Original Article

3D CAD/reverse engineering technique for assessment of Thai morphology: Proximal femur and acetabulum

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A B S T R A C T

Purpose: To assess morphological parameters of proximal femur and acetabulum in Thai population with three-dimensional measurement technique, and to analysis of collateral side symmetric, gender difference, and correlation between morphometric parameters.

Methods: Investigation was performed in 240 femurs. All three-dimensional femur models were acquired from 64-slice spiral CT scanner. Morphometric parameters under consideration included acetabular diameter, femoral head diameter, shaft isthmus location, intramedullary canal diameter, diaphyseal diameter, femoral head height, femoral neck isthmus, femoral neck length, neck shaft angle, bow angle, and anteversion angle. All parameters were measured based on functions and least-square regression function in CAD software. Obtained measured data were then used for analysis of collateral side symmetric, gender difference, correlation between morphometric parameters, and compared with other populations.

Results: Female had a smaller dimension compared with male in most of the parameters. No significant difference was observed between left and right femurs. High correlation pairs of morphometric parameters included femoral head diameter–acetabular diameter, femoral head diameter–neck isthmus diameter, femoral head diameter–diaphyseal diameter at shaft isthmus level, neck isthmus diameter, neck isthmus diameter–diaphyseal diameter at shaft isthmus level, and acetabular diameter–diaphyseal diameter at shaft isthmus level. Some morphometric parameters of Thai are smaller than other Caucasian, and some Asian nation, i.e. femoral head diameter, femoral neck length, and femoral head height.

Conclusions: This study provides essential morphometric data for various orthopedic implant designs relating to proximal femur region.

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1. Introduction

Orthopedic implants are medical devices aiming to restore skeletal functions, for example, facilitating fracture healing [1] and replacing degenerative of joint [2]. Success of the function restoration depends on performance of implant that restores biomechanics of the skeletal as normal as possible. Performance of implant is a composition of various factors including material [3], implant texture [4], fitting categories (cemented/cementless) [5], mechanical design [6,7], and geometry [8]. Among aforementioned factors, geometry of implant is one of the crucial factors which affect the clinical success. Design of implant should compensate well to the morphology of specific population. Mismatching between implant and morphology of bone usually presents post-clinical complications [8]. Most implants currently available in the market have been derived from Caucasian morphology. Clinical complication observed in Caucasian is then less than Asian. This is confirmed by evidence of several reports relating to mismatching in...
recent years occurring in Asian population. For example, Sawaguchi et al. [9] who reported fracture fixation complications from mismatching between proximal femoral nail anti-rotation II (PFNA-II) and Japanese femur. Chang et al. [10] also reported complication due to mismatching of PFNA-II and Chinese femur. In addition, Deakin et al. [11] show the compression mismatch due to the improper neck shaft angle occurring on the dynamic hip screw fixation.

Although custom-made implant is available to make design best-fit for specific patient [12], however cost of production is relatively high and patient needs to wait in a certain time for implant production. Due to these reasons, standard implant is more preferred. In order to reduce the clinical complication from mismatching, morphological study is required to carry out. Dimensional assessment should be carefully performed to obtain precise data for implant design. Obtaining precise dimensions depends on factors including data acquisition technique, method of measurement and measured subject. Data acquisition technique should be able to reconstruct three-dimensional model (3D) based on computed tomography (CT) imaging; this technique is more acceptable than conventional two-dimensional (2D) radiographic image. 3D technique presents more accurate dimension than 2D image and can be accessed in the configuration that 2D cannot be performed [13]. Measurement method should be based on computer aided design (CAD) least-square regression function to minimize error from observer’s direct marking method. Measurement subject should also be a living adult rather than dry bone that was popular in the past [14–16]. In addition, dimension of dry bone is different from living adult approximately 2 mm [17], this can be one of various causes of error in measuring anatomical data.

Mahaisavariya et al. [16] have performed measurement based on CT and 3D CAD methods, but samples were dry bone. Measurement data are then needed to be revised for accurate dimensions that are sufficient for implant design. In addition, previous work [16] has not emphasized the aspect of gender difference. This work will nevertheless not regret the aspect, since current trend of implant design is more considered on gender design. This study then evaluated morphometric parameters of 240 Thai femurs data obtained from living adults. Analysis of collateral side symmetric, gender difference, and correlation between morphometric parameters were also included. Furthermore, data from this work were compared with Caucasian and other Asian population to analyze dimensional difference.

2. Material and methods

2.1. Data acquisition

This study was a 3D imaging study of human subject, which has been approved by the Ethics Committee (Code: ORT-12-1248-EX). The human subjects participated in this study were recruited from adult patients with age over 20 year olds. All participants were informed the description of this study and signed the consent form before the research process involving to their anatomical data began. The inclusion criteria for participants were absence of hip osteoarthritis (OA) and had no contradiction to X-ray. The preliminary OA hip evaluation was performed on the anteroposterior plain film by orthopedic surgeons to exclude OA hip subject. Total number of participants was 120, which composed of 80 females and 40 males. The average age of participant was 47.85 ± 11.2 years.

2.2. 3D model reconstruction

All CT scans were performed using 64 slice spiral CT scanner. The scanning domain covered the lower extremities: pelvis, femur, tibia, fibula, and talus. The protocol of CT scanning from both sides was identical which were 0.625 mm slice-thickness, bone reconstruction algorithm, 0.2–0.5 mm pixel size, and matrix size of 512 × 512. After scanning, the anatomical data of human subjects were recorded as Digital Imaging and Communications in Medicine (DICOM) file format and then imported into medical imaging processing software (Mimics, Materialise N.V., Belgium) to reconstruct necessary 3D models used in this study i.e., femur, pelvis, and talus. 3D models of femur and pelvis were used for anatomical measurement. In the reconstruction process, the proper range of Hounsfield unit (HU) was selected to locate the boundary of cortical bone. By this reconstruction technique, it produced the 3D pelvis, femur with existing of intramedullary canal, and talus models.
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