DIRECTIONAL VARIATION IN THE BIOMECHANICAL RESPONSE OF SUBCHONDRAL BONE IN THE FEMORAL HEAD

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Introduction

Trabecular bone is the principal load bearing tissue of our musculoskeletal system. Fragility fractures are a common mode of failure for cancellous bone as it is highly susceptible to degenerative diseases, manifesting in the form of fractures in the proximal femur. The subchondral cancellous bone of the articular cartilage has a significant influence on the mechanics of the hip joint, as it receives up to 70% of the transferred load in the subcapital region (Lotz et al., 1995). The anisotropy of trabecular bone renders it difficult to assess the strength of the proximal femur based solely on a patient's Bone Mineral Density (BMD), traditionally determined by DXA measurements.

Methods

28 femoral heads were harvested from patients undergoing total hip arthroplasty (17 female and 11 male). Specimens with evidence of bone diseases were excluded from the study. Each of the patients' BMD was measured by DXA and the specimens scanned with a μ-CT device at 10μm resolution to reconstruct their 3D shape. A sphere was isolated from the centre of each sample and the cross-sectional area registered for eight different orientations representing regions subjected to different in vivo loading [Hodge, 1986]. These orientations were perpendicular to the medial, inferior, medial-superior, superior, anterior, anterior-medial, posterior-medial and posterior region. The determined characteristics of the samples (table 1) are in agreement with data found in literature (Baroud, 2004).

Cylindrical specimens were extracted perpendicular to the medial region. Upon defatting, the samples were subjected to uniaxial compression. The corresponding 3D models were meshed in ANSA by BETA CAE Systems to simulate the aforementioned loading scenario.

Gender	BMD	ρ_{ap} [g/cm^3]	BV/TV
Male	0.62±0.07	3.23±0.62	0.24±0.05
Female	0.49±0.11	2.47±0.89	0.21±0.06

Table 1: Volumetric data obtained from the measurements, reported as mean ± standard deviation.

Results

Significant topographical variations of trabecular bone strength in different subchondral bone regions were observed (see figure 1). The variance converges exceptionally with a recent study, investigating the energy required for osteopenetration in the aforementioned sites (Tsouknidas, 2012).

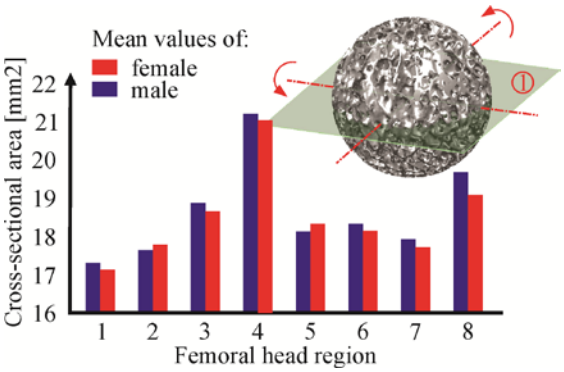

Figure 1: Mean cross-sectional areas registered for the 8 primary subchondral regions.

The results affirm the preliminary hypothesis that bone adapts to the mechanical loads it is subjected to. The compression tests along with the corresponding FE simulation was used for an independent verification of our results.

Discussion

The motivation behind our study was to correlate strength characteristics of trabecular bone to architectural metrics, which can be measured through 3D distance transformation techniques. The integration these information in software platforms of contemporary CT, could provide physicians with a valuable assessment tool for bone quality and strength.

Acknowledgements

The authors would like to thank BETA CAE Systems SA for providing them with the CAE pre-processor ANSA.

References

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