CORRELATION BETWEEN PERIACETABULAR BONE DENSITY CHANGES AND STRESS BEHAVIOUR AFTER TOTAL HIP ARTHROPLASTY

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Introduction  Little is known about periacetabular bone remodeling after insertion of the acetabular cup in total hip Arthroplasty. Dual energy X-ray absorptiometry (DXA) is commonly used for quantitative assessment of bone remodeling after total hip arthroplasty (THA). DXA is limited by low resolution and a lack of three-dimensional information. Computed tomography (CT) is a standardized radiological method for the assessment of bone structure with high validity and resolution [1]. Moreover, data from CT can be used in generating patient-specific finite element (FE) models which gives insight into stress/strain distributions around an implant. The aim of this study is to analyse periacetabular bone changes using quantitative CT-assisted osteodensitometry and quantify their influence on stress patterns using patient specific FE models.

Methods  1. Quantitative CT assisted osteodensitometry

Two acetabular cups with six osteodensitometric regions of interest (ROIs) were inserted by one surgeon using an un cemented total hip prosthesis with a titanium hemispherical press-fit acetabular component and alumina-alumina paring. The average patient age was 58.4 years (range 39 to 65 years). There were 15 men and 11 women. CT investigations were performed within two weeks of surgery and then one year and 3 years postoperatively. Conventional sequential CT examinations were employed. Slice thickness was 2mm and the distance between two scans was 10mm. A standardized scan mode was used with 149kV, 206mA.s. The hips were scanned starting 3mm above the dome of the cup and ending 20mm underneath the tip of the stem. Data evaluation was performed with a dedicated software tool (HIP, VAMP, Erlangen, Germany). For the calibration and validation of the CT values and for the conversion into hydroxyapatite (HA) equivalents a synthetic phantom containing a circular sample with a defined HA concentration was scanned at each examination. Each scan was divided into cancellous and cortical bone and Hounsfield Unit (HU) values were calculated by the computer software for the defined segment. The data was converted into HA equivalent (mgCaHA/ml) using SPSS Version 10 (SPSS Inc., Chicago, USA). We generated an anatomical segmentation of the acetabulum including the region of interest (ROI) 1 (ventral to the implant), ROI2 (dorsal to the implant) and ROI3 (above the implant) (Fig. 1). Cancellous, cortical and overall bone density (BD) were separately analyzed for each ROI.

2. Stress analysis with patient specific FE models

FE models for two of the patients were generated in order to investigate stress distribution patterns around the acetabulum. Since the patient CT scans covered only the ROIs (Fig. 1), we used a hybrid method which is capable of generating FE meshes with a sparse patient dataset by supplementing it with the Visible Human (VH) dataset [2]. High order cubic Hermite basis functions were used and the resulting meshes were made up of large cubic interpolation hexahedral elements. Material properties were assigned using a spatially varying field, which allowed for discrimination between cortical and cancellous regions. The density values were then converted to modulus data using an empirical relationship between the two [3]. For the areas where patient CT slices were not available, we obtained material properties from VH CT slices by calibrating them to match the maximum and minimum BD of the patient. Loading conditions were similar to [4] and the nodes on the superior iliac crest were fixed in three directions. A 600N vertically directed force was applied to the

Results  All 26 hips included in the study were available for investigation at a mean follow-up of one year (range 1 to 1.3 years). Seven patients were available at 3-year follow-up. No hip showed clinical or radiological signs of loosening at follow-up. At 3-years follow-up we found a decrease of cancellous BD proximal to the upper rim of the acetabular prostheses (ROI 3 –18.4%), while cortical BD increased by +5.2% in this region. Cortical BD decreased in ROI 1 by -3.1% and by -2.3% in ROI 2. Of more interest, cancellous BD was observed to decrease by -40.9% in ROI 1 and -32.2% in ROI 2. Among those 7 patients, 2 of them were processed to generate FE models. Von Mises stresses were recorded at the rim of the acetabulum with the three ROIs (red dots in Fig. 1). 3 different FE models were generated for each patient to observe the change in stress distribution patterns at post op, 1 year and 3 years after the surgery.

Discussions  A detailed quantitative analysis of periprothetic acetabular bone was performed in conjunction with finite element modelling. Although the finite element model sample size was small, these were typical cases within the set. Recently, Wright et al [4] reported a 20 to 33% decrease of BD one year after THA with a CT investigation based on circular cross sections of cancellous bone above the dome of the acetabular component. Our results also showed a marked decrease of the cancellous BD in the same anatomical area. FE model based simulation shows that the decrease in cancellous bone BD has direct effect on stress as the local stress values also decreased dramatically. This suggests that the load distribution pattern after THA will modify elasticity properties of the overall bone. This factor can have important implications in the clinical setting.


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