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Greater Medial Compartment Forces During Total Knee Arthroplasty Associated With Improved Patient Satisfaction and Ability to Navigate Stairs

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ABSTRACT

Background: The purpose of this study was to determine if postoperative patient satisfaction, subjective outcomes, and functional force testing differed between those with symmetric or asymmetric intraoperative mediolateral (ML) compressive forces. We hypothesized that the threshold would be similar to the previously reported valued of 15 lb_f and that a significantly greater proportion of those with more symmetrical medial and lateral compressive forces would be satisfied with their total knee arthroplasty.
Methods: A commercially available instrumented trial tibial liner was used to measure ML compressive force differences with the knee at 0°, 20°, and 90°. Patient satisfaction and Knee Society Scores were compared between patients with ML asymmetries above and below the calculated optimal threshold.
Results: Surprisingly, lower ML asymmetries in extension were associated with a greater risk of being dissatisfied. Of the 50 total knee arthroplasties, 6 of 23 (26%) with ML force asymmetries <10 lb_f were dissatisfied compared with 0 of 27 with ML asymmetries >10 lb_f ($P = .01$). Greater asymmetry was associated with significantly greater gains in EQ-5D scores ($P = .05$) and pain scores ($P = .03$) and greater pain relief ($P = .006$) and reduced impact forces when navigating stairs ($P = .05$).
Conclusion: Contrary to our hypotheses, the results of this study support the concept that recreating greater forces in the medial compartment much like that of the native knee may yield improved patient-reported outcomes and increased patient satisfaction. The current results further suggest that recreating greater medial compartment forces may have the greatest affect on more demanding activities such as navigating stairs.

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Two of the primary principles of a technically successful total knee arthroplasty (TKA) are realigning the mechanical axis through the center of the knee and balancing the ligaments in both flexion and extension [1]. Failure to properly balance the ligaments results in unequal contact stresses in the medial and lateral compartments, thus, increasing the risk of increased wear and/or premature failure of the polyethylene [2,3]. Previous authors have also reported that well-balanced TKAs were 2.5 times more likely to achieve significant improvements in patient-reported subjective function 6 months after surgery [4]. Despite recent technological advances allowing for intraoperative ability to quantify the symmetry of compressive forces in the medial and lateral compartments, to date the definitions of a well-balanced knee have been based on cadaveric data and expert opinion. Furthermore, the relationship between intraoperative compressive forces and postoperative patient satisfaction has not been established. The purposes of this study were to determine if ligament balance intraoperatively measured in extension, midflexion, or 90° of flexion were more related to postoperative satisfaction and if a threshold of mediolateral (ML) force asymmetries existed to allow for an evidence-based definition of well-balanced knee. We hypothesized that the threshold would be similar to the previously reported valued of 15 lb_f [4] and that a significantly greater proportion of those with more symmetrical medial and lateral compressive forces would be satisfied with their TKA.

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Materials and Methods

Patients between the ages of 18 and 85 years were recruited to participate in our institutional review board–approved clinical study evaluating the role of ML balance in functional outcomes after primary TKA (50 TKAs; 29 female, 21 male; age = 66.1 ± 7.9 years, body mass index = 34.5 ± 6.9 kg/m^2). Patients undergoing revision arthroplasty, those with inflammatory or rheumatoid arthritis, or those with confounding medical issues that were not expected to survive for the duration of the follow-up period were excluded. All patients underwent posterior cruciate-retaining primary TKA performed by a single, board-certified orthopedic surgeon using a medial parapatellar approach and one of 2 implant systems (Vanguard, n = 22, Persona, n = 28; Zimmer Biomet, Warsaw, IN). The knee was manually balanced in extension using traditional spacer blocks, and a gap balancing technique was used to determine the amount femoral component rotation to create a balanced flexion gap [5]. At the conclusion of each case, a commercially available instrumented trial tibial liner was used to measure compressive force differences between the medial and lateral compartments with the knee at 0°, 20°, and 90° of flexion(eLIBRA, Zimmer, Inc; Fig. 1). Three measurements were recorded for the medial and lateral compartments at each knee angle, and measurements were performed with the patella reduced and the capsule closed with towel clips. The sensor readings were later converted to lb$_f$ and the difference between the medial and lateral compartments were calculated with positive values indicating greater medial forces and negative values indicating greater lateral forces. It should be noted that the instrumented trial liner was solely used for measurement purposes and was not used to provide the surgeon with feedback during the case.

Patients completed the 1993 Knee Society Score Function and Pain subcomponents, single assessment numerical evaluation, Lower Extremity Function Scale, EQ-5D General Health, and patient satisfaction questionnaires before and 6 months after TKA. A dual force platform (Bertec, Columbus, OH) was used to individually collect force data of the involved and uninvolved limbs as patients performed sit-to-stand and stair descent maneuvers. During the sit-to-stand maneuver, the maximum force exerted by the involved limb when rising was used to quantify concentric function with greater forces being associated with improved limb function. Eccentric function was quantified during the stair descent task. Larger impact forces when stepping down with the contralateral limb are associated with poorer eccentric function of the involved limb. For both tasks, patients performed a minimum of 2 successful repetitions, and force data were collected at 1000 Hz and later filtered using a fourth order Butterworth filter with a cutoff frequency of 6 Hz [6].

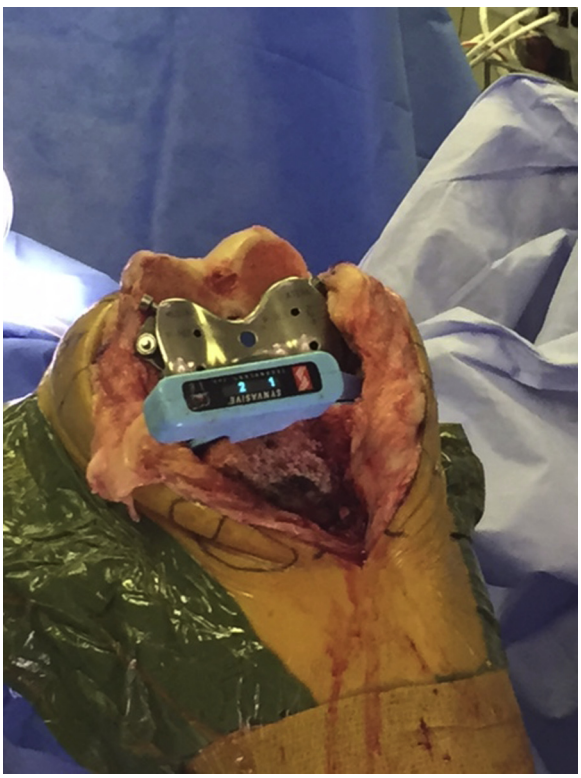

Fig. 1. Commercially available instrumented tibial trial liner being used to independently measure compressive forces in the medial and lateral compartments.

Statistical Analyses

The reliability of intraoperative compressive force measurements was individually evaluated for the medial and lateral compartments at all 3 test angles by calculating intraclass correlation coefficients. The relationships between patient satisfaction at 6 months and intraoperative ML force asymmetries in extension, midflexion, and 90° of flexion were assessed using Pearson product moment correlations. A receiver operating characteristics curve was used to determine if a threshold of ML force asymmetry was associated with a greater likelihood of a patient being dissatisfied after TKA. Preoperative and postoperative patient-reported outcomes and functional force measures were compared between patients with ML force asymmetries above and below the calculated threshold using independent *t* tests or repeated measures analyses of variance as appropriate. An α-level of $P < .05$ was considered statistically significant, and all analyses were performed using SPSS Statistics 21 (IBM, Armonk, NJ).

Results

Measurements of medial and lateral compressive forces were demonstrated to be reliable, with intraexaminer intraclass correlation coefficient values ranging from 0.84 to 0.95. Intraoperative ML force asymmetries in extension significantly correlated with patient satisfaction at 6 months (r = 0.30, $P = .04$), whereas measures at midflexion and 90° did not ($P > .06$). The threshold associated with patient satisfaction was 10 lb$_f$, but surprisingly, greater ML symmetry was associated with a greater risk of being dissatisfied. Of the 50 TKAs, 6 of 23 (26%) with ML force asymmetries <10 lb$_f$ were dissatisfied with their procedures compared with 0 of 27 (0%) with ML asymmetries >10 lb$_f$ ($P = .01$) (Table 1). The group with asymmetries <10 lb$_f$ was predominantly female with

Table 1
Comparison of Patient Demographics and Isolated Medial and Lateral Compartment Compressive Forces for TKA Patients With Intercompartmental Force Asymmetries Less Than or Greater Than 10 lb$_f$ With the Knee Extended.

Variable	Asymmetry <10 lb$_f$	Asymmetry >10 lb$_f$	*P*
Number of TKAs	23	27	
Sex (% female)	[a]78.3%	[a]40.7%	[a].01
Age (y)	65.2 ± 7.3	66.8 ± 8.5	.49
BMI (kg/m^2)	[a]37.4 ± 7.6	[a]32.0 ± 5.1	[a].01
Medial compartment force	[a]22.0 ± 11.4	[a]30.6 ± 13.4	[a].02
Lateral compartment force	21.8 ± 11.4	18.4 ± 14.2	.36
ML force asymmetry	[a]4.7 ± 3.0	[a]23.3 ± 12.4	[a]<.001
# Satisfied with surgery	[a]17 (73.9%)	[a]27 (100%)	[a].01

TKAs, total knee arthroplasties; BMI, body mass index; ML, mediolateral.
[a] Significant difference between groups ($P < .05$).

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