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Original Article

Parameter-based morphometry of the wing of ilium

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ABSTRACT

Introduction: The wing of ilium bone has a very complex shape and therefore requires a series of measurements. For complete morphometry, we suggest 22 parameters and statistical approach, which allows to generate 12 parameters based on regression analysis of already measured 10 parameters from anteroposterior (AP) radiographic projection.

Methods: The study was conducted on a sample of 32 male CT scans of the right hip bone as input data. We imported the CT scans, stored in DICOM format, in Computer Aided Design program and identified 15 anatomical points and 22 parameters (linear distances between the points) on each wing, measured the values of these parameters, and processed them with tools of descriptive statistic and regression analysis in order to generate 12 nonlinear regression models.

Results: The results of our study are presented in the form of 12 simple one-parameter regression equations, where p values for regression coefficients in equations are less then 0.01 and value of variance R^2 is up to 0.543.

Discussion: Obtained nonlinear regression models (3 square, 6 exponential, and 3 logarithmic) are the result of the complex shape of the wing of ilium. According to p-values for coefficients in the regression equations, we can consider the results as statistically significant. This approach is time-efficient because the measuring is conducted only on AP radiographic projection. The findings of this study are useful for predicting subject-specific morphometry.

1. Introduction

Numerical (computer) and physical models are an important tool for engineers, scientists, and experts in all fields, for understanding of physical phenomena, analysis objects, and systems, as well as in the design process. The physical model can be in the form of a simple model of the bone (physical copy) or a solid-model produced by various rapid prototyping technologies, which replicates the morphology of the bone structure.[1]

For an accurate anatomical description of the size, shape, and orientation of the human hip bone that forms the basis for morphometry and production of the predictive geometric model, adequate morphometric measurements are required. The measurements are performed on human remains in the case of forensic or archaeological examination, or using medical images, such as X-ray, computer tomography (CT),

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or magnetic resonance image (MRI). These measurements can be used as input data for statistical approach to predict subject statistic morphometry of the human thoracic and lumbar spine from radiographic images.[2]

The goal of the study is to prove that it is possible to make prediction for 12 additional parameters based on 10 measurements from the anteroposterior (AP) radiographic projection of the wing of ilium. For the purpose of the study, we used CT data recorded in DICOM format, obtained in a sample of 32 human male hip bone. Input data are imported into the appropriate Computer Aided Design (CAD) program, in which a series of measurements of 22 parameters were conducted. Given the large number of parameters necessary for morphometry of the wing of the ilium bone, our main idea was to establish dependencies between them, using statistical analysis procedures.

A large number of morphometric studies of the hip bone were performed in order to implement the population study, determining sex or sexual dimorphism.

Morphometric measurements were taken of 100 hip bones of the Indian population in order to determine the sexual dimorphism of the hip bone, based on 13 variables on ilium bone.[3] In a study conducted over 50 left and right unpaired hip bones of Indian adults of unknown sex, three values were measured and statistically analyzed: mass, length, and width of the hip bone as the maximum distance between anterior superior and posterior superior iliac spines.[4] The width of the pelvic bone was measured in the same way.[5,6]

Morphometric analysis was conducted on a sample of 185 bones in order to determine the sex using the methods of statistical analysis, including measurements of the hip bone, with special emphasis on the determination of measures at the greater sciatic notch and auricular surface elevation.[7] Landmark types and definitions at different hip bone regions are described, with the aim of quantifying the shape and variation of the hip bone using Procrustes ANOVA method.[8] Measurements of linear distances on the hip bone (between anatomical landmarks) were carried out on the samples from different regions of the world in order to determine the correlation between variations in shape, gender, and demographic background, using the techniques of statistical analysis.[9]

The part of the Reference Geometric Entities (RGEs) was defined and a surface model of the hip bone for specific patient in the process of reverse engineering was previously generated.[10,11] Considering that this procedure requires a lot of time, we decided to try another methodology in generating geometric surface model of the hip bone. This methodology involves the application of parameter-based statistical approaches in morphometry of the partial models of the hip bone.

2. Methods

The process of statistical morphometry of the wing of ilium was conducted using Method of Anatomical Features,[12,13] through the following steps:

- obtaining input data from CT scans, segmentation, and 3D reconstruction of the input data,
- importing into CAD program and surfaces reconstruction,
- creating the RGEs, on the wing of ilium bone, based on anatomical and morphological characteristics,[14]
- defining parameters, such as the linear distances between anatomical landmarks,
- establishing correlations between parameters,
- formation of mathematical regression model,
- testing the models, and
- selection of an appropriate model according to the criterion of statistical significance.

2.1. Data source

Due to the fact that CT is one of the best methods for generating 3D data for bones, for purposes of the study, we used a sample of 32 male CT scans of the right hip bone, aged from 20 to 83 years (average 64 years). CT scans were obtained at Toshiba MSCT scanner Aquillion 64 (120 kV, 150 mA, thickness 1 mm, in-plane resolution 0.781×0.781 (pixel size), acquisition matrix 512×512, field of view (FOV) 400×400 mm).

Input data obtained from CT scans written in DICOM format were imported into CAD program as the point clouds in STereoLithography (STL) format. Polygonal models were created, followed by a reconstruction of the surface in terms of healing, eliminating the errors, and smoothing.

2.2. Methodology

At each of the 32 wings of the ilium bone, RGEs are identified as anatomical points (bilateral landmarks) and linear distances (parameters). The following bilateral landmarks are separated and defined at the wing of the ilium bone:

1	the most superior point on the iliac crest – Sup Iliac Crest[4,6,9,15–20];
2	the most lateral iliac crest point ("bi-iliac tuberosity")[15,17,20];
3	anterior superior iliac spine (ASIS) – spina iliaca anterior superior[3,4,6,8,9,15–20];
4	anterior inferior iliac spine (AIIS) – spina iliaca anterior inferior[3,6,8,9,15,17,20];
5	posterior superior iliac spine (PSIS) – spina iliaca posterior superior[3,4,6,8,9,15–18,20];
6	posterior inferior iliac spine (PIIS) – spina iliaca posterior inferior[3,6,8,9,15–17,20];
7	the most superior point at limbus acetabuli[15,17,19,20];
8	point of maximum curvature (the deepest point) at greater sciatic noch[6,7,9,15,17,19,20];
9	superior point at the sacroiliac joint (art. sacroiliaca) at ala ossis sacri s. the most supero-lateral alar-auricular point[15,20];
10	inferior point at the sacroiliac joint (art. sacroiliaca) at ala ossis sacri s. the most infero-lateral alar-auricular point[15,20];
ZS	the point of intersection between the posterior gluteal line with the outer lip of the iliac crest[9];
DS	the point of intersection between the inferior gluteal line with anterior edge of the iliac crest;
PS	the point of intersection between the anterior gluteal line with anterior end of the iliac crest (at the superior edge of the hip bone);
NISUA	the deepest point at the interspinal notch at the anterior edge[9,20];
NISUP	the deepest point at the interspinal notch at the posterior edge[20];