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Measurement and comparison of tibial posterior slope angle in different methods based on three-dimensional reconstruction

Yang Zhang, Jian Wang, Jun Xiao, Liang Zhao, Zhi-han Li, Ge Yan, Zhan-jun Shi *

Department of Orthopaedic Surgery, Nanfang Hospital, Guangzhou 510515, Guangdong Province, China

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ABSTRACT

Background: The tibial posterior slope (PTS) is an important parameter for sagittal alignment which is associated with postoperative range of motion. However, the variations of different population subsets and different referential axes are still uncertain.
Methods: In this study, 80 healthy people from South China were recruited and measured on three-dimensional reconstruction of CT, with application of three referential axes, the proximal tibial long axis, the anterior and posterior cortices.
Results: The averages and standard deviations of medial PTS (MPTS) in the three methods were 8.43 ± 3.06, 11.45 ± 2.82 and 6.31 ± 3.24, separately. The results of lateral PTS (LPTS) were 7.56 ± 2.51, 10.17 ± 2.42 and 5.22 ± 2.59. There was no significant difference between the male and the female, and the two sides of one body. The results of the three axes varied but correlated with each other significantly. Through comparison it was found that, MPTS/LPTS of people from South China were different from the published data of other countries.
Conclusions: Although PTS change markedly according to the reference axis, they show significant correlations with each other, and may be used safely. There are differences associated with races, but not gender nor the two sides of the body.
Clinical relevance: The results of the study provided references for the reconstruction of the knee PTS, if the differences of reference axes, races and genders were considered.

1. Introduction

Total knee arthroplasty (TKA) has been regarded as the most successful and standard procedure for end-stage degenerative disorders of the knee [1]. It is important to reconstruct alignment [2] after TKA to obtain satisfied range of motion (ROM) of the knee [3]. Neutral mechanical axis (MA) is the key to reconstruct alignment, so that the femoral and tibial components should be placed vertical to the neutral MA [2], both in the coronal and sagittal planes. In the coronal plane, the MA is well defined as the line connecting the center of the femoral head and the center of the ankle joint [4]. However, no consensus has been reached concerning the alignment in the sagittal plane [5].

The tibial posterior slope (PTS) has been proven to be important to implant fixation and knee kinematics [6,7] and is used in TKA to determine positioning of the tibial resection in the sagittal plane [8]. The PTS is most frequently defined as the angle created by the tibial plateau and the long axis of the tibia in the sagittal plane. Previous studies have detected variations of knee joint anatomy among different populations [9–11]. Several methods adopting different referential axes, measuring medial posterior slopes (MPTSs) and lateral posterior slopes (LPTSs) have been described in the literature, based on different imaging technologies [12]. However, its relationship to the anterior and posterior cortices may not be fully understood or agreed to, and its variation among populations is also not fully understood. In addition, the relationship of these cortical measurements to the commonly used PTS, the variation from medial to lateral, and gender differences are unknown [2].

The present study was designed to evaluate the medial posterior slope (MPTS) and lateral posterior slope (LPTS) of healthy volunteers in South China, according to different referential axes using three-dimensional (3D) reconstruction. Correlations between the above PTSs are identified and the results were compared to the published data, in order to improve the accuracy of PTS measurement.

2. Methods

2.1. Population selection

This study comprised a nonrandomized, healthy group of 80 volunteers (40 males and 40 females). The inclusion criteria were as follows: people from Guangdong and Guangxi province of China (whose last five generations lived in the two provinces), without knee disorders.

* Corresponding author. Tel.: +86 20 62840916.
E-mail address: mariaresearcher@hotmail.com (Z. Shi).

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Fig. 1. The anterior view of the reconstructed lower limb.

According to the patients' medical history, clinical exam and X-rays, pregnant women and people with the following signs and symptoms of the knee were excluded: pain, deformity, abnormal movement, claudication, rheumatic fever, rickets, rheumatoid arthritis, osteoarthritis, fracture or previous surgery. The average age was 31.38 (20–45) years, the average height was 167.25 (151–185) cm, and the average weight was 59.99 (40–80) kg. Approval from the ethical committee and informed consents were obtained for the protocol. One hundred and sixty scanned knees were available for analysis.

2.2. CT evaluation

All patients were scanned following an identical 64-slice multi slice spiral CT protocol (General Electric, USA). The patients' legs were fully extended and the feet stabilized in a neutral position. The CT scans were taken with a contiguous thickness of 0.625 mm, from the femoral condyle to the heel, with settings of 120 kV and 80 mA. Images from each CT scan were saved as DICOM images and recorded on a separate CD-ROM.

2.3. 3D reconstruction and measurement

The DICOM images were imported into Mimics 10.01 software (MATERIALISE, Belgium) to perform 3D reconstruction. The bone was calculated automatically based on radiodensity and stored as contours. The contours from sequential images were connected using triangular surface tiles to create 3D models, which could then be displayed in any position or orientation. In the software, the following steps were performed to create the 3D bone reconstructions: contrast adjustment (0–350), thresholding (226–1821), region growing, editing masks, editing mask in 3D, calculating polylines, cavity fill, Boolean operations, morphology operations and calculate 3D (Fig. 1). Images in the horizontal, coronal and sagittal planes were defined.

2.4. PTS definitions

The MPTS/LPTS was measured separately as the angle created by a tangential line of the tibial plateau and different sagittal axes. The tangential line of the tibial plateau was defined as the line passing through the center and both the anterior and posterior edge medial/lateral plateaus. The sagittal axes were defined as the following [2]: (1) The proximal tibial long axis, the straight line connecting midpoints of outer cortical diameter at 5 and 15 cm distal to the knee joint (Method I); (2) The anterior tibial cortex line, the straight line from the point on the anterior cortex at 5 cm to 15 cm distal to the knee joint line (Method II); (3) The posterior tibial cortex line, the straight line from the point on the posterior cortex at 5 cm to 15 cm distal to the knee joint line (Method III). The measurement was presented in Fig. 2.

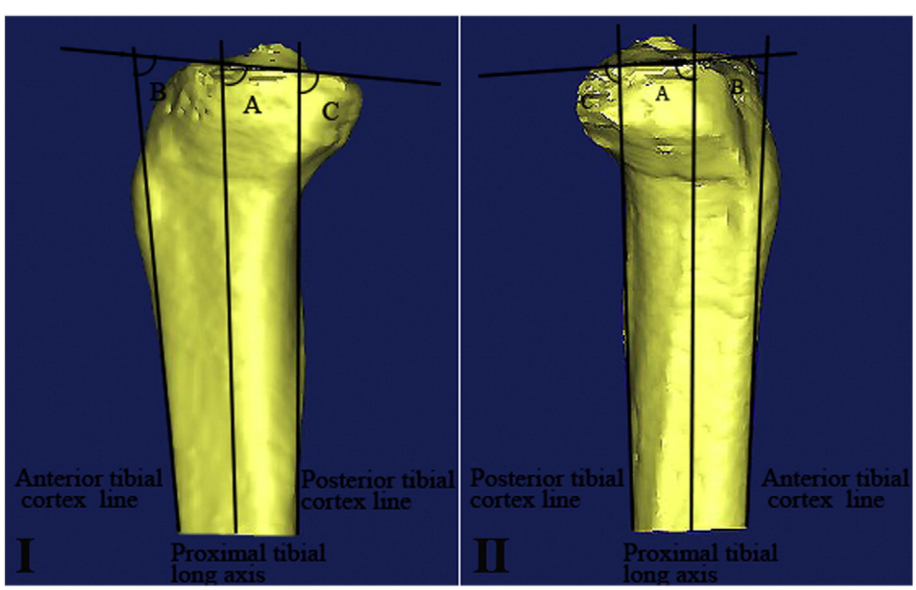

Fig. 2. The measurement of MPTS and LPTS. The MPTS according to different sagittal axes was shown in I. An angle of ∠A was equal to MPTS of Method I, ∠B was equal to MPTS of Method II, and ∠C was equal to MPTS of Method III. The LPTS according to different sagittal axes was shown in II.