BONE COLLAGEN TENSILE PROPERTIES OF THE AGEING HUMAN PROXIMAL FEMUR

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Introduction

Despite the dominant role of bone mass in osteoporotic fractures (OF), ageing bone tissue properties must be thoroughly understood to improve osteoporosis management [1]. In this context, collagen content and integrity are considered important factors, although limited research has been conducted [2]. Therefore, this study aims at investigating bone collagen tensile properties of the ageing human femur.

Methods

Bone sections of eighty fresh frozen cadaveric human proximal femora of 24 female and 19 male donors with a mean age of 81 (57 to 96) years were used in this study. Two cylindrical cortical bone samples were extracted from each section's proximal, lateral side by manual drilling and cut to a length of 25 mm using a band saw. One sample of each section was glued into an aluminum sample holder while sample geometry (6 mm gauge length, 2 mm diameter) was machined on an engineering lathe. Then, samples were scanned by micro computed tomography (µCT) with a spatial resolution of 7.4 µm. Samples were mechanically tested in tension until a maximum engineering strain ε of 0.25 % on a multipurpose servohydraulic testing system while measuring displacement using a video extensometer. Subsequently, the same samples were demineralized in a buffered (pH 7.4) 0.5M EDTA solution at room temperature for 12 days before monotonically tested to failure on the same system. One sample of each section was used for compositional analyses. Gravimetric methods were used to determine mineral, organic, and water weight as well as bone tissue density.

Figure 1 Experimental setup showing a cylindrical bone specimen being tested elastically in tension.

Ultimate stress was defined on the apparent (σ_{app}), extracellular matrix (ECM) (σ_b) and collagen (σ_c) level as the division of ultimate force by apparent area (A_{App}), mean ECM area ($A_{F,mean}$), and minimum ECM area ($A_{F,min}$) respectively. Similarly, Young's modulus of the mineralized ($E_{app,m}, E_m$) and demineralized ($E_{app,c}$) state at the different levels was defined as the ratio of the respective stress and strain. A coefficient of variation (CV) describing heterogeneity of the sample porosity was computed as the ratio of the standard error of A_F and $A_{F,mean}$.

Results

Samples exhibited mineral, organic, and water weight fractions of 58.7 ± 1.3 %, 35.0 ± 0.9 %, and 6.4 ± 1.6 %, and a bone volume fraction (BV/TV) of 0.93 ± 0.05 %. $E_{app,m}$ (15.6 ± 1.8 GPa) correlated with BV/TV ($p<0.001$, r=0.55), and relative mineral weight ($p<0.01$, r=0.32). Interestingly, $E_{app,c}$ does not depend on BV/TV but decreases with mineralization ($p<0.001$, r=-0.43) and correlates moderately with E_m ($p<0.001$, r=0.56). σ_{app} exhibits a correlation with BV/TV ($p<0.05$, r=0.27), and σ_b with CV ($p<0.05$, r=-0.25). It was further observed, that σ_c is related to tissue mineral density (TMD) ($p<0.001$, r=-0.39) (Figure 2).

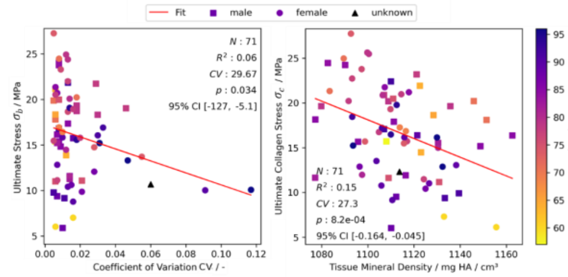

Figure 2 Linear regression of σ_b versus CV (left) and σ_c versus TMD (right) yielded weak but significant correlations.

Discussion

BV/TV, compositional and mechanical variables are in very good agreement with values reported in previous studies [3]. The negative correlations of both E_c and σ_c with TMD suggest that collagen-collagen bonds may be competing against collagen-mineral bonds. Further prospective work includes analysis of cement line density and collagen crosslink maturation by optical and Raman spectroscopy respectively.

References

1. Voumard et al, Bone Rep, 17:101638, 2022.
2. Willet et al, Bone, 163:116485, 2022.
3. Wang et al, Bone, 31:1-7, 2002.

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