COMPRESSIVE RELAXATION PROPERTIES OF HUMAN MENISCUS INCREASE UNDER COMBINED TRACTION AND COMPRESSION

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Introduction

Physiologically, the meniscal horns are subjected to a complex loading combination of compressive axial forces and internal circumferential tensile loading [1]. However, while the compressive properties of human menisci have been extensively studied [2-5], the impact of tensile loading on the compressive properties is unknown. Therefore, the aim of this study was to analyze the changes in the compressive relaxation properties of the meniscal horn under combined axial compression and circumferential traction.

Methods

The study included 27 human meniscal horns, derived from 16 patients (65 ± 6yrs; 10 female, 6 male), who underwent total knee replacement surgery. Each horn was sutured with Nº2 UHMWPE surgical thread using a simple stitch. In the cranial surface around the suture hole, seven measurement points were marked using a tissue marker. A multiaxial mechanical tester (MACH-1 v500css, Biomomentum Inc., Laval, QC, Canada) was employed to conduct a non-destructive indentation test using a spherical indenter of ∅2 mm (Figure 1) to determine the relaxation behavior under three conditions of traction induced by a single suture: unloaded, 10 N and 20 N. The pulling force is applied to the horn by a thread simulating a root repair by suturing. The test was run at contact velocity of 0.5 mm/s, contact criteria of 0.049 N, indentation amplitude of 0.5 mm, indentation velocity of 0.25 mm/s, and relaxation time of 20 s [4].

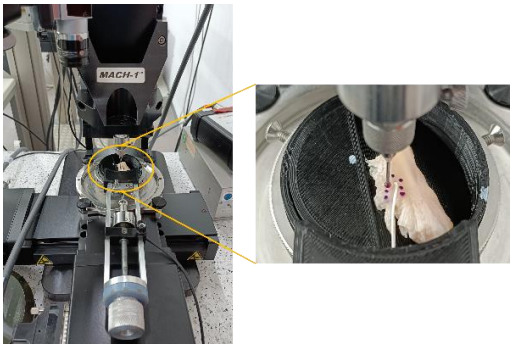

Figure 1: Sutured meniscal horn placed in the multiaxial mechanical tester.

For each traction condition two parameters where computed: the maximum force in the relaxation period ($F_{max}\ in\ N$) and the relaxation modulus at 20s ($E_{t20}\ in\ MPa$):

$$E_{t20} = \frac{\sigma_{t20}}{\varepsilon} = \frac{F_{t20}/A}{\Delta L/h} \qquad (1)$$

with F_{t20} being the force at 20s, A the meniscus-indenter contact area after reaching the indentation amplitude, ΔL, and h the thickness of the sample. Differences between groups were evaluated by an ANOVA test. When a global significant difference was detected (p values $\leq$ 0.05), a Student´s t-test with Bonferroni correction was performed between the groups.

Results

Significant higher values for F_{max} (Figure 2a) and E_{t20} (Figure 2b) were found under simultaneous traction at 10N and 20N levels compared to the unloaded group.

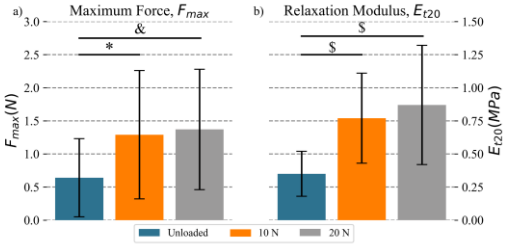

*Figure 2: Meniscal horn properties: a) Maximum force; b) Relaxation modulus. *: p=0.02; &: p=0.007; $: p<0.001.*

Between the two traction levels, 10N and 20N, no significant differences were found in any parameter.

Discussion

When applying 10 or 20N of traction, the values of the maximum force in the relaxation period and the relaxation modulus at 20 s of the meniscal horn are more than the double of the values in the no-traction state. Therefore, the values obtained with isolated compression should not be transferred to physiological loading conditions that involve combined traction and compression. This study focuses on suture-repaired meniscal roots, further research is needed to confirm whether the results are applicable to healthy meniscal roots with natural anchoring.

References

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