

Change in Limb Length After Total Knee Arthroplasty

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Abstract

The clinical outcome of total knee arthroplasty (TKA) remains suboptimal in some patients. One of the factors that might hinder improved functionality may be postoperative limb length discrepancy due to increase in limb length of the operative limb. The objective of this cross-sectional prospective study was to examine the extent to which limb length change occurs after TKA and to compare the change in limb length to the degree of valgus or varus joint position preoperatively. The role of body mass index and Kellgren-Lawrence grade in limb length change was also assessed. The data of 137 TKAs were analyzed and separated into categories to compare change in limb length pre- versus postoperatively. In all, 59.1% of patients experienced an increase in limb length with an average increase of 0.438 cm, but overall, there was no statistically significant difference in limb length pre- versus postoperatively (P value 0.598). Similar trends were seen within all other groups. It is the conclusion of this study that limb lengthening after TKA does not frequently occur to a statistically significant extent, regardless of preoperative joint state.

Keywords

total joint arthroplasty, limb length discrepancy, knee joint, varus deformity, valgus deformity

Introduction

The clinical outcome of total knee arthroplasty (TKA) remains suboptimal in some patients. Recently, a level II study suggested that although there is a substantial improvement in functionality, the effect size of that improvement is greater for the physician-derived measures than it is for the patient-derived measures.¹ This suggests that there is some discord between end points for physicians when compared with patients. Many factors may be involved in the differences observed in the clinical and functional outcome following TKA. One possible underlying variable that may be affecting this discrepancy is postoperative limb length discrepancy (LLD). Change in limb length is not commonly measured after TKA, yet LLD has been shown to increase the incidences of back pain and sciatica, gait disorders, and general dissatisfaction.²

Gait disturbances are one of the main concerns associated with LLD. It has been demonstrated that mechanical load and isometric torque placed on the long limb are significantly greater than that of the shorter limb.³ These biomechanical differences in gait have been implicated in many clinical presentations, including low back pain, arthritic changes of the hip, running associated injuries, and others.⁴ The amount of LLD necessary to generate such pathologies is widely debated with sources suggesting 20 to 50 mm as being clinically relevant.⁴ A wide range of treatments are available for LLD. For mild LLD (up to 60 mm), shoe lifts and inserts are suggested.⁴ For severe

cases, limb shortening by bone resection is sometimes performed. This is not likely to be necessary after TKA.

The LLD after TKA can occur due to lengthening of the operative limb.^{2,5,6} The LLD is common in the general population in as much as 40% to 70% of the population.^{7,8} The extent of LLD after TKA has been correlated to the degree of the preexisting hip-knee-ankle angle (HKA) of the lower extremity. It was determined that in a "severe" preoperative offset (varus or valgus) from neutral alignment there tended to be a greater increase in postoperative leg length.^{5,6} Severity of osteoarthritis in the knee may also play a role in LLD after TKA. It is debated whether or not body mass index (BMI) affects the outcome of total joint arthroplasty, and its role in LLD has not been well-delineated. Lange et al found that a Kellgren and Lawrence (KL) grade above 2 does not produce a larger difference in postoperative leg length between the operative and nonoperative limbs.⁵

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The purpose of this study is to examine the extent to which limb length change occurs after TKA and to compare the change in limb length to the degree of valgus or varus joint position preoperatively. The role of BMI and KL grade in limb length change will also be assessed. It is expected that overall there will be an increase in limb length after TKA and that the limb length change postoperatively will be greater in those with severe preoperative malalignment. It is also suspected that the limb length change will be greater in those with a higher KL grade but will not be dependent on BMI.

Materials and Methods

This study received institutional review board's approval and was compliant with the Health Insurance Portability and Accountability Act. A cross-sectional prospective study was conducted using a joint replacement database from 203 patients at a university medical center, who received a primary TKA from November 2012 to July 2014. Both preoperative and postoperative standing full-length radiographs were used to assess the limb length and HKA for the analysis. Thus, those individuals who had not received adequate imaging were excluded from the study. Other exclusion criteria included those with gross bony deformities or poor quality radiographs, which prevented accurate measurement. Of the 203 patients originally identified, 57 did not have the adequate imaging required, 2 had significant bony deformity, and 7 had additional hardware that would have impacted the measurement. After excluding these patients, 137 TKAs were included. For the purpose of this study, 0° was considered neutral, negative values were assigned to the valgus category, and positive values were assigned to varus.

All TKAs were performed by a single attending physician. A standard approach was used, and access to the joint space was obtained in a medial parapatellar fashion. Minimal amount of bone resections was attempted in order to be able to use the thinnest polyethylene insert available.

Standing anteroposterior full-length digital images of the lower extremities were obtained using Fujifilm computed radiography system (Fujifilm, Valhalla, New York) before and after TKA using standard departmental protocol. The images were processed using Fujifilm Automatic Image Stitching software. The digital images were viewed on AGFA Impax PACS software (AGFA Morsel, Belgium), and measurements were obtained using a digital cursor.

Measurement of the HKA was done using 2 intersecting lines on the film following the protocol outlined by Cooke et al.⁹ Briefly, the mechanical axis was obtained using a line intersecting the center of the femoral head extending to the intercondylar notch of the distal femur. This is called the femoral mechanical axis. Next, the tibial mechanical axis was obtained by drawing a line from the center of the tibial plateau extending distally through the center of the tibial plafond. The HKA is defined as the angle between the 2 axes as shown in Figure 1. As outlined by Lang et al, the leg length was measured using the full-limb radiograph by measuring the distance from the top of the femoral head to the base of the tibial plafond



Figure 1. The image demonstrates the measurement of the hip–knee–ankle angle (HKA). The tibial and femoral mechanical axes are measured on the film, and the axis between them is the HKA.

as shown in Figure 2.⁵ Each of these measurements was obtained on full-length radiographs in both a pre- and postoperative setting.

To ensure accuracy of the individual who performed the measurements, a second individual measured each of the end points on a randomly selected group of patients in the study. Neither of the 2 individuals who measured the said parameters was the primary surgeon. To determine the variability in the measurement, an intraclass correlation coefficient was measured and found to be greater than 0.9. This coefficient was calculated for each of the end points in this study and demonstrates that the variability in measurements was insignificant.

The change in limb length was evaluated after organizing the patients into several different groups. First, the overall average change in limb length after TKA was determined and compared using a 2 sample *t* test. Next, the patients were separated into preoperative limb alignment (valgus/varus), and the average limb length differences for each group were determined and compared. Next, the sample was separated by the severity of HKA, with those in either alignment greater than 10° placed into a separate group. Again, the average change in limb length was calculated and compared. The patients were then separated based on BMI (>35 placed in a separate group), and the same calculations were obtained. Finally, the patients were separated on degree of osteoarthritis as classified by the KL scale. Those with a grade of 3 or greater were compared with those with a lesser grade.



Figure 2. The image demonstrates the measurement of limb length. The line is extended from the top of the femoral head to the base of the tibial plafond.

Table 1. Patient Demographics.

Parameter	Whole Sample	Valgus, <0°	Varus, >0°
Number of TKAs	132	45	87
Age	68 ^a (10)	67 ^a (11.7)	68 ^a (9.7)
BMI	30 ^a (5.0)	29 ^a (4.8)	31 ^a (4.8)
Female	82	31	51

Abbreviations: SD, standard deviation; TKAs, total knee arthroplasties; BMI, body mass index.

^aValues are expressed as mean (SD).

All statistical analyses were performed using Microsoft Office 2010. Using the data analysis tool, the calculations of averages and standard deviations (SDs) were obtained, and a 2 sample *t* test was executed giving the associated *P* value and SD for each of the different categories.

Results

The demographics of the patients selected for this study are listed in Table 1. Varus alignment is much more common in the general population and was more common in this study as well. Females are more likely to receive TKA, and this is consistent with the population included in our study.

For this study, 59.1% of the patients experienced an increase in limb length with an average increase of 0.438 cm. Overall,

Table 2. Measurement Results Grouped by Preoperative Alignment.^a

Parameter	Whole Sample	Valgus, <0	Varus, >0
Preoperative HKA	4.16° (8.71)	-6.67° (5.79)	9.34° (4.66)
Postoperative HKA	2.76° (4.29)	-0.468° (3.57)	4.86° (3.03)
Change in alignment	-1.40° (7.49)	6.08° (5.72)	-4.99° (4.77)
Lengthening, cm	0.438 (1.12)	0.556 (1.13)	0.377 (1.11)
<i>P</i> value	0.598	0.735	0.686
Percentage lengthening, %	0.500 (1.40)	0.702 (1.46)	0.457 (1.33)

Abbreviations: HKA, hip-knee-ankle angle; SD, standard deviation.

^aPre- and postoperative HKA, change in alignment, lengthening, and percentage lengthening given as average. Values in parentheses indicate SD.

Table 3. Measurement Results Stratified by Preoperative Degree of Deformity.

Parameter	Moderate, -10° to 10°	Severe valgus, <-10°	Severe varus, >10°
Number of TKAs	93	9	35
Preoperative HKA	2.18° (5.38)	-15.0° (2.86)	14.1° (2.91)
Postoperative HKA	2.11° (4.21)	-1.18° (4.74)	5.41° (2.62)
Change in HKA	-0.07° (5.22)	13.8° (5.81)	-8.67° (4.14)
Change in limb length, cm	0.164 (1.03)	1.51 (1.00)	0.851 (1.07)
<i>P</i> value	0.870	0.730	0.567
Percentage lengthened, %	0.20 (1.24)	1.95 (1.50)	1.02 (1.30)

Abbreviations: HKA, hip-knee-ankle angle; SD, standard deviation; TKAs, total knee arthroplasties.

^aPre- and postoperative HKA, change in alignment, lengthening, and percentage lengthening given as average. Values in parentheses indicate SD.

there was no statistically significant change, as the *P* value from the 2 sample *t* test of the total sample was 0.598. In an effort to delineate potential confounding factors, the patients were separated into different groups, and their change in limb length was compared.

As seen in Table 2, the patients were separated into valgus and varus groups based on their preoperative alignment. The average increase in limb length was greatest in those who were preoperatively valgus (0.556 cm), despite the fact that the original average alignment (-6.67°) in this group was closer to neutral than the preoperative varus group (9.34°). The preoperative valgus group did, however, have a greater average change in limb alignment (6.08°) when compared to the preoperative varus group (-4.99°).

Using the HKA, the data were separated into moderate and severe alignment. Those within 10° of neutral alignment were placed into 1 group, and those with severe valgus or severe varus, classified as greater than 10° from neutral, were placed into 2 other groups. Table 3 shows the change in limb length was greatest in the severe valgus group (1.51 cm). The change in alignment was also greatest for this group at 13.8°, as it was -0.07° and -8.67° for the moderate and severe varus groups, respectively. The *P* value for the change in limb length after a 2 sample *t* test for each of the groups was 0.870, 0.730, and

Table 4. Measurement Results Grouped by Preoperative Kellgren and Lawrence Grade.^a

	Preoperative KL Grade	
	1 and 2	3 and 4
Preoperative HKA	2.87° (4.75)	4.48° (9.41)
Change in alignment	-0.704° (4.52)	-1.57° (8.04)
Lengthening, cm	-0.200 (.887)	0.594 (1.11)
P value	0.916	0.521
Percentage lengthening, %	-0.206 (1.07)	0.723 (1.40)

Abbreviations: HKA, hip-knee-ankle angle; SD, standard deviation.

^aPreoperative HKA, change in alignment, lengthening, and percentage lengthening given as average. Values in parentheses indicate SD.

0.567 for the moderate, severe valgus, and severe varus groups, respectively. The pre- versus postoperative alignment and percentages lengthened are also shown in Table 3.

The preoperative KL grade was determined, and the patients were separated into 2 groups as seen in Table 4. Those with severe osteoarthritic deformity (KL grade >2) demonstrated an average lengthening of 0.594 cm, while those with less severe deformity had an average shortening of 0.2 cm. The limb length of the 2 groups was compared pre- and postoperatively and did not demonstrate a significant difference, as the *P* value was 0.916 and 0.521 for the less severe and severe osteoarthritic deformity groups, respectively.

Those with a BMI of greater than 35 were isolated, and the pre- versus postoperative leg lengths were compared. An analysis was also done with the group of individuals with a BMI of less than 35. The average change in limb length and associated *P* value was 0.86 cm and 0.617 for the group with BMI of less than 35 and 0.31 cm and 0.869 for the group with BMI greater than 35.

Discussion

Several studies have demonstrated statistically significant limb lengthening after TKA.^{5,6} This study was executed to further characterize the change in limb length after TKA. This was done by comparing change in limb length after TKA based on HKA, BMI, and KL grade. The results of this study though were inconsistent with those done previously that showed limb lengthening after TKA.^{5,6} This study does not demonstrate significant limb lengthening after TKA.

There were some trends found within the data. Those with a valgus alignment tended to have a greater increase in limb length. For this group, the average change in alignment was also greater, and this could be the reason for the increased length. Lange et al showed that in patients with severe malalignment, the limb lengthening is greater after TKA when compared to patients with less severe malalignment.⁵ In this study, the trend found is consistent with their findings, but was not found to be statistically significant. Notably, there were only 9 TKAs with a severe preoperative valgus deformity ($\leq 10^\circ$) and 35 with a severe preoperative varus deformity ($> 10^\circ$). A

larger number of patients within these groups would strengthen the power of this study.

Lange et al did not find a difference in limb length based on KL grade.⁵ In this study, there was a reduction in limb length for the patients with minimal radiographic osteoarthritis (KL grades 1 and 2), while the group with severe osteoarthritis (KL grade > 2) did have an average increase in limb length. This could be due to the loss of joint space in severe osteoarthritis. Patients with minimal osteoarthritis have less joint space narrowing, and thus, the tibial insert does not serve as a source of increased joint length because that space was still partially intact preoperatively. There are several other possible explanations for why there was no significant limb lengthening in this study. One possibility is the surgical technique in selecting the tibial insert prosthetic size. A further investigation of the protocol followed by the senior author could help identify a surgical reason for the lack of limb lengthening.

There are several limitations to this study. First, lateral images were not used to assess changes in the limb length. Standing AP full-length radiographs were used for the measurement of both limb length and alignment. Thus, it is possible that deformity other than that in the coronal plane may have had a role and gone unrecognized. Second, flexion contracture preoperatively may have affected limb length measurement. One study suggests, however, that the measurement of limb length is not affected by flexion contracture if it is less than 15° .¹⁰ Third, when measuring the angles, identifying the pertinent landmarks occasionally proved difficult. Digitally manipulating the contrast of the film to compensate for over penetration of the lower extremities was done to assist in identifying these landmarks. Finally, the clinical significance of LLD after TKA is not well known.

Correction of LLD during TKA is difficult due to the high priorities of ligament and gap balancing and the correction of preoperative deformity.⁵ Fang et al demonstrated that maintaining a postoperative HKA between 2.4° and 7.2° valgus produces improved outcomes.¹¹ Their results indicated that failure rates are significantly higher when the postoperative HKA alignment is not within this range.¹¹ This study suggests that it may be possible to minimize limb lengthening in TKA while still achieving adequate alignment and stability. A deeper analysis of the technique used by the senior author may be beneficial in determining what was done to prevent postoperative limb lengthening.

In conclusion, limb length after TKA was not significantly different on postoperative radiograph. The LLD is associated with increased incidences of pathologies that reduce patient satisfaction and quality of life. Increased limb length after TKA may be a contributing factor for a poor outcome. Further research is necessary to better characterize the incidence of LLD after TKA and to determine whether a need exists to adjust surgical techniques to prioritize maintaining limb length during the procedure.

Declaration of Conflicting Interests

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