# Collagen Tensile Properties in the Ageing Human Proximal Femur

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## Introduction

Despite bone mineral density's (BMD) dominant role in osteoporotic fractures (OF) [1], other bone strength determinants such as tissue ageing must be thoroughly investigated to improve osteoporosis management. In this context, collagen content and integrity are considered major parameters [2], although little research has been conducted. Thus, this master's thesis aims at investigating collagen tensile properties of the ageing human femur. It is hypothesized that bone volume fraction (BV/TV) and collagen volume fraction could explain a possible deterioration of the collagen network in aged bone.

## Materials and Methods

Human cortical bone cylinders (n=80) were extracted from cadaveric proximal diaphyseal femora (n=40). Morphology and composition were analysed employing micro-computed tomography (µCT), Raman spectroscopy, and gravimetric techniques on 40 of them. The other 40 specimens were quasi-statically tested in tension (displacement-controlled, $\varepsilon$ = 0.25 %, $\dot{\varepsilon}$ = 0.7 mm/min) on a servo-hydraulic testing system (MTS 858 Mini Bionix, MTS Systems, Eden Prairie, MN, USA). Samples were subsequently demineralised within 10 days in a buffered (pH 7.4) 0.5 mol/l ethylene-diamine tetraacetic acid (EDTA) solution at room temperature and tested in tension until failure under the same conditions. Simple linear regression was used to relate morphological, compositional, and mechanical variables.

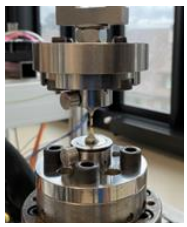

*Fig. 1 Cylindrical specimens from the proximal femoral diaphysis were uniaxially tested in tension elastically (mineralized, $\varepsilon$ = 0.25 %, $\dot{\varepsilon}$ = 0.7 mm/min) and until failure (demineralized, $\dot{\varepsilon}$ = 0.7 mm/min) under hydrated conditions.*

## Results

No dependency on any morphological variable could be found when related to age. Mineral weight (ashing) ($m_w$) is positively correlated with bone mineral content (BMC) (µCT) ($p<0.05$, $R^2 = 0.55$) and mineral weight fraction ($WF_m$) is positively correlated with mineral-to-matrix ratio (MMR) by Raman spectroscopy ($p<0.001$, $R^2 = 0.3$). As far as mechanical variables are concerned, negative correlations were found for apparent modulus in the demineralised state ($E_c$) with age ($p<0.05$, $R^2 = 0.22$) and ultimate stress $\sigma_u$ with age ($p<0.05$, $R^2 = 0.26$), whereas apparent modulus in the mineralised state ($E_m$) and ultimate strain ($\varepsilon_u$) are independent of age. Linear regression between $E_c$ and $E_m$ ($p<0.05$, $R^2 = 0.26$) but also between $\sigma_u$ and $E_c$ ($p<0.001$, $R^2 = 0.62$) yielded significant positive correlations. Furthermore, positive correlations between $E_m$ and BV/TV ($p<0.05$, $R^2 = 0.24$) and between $E_m$ and BMD ($p=<0.05$, $R^2 = 0.24$) were obtained.

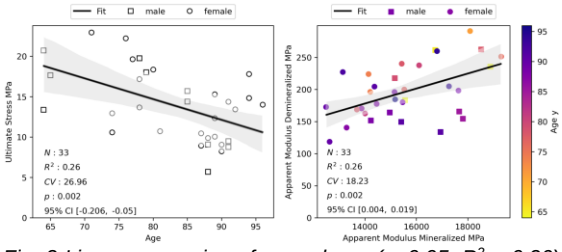


*Fig. 2 Linear regression of $\sigma_u$ and age ($p<0.05$, $R^2 = 0.26$) and of $E_c$ and $E_m$ ($p<0.05$, $R^2 = 0.26$) shows significant negatively and positively correlation, respectively. 95 % CI is reported for the slope; CV: coefficient of variance.*

## Discussion

Porosity was independent of age, possibly due to an elderly cohort. Measurements of other morphological variables are in good agreement with earlier research. Compositional analysis revealed no dependency of collagen content on donor age, possibly due to similar reasons as mentioned above. It, therefore, seems that, although the mechanical properties of the organic phase deteriorate with age, neither collagen content nor bone porosity explains such a deterioration. Finally, it is suggested to investigate if enzymatic and especially non-enzymatic collagen cross-links could play a role in age-related changes leading to the decreasing post-yield properties of aged bone.

## References

[1] Compston, J. et al., Lancet, 393(10169): 364-376, 2019.
[2] Wang, X. et al., Bone, 31(1): 1-7, 2002.

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