THE GAPPING BEHAVIOUR OF THE MENISCUS VARIES ACCORDING TO THE TEAR TYPE

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Introduction

The main biomechanical function of the menisci is to homogenize the tibiofemoral load with the superior aim to prevent the knee joint from early degeneration. Tears of the menisci lead to an increased tibiofemoral contact pressure (CP), which can be mechanically explained by gapping of the torn meniscus tissue. Adequate suturing is able to restore the CP almost to the native state [1]. However, it is not known if different meniscus tears result in a different gapping behaviour, which is associated with an altered CP. Therefore, the aim of this study was to quantify both, the gapping of radial and longitudinal tears and their concomitant impact on CP.

Methods

Based on a statistical sample size calculation twelve fresh-frozen porcine knee joints were equally divided into a radial and a longitudinal tear group. Each knee underwent unicondylar, convertible osteotomy for exact tear application and consecutive suturing [2]. A total of six 0.8 mm tantalum marker beads were positioned along the meniscus tears (Fig. 1 B, C). Peak CP was determined using calibrated pressure sensitive films (K-Scan 400, Tekscan Inc.) which were placed between the tibial plateau and the medial meniscus.

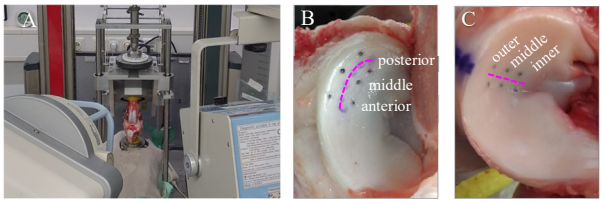

Fig. 1: Test setup (A) and representative images of a longitudinal (B) and a radial tear (C) (purple dashed lines) located at the posterior horn of the medial meniscus and the according RSA marker bead pairs for gapping analysis.

The joints were preloaded by 75 sinusoidal loading cycles ranging between 0-350 N using a customized loading rig (Fig. 1 A), which was integrated in a material testing machine. Then, the peak load (350 N) was hold constant and two synchronized x-ray images were acquired under Roentgen Stereophotogrammetric Analysis (RSA) conditions, visualizing the six markers. Gapping and peak CP were investigated in the native, torn and repaired state (longitudinal = vertical mattress suture; radial = inside-out suture). Gapping was evaluated by analyzing the change in distance of the marker bead pairs (RSAcore, Leiden University) (Fig. 2). Non-parametric statistical analysis was performed, while $p < 0.05$ was considered significant *(Friedman)*.

Results

There was no change in gapping ($p>0.43$) and peak CP ($p=0.18$) in the longitudinal tear group (Fig. 2 A). In contrast, the radial tear led to a significant gapping (Fig. 2 B; $p<0.02$) when comparing the native and the tear state, while the inside-out suture was able to restore gapping in the middle and outer zone of the meniscus. Accordingly, a trend towards an increase in CP after radial tear application was detected, which was again normalized after suture application.

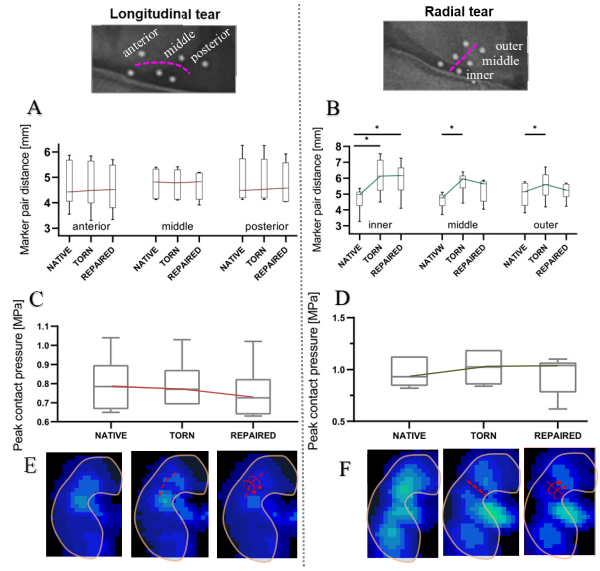

*Fig. 2: Comparison in distance change (median, min-max) of the three marker pairs during consecutive meniscal states and two tear types (A, B) and peak CP change (median, min-max) (C, D). Visualization of the CP change of the respective meniscal states (E, F); * = $p < 0.05$.*

Discussion

The most important finding of the study is that not every meniscus tear type gap. Longitudinal tears do not gape under pure axial loading while radial tears tend to separate the tear interfaces. Accordingly, CP did not change after longitudinal tear simulation while untreated radial tears tended to increase the CP, especially in the inner zone next to the cartilage-cartilage contact. Concomitant, the suture for radial tear repair reduced gapping, thus, contributing to a reduced CP. However, the study is not free of limitations, which are mainly the lack of flexion/extension movements and the invasive osteotomy. To the best of the authors knowledge, this is the first in-vitro study, that combines RSA with pressure sensitive films for correlation between meniscal tear gapping and CP change. This study could provide a solid basis for in-vitro determination of rehabilitation knee loading regimes and possible negative influences on the gapping behaviour of injured/repaired menisci and respective reduced healing possibility.

References

1. Sukopp et al., Front. Bioeng. Biotechnol., 2021, 9
2. Hirose et al., J Exp. Orthopaedics (2020) 7:21.