A COMPARATIVE STUDY ON THE BIOMECHANICAL PROPERTIES OF PORCINE MENISCUS IN CONFINED COMPRESSION

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Motivation

The biomechanical function of the meniscus is of utmost importance to understand associated knee pathologies such as meniscal tears [1]. One of the most commonly performed mechanical test to characterize the menisci in vitro is confined compression testing. Using this test configuration, biomechanical properties such as the tissue stiffness via its aggregate modulus (H_A) and its resistance to fluid flow, its hydraulic permeability (k) are assessed. However, variations in H_A and k have been reported between research groups [2,3,4,5]. Therefore, the objective of this study was to determine the effect of the test equipment, environmental conditions and sample preparation methods on the biomechanical properties at two laboratories.

Material and Methods

Both laboratories (Lab A: Miami, USA and Lab B: Ulm, Germany) performed confined compression tests of twenty porcine meniscal samples (n = 20). Lab A obtained the samples from a professional animal tissue provider (Animal Technologies Inc., TX, USA) and Lab B from a local slaughter. Both laboratories used a uniaxial mechanical tester (Univert, Cellscale in Lab A, Z10 Zwick GmbH & Co. KG in Lab B), each equipped with a porous indenter to allow for fluid exudation during compression. A total of three consecutive stress-relaxation tests were carried out at 10, 15 and 20% strain (loading rate 100% strain/min). Each strain level was hold for 1800 s to allow complete load equilibrium. Ha and k were determined by solving a 1-D biphasic analytical model [6]. Wilcoxon testing was performed at all three strain levels to analyse differences in H_A and k between Lab A and Lab B. Friedman testing was used to analyse differences between the three strain levels. $p \leq 0.05$ was considered statistically significant

Results

For all strain levels, H_A values in Lab A averaged about double of Lab B ($p > 0.05$) (Figure 1, left). In Lab B, H_A was significantly higher at 10 % strain when comparing to the respective values at 15 and 20% strain. In Lab A, no significant differences for H_A between different strain levels were observed. K values were significantly higher in Lab B compared to Lab A ($p < 0.001$) (Figure 1, right). In Lab A, k decreased significantly with increasing strain level ($p < 0.05$). No differences were found for k between the strain levels in Lab B ($p > 0.05$).

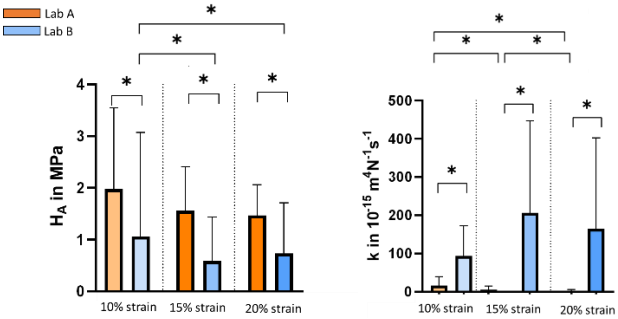

Figure 1: Results of the confined compression tests: (left) aggregate modulus (H_A) and (right) hydraulic permeability (k) assessed in Lab A (orange) and Lab B (blue).

Discussion

The assessed H_A values of Lab A are in the range of previous measurements on porcine meniscus [4,7]. In general, H_A was statistically higher in Lab A. This could have resulted from differences in porcine age (Lab A: 24 months vs. Lab B: 6 months). k was always significantly higher in Lab B than in Lab A. Lab A obtained k values in the range of those found in previous studies [2,3,7,8]. Moreover, k significantly decreased with increasing strain in Lab A, which was not evident in the tests of Lab B. An explanation for the differences in the k results between the two laboratories could be differences in the confined compression setup itself (indenter material, dimensional tolerances within the test chamber) and the age of pigs sampled. This study confirms that the specific test conditions can play a significant role for in-vitro determined biomechanical properties of meniscus tissue. Hence, protocol standardization may be necessary to ensure comparability of results.

Acknowledgements

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References

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