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Automated Measurement on Morphological Parameters of Proximal Femur Based on Three-Dimensional Model

Junlei Hu[1], Liyu Xu[1], Liao Wang[2], Xiaojun Chen[1*]
[1] Shanghai Jiao Tong University, School of Mechanical Engineering, Institute of Biomedical Manufacturing and Life Quality Engineering, Shanghai, China
xiaojunchen@sjtu.edu.cn
[2] Shanghai Ninth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Shanghai, China

Abstract

In order to measure anatomic parameters of proximal femur, an automatic femoral measurer, which allows importing the femur models and automatically modeling femoral medullary canal, is developed. The accuracy and reliability are verified according to the intra- and inter-class correlation coefficients and the measured result of standard model.

1 Introduction

Cementless total hip arthroplasty has become commonly used surgical interventions among the orthopedic community (Engh & Philippe, 1989). The morphological parameters of proximal femur are essential in preoperative planning when femoral implants are designed or selected (Harrysson, Hosni, & Nayfeh, 2007). However, these parameters are difficult to be determined because the traditional methods to measure on femoral, such as measurement based on X-ray films (Yoshikawa, Turner, & Peacock, 1994), are not quantified with less reliability. With the development of computer aided design (CAD) and medical image processing, it is possible to measure femoral intramedullary canal by CAD software, but it is not applicable to clinical practice.

In this study, the method to automatically measure anatomic parameters of proximal femur under the three-dimension coordinate system is proposed, aiming at provide accurate parameters, including femoral head radius, neck-shaft angle, anteversion and so on, to preoperative planning and design of implants.

2 Materials and Methods

The software is developed for measurement on 16 anatomic parameters of proximal femur with the aid of some open-source software, such as QT, Visualization Toolkit (VTK) and Insight Toolkit (ITK). After femur model is imported and bony landmarks are located, the software will automatically output the 16 anatomic parameters, as shown in Figure 1(a).

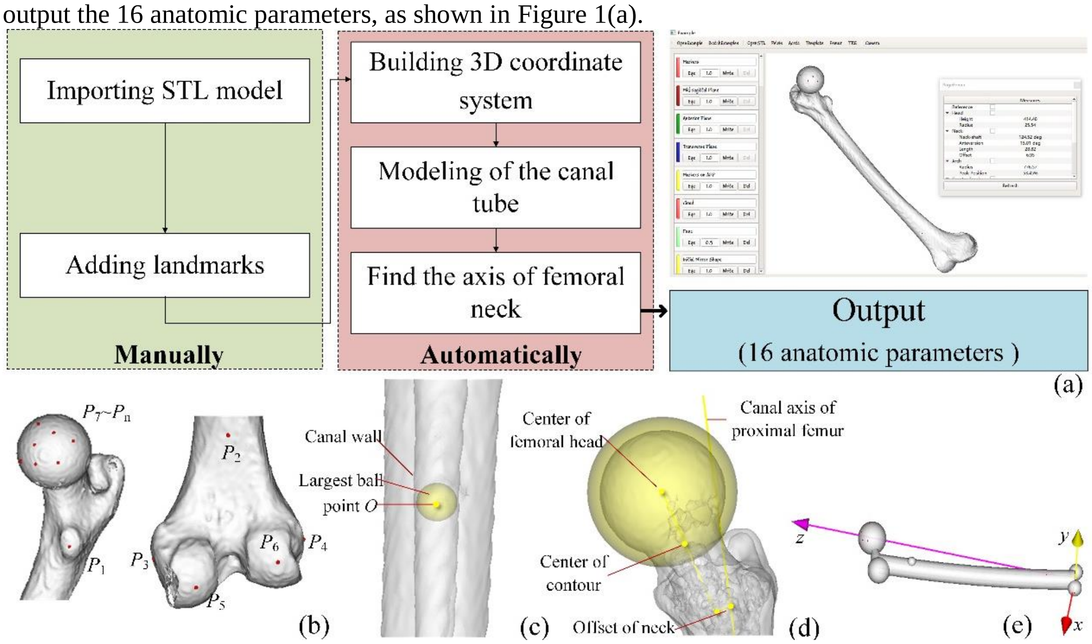

Figure 1: (a)The workflow of the software. (b) The landmarks on femur. (c) Largest-ball searching method. (d) The method to find axis of femoral neck. (c)The standard model

The landmarks are successively located on the lesser trochanter, condyles and femoral head, as shown in Figure 1(b). The 3D coordinate system of the femur is determined by the landmarks on condyles and center of femoral head, which is fitted through least squares method. Accordingly, some parameters, such as radius and eccentricity of femoral head, can be computed easily under the coordinate system.

As for the modeling of rough shape of femoral medullary canal, largest-ball searching method is used to find center and radius of ball at every section of the canal. If the distance between point *O* and the wall of canal is largest, point *O* is regarded as the center of this ball, as shown in Figure 1(c). The number of balls is determined by the resolution of model and length of the femoral canal. After iterations, all the centers and radiuses are recorded and model of femoral canal can be established by morphological interpolation and linear fitting. Then, canal axis of proximal femur, anterior bow, isthmus and canal flare index (CFI) can be obtained easily based on model of femoral canal (Rubin, Leyvraz, & Aubaniac, 1992).

To calculate the parameters of femoral neck, the concentric ball of femoral head with a slightly larger radius is used. The center of the contour of the intersection between femoral neck and concentric ball is considered to be on the axis of femoral neck, which is the most important reference line to describe femoral neck, as shown in Figure 1(d).

A standard model composed of balls, cone and pipeline is established to evaluate the accuracy of aforementioned methods by comparing the automatic output and the parameters calculated according to known size, as shown in Figure 1(e).

3 Result

By experimenting on 150 femur STL models of both left and right femur from 40 males and 35 females at mean age of 44 ± 23 years, the average time cost of automatic measurement for a single femur model is 0.89 seconds. The intra- and inter-class correlation coefficients (McGraw & Wong, 1996) of parameters are between 0.941 and 0.999, indicating a reliable and repeatable performance. As for the measurement result of the standard model, the average relative error coefficient of anatomic parameters is 0.003, with a 95% confidence interval of -0.010 to 0.010, showing the accuracy of the measurement.

4 Discussion

In this study, the new method for automatic analysis on morphology of femur is developed and is proved to be acceptable. The software for three-dimension measurement on anatomic parameters on femur provides an automatic measuring method to help doctors to design and select customized femoral stem in preoperative planning of total hip arthroplasty through a fast, easy and three-dimensional alternative to the traditional measurement on femur. The software with accuracy, reliability and measurement repeatability can be used in clinical practice. It helps to conduct large-scale anatomy studies among Chinese people and to analyze the inherent correlations of various femoral anatomy with factors such as gender, age, height and so on.

Measurements	Intra-class correlation coefficients	Inter-class correlation coefficients	Relative error coefficients
Radius of femoral head/mm	0.998 (0.989,0.999)	0.997 (0.986,0.999)	0.001 (-0.002, 0.003)
Eccentricity of femoral head/mm	0.976 (0.955,0.986)	0.959 (0.951,0.994)	-0.004 (-0.012,0.003)
Isthmus/%	0.944 (0.930,0.950)	0.948 (0.930,0.964)	0.012 (0.002, 0.022)
Radius of Isthmus/mm	0.945 (0.930,0.974)	0.940 (0.930,0.959)	0.013 (-0.005,0.032)
CFI	0.984 (0.956,0.990)	0.971 (0.954,0.989)	-0.003 (-0.010,0.008)
Femoral neck anteversion(1)/°	0.956 (0.945,0.982)	0.990 (0.984,0.992)	0.010 (0.003,0.018)
Femoral neck anteversion(2)/°	0.987 (0.967,0.993)	0.968 (0.954,0.973)	0.003 (-0.007,0.012)
Neck shaft angle of femur/°	0.991 (0.980,0.996)	0.983 (0.960,0.999)	-0.010 (-0.021,-0.001)

Table 1: The ICC coefficients and relative error coefficients of some key parameters of femur

5 Disclosures

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