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Effects of measurement methods for tibial rotation axis on the morphometry in Korean populations by gender

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ABSTRACT

Background: There have been arguments for methodology in tibial rotation axis measurement, which accordingly determines the morphometry of the proximal tibia in total knee arthroplasty. The morphometry of the proximal tibia for the Korean population is determined by gender, based on the anatomical tibial axis and reliable rotational orientation in knee replacements, to evaluate the size suitability of the currently available prostheses in Korea.
Methods: This study reconstructed the MRI images in three-dimensions for identification and measurement of the mediolateral (ML) and anteroposterior (AP) lengths of the proximal tibia and the tibial aspect ratio (ML/AP) using proximal tibial anthropometric data for 700 osteoarthritic knees (587 females and 113 males). The ML and AP lengths were measured using tibial rotation axis techniques based on the medial one-third tibial tubercle and Cobb's method.
Results: Significant differences ($P < 0.05$) in ML, medial anteroposterior (MAP), lateral anteroposterior (LAP) lengths, and aspect ratio (ML/LAP) were observed for males and females with respect to different measurement techniques for the tibial rotation axis. However, the measured aspect ratio (ML/MAP) of tibiae for the Korean population did not show significance. The measured aspect ratio (ML/AP) ratio of tibiae for the Korean population was higher than that of currently available tibial components.
Conclusions: Results from this study can guide development of gender-specific tibial prosthesis designs with different ML and AP aspect ratios based on the tibial anatomical rotation axis for the Korean population.

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1. Introduction

Total knee arthroplasty (TKA) is known to be the most effective treatment for improving function in pathologic knees. However, postoperative complications have been reported in which the important factor for long-term TKA survivorship is congruent geometry between the knee prosthesis and the resected knee surface [1–6]. A mismatch between the implant sizes with the

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resected bony surface may be problematic in Asian patients. Complications following TKA are more of a concern in tibial rather than femoral components [7,8]. To optimize stability and longevity in TKA, the most important factor is fitting a properly sized tibial prosthesis to the resected proximal tibial surface [8,9]. In addition, the effect of gender differences in TKA has recently been considered, and new TKA designs have been proposed to accommodate gender-related anatomical differences [10–12].

In Korea's orthopedics field, the TKA market is the largest, grossing approximately 80 million dollars annually, with a three percent annual market growth [13]. Major TKA companies currently lack sufficient gender-specific and Korean population-specific clinical data for mediolateral (ML) and anteroposterior (AP) lengths of the proximal tibia [7,14,15]. Moreover, a few prior studies have used data from cadavers or young patients, which are less reliable because of the small number of observation limits [7,14,15]. In previous studies, the ML length of the tibia has been recorded as the length of the longest ML line in proximal tibia axial images. The AP length of the tibia has been determined using a line drawn perpendicular to the ML line and passing through the midpoint of the resected surface [7,14,15]. The proximal tibia is not, however, composed with circular geometry. Thus, accurate AP and ML lengths may be dependent on the tibial rotation axis, which is related to their reference axes. The restoration of proper rotational alignment of the tibia is challenging during knee replacement; improper rotational alignment can lead to malrotation of the tibial component [16–19]. It is believed that, to date, there has been no study that has evaluated the tibial anatomical rotational axis using ML and AP lengths and ML/AP aspect ratios with respect to gender differences in the Korean population.

In the present study, morphometric data of AP, ML and ML/AP aspect ratio for proximal tibiae from 700 patients with osteoarthritis (OA) was evaluated using three-dimensional (3D) magnetic resonance imaging (MRI). The ML and AP lengths of the proximal tibiae were measured by gender, using tibial anatomical rotation axis techniques based on: [1] the medial one-third tibial tubercle and [2] Cobb's method. In addition, the measurements of TKA tibial component designs commonly available in Korea were compared.

2. Material and methods

2.1. Subject enrollment

The hospital's Institutional Review Board approved this study. A total of 700 subjects (587 females and 113 males) who underwent knee joint MRIs for diagnosis and treatment of OA between January 2008 and December 2014 were enrolled. The mean age for females and males was 70.31 (range 55 to 92) and 72.24 (range 62 to 88) years old, respectively.

2.2. MRI techniques

MRI was performed using a 1.5 T MRI scanner (Achieva 1.5 T from Philips Healthcare, The Netherlands). The MRI scans were obtained using a two-millimeter slice thickness in the sagittal plane for tibiofemoral knee joints, and five-millimeter slice thickness in the axial plane for hip and ankle joints. For the non-fat saturation condition, the MRI consisted of an axial proton-density sequence. A high-resolution setting was used for the spectral presaturation inversion recovery sequence (TE: 25.0 ms, TR: 3590.8 ms, acquisition matrix: 512 × 512 pixels, NEX: 2.0, field of view: 140 × 140 mm). This MRI methodology used in patient-specific instrumentation allowed 3D reconstructed models to be effectively developed [20,21].

2.3. Measurement and surgical simulation methods

The 3D data were acquired through MRI scans, and 3D reconstruction was performed using the Mimics software (version 17.0 from Materialise, Leuven, Belgium). These 3D images were converted to standard tessellation language (STL) files and loaded into the 3-Matic (version 9.0 from Materialise, Leuven, Belgium) computer-aided design (CAD) software, which allows the user to combine geometry data from mixed sources into a single project. Data for bony resections and their measurements were analyzed using the 3-Matic software.

An experienced surgeon (last author) completed all operations following TKA surgical simulations. A computer-generated preoperative plan was created according to surgeon's preferences as follows: the tibial default alignment was rotated 0° to the AP axis, the coronal alignment was 90° to the mechanical axis, and the sagittal alignment was five degrees of the posterior slope with an eight millimeter resection below the highest point of the lateral plateau.

Two different AP axes were used in this study. The first was the AP line connecting the center of insertion of the posterior cruciate ligament (PCL) with the medial one-third of the tibial tubercle. The condylar AP dimensions were defined as the width of the medial and lateral condyles measured at the center of each condyle parallel to the AP line (Figure 1). The second was the AP line bisecting a line connecting the circle centers perpendicularly based on Cobb's method (Figure 1) [19].

The resected tibial surface was measured in 3D based on the tibial rotational axis: ML, medial anteroposterior (MAP), and lateral anteroposterior (LAP) (Figure 1). The condylar aspect ratio of ML and AP [(ML dimension / AP dimension) × 100] was calculated [22]. This aspect ratio was compared with five TKA systems currently used in Korea: Genesis II (from Smith & Nephew, London, UK); Scorpio and Triathlon (from Stryker, Kalamazoo, MI, USA); NexGen (from Zimmer, Warsaw, IN, USA); and PFC-Sigma (from DePuy-Johnson and Johnson, Warsaw, IN, USA).

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