Original Article
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Tibial Base Plate for Total Knee Arthroplasty: Symmetric or Asymmetric?

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Background: Ideal positioning and best coverage of the tibial base plate are essential in total knee arthroplasty. There are 2 types of tibial base plates: symmetric and asymmetric. The superiority of one to the other is still controversial. The aim of this study was to compare symmetric and asymmetric tibial base plates for total knee arthroplasty in terms of rotational alignment and coverage.

Methods: The study was conducted on a total of 80 cadaveric tibial bones. Two surgeons were asked to place 20 symmetric (group 1) and 20 asymmetric (group 2) tibial base plates taking care to ensure the best coverage that they were able to determine. Afterwards, the rotational errors and coverage were assessed with reference to the posterior tibial margin and posterior condylar axis on the three-dimensional computed tomography (3D CT) scan. In the second part of the study, the surgeons were asked to place 20 symmetric (group 3) and 20 asymmetric (group 4) base plates taking care to ensure the best rotational alignment. The rotational errors and the areas uncovered or overstuffed after the application were measured on the 3D CT scan.

Results: On the comparison of rotational errors, while there was no significant difference between group 1 and group 2 in terms of coverage ($p = 0.624$), the mean external rotation error was significantly greater in group 2 ($p = 0.034$). On the comparison of coverage, while there was no significant difference between group 3 and group 4 in terms of rotation ($p = 0.36$), the mean ratios of the uncovered tibial surface to the total tibial surface ($p = 0.041$) and also the overstuffed area to the total base plate surface ($p = 0.029$) were significantly greater in group 4.

Conclusions: The determination of correct size and rotation of the tibial component is essential for favorable outcomes of total knee arthroplasty. In this study, the symmetric tibial base plate design was more effective than the asymmetric design in providing the ideal tibial rotation and coverage.

Keywords: *Knee, Arthroplasty, Rotation, Prosthesis implantation*

In total knee arthroplasty (TKA), the tibial base plate should be placed in the appropriate rotational axis and it should be of a size that fully covers the plateau. If the component is smaller than the ideal size, it may cause collapse, early loosening, and plateau factures and if the size is larger than the ideal, it may cause chronic pain or restricted range of motion.[1-3] The shape and size of the TKA design is one of the most important factors to provide ideal coverage and rotation. In this context, various symmetric and asymmetric tibial base plates have been produced.

In the literature, several studies have reported that symmetric or asymmetric base plate designs do not fit global population equally well. While using asymmetric base plates, an attempt is generally made to increase the coverage through rotational movements and this may cause serious rotational errors even though they may seem minor initially.[4] In contrast, the symmetric tibial components are expected to ensure better tibial coverage.[5]

In this study, we hypothesized that (1) the sym-

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metric tibial component would provide greater coverage than the asymmetric component when placed in the same rotational axis and (2) the asymmetric component would result in more rotational errors than the symmetric component. The aim of this study was to evaluate two contemporary tibial base plate designs in terms of coverage and rotation.

METHODS

The study was conducted on 80 cadaveric tibias known to be of adults (> 18 years of age) with no anomaly and rigidity of the areas to be evaluated. The study was approved by the Instutional Review Board of Yildirim Beyazit University (No. 98212577-40329095-1582).

The application sets used were Genesis II (Smith & Nephew, Memphis, TN, USA) for the symmetric arthroplasty and Nex-Gen (Zimmer, Warsaw, IN, USA) for the asymmetric arthroplasty.

Preparation

The bones were fitted to the clamp vertical to the ground and were checked with a spirit level (Fig. 1). The application was carried out by 2 orthopedic surgeons, both of whom were experienced in arthroplasty (one was familiar with the symmetric system and the other with the asymmetric system). Before the tibial cut, the center of the distal articular surface of the tibia was measured and the location meeting the center of the talus articular surface was determined and the center of the distal tibia was marked.

For the First Research Question

Application

Forty dry tibias were used. The surgeons were asked to make the tibial cut using an extramedullary guide (Fig. 2). Immediately afterwards, the surgeons placed suitable tibial base plates (20 symmetric and 20 asymmetric) taking care to ensure the best coverage that they were able to determine with reference to the the anterior surface of tibia. The 20 tibias with the symmetric base plate constituted group 1 and the 20 tibias with the asymmetric base plate group 2.

Measurements

All the measurements were made by a musculoskeletal radiologist blinded to the purpose of study. After the application of tibial base plates, the coronal, sagittal, and horizontal plane images of the bones were obtained by computed tomography (CT), and then three-dimensional (3D) reconstruction was performed (Fig. 3).

On all tibias, the posterior tibial margin (PTM) was determined by aligning the x-axis to the most posterior points of the medial and lateral plateaus as the rotational axis (Fig. 4).[6,7] The posterior condylar axis (PCA) was drawn on 3D reconstructions by drawing a line passing vertically through the midpoint of the PTM.

The location of PCA was drawn on the 3D image (Fig. 5). The area of the tibial surface uncovered and the area of the tibial base plate overstuffed after application were measured by pixel count and the proportion to the total area was calculated as a percentage. Then, a line connecting the anterior and posterior center points of the tibi-

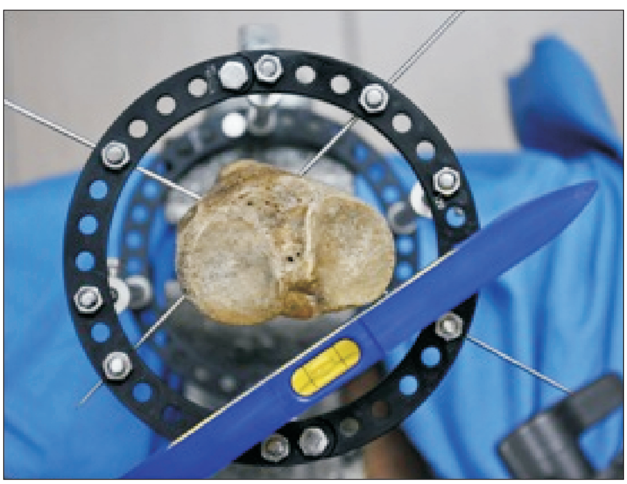

Fig. 1. The tibia was fixed using an Ilizarov frame.

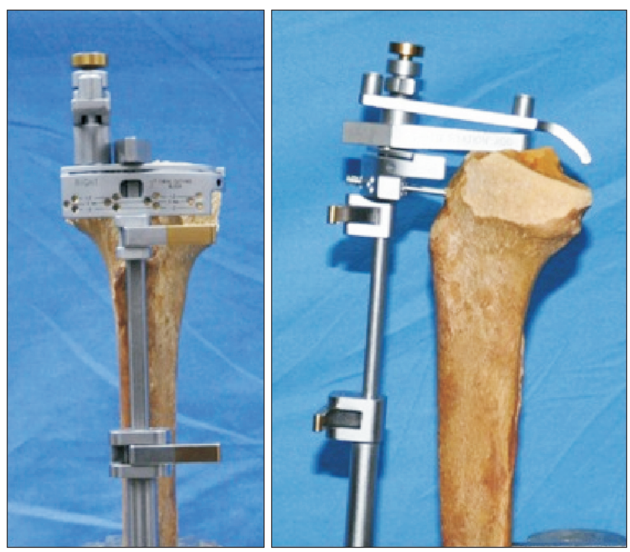

Fig. 2. Setting of the external guide for proximal tibial cutting.

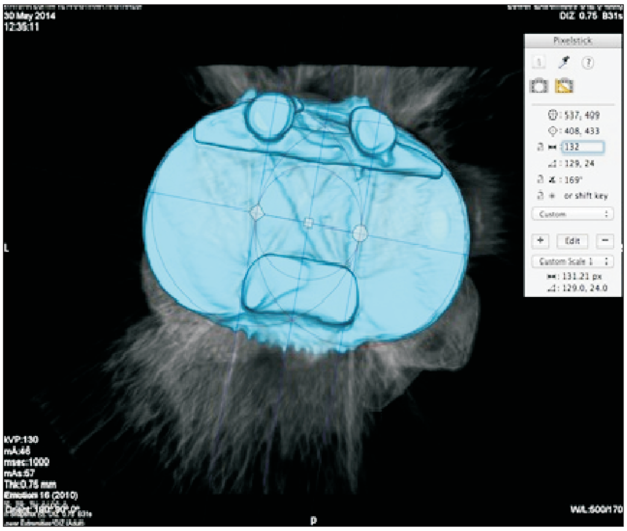

Fig. 3. Three-dimensional computed tomography reconstruction model.

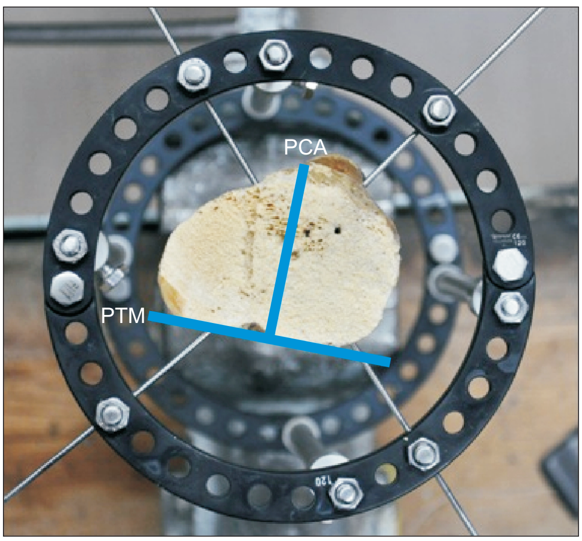

Fig. 4. Schematic display of the posterior condylar axis and the posterior tibial margin. PCA: posterior condylar axis, PTM: posterior tibial margin.

al base plate (APTP) was drawn and the angle created with PCA was calculated (Fig. 6) to determine any rotational malalignment.

For the Second Research Question

Application

Forty dry tibias were used. The surgeons were asked to place the base plates (20 symmetric and 20 asymmetric) taking care to ensure the best rotation. Tibias with the symmetric base plate were assigned to group 3 and tibias with the asymmetric base plate to group 4.

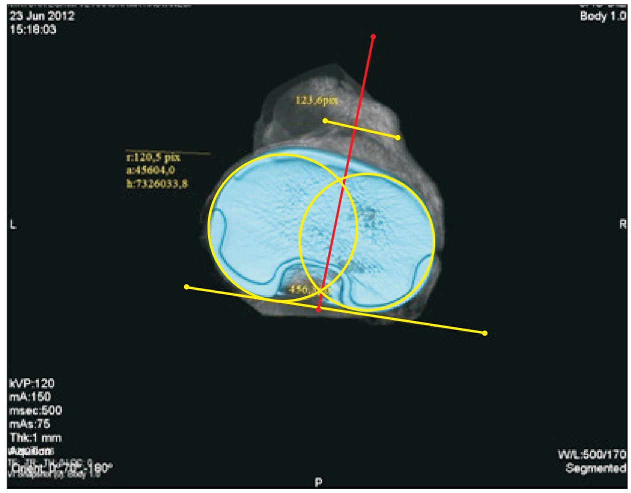

Fig. 5. The posterior condylar axis and the posterior tibial margin on the 3-dimensional reconstruction model. The long yellow line indicates the posterior tibial margin and the red line indicates the posterior condylar axis.

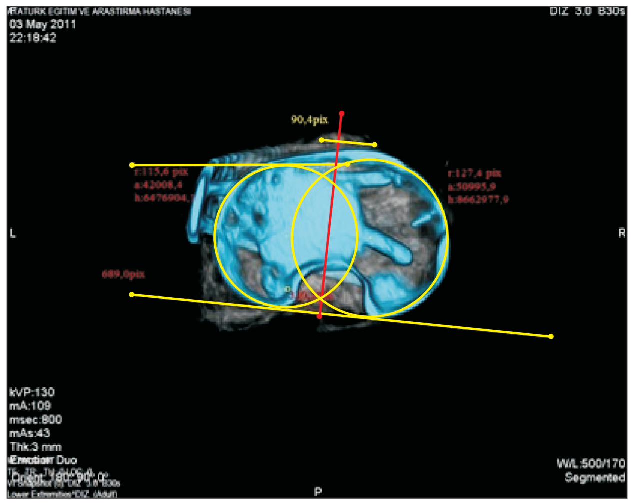

Fig. 6. Assessment of the relationship between the central antero-posterior line of the tibial base plate and the posterior condylar axis. The long yellow line indicates the posterior tibial margin and the red line indicates the posterior condylar axis.

Measurements

The areas uncovered and overstuffed after application were measured and the percentage was calculated in the same manner as described above. Also, the angle between APTP and PCA was calculated.

Statistical Analysis

Data were analyzed with SPSS ver. 15.0 (SPSS Inc., Chicago, IL, USA). Student *t*-test was used for variables with normal distribution and the values were presented as mean ± standard deviation. Continuous variables without normal distribution were analyzed using the Mann-Whitney *U*-test and the obtained values were presented as median (50th) values with interquartile ranges (25th and 75th). A two-tailed *p*-value of < 0.05 was considered statistically significant.

RESULTS

First Research Question

The mean ratio of the uncovered area of the tibial plateau to the total tibial plateau surface was 3.8% ± 1.8% in group 1 and 4.4% ± 2.6% in group 2, showing no significant difference between groups ($p = 0.624$). The mean ratio of the area of the tibial base plate overstuffed to the total base plate surface was 2.2% ± 0.4% in group 1 and 2.7% ± 1.6% in group 2, showing no significant difference between groups ($p = 0.819$). The mean angle between APTP and PCA in group 1 was 3.1° ± 1.4° and in group 2 was 7.5° ± 3.2°. All of the tibial base plates were externally rotated. The difference was statistically significant ($p = 0.034$) (Table 1). So, while there was no significant difference in coverage between the 2 groups, the rotational errors were significantly greater in the asymmetric group (group 2).

Second Research Question

After drawing the PCA line on all tibias following the tibial cut, the rotation of the base plates was determined with reference to the line. The mean angle between APTP and PCA in group 1 was 3.4° ± 1.6° and in group 2 was 4.1° ± 2.2°, showing no significant difference between groups ($p = 0.36$). The mean ratio of the uncovered area of the tibial surface to the total tibial surface in group 3 was 2.9% ± 1.7% and in group 4 was 6.7% ± 3.1%, showing statistically significant difference between the groups ($p = 0.041$). The mean ratio of the area of the tibial base plate overstuffed to the total base plate surface in group 3 was 1.9% ± 0.6% and in group 4 was 4.3% ± 2.4%, showing statistically significant difference ($p = 0.029$) (Table 2).

DISCUSSION

The principal findings of this study include that (1) symmetric tibial components ensure greater coverage than asymmetric components when they are placed in the same rotational axis and (2) it is possible to make more rotational errors with asymmetric components when placed focusing on providing best coverage compared with symmetric designs.

The current study can be considered to make a significant contribution to literature due to the viewpoint and

Table 1. Comparison of Coverage and Rotation between Group 1 and Group 2 for the First Research Question

	Tibial surface not covered/total tibial surface (%)	Base plate overstuffed/total base plate surface (%)	Angle between PCA and APTP (°)
Group 1	3.8 ± 1.8	2.2 ± 0.4	3.1 ± 1.4
Group 2	4.4 ± 2.6	2.7 ± 1.6	7.5 ± 3.2
p-value	0.624	0.819	0.034

Values are presented as mean ± standard deviation.
PCA: posterior condylar axis, APTP: anterior and posterior center points of the tibial base plate, Group 1: ensuring the best coverage with symmetric design, Group 2: ensuring the best coverage with asymmetric design.

Table 2. Comparison of Coverage and Rotation between Group 3 and Group 4 for the Second Research Question

	Tibial surface not covered/total tibial surface (%)	Base plate overstuffed/total base plate surface (%)	Angle between PCA and APTP (°)
Group 3	2.9 ± 1.7	1.9 ± 0.6	3.4 ± 1.6
Group 4	6.7 ± 3.1	4.3 ± 2.4	4.1 ± 2.2
p-value	0.041	0.029	0.36

Values are presented as mean ± standard deviation.
PCA: posterior condylar axis, APTP: anterior and posterior center points of the tibial base plate, Group 3: ensuring the best rotation with symmetric design, Group 4: ensuring the best rotation with asymmetric design.

research into simple answers to simple questions, although there are similar studies in current literature comparing symmetric and asymmetric designs.[2,8]

There are 2 essential factors to consider in positioning of the tibial component in TKA. First, rotation of the tibial base plate must be accurately adjusted to ensure optimal knee kinematics. Second, coverage of the tibial base plate should be optimized to ensure appropriate load transfer and optimal implant stability without overstuffing.[9] The optimum size in anterior-posterior and lateral-medial planes is selected by making various trials. While the surgeon determines the size, the rotation of the tibial component is also adjusted. If a small size is selected to prevent protrusion of the base plate from the plateau while determining the appropriate rotation, problems may arise such as revelation of the uncovered plateau.

Component overhang has been known to cause soft tissue irritation, overstuffing of the joint space and associated compromise of range of motion and persistent knee pain after TKA.[10] Overhang of a properly rotated component is determined by the shape and size of the TKA design, and reducing excessive overhang may entail compromise of alignment or size of the component, potentially leading to component subsidence and loosening due to compromised cortical support.[11,12] Bonnin et al.[13] reported that the incidence of oversized tibial plateau components was high and that functional outcomes were poorer in the case of mediolateral or anteroposterior oversizing. They stated that the risk of oversizing could be predicted as it occurred predominantly in patients with asymmetric proximal tibia and/or small tibias.[13] In our study, the uncovered area was greater in the group where the asymmetric tibial base plate was applied. Maximum coverage is required for uniform load transfer over the tibial base plate.[14] However, insufficient tibial coverage may occur unintentionally even if close attention is paid and the compatibility of femoral cut and component is highly focused in surgery. Furthermore, an error made with one of the components can ultimately affect the outcomes of TKA. Deviation from the PCA was greater in the asymmetric group. This indicates that small movements made to increase the coverage with the asymmetric tibial component can result in rotational errors.

There is little consensus in the literature on the ideal rotational alignment of the tibial component in TKA and it has been the controversial subject of scientific discussion.[15,16] Our findings support the idea that the best rotational orientation of the tibial component is close to the medial border of the attachment of the patellar tendon[17] as opposed to the claim that it is located at the medial third of tibial tuberosity than at the medial border.[18] A number of recent studies have suggested rotation with reference to the PTM.[6,19] Bonnin et al.[6] concluded that anterior tibial tuberosity (ATT) was not a reliable landmark for rotation of the tibial component. They analyzed 100 arthritic knees and compared 3 reference axes of rotation: transepicondylar axis (TEA), PTM, and ATT. They reported that proper rotation of the tibial base plates available on the market was easier to obtain when they were aligned to the PTM or TEA rather than the ATT.[6] Based on our experience, PTM was considered the best reference for tibial component rotation and thus this reference was used in this study. However, the proper rotational alignment of tibial base plate is still controversial and determined according to the anterior surface of tibia. The limitations of this study include that it was a cadaveric study and the number of tibias was relatively small.

In conclusion, determination of the correct size and rotation of the tibial component is essential for favorable outcomes of TKA. In this study, the symmetric tibial base plate design was better than the asymmetric design in terms of tibial rotation and coverage.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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