

**DO MEDIAL PIVOT KINEMATICS CORRELATE WITH PATIENT-REPORTED OUTCOMES
AFTER TOTAL KNEE ARTHROPLASTY?**

Lucian C. Warth, MD^{1,2}
Marshall K. Ishmael, BS²
Evan R. Deckard, BS²
Mary Ziemba-Davis, BA²
R. Michael Meneghini, MD^{1,2}

¹ Indiana University School of Medicine, Department of Orthopaedic Surgery, 1120 W. Michigan Street, Room 600, Indianapolis, IN 46202

² Indiana University Health Physicians Orthopedics and Sports Medicine, IU Health Saxony Hospital, 13100 East 136th Street, Suite 2000, Fishers, IN 46037

Corresponding Author:

Lucian C. Warth, MD
Indiana University Health Physicians Orthopedics and Sports Medicine
Indiana University School of Medicine, Department of Orthopaedic Surgery
13100 136th Street
Suite 2000
Fishers, IN 46037
Phone: 317-688-5980
lcwarth@iuhealth.org

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4

5 **Abstract**

6 **Introduction:** Many total knee arthroplasty (TKA) implants are designed to facilitate a medial pivot
7 kinematic pattern. The purpose of this study was to determine whether intraoperative medial pivot
8 kinematic patterns are associated with improved patient outcomes.

9 **Methods:** Retrospective review of consecutive primary TKAs with a modern implant design was
10 performed. Sensor-embedded tibial trials determined kinematic patterns intraoperatively. The center of
11 rotation (COR) was identified on medial and lateral condyles from 0° to 90° and from 0° to terminal
12 flexion, and designated medial-pivot or non-medial pivot based on accepted criteria. Patient-reported
13 outcomes were measured preoperatively and at minimum one-year follow-up.

14 **Results:** The analysis sample consisted of 141 TKAs after exclusions for potential confounds (53) and
15 loss to minimum one-year follow-up (9). Seventy-five percent of patients were female. Mean age and
16 median BMI were 63.7 years and 33.8 kg/m², respectively. Forty-percent of TKAs had a medial pivot
17 kinematic pattern from 0 to 90° and 0° to terminal flexion. A medial pivot pattern was greatest with
18 cruciate-retaining compared to PCL-sacrificing TKAs ($p \leq 0.0150$). Regardless of bearing type,
19 minimum one-year Knee Society objective, satisfaction, function, walking pain, stair pain and UCLA
20 Activity Level did not differ based on medial vs. non-medial pivot patterns from 0 to 90° ($p \geq 0.292$).
21 Improvement in outcomes largely did not differ based on pivot type, although for patients with PCL-
22 sacrificing implants, there were trends for greater median improvement in Knee Society objective (46
23 vs. 31.5 points, $p = 0.057$) and satisfaction (23 vs. 14 points, $p = 0.067$) scores in medial pivot knees.
24 Outcomes did not vary based on pivot classifications from 0° to terminal flexion.

25 **Discussion:** A medial pivot pattern may not govern clinical success based on intraoperative kinematics
26 and modern outcome measures. Further research is warranted to determine if a particular kinematic
27 pattern promotes optimal clinical outcomes after TKA.

28 **Keywords:** total knee arthroplasty, medial pivot, kinematics, patient-reported outcomes

29 Introduction

30 Total knee arthroplasty (TKA) is a well-accepted procedure for the treatment of end stage knee
31 arthritis. The procedure has proven to be exceptionally reliable in terms of implant longevity, with 20-
32 year revision free survival rates between 70.9%-91.0%.[1-11] Unfortunately, achieving a comparable
33 level of subjective clinical success has proven to be elusive. A host of reports evaluating patient reported
34 outcomes after TKA quote up to 20% of patients are not satisfied, often citing continued pain, stiffness,
35 or an 'unnatural' feel to the joint.[12-14]

36 Traditional surgical principles of TKA have focused on re-establishing limb alignment and
37 ligament balance during surgery. Bone cuts and soft tissues releases are combined to correct
38 tibiofemoral malalignment, balance extension and flexion gaps, enhance patellar tracking, and optimize
39 range of motion. Variations in ligament balance and tension logically affect knee kinematics and
40 furthering the lack of predictability is that ligament balance is subjective, surgeon specific, and highly
41 variable. Understandably, limb alignment and ligament balance as drivers of outcome have
42 overshadowed kinematics, however, this has been due to a lack of readily available tools to quantify
43 intraoperative and post-operative kinematics, as well as insufficient knowledge regarding the complexity
44 of kinematic patterns in native and TKA knees.

45 Intuitively, a well done TKA would restore normal knee kinematics and thereby function. The
46 potential of new technology to provide intra-operative feedback during TKA including computer
47 guidance, robotic assistance, and digital sensors in tibial trials has led to resurgent interest in kinematics.
48 Understanding how alignment and balance relates to kinematics and subsequently how this correlates
49 patient with satisfaction remains in its infancy.

50 Dennis et al found that 60% of patients with normal knees presented with a medial pivot pattern
51 during gait, and 80% of patients with normal knees presented with a medial pivot location during a deep
52 knee bend.[15] While a number of modern TKA implants are theoretically designed to facilitate or

53 guide a medial-based kinematic pattern during knee motion, [16-20] there is a dearth of literature
54 evaluating how consistently surgeons hit the kinematic target, and if that goal yields improvements
55 clinically. Recently, Nishio and colleagues[21] analyzed intraoperative kinematic patterns from 0-90
56 degrees in posteriorly stabilized TKAs using a computed tomography (CT)-based navigation system and
57 identified significantly better subjective outcomes and knee flexion angles after TKA in patients with a
58 medial pivot kinematic pattern when compared to non-medial pivot knees.

59 The purpose of the present study was to determine if intraoperative kinematic patterns provided
60 by digital sensor technology correlate with postoperative function, pain, and satisfaction at minimum
61 one-year follow-up after primary TKA. We hypothesized that TKAs which demonstrated a medial-based
62 kinematic pattern intraoperatively would be associated with improved patient-reported outcomes
63 postoperatively.

64 **Methods**

65 After institutional review board approval was obtained, a retrospective review of a prospectively
66 collected database of consecutive primary TKAs was undertaken. Procedures were performed between
67 April 2013 and April 2014 by two board-certified arthroplasty surgeons at a single institution. Of the
68 original 203 TKAs, 53 were excluded due to unavailability of the required size of the Verasense™
69 device (31), device malfunction (5), atypical hardware creating additional soft tissue trauma (5), surgery
70 performed at a non-study hospital (4), unresurfaced patella (1), early revision (2), significant medical
71 complication affecting outcomes (2), death unrelated to the index TKA (1), and statistically outlying
72 intraoperative sensing device values (2). The two cases excluded for revision resulted from infection
73 and aseptic tibial component loosening after a fall. Of the remaining 150 TKAs, nine (0.6%) were lost
74 to minimum one-year follow-up.

75 A median parapatellar approach was used for all procedures. Standard coronal plane tibial and
76 femoral bone cuts were made with computer-aided navigation. One knee arthroplasty system

77 (Triathlon®; Stryker, Inc., Mahwah, NJ) was used in all patients. One surgeon used cruciate-retaining
78 femoral components with CR or CS/anterior lipped inserts and one surgeon routinely sacrificed the PCL,
79 and used posterior stabilized femoral components or a cruciate-retaining femoral component with
80 CS/anterior lipped inserts based on femoral component size.

81 In each case, sensor-embedded tibial trials (Verasense™; OrthoSensor™, Sunrise, FL) were
82 used to quantify tibio-femoral contact points and medial and lateral compartment forces and following
83 implantation of a TKA using traditional balancing techniques based on manual and tactile surgeon
84 judgment. During acquisition of tibial trial sensor data, the foot was held at the heel without any
85 specific rotational constraint with light support underneath the leg as the knee was taken through a range
86 of motion by flexing the leg at the hip joint. This is the standard methodology utilized in previous
87 studies by developers of the technology [22, 23] and is consistent with instructions provided by the
88 industry representative present in the initial series of patients to ensure proper use and operation of the
89 tibial insert sensor.

90 The measure of interest in this study -- tibio-femoral contact point measurements -- were
91 calculated and recorded for each patient at terminal extension, and at 45°, 90°, and terminal flexion.
92 Measurements from terminal extension to 90° of flexion were averaged to generate best estimates of the
93 center of rotation (COR 0° to 90°). Measurements from terminal extension to terminal flexion also were
94 averaged to generate a second best estimate of the COR (0° to terminal flexion). Patient age, sex, and
95 body mass index (BMI); and femoral implant type (cruciate-retaining with CR insert, cruciate retaining
96 with CS/anterior lipped insert, or posterior stabilized) were recorded.

97 *Data Extraction*

98 Four images per patient were cropped from the tibial sensor trial video output data, one for each
99 of the flexion angles (0°, 45°, 90°, terminal flexion). Each image displayed a visual representation of
100 tibial sensor trial insert with a graphical user interface for the compartmental compressive contact forces

101 and associated contact location on the medial and lateral tibial plateau as shown in Figure 1. The
102 cropped image shown in Figure 2 was imported into MATLAB® (The Mathworks, Natick, MA) after
103 alterations conducted in Microsoft Paint® (Microsoft, Redmond, WA) to determine the exact position of
104 the force contact points by a custom image processing program. The custom image processing program
105 operated based on detecting color differences within the cropped image. Potential error in calculations
106 by MATLAB® was eliminated by “blacking out” all unnecessary color from the image. The only
107 remaining items from the original cropped image were the contact points (Figure 2). The exact
108 placement of the dot within the contact point was irrelevant due to the entire dot being engulfed when
109 the image was processed. The dot was placed to create a larger color difference to allow the program to
110 easily detect the condylar contact points. Next, a white dot was placed at the center of the graphic user
111 interface to create an origin for that particular image. To eliminate this potential for error, the graphic
112 user interface inherently had a circle at the center of each implant which could be used as reference to
113 the origin and allow an accurate placement of the white dot for each image (Figure 2).

114 The centroid of each isolated contact point was calculated with built-in MATLAB® commands
115 from the image processing toolbox. Each image was appropriately scaled based on the screen size (in
116 pixels) and manufacturer specified dimensions (in mm) of that particular trial tibial insert size. All
117 screen resolutions were constant throughout COR measurements (1280x1024 pixels). A universal origin
118 was determined based on the center of the tibial sensor trial and remained constant throughout data
119 extraction for each patient and different implant sizes. The delta values between the force contact points
120 and the universal origin were then calculated and exported to an Excel (Microsoft Corporation,
121 Redmond, WA) spreadsheet for further analyses via MATLAB®. Other calculated values extracted to
122 the Excel spreadsheet from MATLAB® were the implant’s center of rotation, pivot type and pivot
123 angle. Pairs of contact points for each measurement were plotted as shown in Figure 3 together for
124 visual representation of contact locations on the tibial surface. Vector equations created lines between

125 the two tibio-femoral contact points on the medial and lateral sides and were used to calculate the center
126 of rotation between measurement positions. As noted previously, CORs were calculated based on
127 vectors from extension to 90° of flexion similar to Nishio et al.[21] and from extension to terminal
128 flexion. Each patient was assigned a kinematic pattern– medial or non-medial – based on the location of
129 the center of rotation in these ranges of motion. Regardless of laterality, a COR of 0 is located in the
130 center of the tibial trial insert. To the sides of this 0 point, 5 mm to 1000 mm (for the left leg) and -5
131 mm to -1000 mm (for the right leg) were identified as the areas in which a COR value could reliably be
132 classified as either a medial or lateral pivot depending on the laterality of the knee. If the COR value
133 was less than 5 mm in the left knee or greater than -5 mm in the right knee, it was classified as a central
134 pivot. If it was greater than 1000 mm in the left knee or less than -1000 mm in the right knee, it was
135 classified as a translating pivot.

136 *Patient-Reported Outcomes*

137 Patient-reported outcomes were evaluated preoperatively and at minimum one-year
138 postoperatively utilizing the new Knee Society Scoring System.[24, 25] The Knee Society Scoring
139 consists of validated objective and subjective scores. The Knee Society objective score, denoted
140 “KSSO” in this manuscript, evaluates knee pain (25 points), alignment (25 points), stability (25 points),
141 and range-of-motion (ROM) (25 points) for a total possible score of 100. Total possible points for the
142 subjective scores, satisfaction component (denoted “KSSS” in this manuscript) and functional
143 component (denoted “KSSF” in this manuscript), are 40 points and 100 points, respectively. Individual
144 items from the Knee Society questionnaire, including pain with level walking and pain with stairs or
145 inclines (both scored 0 = none to 10 = severe) and the question “Does this knee feel normal to you?”
146 (always, sometimes, never) also are reported. The University of California Los Angeles (UCLA)
147 Activity Level Score [26, 27] ask patients to choose their highest level of current activity, ranging from

148 0 (Wholly Inactive: dependent upon others, cannot leave residence) to 10 (Regularly participate in
149 impact sports such as jogging, tennis, skiing, acrobatics, ballet, heavy labor, or backpacking).

150 *Statistical Analysis*

151 Minitab 17 (State College, PA) was used for data analysis. Anderson-Darling (AD) tests using
152 $\alpha \leq 0.05$ revealed that, among all independent and dependent continuous variables, only patient age
153 was normally distributed. Student's t-test was used to compare patient age in medial and non-medial
154 pivot knees. Non-normally distributed continuous variables were compared with the Mann-Whitney
155 (W) test adjusted for ties. Pearson's Chi-Square (X^2) test was used to test independence among
156 categorical variables, with Fishers Exact test p values reported for 2 x 2 contingency tables.

157 **Results**

158 Medial and Non-Medial Pivot Based on the Average COR from 0° to 90° Flexion

159 Pivot type could not be determined based on the COR from 0° to 90° for two TKA's. For the
160 remaining 139 knees, the average center of rotation in the 90-degree flexion arc ranged from -324.03 to
161 605.81 mm with positive signifying the medial side. Medial pivot knees comprised 40% (55/139) of the
162 total sample.

163 Pivot classification did not differ based on patient sex (75% female, $X^2 = 0.739$, $p = 0.428$),
164 median BMI (32.9 kg/m², $W = 3723.5$, $p = 0.587$), or median length of follow-up (19.6 months, $W =$
165 3947.5 , $p = 0.676$). There was a trend for patients with medial pivot knees (mean 65.7 years, SD 9.4) to
166 be slightly older than those with non-medial pivot knees (62.4 years, SD 10.2) ($t = 1.92$, $p = 0.06$).
167 Forty-nine percent of knees with CR/CS anterior-lipped implants were classified as medial pivots
168 compared to 28% of knees with PS implants ($X^2 = 6.223$, $p = 0.015$). Separate analyses were performed
169 based on implant type to control for the interaction between pivot and implant type.

170 As shown in Table 1, for patients with CR/CS anterior-lipped implants and those with PS
171 implants, minimum one-year KSSO, KSSS, KSSF, UCLA Activity Level, and walking and stair pain

172 did not statistically differ based on medial vs. non-medial pivot type ($p = 0.292$ to 0.951). Preoperative
173 to postoperative improvement in these outcomes also largely did not differ based on pivot type, although
174 for patients with PS implants, there were trends for greater median improvement in KSSO (46 vs. 31.5
175 points, $p = 0.057$) and KSSS (23 vs. 14 points, $p = 0.067$) in medial pivot knees.

176 Examination of the Knee Society question “Does this knee feel normal to you” revealed no
177 statistically significant differences based on medial and non-medial pivot classification within each of
178 the two implant types (Figure 4). Fifty-six percent of patients with CR/CS anterior-lipped implants and
179 medial pivot knees reported that their knee always felt normal compared to 47% of patients with CR/CS
180 anterior-lipped implants and non-medial pivot knees ($X^2 = 4.659$, $p = 0.097$). Among patients with PS
181 implants, 47% and 36% of those with medial pivot and non-medial pivot knees, respectively, reported
182 that their knee always feels normal ($X^2 = 0.797$, $p = 0.671$).

183 Medial and Non-Medial Pivot Based on the Average COR from 0° to Terminal Flexion

184 Pivot type could not be determined based on the COR from 0° to terminal flexion for one TKA.
185 For the remaining 140 knees, the average center of rotation in the full flexion arc ranged from -1016.7 to
186 982.9 mm with positive signifying the medial side. Medial pivot knees comprised 40% (56/140) of the
187 TKAs in this cohort of expanded motion to include terminal flexion.

188 Patient sex (75% female, $X^2 = 0.000$, $p = 1.00$), mean age (63.7 years, $t = 0.160$, $p = 0.870$),
189 median BMI (32.9 kg/m², $W = 3662.5$, $p = 0.870$), and median length of follow-up (22.0 months, $W =$
190 4253.5, $p = 0.185$) were unrelated to pivot classification. Fifty-one percent of knees with CR/CS
191 anterior-lipped implants were classified as medial pivots compared to 26% of knees with PS implants
192 ($X^2 = 8.541$, $p = 0.005$). Separate analyses were performed based on implant type to control for the
193 interaction between pivot and implant type.

194 As shown in Table 2, only one outcome score statistically differed based on pivot type. Patients
195 with CR/CS anterior-lipped implants and medial pivot knees had greater improvement in walking pain (-

196 5.5 median points vs. -4 median points in CR/CS non-medial pivot knees, $p = 0.020$). It is important to
197 note, however, that these patients had significantly higher preoperative pain scores (medians of 7 and 4
198 points, respectively. $W = 1921.0$, $p = 0.002$), and their final follow-up pain scores were not different.
199 Forty-seven percent of patients with CR/CS anterior-lipped implants and medial pivot knees reported
200 that their knee always felt normal compared to 54% of patients with CR/CS anterior-lipped implants and
201 non-medial pivot knees ($X^2 = 2.220$, $p = 0.330$). Among patients with PS implants, 47% and 39% of
202 those with medial pivot and non-medial pivot knees, respectively, reported that their knee always feels
203 normal ($X^2 = 0.701$, $p = 0.697$).

204 **Discussion**

205 Total knee arthroplasty is a successful procedure which benefits thousands of patients annually.
206 With the aging baby boomer population and an increase in younger patients indicated for surgery, the
207 number of primary and revision TKAs are expected to drastically increase within the next 20 years.[28]
208 While TKA provides substantial benefits in terms of pain control and function to the majority of
209 patients, our profession has been unable to replicate the nearly universal satisfaction rates seen with total
210 hip arthroplasty. In an environment where patient satisfaction and clinical outcomes are increasingly tied
211 to reimbursement and fiscal solvency, improving primary TKA outcomes and minimizing revision
212 burden is paramount.

213 Traditional surgical principles of total knee arthroplasty have not changed significantly in recent
214 years and continue to focus on alignment and ligament balance presupposing that if these two elements
215 were optimized appropriate kinematics and increased patient satisfaction would result. Total knee
216 arthroplasty component characteristics including articular topography and congruence and femoral
217 geometry vary among commercially available implants, however many are designed in the hopes of
218 consistently replicating a medial kinematic pattern based on literature suggesting medial based native
219 knee kinematics. [16-20]

220 The modern arthroplasty system utilized in this study was designed to facilitate natural knee
221 motion, however, in the hands of two high volume arthroplasty surgeons only 40% of TKAs were
222 identified to have a medial pivot kinematic pattern during the first 90° of flexion, and through
223 full/terminal flexion. Significantly more knees with CR/CS anterior-lipped implants were classified as
224 medial pivots compared to knees with PS implants in both ranges of motion (0° to 90° and 0° to terminal
225 flexion). Nishio et al. [21] evaluated intraoperative knee kinematics of 40 PS TKAs using a CT-based
226 computer navigation system and observed that the cohort with medial pivot kinematics averaged across
227 0° to 90° had significantly better subjective outcomes with the new Knee Society Score. In our 0° to
228 terminal flexion cohort, there were no differences in outcome scores based on pivot type regardless of
229 implant type. In the 0° to 90° cohort, most patient-reported outcomes, including Knee Society scores,
230 did not differ in medial and non-medial pivot knees regardless of implant type (CR/CS anterior-lipped
231 implants and PS implants). However, for patients with PS implants, there were trends for greater
232 median improvement in KSSO (46 vs. 31.5 points, $p = 0.057$) and KSSS (23 vs. 14 points, $p = 0.067$) in
233 medial pivot knees, although minimum one-year outcomes were not different between groups,
234 potentially obviating the clinical significance of these statistical trends. Nishio et al. [21] observed
235 significantly better KSSS and KSSF, but not KSSO, scores in medial pivot PS knees. Our results using
236 intraoperative sensor-based technology are counter to the most commonly accepted thought regarding
237 the ideal target for post-operative TKA kinematics.

238 The study has several limitations. Measurements using the tibial sensor were taken intra-
239 operatively with an anesthetized patient during passive motion and incomplete closure of the arthrotomy.
240 There is some support for the hypothesis that intra-operative passive kinematics correlate with
241 postoperative kinematics during weight bearing, [29] but the influence of scarring, healing, and post-
242 operative soft tissue maturation remain an important area for further study. In addition, error terms
243 associated with the tibial sensing device, if applicable, are unknown. While the study group is

244 comparable to cohort size in relevant kinematic literature, statistical power may be a limitation but it is
245 worth noting that group scores were very similar for most outcome metrics.

246 In conclusion, intra-operative medial pivot kinematic patterns were produced in only 40% of
247 TKA patients utilizing a modern implant designed to facilitate natural knee motion, and these patients
248 did not have significantly improved subjective outcomes when compared to TKAs non-medial pivot
249 kinematic patterns. The results suggest that a medial pivot pattern may not be a substantial governor of
250 clinical success based on intraoperative kinematics and modern outcome measures. The understanding
251 of how alignment and balance relate to kinematics and subsequently how this correlates with patient
252 satisfaction remains in its infancy. Further research is warranted to determine if a particular kinematic
253 pattern promotes optimal clinical outcomes after TKA.

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Table 1: Patient-Reported Outcomes by Implant Type and Pivot Classification Based Upon the Average COR from 0° to 90° of Flexion

	CR/CS Anterior-Lipped Implants				PS Implants			
	Medial Pivot Knees	Non-Medial Pivot Knees	W	<i>p</i>	Medial Pivot Knees	Non-Medial Pivot Knees	W	<i>p</i>
n	38	40			17	44		
Minimum One-Year Outcomes								
Median KSSO	97	95	1045.0	0.951	97	94	523.5	0.300
Median KSSS	38	37	1518.5	0.860	37	30	537.5	0.326
Median KSSF	75	77	1414.0	0.937	67	75	406.0	0.522
Median UCLA Activity Level	5	5	1524.0	0.292	4.5	5	423.5	0.326
Median Pain with Level Walking	0	0	1480.0	0.813	1	0	533.5	0.918
Median Pain with Stairs or Inclines	1	1	1494.5	0.950	2	2	507.5	0.756
Improvement in Outcomes								
Median KSSO	39.5	46.5	989.0	0.497	46	31.5	559.5	0.057
Median KSSS	21	23	1478.5	0.825	23	14	569.0	0.063
Median KSSF	37	35.5	1391.0	0.878	36	37	418.5	0.772
Median UCLA Activity Level	1	0	1580.5	0.101	1	1	452.5	0.737
Median Pain with Level Walking	-5	-5	1427.5	0.462	-4	-4	470.0	0.427
Median Pain with Stairs or Inclines	-6	-6	1363.5	0.167 7	-5	-4	459.0	0.330
KSSO, objective component; KSSF, functional component; KSSS, satisfaction component; UCLA, University of California Los Angeles								

Table 2: Patient-Reported Outcomes by Implant Type and Pivot Classification Based Upon the Average COR from 0° to Terminal Flexion

	CR/CS Anterior-Lipped Implants				PS Implants			
	Medial Pivot Knees	Non-Medial Pivot Knees	W	<i>p</i>	Medial Pivot Knees	Non-Medial Pivot Knees	W	<i>p</i>
n	40	39			16	45		
Minimum One-Year Outcomes								
Median KSSO	96.0	98.0	1021.0	0.489	95.0	95.0	361.0	0.738
Median KSSS	36.0	38.0	1436.5	0.097	37.0	30.0	523.5	0.459
Median KSSF	76.0	71.5	1550.5	0.366	75.0	68.0	433.5	0.880
Median UCLA Activity Level	6.0	4.0	1671.5	0.118	5.0	5.0	425.0	0.660
Median Pain with Level Walking	0.0	0.0	1712.5	0.207	0.5	1.0	487.0	0.882
Median Pain with Stairs or Inclines	1.0	1.0	1717.0	0.234	1.0	2.0	448.0	0.427
Improvement in Outcomes								
Median KSSO	49.0	41.0	1174.5	0.172	40.0	39.5	390.5	0.695
Median KSSS	22.0	22.0	1626.0	0.802	20.0	16.0	501.5	0.510
Median KSSF	38.0	33.5	1496.5	0.732	36.0	37.0	415.0	0.724
Median UCLA Activity Level	1.0	0.0	1635.5	0.238	0.0	1.0	408.5	0.546
Median Pain with Level Walking	-5.5	-4.0	1364.0	0.020	-4.5	-4.0	434.0	0.367
Median Pain with Stairs or Inclines	-6.0	-6.0	1590.0	0.952	-5.0	-4.0	430.0	0.334
KSSO, objective component; KSSF, functional component; KSSS, satisfaction component; UCLA, University of California Los Angeles								

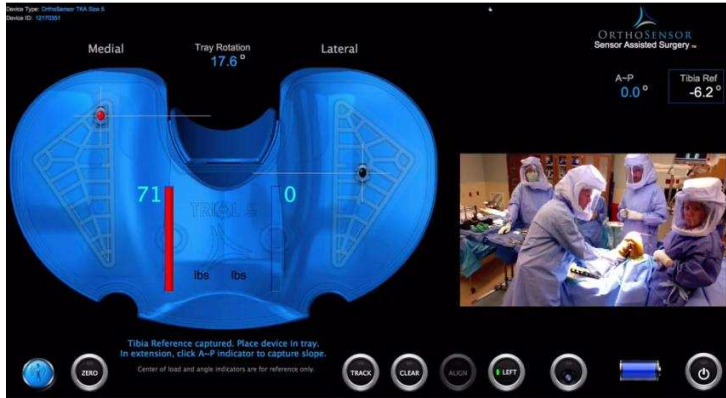
Figure Legends

Figure 1: Intraoperative measurements with embedded sensor tibial trial showing graphic user interface identifying loading contact points and peak loading forces (in lbs.) in the medial and lateral compartments.

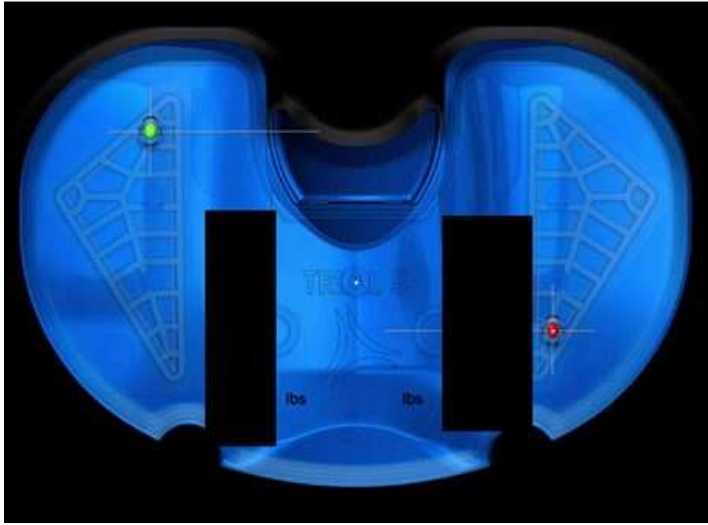
Figure 2: Cropped images of embedded sensor tibial trial were imported into MATLAB® to identify loading contact points and calculate center of rotation values for pivot groupings.

Figure 3: Overlay of vector equations and trial tibial insert used to calculate center of rotation values to group patients into medial or non-medial cohorts.

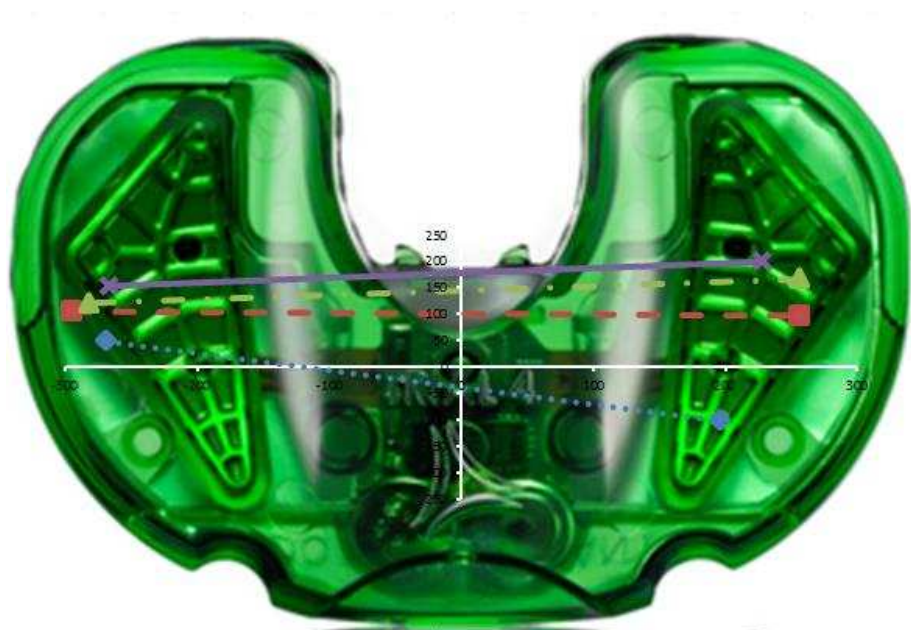
Figure 4: Proportion of patients reporting that there TKA always, sometime, or never feels normal by implant and pivot type.



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