Are Current Total Knee Arthroplasty Implants Designed to Restore Normal Trochlear Groove Anatomy?

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Abstract: Biomechanical studies have shown that external rotation of the femoral TKA component improves patellar tracking but does not restore it to physiologic values. We hypothesized that this could be due to differences in the trochlear groove geometry of TKA and normal knees. This was investigated via a virtual TKA procedure that mounted femoral components on to 3-dimensional models of healthy femurs, followed by measurement of the trochlear geometry before and after the simulated TKA. The results showed that (1) external rotation of the component brought the trochlear groove closer to normal anatomy than no external rotation; (2) however, even with external rotation, the trochlear anatomy was only partially restored to normal. Further work is needed to determine implications for patellofemoral complications observed with current TKA designs. Keywords: patellar tracking, trochlear groove geometry, total knee arthroplasty, virtual TKA, knee biomechanics.

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Although total knee arthroplasty (TKA) has proven to be a highly successful surgical procedure, patellofemoral complications are commonly observed postsurgery. These complications include chronic pain, patellar subluxation, patellar tilt, patellar dislocation, patellar component loosening, patellar component fracture, and patellar component wear [1-4]. With recent improvements in implant designs and surgical techniques, the reported complication rates have reduced from 1% to 20% [5-8], down from 10% to 35% rate reported historically [9-11]. Nonetheless, patellofemoral complications have been implicated as a major cause of revision surgeries [4,7,8,12], with similar revision rates for TKAs with resurfaced and unresurfaced patella [13-16].

One of the key factors leading to patellofemoral complications is malpositioning of the TKA component [1,3,7,17]. For example, Berger et al [1] showed that small amounts of combined femoral-tibial internal rotation correlated to lateral patella tracking and tilting, whereas large amounts of rotation correlated to patellar dislocations and component failure. Current surgical protocol involves placement of the femoral TKA component in approximately 3° external rotation relative to the posterior condylar line (in absence of significant condylar deficiencies) or in line with the femoral transepicondylar axis (TEA). This allows both for a balanced flexion gap and favorable patellar tracking [18-22]. It is somewhat surprising that the optimal positioning of the femoral component has arisen from the results of clinical and biomechanical studies [18-22] rather than being directly provided by the implant manufacturers/designers. Perhaps this indicates that the design of the patellofemoral compartment in TKA has been developed somewhat independent of considerations regarding the effect of component positioning, and surgical protocol has evolved to work with the given component design and to optimize its performance. Nonetheless, biomechanical studies have shown that even the externally rotated position of the femoral component does not fully restore normal patellar tracking [23-26]. This suggests that even with external rotation of the component, the TKA trochlear groove may still be significantly different from the normal trochlea, and this may in part explain why patellar tracking is not fully restored to physiologic values.

A review of literature showed that although there are many studies relating to patellar kinematics in TKA knees and its relationship to femoral component position [23,25-27], there is little information regarding how the complex anatomy of the normal trochlea compares to that of the TKA component [28,29].
Although it is well established that external rotation of the femoral component improves patellar tracking, how this external rotation affects the effective geometry of the trochlea is poorly understood. A detailed and quantitative knowledge of the trochlear geometry in normal and TKA knees is critical for improvement of existing implant designs and for better understanding of relationship between femoral component position and resulting patellar tracking patterns so as to improve the surgical technique.

The present study aimed to provide this knowledge via investigation of 2 hypotheses: (1) external rotation of the TKA component brings the trochlear groove closer to the normal anatomy than no external rotation, and (2) even with external rotation of the component, the trochlear groove in current TKA does not fully restore normal trochlear anatomy. These hypotheses were investigated via a virtual TKA procedure to mount femoral components on to 3-dimensional models of healthy femur, followed by direct comparison of trochlear geometry before and after simulated TKA.

Materials and Methods

Overview

To test the hypotheses discussed above, the trochlear geometry was first measured using 3-dimensional models of normal femurs created from magnetic resonance imaging scans of healthy subjects' knees. Next, the trochlear geometry was remeasured after a virtual TKA procedure performed in a solid modeling software to mount femoral TKA components on to the knee models in accordance with standard surgical protocol, including 3° external rotation of the component relative to the posterior femoral condyle. In addition, the trochlear anatomy was also measured with the femoral component aligned with the posterior condyle, that is, with no external rotation. Finally, a direct comparison of the trochlear groove anatomy before and after the simulated TKA implantations was performed using paired t test, with significance level set at P < .05. The virtual TKA procedure allowed for (1) incorporation of surgical procedure that determines the position and orientation of the implant and thereby has significant effect on the effective geometry of the trochlea and (2) a direct comparison of trochlear geometry before and after TKA within the same knees, thus, minimizing the effect of interspecimen variations.

Subject Recruitment and Creation of 3-Dimensional Femur Models

Twenty-three subjects (12 male and 11 female) were recruited for this study following approval by our institute review board, and informed consent was obtained from all subjects. Only one knee from each subject was studied, and the choice of side was made randomly (9 right, 12 left). There was no significant difference in the age of the male and female subjects (32.2 ± 7.1 years and 29.6 ± 10.8 years; P = .51). All knees included in this study were healthy without any symptoms of soft tissue injuries or osteoarthritis, as verified via clinical examination and magnetic resonance imaging.

Magnetic resonance scans of each knee were obtained using a 3.0 Tesla magnet (Siemens, Malvern, Pa) and fat suppressed 3-dimensional spoiled gradient-recalled sequence. Sagittal plane image slices (1-mm spacing, 512 × 512 resolution, 180 × 180-mm field of view) were then segmented within a 3-dimensional modeling software (Rhinoceros, Robert McNeel and Associates, Seattle, Wash) to create 3-dimensional mesh models of the femur including the bone and articular cartilage [30,31].

Virtual TKA to Mount Femoral Component on Knee Models

The virtual TKA procedure was performed within the solid modeling software using custom written programs to mount NexGen Cruciate-Retaining (CR) and Legacy Posterior-stabilized (LPS) femoral components (Zimmer Inc, Warsaw, Ind) onto the 3-dimensional femur models. The NexGen CR and LPS components had identical trochlear groove geometries except that the trochlea extended more distally in the CR components. Therefore, only the data for CR components are presented in the results section. In coronal plane, the femoral component was mounted with a 5° valgus angle relative to the axis of the distal femoral shaft. In the sagittal plane, the distal femoral cut was made perpendicular to the shaft axis. The distal and posterior femoral cuts equaled 9 mm, measured relative to the lateral femoral condyle, and matched the thickness of the TKA component.

In the axial view, the TKA component was mounted first with a 3° external rotation relative to the posterior condylar line and next with no external rotation, that is, aligned with the posterior condylar line. In mounting the femoral component in an externally rotated position, we used the posterior condylar line as reference. Although this is one of the surgical landmarks defined in clinical literature, this landmark has been shown to be not as reliable as the TEA in case of condylar deficiencies, particularly for knees with valgus deformity [20,22,32]. However, the knee models used in this study were healthy and did not have varus or valgus deformity. In addition, the angle between TEA and posterior condylar line for knees in this study was measured to be 3.1° ± 2.1°, which agrees with values reported in literature [22,32].

Overall, the mounting protocol was similar to a measured resection technique with posterior referenc- ing. In situations where the anteroposterior size of the femur fell between component sizes, the component closest to the femoral size was chosen. The exception was in cases of excessive mediolateral overhang, where
the smaller sized component was chosen. When smaller sized component was used, notching of the anterior femur was avoided with the aid of slight flexion (≤3°) and/or slight anterior shift (<2 mm) of the femoral component if needed. A trained orthopedic surgeon verified the mounting of the femoral TKA components.

Automated Measurement of Trochlear Groove Geometry

To measure the trochlear groove geometry, a custom written computer program was used to create cutting planes through the distal femur spanning the most proximal point on the mounted femoral TKA component (point A, Fig. 1) to the most distal point on the femoral intercondylar notch (point C, Fig. 1). The cutting planes were rotated about the femoral TEA to create 47 cross sections in approximately 2.3° increments. Points representing intersection of the cutting planes and the femoral cartilage and intersection of the cutting planes and femoral component surface were then exported to a MATLAB-based (Mathworks, Natick, Mass) program for automatic measurement of geometric parameters at each cross section. The parameters measured included the mediolateral location and anteroposterior height of the deepest point of the trochlear sulcus, anteroposterior heights of the medial and lateral femoral condyles, and the trochlear bisector angle (Fig. 2).

Results

In general, all measured geometric parameters showed substantial variation along the trochlear groove, particularly for the normal knees before mounting of the TKA components (Figs. 3-7). Therefore, the results are presented in terms of the measured geometric parameters as a function of a normalized variable \( \theta_o = \theta_{100}/\theta_{\text{max}} \) (or \( \theta/\theta_{\text{max}} \% \)), that represents different cutting plane locations along the trochlea. Herein, \( \theta \) represents orientation of the cutting plane relative to the first cutting plane passing through the most proximal point on the TKA component, and \( \theta_{\text{max}} \) represents the orientation of the last cutting plane through the most distal point on the TKA trochlea (Fig. 1). It is also to be noted that the TKA component extended more proximally than the articular cartilage of the normal trochlea [28]. Therefore, although the TKA trochlear groove was discernable from \( \theta_o \) (\( \theta/\theta_{\text{max}} \% \) 15.2% or higher, the normal trochlear groove was discernable only for \( \theta_o \) 43.5% or higher (point B, Fig. 1).

Results of the study showed that the deepest point of the trochlear sulcus in both the normal and TKA knees

Fig. 1. Cutting planes rotated about femoral TEA used to section cartilage of normal knee and surface of TKA component (\( \theta \) = orientation of cutting plane). Point A represents first cutting plane (\( \theta = 0° \)) through the femoral TKA component, point B represents first section through the articular cartilage of the normal knee at which trochlear sulcus becomes discernable, and point C represents the last section through the femoral TKA component.

Fig. 2. Trochlear groove geometric parameters measured using custom-written MATLAB-based program. AP indicates anteroposterior; ML, mediolateral.

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Fig. 3. Mediolateral (ML) location of deepest point of trochlear sulcus at different locations along the trochlear groove. Point B marks first cross section at which the trochlear groove of the normal femur is definable, and point C marks the most distal point on the femoral intercondylar notch. (*) indicates significant difference between geometry of normal trochlea (cartilage) and that for TKA with 3° external rotation (CR TKA [3°]). Cruciate-retaining TKA (0°) refers to data for TKA mounted with no external rotation, and vertical lines represent 1 SD. Approximate patellofemoral contact locations at 0°, 30°, and 105° knee flexion are indicated with vertical dotted lines.
Fig. 4. Anteroposterior (AP) height of deepest point of trochlear sulcus measured at different locations along the trochlear groove. Point B marks first cross section at which the trochlear groove of the normal femur is definable, and point C marks the most distal point on the femoral intercondylar notch. (*) indicates significant difference between geometry of normal trochlea (cartilage) and that for TKA with 3° external rotation (CR TKA [3°]). Cruciate-retaining TKA (0°) refers to data for TKA mounted with no external rotation, and vertical lines represent 1 SD. Approximate patellofemoral contact locations at 0°, 30°, and 105° knee flexion are indicated with vertical dotted lines.

Fig. 5. Trochlear bisector angle measured at different locations along the trochlear groove. Point B marks first cross section at which the trochlear groove of the normal femur is definable, and point C marks the most distal point on the femoral intercondylar notch. (*) indicates significant difference between geometry of normal trochlea (cartilage) and that for TKA with 3° external rotation (CR TKA [3°]). Cruciate-retaining TKA (0°) refers to data for TKA mounted with no external rotation, and vertical lines represent 1 SD. Approximate patellofemoral contact locations at 0°, 30°, and 105° knee flexion are indicated with vertical dotted lines.

Fig. 6. Anteroposterior height of lateral condyle measured at different locations along the trochlear groove. Point B marks first cross section at which the trochlear groove of the normal femur is definable, and point C marks the most distal point on the femoral intercondylar notch. (*) indicates significant difference between geometry of normal trochlea (cartilage) and that for TKA with 3° external rotation (CR TKA [3°]). Cruciate-retaining TKA (0°) refers to data for TKA mounted with no external rotation, and vertical lines represent 1 SD. Approximate patellofemoral contact locations at 0°, 30°, and 105° knee flexion are indicated with vertical dotted lines.

Fig. 7. Anteroposterior height of medial condyle measured at different locations along the trochlear groove. Point B marks first cross section at which the trochlear groove of the normal femur is definable, and point C marks the most distal point on the femoral intercondylar notch. (*) indicates significant difference between geometry of normal trochlea (cartilage) and that for TKA with 3° external rotation (CR TKA [3°]). Cruciate-retaining TKA (0°) refers to data for TKA mounted with no external rotation, and vertical lines represent 1 SD. Approximate patellofemoral contact locations at 0°, 30°, and 105° knee flexion are indicated with vertical dotted lines.
was located lateral to the TEA midpoint (Fig. 3). However, significant differences were noted between sulcus location for normal knees and knees with externally rotated TKA component (Fig. 3). Proximally, between $\theta_a = 43.5\%$ and 58.7\%, the TKA sulcus was more lateral than in the normal knees (difference, 0.6-3.5 mm; average, 2.0 mm; $P < .034$), and distally for $\theta_a = 73.9\%$ to 83.1\%, the TKA sulcus was more medial (difference, 0.7-0.9 mm; average, 0.8 mm; $P < .047$). In addition, although the normal knees showed a progressive lateralization of the sulcus over the proximal half of the trochlea, the TKA knees showed little variation in sulcus location through the entire trochlear length.

Failure to externally rotate the femoral component shifted the sulcus medially, making the difference between TKA and normal sulcus location (difference, 0.5-2.0 mm; average, 1.6 mm) more apparent over most trochlear length ($\theta_a = 54.4\%$-97.8\%). Both the normal and TKA knees showed a progressive decrease in anteroposterior sulcus height from proximal to distal location on the trochlea (Fig. 4). However, significant differences were noted between sulcus height in normal knees and in knees with externally rotated TKA component (Fig. 4). Proximally between $\theta_a = 43.5\%$ and 82.6\%, the TKA sulcus height was smaller than in the normal knees (difference, 0.7-4.1 mm; average, 3.1 mm; $P < .013$), and distally from $\theta_a = 89.1\%$ to 100\%, the TKA sulcus height was larger than in normal knees (difference, 0.6-3.4 mm; average, 2.0 mm; $P < .02$). Failure to externally rotate the femoral component reduced the TKA sulcus height further by a small amount (~1 mm).

Trochlear bisector angle showed a progressive decrease from proximal to distal location along the trochlea in both normal and TKA knees (Fig. 5). However, the pattern of change was different, with the TKA knees showing a steady reduction in bisector angle, whereas the normal knees showed a sharp initial decrease followed by a near constant value and further decrease toward the distal end of the trochlea. Although the normal knees and knees with externally rotated TKA component showed similar bisector angles over a substantial length of the trochlea ($\theta_a = 58.7\%$-89.1\%), significant differences were noted at the proximal and distal extremes. Proximally for $\theta_a = 43.5\%$ to 56.5\%, the TKA knees showed smaller values of bisector angle (range, 0.8°-4.9°; average, 2.4°; $P < .018$), and distally between $\theta_a = 93.5\%$ and 100\% (range, 1.1°-2.5°; average, 1.7°; $P < .034$), the TKA knees showed larger values. Failure to externally rotate the TKA component reduced differences in bisector angle proximally but increased the differences over the central and distal portions, tilting the trochlear groove more medially (Fig. 5).

Significant differences were also noted between medial/lateral condyle heights of normal knees and TKA mounted with 3° external rotation (Figs. 6, 7). In general, the condyles, particularly the lateral condyle, were higher in normal than in TKA knees. Proximally between $\theta_a = 43.5\%$ and 82.6\%, the TKA knees had smaller lateral condyle height (difference, 0.8-5.9 mm; average, 3.6 mm; $P < .013$), and distally from $\theta_a = 95.5\%$ to 100\%, the TKA knees had slightly larger lateral condyle height compared to normal knees (difference, 0.9-1.1 mm; average, 1.0 mm; $P < .003$; Fig. 6). In addition, between $\theta_a = 43.5\%$ and 73.9\%, the TKA knees had smaller medial condyle height compared to normal knees (difference, 0.8-2.5 mm; average, 1.8 mm; $P < .012$; Fig. 7). Failure to externally rotate the femoral component had negligible effect on lateral condyle height; however, the TKA medial condyle height was reduced significantly, thereby, increasing the difference between TKA and normal knees (difference, 1.0-4.2 mm; average, 2.5 mm).

**Discussion**

The current study presented a detailed comparison of the complex 3-dimensional geometry of the trochlear groove in normal and TKA knees (NexGen CR and LPS, Zimmer Inc). This was accomplished via a virtual TKA procedure to mount femoral components on to 3-dimensional models of healthy femurs, followed by measurement of the trochlear geometry before and after the simulated TKA using custom computer programs. The results of the study confirmed our hypothesis that (1) external rotation of the TKA component brings the trochlear groove closer to the normal anatomy than no external rotation; (2) however, even with external rotation the trochlear groove in current TKA is not designed to exactly restore normal anatomy.

It is to be noted that all measured parameters changed substantially from proximal to distal location on the trochlea, thus, highlighting the importance of characterizing trochlear geometry along its entire length. In addition, all measurements were made using cross sections of the 3-dimensional knee and TKA models, thus, avoiding projection artifacts associated with use of skyline views or 2-dimensional projections [33].

Results of the study showed significant differences between mediolateral position of the trochlear sulcus in normal knees and in knees with externally rotated TKA component. Over the proximal 27% of the trochlea, the sulcus in TKA knees was on an average 2 mm more lateral than in normal knees. Distally, the sulcus in TKA knees was slightly medial relative to its position in normal knees (average difference, 0.8 mm). Barink et al [28,34] measured coronal plane orientation of the trochlea and showed that proximally the trochlea was oriented medially in normal knee and neutrally in the TKA component (Continuum Knee System [CKS]; Biomet, Warsaw, Ind). Similar results were noted in
this study, with the TKA sulcus showing little variation in mediolateral position from proximal to distal direction (Fig. 3). Meijerink et al [29] compared the normal and prosthetic sulcus at the most distal point on the femoral notch and found the sulcus in TKA (Low Contact Stress [LCS] and Press Fit Condylar [PFC] prosthesis; DePuy, Warsaw, Ind) to be located medially (average, 2.5 mm). This is in agreement with our results, although the difference in distal sulcus location of normal and TKA knees was smaller in our study.

Changes in sulcus location after TKA can have profound effect on patellar tracking [35]. Barink et al [25] noted a trend toward lateral tracking of the unresurfaced TKA patella (CKS, Biomet/STRATEC, Warsaw, Ind) in early flexion and significant medial patellar tracking between 65° and 90° knee flexion, compared to intact knees. Ostermeier et al [26] noted that at low flexion, the unresurfaced patella was shifted significantly laterally in TKA knees (Interax prosthesis; Stryker/Howmedica, Limerick, Ireland) compared to intact knees. Tanzer et al [24] noted lateral tracking in early flexion for 3 (Anatomic Modular Knee [AMK]; DePuy, Warsaw, Ind; Miller/Galante II [MG II]; Zimmer, Warsaw, Ind; and PFC prostheses) of 5 implant systems. These changes in tracking of the unresurfaced patella may be related to changes in sulcus location after TKA, as observed in the current study.

If the TKA component was not externally rotated, then the sulcus was located approximately 1.6 mm medial to its position in normal knees over 77% of the trochlear groove length (Fig. 3). Thus, failure to rotate the component externally leads to differences in sulcus location over a greater proportion of the trochlear groove length. This medial shift of the sulcus could explain the medial shift of the patella when the TKA component is positioned parallel to the posterior condyle [23,27,36,37], and the associated increase in laterally directed force on the patella [36]. Therefore, although external rotation of the TKA component did not fully restore normal sulcus location, it reduced the overall change in sulcus position and may be beneficial for reducing laterally directed forces on the patella.

Significant differences were also noted in the anteroposterior height of the sulcus in normal and TKA knees. Over 70% of the trochlear groove length, the sulcus height in TKA knees was less than in normal knees (average difference, 3 mm; Fig. 4). The general implications of this difference for the sagittal plane biomechanics of the TKA are unclear, although it could affect knee flexion moment and patellofemoral joint forces. In studies by Ostermeier et al [26], Tanzer et al [24], and Barink et al [25], patellar anteroposterior translation and flexion did not show any statistically significant difference between TKA (unresurfaced patella) and normal knees. Therefore, the anteroposterior sulcus height could be different among different implant systems. Failure to externally rotate the component decreased the anteroposterior height of the TKA sulcus by a relatively small amount (<1 mm).

Orientation of the trochlear groove in the transverse plane as characterized by the trochlear bisector angle was similar between the normal knees and knees with externally rotated TKA over the central 70% of the trochlea (Fig. 5). However, significant differences were noted over the proximal (average difference, 2.4°) and distal (average difference, 1.7°) ends of the trochlea. The transverse plane orientation of the trochlear groove has a strong effect on patellar tilt [35]. Therefore, abnormal patellar tilt could occur at early and/or deep flexion in TKA due to differences in the bisector angle at these positions. For example, Barink et al [25] found the unresurfaced patella to be more laterally tilted in TKA knees (CKS prosthesis) from 10° to 45° flexion. Tanzer et al [24] noted medial tilt in 2 TKA designs from 60° to 105° (Insall-Burstein (IB) II prosthesis, Zimmer, Warsaw, Ind) and 90° to 105° flexion (PFC prosthesis) and in one design (Ortholoc prosthesis; Wright Medical Technology, Arlington, Tenn) between 15° and 105° flexion, compared to normal knees. However, Ostermeier et al [26] did not see any difference in tilt of unresurfaced patella in TKA (Interax prosthesis) compared to normal knees.

Failure to externally rotate the TKA component reduced differences in bisector angle proximally but increased the differences over the central and distal portions, tilting the trochlear groove more medially (Fig. 5). This could explain the increase in medial patellar tilt when the TKA component is positioned parallel to posterior condyle [27,36,37], and the associated increase in laterally directed force due to increased lateral constraint [36,38]. Thus, although external rotation of TKA component did not fully reproduce normal trochlear orientation in the transverse plane, it minimized the difference over most the trochlear groove length and may be beneficial for minimizing laterally directed forces in this TKA design.

In general, the anterior condyles, particularly the lateral condyles, were higher in normal knees than in knees with externally rotated TKA component (average, 3 mm lateral side; average, 1.8 mm medial side; Figs. 6, 7). The larger difference on the lateral side was a result of the external rotation of the femoral component. Failure to externally rotate the component had negligible effect on lateral condyle height but significantly reduced the medial condyle height (average reduction, 1.7 mm). Thus, although external rotation of TKA component did not reproduce normal condyle heights, it minimized the difference particularly on the medial side.

An important limitation of this study is that only 2 particular designs of the TKA component from one major manufacturer was tested (NexGen CR and LPS, Zimmer Inc), and therefore, the results many not be
generalizable to all designs [39]. However, these implant systems are few of the widely used systems currently on the market, and the technique presented in this study can be readily applied to analyze other implant designs. It is also important to note that interpretations of the results for TKA patellar tracking are more applicable to TKA with unresurfaced patella. For TKA with resurfaced patella, the placement and geometry of the patellar button may have significant effect on resulting patellar tracking [26,40].

In conclusion, this study presented a detailed comparison of the 3-dimensional geometry of the trochlear groove in normal and TKA knees. This was accomplished via a virtual TKA procedure to mount femoral components on to 3-dimensional models of healthy femurs, followed by measurement of the trochlear geometry before and after the simulated TKA. The results showed that for the particular implant designs investigated in this study (NexGen CR and LPS, Zimmer Inc) (1) external rotation of the component brought the trochlear groove closer to the normal anatomy than no external rotation; (2) however, even with external rotation the trochlear groove in the current TKA only partially restored normal anatomy. This suggests that current TKA may not be designed to fully restore or replicate normal trochlear groove anatomy, and other considerations such as minimizing patellofemoral contact forces [41] and ensuring capture of patella in early flexion [28] may guide the design decisions. Therefore, surgeons should be aware that manufacturer’s definition of anatomical groove geometry may not imply exact replication of normal anatomy, and exact restoration of physiologic patellar tracking may not be feasible with current designs. Further work is needed to determine if this compromise may be responsible for observed patellar complications and how implant designs can be modified to obtain improved performance.

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References


