Anatomical References to Assess the Posterior Tibial Slope in Total Knee Arthroplasty: A Comparison of 5 Anatomical Axes

Jae Ho Yoo, MD,* Chong Bum Chang, MD, PhD,†† Kwang Sook Shin, MS,† Sang Cheol Seong, MD, PhD,‡ and Tae Kyun Kim, MD, PhD††

Abstract: There has been no consensus on an ideal anatomical reference to determine the posterior slope of tibia plateau. Posterior slope of the medial tibia plateau was measured with reference to a proposed mechanical axis (MA) and 5 clinically relevant anatomical references in 90 osteoarthritic knees of 66 female patients undergoing total knee arthroplasty. The MA was defined as the line connecting the midpoints of the medial tibia plateau and the tibial plafond, and 5 anatomical references included the anterior cortical line of tibia, anatomical axis of proximal and central tibia, posterior cortical line of proximal tibia, and fibular shaft axis. The average posterior slope was 10.6° with reference to the MA, and the amount of posterior slope varied widely among the patients and depending on the anatomical reference used to measure. This study indicates that the anatomical reference used to measure the posterior slope should be identified in studies where posterior slope is used to evaluate the sagittal alignment of total knee arthroplasty.

Key words: total knee arthroplasty, sagittal alignment, posterior slope, mechanical axis, anatomical reference.

© 2008 Elsevier Inc. All rights reserved.

One of the crucial factors for successful total knee arthroplasty (TKA) is to establish the proper alignment of the limb and prostheses, which is well known to influence the joint kinematics and longevity of the implants [1-4]. In the coronal plane, the mechanical axis (MA) is well defined as the line connecting the center of the femoral head and the center of the ankle joint [5-7]. The surgical principle for proper alignment in the coronal plane is to restore the MA to neutral, and the technique to achieve the neutral MA is to place the femoral and tibial components vertical to the MA [6,7]. Relevant anatomical references in the coronal plane are well known [6,7]. In contrast, alignment in the sagittal plane has not been studied thoroughly [5,8,9].

Posterior slope of the tibial component influences various aspects of the replaced knee including knee kinematics, implant fixation, and wear of ultra-high molecular weight polyethylene insert [10,11]. Reflecting its importance, the posterior slope was adopted in the radiographic evaluation of the American Knee Society [12] and reported in most of the studies that involve the sagittal alignment of a tibia component [9-11,13]. However, despite its frequent use, there is little consensus on the ideal reference for measuring the posterior slope, and many studies did not reveal detailed information of the reference used in the study [8-10,14]. Although
various anatomical references are used, there is little information on the amount of the posterior slope with reference to relevant anatomical references, and it is difficult to compare the results among different studies.

One possible alternative to the use of various anatomical references is to use an MA where the load is transmitted, but the sagittal plane has no equivalent to the MA of the coronal plane [5,15]. As the articulating point changes instantly with the degree of flexion, the same definition for the coronal MA might not be applied to the sagittal MA [5,15]. However, defining the sagittal MA as the connecting line between the midpoints of the tibia plateau and the tibia plafond, which is similar to that of the coronal MA, comes with several advantages [16-18]. It is not influenced by the intervening diaphyseal deformity, the bowing of the diaphysis, or individual anatomical variations, and the orientation of the entire bone between the proximal and distal joint can be described efficiently. It can be a universal reference to compare the data generated with various anatomical references once the association between the sagittal MA and the anatomical references is documented.

The purpose of this study was to document the data of posterior slope of the tibia plateau with reference to the sagittal MA and 5 clinically relevant anatomical references in Korean female patients undergoing TKA for advanced osteoarthritis. We also sought to determine the most representing anatomical reference for the sagittal MA by investigating the relationship between the sagittal MA and the anatomical references.

**Methods**

A total of 90 knees in 66 consecutive female patients undergoing TKA for advanced osteoarthritis at the authors’ institute for 6 months (between May and November of 2004) were evaluated for the inclusion of this study. Patients with any morbid condition affecting the limb alignment such as previous fracture, deformity, and congenital anomaly were excluded. As this study focused on female patients, 3 male patients (5 knees) who had received TKA in the same period were excluded from this study. The average patient age was 67.6 years (range, 56-87). The average body height, weight, and body mass index was 151.5 cm (range, 139-159), 60.3 kg (range, 46-77), and 26.3 kg/m² (range, 19.7-32.1), respectively. Informed consent was obtained from each patient, and an approval from the institutional review board of our hospital was given to this study.

All measurements were carried out by a trained investigator (one of the authors, K. S. S.). In the measurements, a true lateral radiograph of the lower leg covering the whole length of the tibia
was used. The measurements were done with the use of a working software of PACS (picture archiving and communication system) (Impax, Agfa, Antwerp, Belgium). The sagittal MA of the tibia was defined as the line connecting the midpoints of the medial tibia plateau and the tibia plafond. Five anatomical references were identified: the anterior cortical line (ACL) of tibia, the proximal anatomical axis (PAA), the central anatomical axis (CAA), the posterior cortical line (PCL) of proximal tibia, and the fibular shaft axis (FSA) (Fig. 1). Definition for each anatomical reference was made.

Fig. 2. Posterior slope of tibial plateau was measured with reference to the sagittal MA, ACL, PAA, CAA, PCL, and FSA.

Fig. 3. The angle between the sagittal MA and 5 anatomical references was measured to investigate the spatial relationship.
Table 1. Results of the measurements of the posterior slope and the angles between the sagittal MA and the 5 anatomical references

<table>
<thead>
<tr>
<th>Reference</th>
<th>Posterior slope *</th>
<th>Angle between the sagittal MA and the anatomical reference †</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagittal MA</td>
<td>10.6 3.5 1.9 to 19.6</td>
<td>Mean (SD) Range</td>
</tr>
<tr>
<td>ACL</td>
<td>13.8 3.5 5.0 to 23.2</td>
<td>−3.2 1.3 −6.2 to −0.4</td>
</tr>
<tr>
<td>PAA</td>
<td>10.8 3.4 2.7 to 21.2</td>
<td>−0.2 1.0 −2.5 to 1.8</td>
</tr>
<tr>
<td>CAA</td>
<td>12.9 3.8 3.1 to 22.3</td>
<td>−2.2 0.7 −4.0 to −0.9</td>
</tr>
<tr>
<td>PCL</td>
<td>7.8 3.5 −0.2 to 19.3</td>
<td>2.9 1.1 0.2 to 5.0</td>
</tr>
<tr>
<td>FSA</td>
<td>9.5 3.9 −1.3 to 19.3</td>
<td>1.1 1.1 −1.2 to 3.9</td>
</tr>
</tbody>
</table>

*A negative value means the tibia slope is tilted anteriorly (reverse slope) to the reference.
†A negative value means that the anatomical reference tilted anteriorly to the sagittal MA.

The degree of posterior slope of the medial tibia plateau was measured with the reference of the sagittal MA and the other 5 anatomical references (Fig. 2). Relation between the sagittal MA and the anatomical references was investigated by comparing the angles between the sagittal MA and each of 5 anatomical references (Fig. 3). The spatial relationship between the sagittal MA and each anatomical landmark was noted by giving a negative value to the cases where the anatomical reference tilted anteriorly and a positive value to the ones where it tilted posteriorly with regard to the sagittal MA. All data were entered in a statistical program (SPSS, version 12.0) and summarized in mean, SD, and range.

To assess the reliability of the measurements using the references mentioned above, 3 orthopedic surgeons and 1 clinical investigator performed the measurements twice with an interval of 1 week in 30 knees randomly selected from the 90 knees. The degree of measurement reliabilities was assessed using the intraclass correlation coefficient (ICC). A typical interpretation of an ICC value is as follows: 0.00 to 0.20, poor agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; and 0.81 to 1.00, almost perfect agreement [19]. The ICCs for intra- and interrater agreement were greater than 0.947 for all measurements of the posterior slope and the angles between the sagittal MA and the 5 anatomical references. These findings led us to rely on the validity of the measurements using the references. Because there were no significant differences among the measurements by 5 examiners, the measurement data by a single investigator were used in the following analyses.

Results

The mean posterior slope of the medial tibia plateau with reference to the sagittal MA was 10.6°, ranging from 1.9° to 19.6°. The degree of posterior slope varied widely among the patients (Table 1). In addition, it varied widely depending on the anatomical reference used in the measurements. The mean posterior slope was 13.8° with ACL, 10.8° with PAA, 12.9° with CAA, 7.8° with PCL, and 9.5° with FSA. All differences by the anatomical reference were statistically significant (P < .05, paired t test). The maximum difference in the mean value was 6° between the ACL and the PCL. The range of the posterior slope was wide in all 5 anatomical references (minimum 18.2° in the ACL and maximum 20.6° in the FSA).

The 5 anatomical references showed various relationships to the sagittal MA. Of the 5 anatomical axes, 3 (ACL, PAA, CAA) showed negative mean values suggesting that they tilted anteriorly to the sagittal MA in most cases (100%, 60%, 100%, respectively). In contrast, the PCL and the FSA tilted posteriorly to the sagittal MA in 100% and 86%, respectively. The anatomical axis most parallel to the sagittal MA was the PAA (mean angle between the sagittal MA, −0.2°), followed by the FSA (1.1°), the CAA (−2.2°), the PCL (2.9°), and the ACL (−3.2°).

Discussion

The sagittal alignment of a replaced knee is kinematically important because most of the knee motion occurs in the sagittal plane [5]. The degree of posterior slope of the proximal tibia has been used to indicate the proper sagittal alignment in TKA [5,10,20]. However, there is little consensus on the ideal reference to measure the posterior slope, and different anatomical references are used variously in relevant studies [8,9,14]. This study documents the
data of the tibia posterior slope measured with the relevant mechanical and anatomical references identified with clear anatomical landmarks. The amount of the posterior slope varied widely among the female patients undergoing TKA for advanced osteoarthritis, and it could also be various depending on the anatomical reference used in measuring.

The sagittal plane does not have an equivalent to the MA of the coronal plane because the load bearing line changes instantly with the degree of flexion [5], and some investigators defined the sagittal MA in their own ways with no verification of its validity [16,18]. Oswald et al [16] defined the MA of tibia in sagittal plane as the line between the intersection of the plane of the tibial plateau and a line running through the midpoints of the outer shaft diameter at distances of 10 and 20 cm from the tibial plateau, and the midpoint of the width of the tibiotalar joint. Denis et al [18] defined the MA of the tibia in sagittal plane as the line connecting the midpoint of the plane of the tibial plateau and the midpoint of the talus. In the current study, we defined the sagittal MA as the line connecting the midpoints of the medial tibia plateau and the tibia plafond in the sagittal plane, which is similar to that of the study by Denis et al [18]. We found several advantages with the use of this definition for the sagittal MA. It can avoid the effects of intervening bone deformity because the overall orientation of the entire bone is reflected. It can be used as a standard to compare other anatomical references as in this study. It is in accordance with the definition of the coronal MA [5], but this study does not convey the data revealing its mechanical significance. Future studies are warranted to elucidate its mechanical significance.

The variations in the status of the knees to be studied and anatomical references to measure the posterior slope make it difficult to directly compare our findings with those of previous studies [8-10,14]. In the studies of 33 knees for TKA, Hofmann et al [10] reported that the mean posterior slope of the tibia plateau was 7° (range, 2°-12°), but they did not differentiate the medial and lateral plateaus and did not mention in detail the anatomical reference to measure. The subjects in the study included both osteoarthritic and rheumatoid arthritic knees. In the study of 25 pairs of Chinese cadaveric tibiae, Chiu et al [8] reported that the posterior slope of the medial tibia plateau was 11.5° and 14.7° with the reference of intramedullary method and extramedullary method, respectively. In their study, the intramedullary method used the midmedullary line connecting the anterior insertion site of the anterior cruciate ligament and the midpoint at the midshaft of the tibia. The extramedullary method took advantage of the line tangential to the anterior cortex of the tibia. Their study included normal knees and the knees with osteoarthritic changes. They noted that the knees with osteoarthritic changes had greater posterior slope, but detailed information was not provided. In the analyses of Japanese 30 normal and 30 osteoarthritic varus knees using magnetic resonance studies, Matsuda et al [14] found that the mean posterior slope of the medial tibia plateau was 10.7° (range, 5°-15.5°) in the normal knees and 9.9° (range, 1.5°-19°) in the varus knees, of which difference was not statistically significant. In their measurements, the reference was defined as the line through 2 bisection points on the tibia shaft on the intercondylar section of the magnetic resonance image, but the exact site taken to identify the points was not presented. Recently, Kuwano et al [9], in the study of 50 Japanese knees with osteoarthritis using computerized tomography images checked before high tibial osteotomy or TKA, reported that the mean posterior slope of the medial tibial plateau was 9.0°. Their reference to measure the posterior slope was defined as the longitudinal axis of the tibia shaft. Their illustration suggested the longitudinal axis of the proximal tibia, but detailed information was not provided. Our review of the previous studies indicates the necessity of clarification in the status of the knees studied and the anatomical references for the longitudinal axis of the tibia to make it possible to compare different studies.

In our study, the most representing anatomical reference for the sagittal MA was the PAA, but each of the 5 anatomical references has its own characteristic clinical implications. The ACL can be used to set the extramedullary guide for tibia resection, taking it under consideration that the soft tissue anterior to the tibia may obscure exact demarcation [8]. The CAA is relevant to the positioning of intramedullary guide for tibia resection or the use of an extension stem in revision scenarios [8]. The FSA can be a useful guideline in performing a surgical procedure because it can be determined intraoperatively by palpating the proximal and distal portions of the fibula. In the authors’ experience, the PCL can be a useful landmark to appreciate the orientation of the stem of a tibia component, and it can be drawn easily in a routine radiograph (14 × 17 in) of the knee. The PAA in this study is equivalent to the reference suggested in the System of the American Knee Society, although it was not clarified explicitly in the publication [12]. The fact that the PAA is the most parallel to the sagittal MA advocates the clinical value of the anatomical
implications for the knees that become the subjects of the study. Knees with advanced osteoarthritis may have differences in anatomical features of the tibia compared to normal knees [8]. All subjects in our study were female, and there were only 3 male patients (5 knees) undergoing TKA in the same period during which the study subjects received surgery. As the small number of male knees could not provide enough power to demonstrate the differences between female and male knees, we decided to exclude the male patients. Most of the TKA series have reported female sex dominance (61%-96%) whether in western or Asian subjects [22-26]. For some reasons, this female sex dominance seems to be more remarkable in Korean patients [25,26]. In the studies of Korean patients who underwent TKA, Kim and Moon [24] and Kim et al [25] reported female sex composition of 84% (39/47) and 96% (2/50), respectively. Of 835 TKAs performed between May 2003 and February 2006 at the authors’ institute, 790 (94.6%) were in female patients. This female sex dominance in patients undergoing TKA is expected to continue or increase considering the pattern of female sex dominance in elderly population [23]. Although our findings have implication for the major patient population undergoing TKA, it may not be appropriate to directly extrapolate our findings to the knees of male patients.

This study is not free from limitations. First, anatomical features of the tibia can vary with the ethnic origin of patients [8,10,14]. All subjects in this study were ethnically Korean, and it might be difficult to directly extrapolate our findings to a patient population of a different ethnic origin. Second, this study was performed in the knees with advanced osteoarthritis warranting TKA, and our findings might not represent normal knees without osteoarthritic changes. A previous study reported that the amount of posterior slope was larger in the knees with osteoarthritis than the normal knees [8]. However, our findings in the knees with advanced osteoarthritis may have better implications for the knees that become the subjects to evaluate posterior slope after TKA. Future comparative studies of the normal knees and the knees with osteoarthritis are warranted. Finally, designation of the proportional landmarks for the anatomical references might make better representation of overall features of the tibia. In the current study, however, in an effort to make our definition of the anatomical references consistent, we designated the landmarks for the anatomical references of ACL, PAA, PCL, and CAA by the fixed distances from the joint line. Although we found no notable difficulties in using the landmarks based on the fixed distances, adjustment of the landmarks for the anatomical references may be necessary for much smaller or larger knees.

In summary, this study demonstrates that the amount of posterior slope of the proximal tibia varies widely among patients undergoing TKA for advanced osteoarthritis and that it can also be various depending on the anatomical reference used in measuring. Each of the 5 anatomical references has a unique relationship to the sagittal MA and involves different clinical implications. This study indicates that the anatomical reference used to measure the posterior slope should be identified in studies where posterior slope is used to evaluate the sagittal alignment of TKA.

References

学霸图书馆

www.xuebalib.com

本文献由“学霸图书馆-文献云下载”收集自网络，仅供学习交流使用。

学霸图书馆（www.xuebalib.com）是一个“整合众多图书馆数据库资源，提供一站式文献检索和下载服务”的24 小时在线不限IP 图书馆。

图书馆致力于便利、促进学习与科研，提供最强文献下载服务。

图书馆导航：
图书馆首页 文献云下载 图书馆入口 外文数据库大全 疑难文献辅助工具