Clinical Assessment of Proximal Tibial Morphology at Total Knee Arthroplasty

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Abstract:

Introduction

In light of increasing patient demands and expectations in TKA, a detailed understanding of bone morphology may be the key to optimizing tibial component performance. Current tibial components in TKA fail to reproduce native human geometry. Accurate measurements and ratios of proximal tibia dimensions are important as components move towards more anatomic designs.

Methods

A consecutive series of TKAs were performed at one center. Proximal tibial measurements were obtained following proximal tibial resection at the time of TKA. These were compared with demographic parameters including height, weight, and gender.

Results

145 consecutive primary TKAs (21 bilateral) in 124 patients (85 females, 60 males) were analyzed for this study. Statistical analysis revealed multiple correlations and trends. The tibial dimensions increase linearly in males and females as tibial

component size increases. The AP/ML ratio (aspect ratio) of the proximal tibia is fairly constant over the range of bone sizes for both males and females. There is no correlation between aspect ratio and tibial size, nor are there statistical differences between the aspect ratios in males and females. Tibial measurements and component size are positively correlated with both patient height and weight for males and females, although a stronger correlation exists for male patients. On average, the asymmetry between the lateral and medial condyles increases as a function of tibial size. This asymmetry increases more dramatically in males than females.

Conclusions

These important clinical observations of tibial morphology can be used in designing component lines that more closely resemble native human anatomy, possibly improving performance.

Summary Sentence

Proximal tibial morphological measurements and ratios provide the design rationale for advanced, conforming components, possibly improving implant positioning, performance and longevity.

Introduction:

Total knee arthroplasty (TKA) is one of the most successful and cost effective⁶ procedures in orthopedics. Despite significant clinical improvements in the majority of patients, there remain a minority who are not as pleased with the function of their knee. Multiple factors have converged to create a new patient population with altered expectations and demands of their knee

replacements. Patients are undergoing surgery at a younger age, are pursuing physical activity following reconstruction, and are living longer. This shift has prompted the Knee Society to seek a newer and more sensitive score to assess

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the important clinical and functional parameters in the modern TKA patient^{9,10}.

Knee replacements themselves have also undergone significant changes over the years, though somewhat lagging, and often responding to, specific functional concerns in patients. Early designs featured few sizes which were neither modular, nor side specific. Multiple iterations have subsequently been used, with recent modifications including: higher flexion prostheses¹¹, gender specific designs¹², improved wear characteristics, and side specific tibial baseplates.

Interestingly, the anatomic bases for these recent changes have long been understood. A morphologic study in 1975 by Mensch and Amstutz¹ analyzed the dimensions of the knee in cadavers and radiographs. They reported gender differences, and asymmetries that were only much later incorporated into designs.

Renewed interest in anthropomorphic measurements has resulted in clinical^{2,4,8}, and image^{3,4,5,7} based assessments of dimensions about the knee. These have focused on American^{2,8}, Indian³, Japanese⁴, European⁵, and Korean⁷ populations. Our study sought to closely examine one specific aspect of the knee in greater detail to determine whether specific trends occurred in tibial anatomy that could be used to better design a conforming tibial baseplate at the time of TKA.

Materials and Methods:

Institutional review board approval was obtained for this study.

A clinical study involving measurements of the proximal tibial cut surface following proximal tibial resection, but prior to prosthesis implantation was performed in a consecutive series of TKAs performed by one of four surgeons (GRS, WNS, FDC, MAK). In all cases, measurements were made with a metal ruler with millimeter increments, and recorded at the time of the procedure (Figure 1).

145 consecutive primary total knee arthroplasties (85 female knees, 60 male knees) in 124 patients were

analyzed for this study. Height weight and BMI were recorded for all patients pre-operatively. Twenty one patients underwent sequential bilateral total knee arthroplasty during the same operative setting. Patients were excluded if they had prior bony surgery (osteotomy or peri-articular fracture fixation), significant deformity ($>15^\circ$ valgus or varus), or if there was bone loss requiring augmentation.

The surgeons performed the index procedure with a similar technique, the proximal tibia was resected with an extra-medullary tibial cutting guide, and proximal tibial measurements were taken using a standardized protocol. Anterior-posterior (AP) and the medio-lateral (ML) dimension were then taken following proximal tibial resection of approximately 2mm from the lower side at the time of a perpendicular proximal tibial cut with an extra-medullary cut guide. All measurements were rounded to the closest mm after removal of osteophytes. The overall ML width of the tibia and the AP depth of the medial and lateral plateaus were recorded.

The aspect ratio (AR) of the, tibia (ML/AP) was analyzed using all recorded measurements. Measurements were taken by the same investigator (VD). Statistical analysis was performed using Minitab Statistical Software (version 14, Madison, WI). Measurements which followed the normal

Figure 1: Tibial Measurements

Gaussian shaped curve were analyzed using ANOVA. Those measurements which did not follow the normal curve were analyzed using a non-parametric test, Mann-Whitney U test.

Results:

The mean age for women was 65 years (range 38 to 94) and 63 years (range 40 to 78) for men. The mean AR of the tibia using the medial plateau was 1.51 for men and 1.51 for women ($p > 0.05$). The mean AR of the tibia using the lateral plateau was 1.62 for men and 1.67 for women ($p < 0.05$). There was no significant difference when using the medial plateau between gender, however, when using the lateral plateau there was a statistically significant difference between gender (Figure 2).

Figure 2: The left panel shows the gender difference using the AR of the tibia using the medial plateau ($p > 0.05$) and on the right the lateral tibial plateau ($p < 0.05$)

Statistical analysis revealed multiple correlations and trends. The tibial dimensions increase linearly in males and females as tibial component size increases. The AP/ML ratio (aspect ratio) of the proximal tibia is fairly constant over the range of bone sizes for both males and females. There is no correlation between aspect ratio and tibial size, nor are there statistical differences between the aspect ratios in males and females. Tibial measurements and component size are positively correlated with both patient height and weight for males and females, although a stronger correlation exists for male patients. On average, the asymmetry between the lateral and medial condyles increases as a function of tibial size. This asymmetry increases more dramatically in males than females.

Discussion:

Previous studies have analyzed the anthropometric measurements of the proximal tibia^{1,5,7,8}. In our study, the tibia did not show a difference in AR between men and women when using the medial plateau and a slight difference when using the lateral plateau with women increasing width faster than men.

Tibial component alignment has traditionally been based on fixed anatomic landmarks such as the medial third of the tibial tubercle, though anatomic variations exist leading to mal-rotation if this is the only guide used^{15,16}. Unfortunately, a symmetric tibial baseplate forces the surgeon to compromise between bone coverage and appropriate rotation on an asymmetric tibial plateau. TKA performance has been demonstrated to improve with well-aligned prostheses¹⁴ and early failures are associated with mal-rotation¹⁷. Tibial baseplates that better match the proximal tibial geometry may allow surgeons to better align the prosthesis through a range of sizes and morphologies.

The important clinical observations of tibial morphology that we have made can be incorporated in designing component lines that more closely resemble native human anatomy. The engineering goal is to improve motion characteristics¹³ and clinical performance of TKAs. Proximal tibial morphological measurements and ratios provide the design rationale for advanced, conforming components, possibly improving performance and longevity. An anatomically shaped asymmetric tibial component offers the opportunity to maximize bone coverage and assure accurate rotational position.

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