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THE ROLE OF GEOMETRIC PATTERNS IN THE OSTEOPOROTIC FRACTURE: A STATISTICAL SHAPE MODELLING APPROACH

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Introduction

Osteoporosis is a bone disease characterized by a reduction of bone density in terms of reabsorption and thinning of bone trabecula. Osteoporosis increases the risk of hip fracture, a major economic and social burden in western countries [1], affecting quality of life and increasing mortality. The predictability of osteoporotic hip fracture by means of the current gold standard, Bone Mineral Density (BMD) measurement through dual energy X-ray absorptiometry (DXA), remains limited. This study explores the predictive potency of specific femur shapes patterns by means of a statistical shape modelling approach. The approach, applied to a dataset of 2D femur models, promises to be very effective in (1) gaining further insights into the role played by geometry in osteoporotic risk fracture, and (2) empowering geometry-based prediction of fracture.

Methods

The statistical shape modelling framework proposed elsewhere [2] and implemented in Deformetrica (www.deformetrica.org) was applied to 2D profiles of proximal femur reconstructed from DXA images of 28 post-menopausal women. Briefly, the approach allowed the extraction of a template $\overline{\mathrm{T}}$, representing the mean anatomical shape, as well as of the individual deformation functions, ϕ_i, which map $\overline{\mathrm{T}}$ to each single shape in the dataset and gather the subject-specific shape patterns. The existence of possible associations among shape features and the risk of an hip fracture was here explored applying the Partial Least Square (PLS) regression method [3]. PLS was carried out to identify deformation modes most relevant to Risk Factors (RF) derived in a previous study [4], where FEM was applied to 3D models of the same subjects. Bivariate correlations between most relevant PLS modes and the response variable RF as well as standard geometric descriptors [4] were computed.

Results

PLS modes were ordered with respect to the explained RF variability. In Fig. 1, the first 4 identified PLS modes are presented. Those PLS modes represent not only the most relevant modes with respect to the RF, but also the most significant with respect to DXA derived geometric features. The first mode (1) turned out to be, as expected [3], the most correlated with RF, and (2) was associated to the hip axis length (r = -0.68, p < 0.001), narrow neck width (τ = -0.45, p < 0.001) and intertrochanter width (r = -0.29, p < 0.01). As for the neck shaft angle, it was found to be associated to the second and third PLS modes (II mode: r = 0.52, p < 0.01; III mode: r = 0.52, p < 0.01).

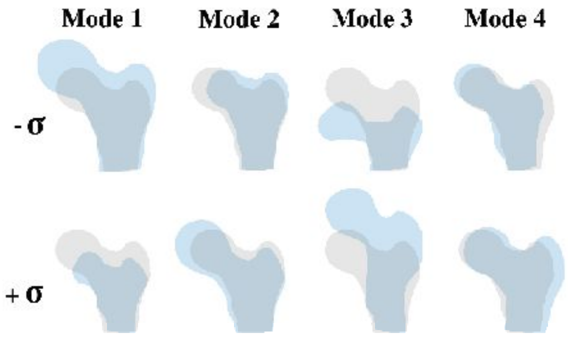

Figure 1: Visualization of the first PLS deformation modes for a $\pm\,\sigma$ RF deviation from its average value.

Discussion

Here a new strategy to identify morphological features associated to osteoporotic hip rupture risk is presented. The approach promises to be effective in supporting clinicians, enhancing fracture risk prediction based on subject-specific femur shapes and, from this perspective, an analysis widened to larger datasets will strengthen its predictive power. Due to the encouraging results obtained from 2D shapes, the framework could be successfully employed on the 3D geometries derived from CT scans [4], also enabling 3D patient-specific shapes prediction. To the best of the authors' knowledge, this study represents the first attempt to apply statistical shape analysis in this field, where a consensus on the identification of an effective predictor has not been accomplished yet.

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