MICROSCALE COMPACT BONE PROPERTIES OF PATIENTS WHO UNDERWENT HIP ARTHROPLASTY: INFLUENCE OF AGE AND GENDER

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Introduction

In the nowadays aging society, fragility fractures pose a significant health and economic burden. Bone strength is primarily determined by mineral density, but also by tissue-level mechanical properties. The elastic properties of the bone extracellular matrix (ECM) have been extensively investigated over the past two decades. However, there is still limited knowledge on the yield properties and their relationship to composition and architecture. Thus, this work aims at the multimodal characterization of human femoral bone ECM in relationship to the patient's age, gender and hip fracture status. Here, we report the first collective micropillar compression data and its relationship to other ECM properties.

Materials and Methods

Femoral neck samples from 42 patients who underwent hip arthroplasty were collected together with anonymous clinical information about age, gender, and primary diagnosis (coxarthrosis or hip fracture). Cortical bone from the inferomedial region was analyzed in a site-matched manner using a combination of micromechanical testing (high-throughput micro-pillar compression [1], nanoindentation), with micro-CT and quantitative polarized Raman spectroscopy [2] for both morphological and compositional characterization (fig. 1).

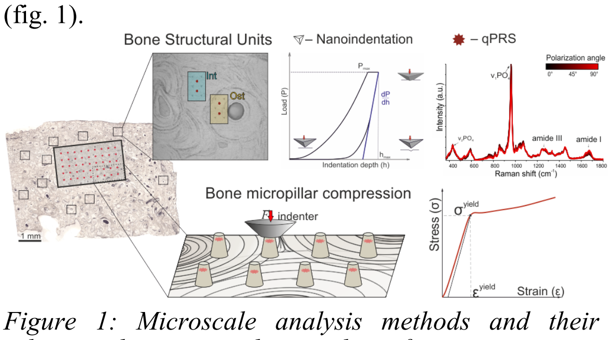

Figure 1: Microscale analysis methods and their schematic location on the sample surface.

Results and Discussion

All investigated bone properties were found to be independent of the patient's gender and diagnosis. Yield stress and elastic modulus demonstrated a positive correlation with the mineral fraction of bone ($p<0.0001$), yet all mechanical properties as well as the sample-level mineral density were nearly constant over age, in line with previous studies [3]. On the contrary, compositional properties demonstrate dependence on the patient's age (fig. 2): declining mineral to matrix ratio ($p=0.02$, $R^2=0.13$, 2.6% per decade), surprisingly in contrast to tissue mineral density (TMD), and increasing collagen cross-link ratio ($p=0.04$, $R^2=0.11$, 1.5% per decade). This suggests that an increase in bone collagen with age leads to decreasing mineral to matrix ratio.

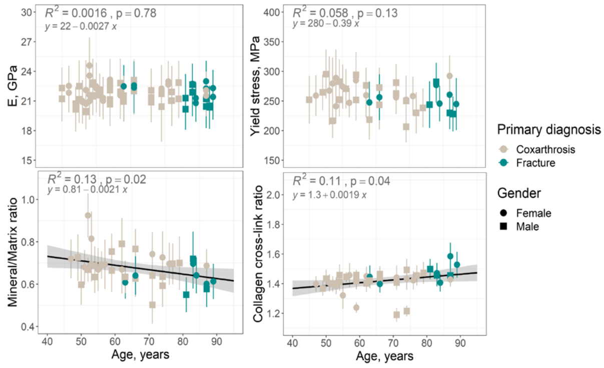

Figure 2: Compact bone microscale mechanical properties are independent of the patient's age, while compositional properties demonstrate a correlation.

Logistic regression classification was further applied to the final combined dataset of measured bone properties with the patient's clinical information to predict the presence of a fracture. The analysis showed that the patient's age, bone micropillar yield stress, indentation hardness and TMD are the most relevant parameters for bone fracture risk prediction at 67% model accuracy.

The output database is the first to integrate the experimentally assessed microscale yield properties, local tissue composition and morphology together with the available patient clinical information. It can be used for the future comparison of existing methods to assess bone quality as well as to form a better understanding of the mechanisms through which bone tissue is affected by aging.

References

1. Kochetkova et al, J Mech Behav Biomed Mater, 134, 2022.
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3. Mirzaali et al, Bone, 93, 2016.

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