MECHANICAL PROPERTIES OF HEALTHY TRAPEZIOMETACARPAL CARTILAGE USING INDENTATION TESTING AND CONTRAST-ENHANCED COMPUTED TOMOGRAPHY

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INTRODUCTION

Osteoarthritis (OA) of the basal thumb joint is a very disabling degenerative joint disease. It stands among the most common types of arthritis and can lead to severe articular pain and loss of mobility and strength. Such symptoms are usually caused by the degradation of the articular cartilage, whose primary function is to distribute load and avoid excessive peak pressure on the subchondral bone [1]. While it is known that cartilage thickness diminishes with OA progression, the mechanical properties of healthy human trapeziometacarpal (TMC) cartilage have not yet been assessed. Such information is, however, important to improve our understanding of TMC joint mechanics in the context of OA development.

The objective of this study was to assess the mechanical properties of first-metacarpal (MC1) and trapezial cartilage using a protocol combining indentation testing with contrast-enhanced computed tomography (CECT).

METHODS

The TMC joint of 16 fresh-frozen cadaver hands (10 female, 6 males, age: 66-101 years) was excised and the stiffness of the articular cartilage was assessed at nine articular sub-regions using a standardized indentation testing device (Mach 1, Biomomentum Inc, Laval, Quebec, Canada) with a spherical indenter (1 mm diameter). Indentation parameters were kept constant for each specimen (indentation depth: 0.1 mm, velocity: 0.5 mm/s, relaxation time: 10 s). This novel indentation protocol automatically detects cartilage orientation and moves the spherical indenter perpendicularly to the articulating surface. The compressive Young's modulus was calculated using an elastic model based on the force-position data [2].

A CECT imaging method was used to enhance cartilage visualization and to facilitate cartilage thickness measurement. Each sample was immersed in a cationic contrast-agent solution (CA4+, concentration of 12 mg of iodine/mL) mixed with protease inhibitors for 48h to allow a complete diffusion [3]. CECT images were acquired using a High Resolution peripheral Quantitative Computed Tomography (HR-pQCT) scanner (Xtreme CT, Scanco Medical, Zurich, Switzerland) with an isotropic voxel resolution of 41µm. Each scan was reconstructed as DICOM format, and segmented using a medical imaging processing software (Mimics Research 18.0 x64, Materialise, Leuven, Belgium). Cartilage thickness was manually measured perpendicularly to the direction of the subchondral bone at each testing location. The differences between bones and between articular sub-regions (Young's modulus and thickness) were tested with a Welch two sample t-test.

RESULTS AND DISCUSSION

The cartilage layer of the MC1 had a significantly higher Young's modulus than the trapezium ($p = 0.002$) (Figure 1). In terms of cartilage thickness, no statistical differences were found between the MC1 and trapezium. No significant changes were observed while comparing between articular sub-regions.

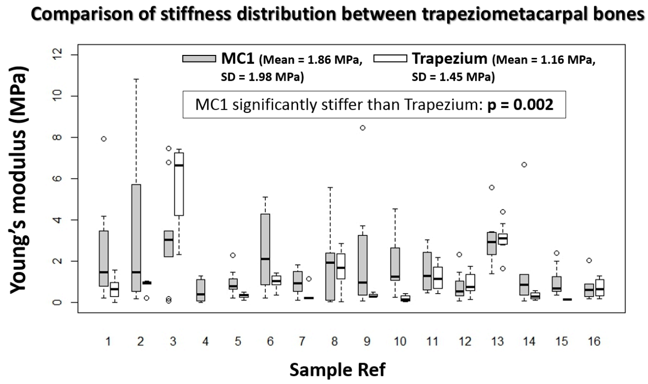

Figure 1: Comparison of cartilage Young's modulus.

CONCLUSIONS

This study is, to our knowledge, the first to report the mechanical properties of TMC joint cartilage. Such data might lead to more accurate computational simulations and therefore improve our understanding of TMC joint mechanics and OA development. The results show that cartilage stiffness differs between opposing articular facets of a single joint. This could imply a higher risk of cartilage eburnation at the trapezial facet, as reported by Pellegrini [4].

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