Stress-strain characterization of human bone

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Diplôme : Master en ingénieur civil biomédical, à finalité spécialisée
Année académique : 2022-2023
URI/URL : http://hdl.handle.net/2268.2/22264

Stress-strain characterisation of fibrolamellar bone

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Fibrolamellar bone is found in animals experiencing rapid growth phases, which makes it intriguing to researchers studying rapid bone development, such as during bone healing. This bone variety is composed of three discernible structures located between two blood vessels. The initial stage involves the formation of hypercalcified bone, acting as a supportive scaffold for the subsequent emergence of parallel-fibered bone. Eventually, a layer of lamellar bone is laid down, further enhancing this structure. The mechanical characteristics of fibrolamellar bone across these distinct layers remain largely unexplored, which is regrettable given its potential significance and interest.

This thesis strives to enhance our comprehension of the mechanical characteristics exhibited by fibrolamellar through a detailed analysis of its stress-strain behaviour with a keen focus on the lamellar region. Furthermore, another objective is to gain deeper insights into how variations in surface roughness impact the analyses. The results are derived using a method known as nanoindentation, which is utilised to measure mechanical properties with nanoscale precision. Utilising the data from nanoindentation, and applying the Olivier-Pharr model, it becomes possible to compute stress-strain behaviour.

The initial phase of this thesis required a calibration procedure to ensure precise outcomes. This calibration process was executed on fused quartz, chosen due to its well-established Young's modulus and being considered as perfect with no impurity.

In the second part, a more comprehensive exploration of fibrolamellar bone is conducted. Nanoindentation is employed to derive stress-strain curves and determine the Young's modulus in a specific location. Furthermore, scanning electron microscopy aids in pinpointing indentation locations and quantifying lamellar thickness. The investigation revealed that thick lamellae are stiffer than their thin counterparts. However, establishing a direct correlation with the stress-strain curves proved challenging due to the influence of surface roughness on the sample, which affected the outcomes. The curves of thick lamellae display an initial linear elastic phase followed by a swift yielding, while those from thin lamellae showcase a more compliant behaviour. This contrast is likely attributed to the differing orientation of collagen fibers between the two lamellae types. Furthermore, the study also revealed that parallel-fibered bone displays a high stiffness.

In conclusion, this study is pioneering, offering a methodology to comprehensively understand and correlate mechanical properties with underlying structures. Future research could apply this approach to further elucidate the impact of roughness on fibrolamellar bone or explore its applicability to osteons, given their shared characteristics.