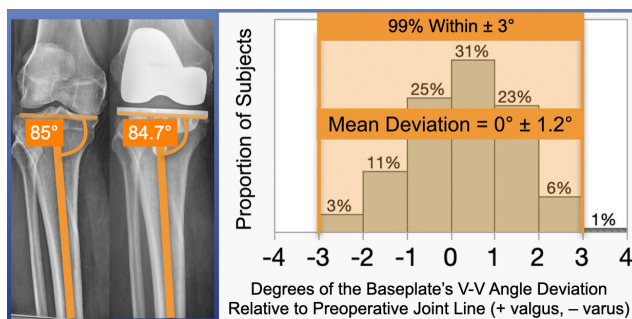


Figure 5. Column graph showing the proportion of subjects with degrees of V-V angle deviation from the preoperative joint line. Ninety-nine percent of baseplates had a V-V angle deviation within $\pm 3^\circ$ of the pre-arthritis joint line.

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