Biomechanical Performance of a Polycarbonate Urethane Total Meniscus Replacement

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Disclosures:

Introduction: Patients that remain symptomatic following total meniscectomy (Mx) can currently only be treated by meniscal allograft transplantation. We have developed a polycarbonate urethane (PCU) anatomically shaped, total meniscus replacement, that should overcome the problems related to the availability, sizing, shrinkage and remodeling of meniscal allografts [1]. The objective of this study was to evaluate the biomechanical performance of this implant, with respect to the native meniscus, a meniscal allograft and a total Mx case.

Methods: Left male human cadaveric knees (n=5, aged 70-88, no radiographic signs of joint degeneration) were loaded in a loading rig [2] and flexed from 0° to 90° with 30° increments, under compressive loads up to 1200N in 90°. Furthermore, anterior laxity tests were performed in 30° and 90° flexion for a load of 67N [3]. Biplanar X-ray images were taken after each change in loading condition. Roentgen stereophotogrammetric analysis of radiopaque beads fixed inside the medial meniscus (MM), implant, tibia and femur, was used to evaluate anteroposterior (AP) and mediolateral (ML) translations of the MM and implant between 0° and 90° flexion, and AP laxity in 30° and 90° flexion. In addition, tibial contact mechanics were evaluated in 90° flexion, using Tekscan pressure sensors (K-scan 4010N, Tekscan Inc, Boston, USA). In each knee joint, measurements were repeated for the native MM, the PCU implant, a total medial Mx and after meniscal allograft transplantation. Multi-way repeated measures ANOVA tests were performed, followed by post-hoc tests using the Bonferoni criterion for multiple comparisons. P-values <0.05 were considered significant.

Results: Mean pressure and contact area under the implant were significantly different from the native MM (p=0.031 and p=0.020), however no significant differences were found between the PCU implant and the allograft (Fig. 1). AP laxity of the knee increased after replacing the native MM (p=0.014 in 30° and p=0.028 in 90°), yet after pairwise comparisons no significant differences were found between the specific conditions (Table 1). Posterior translation of the implant and allograft seemed to be larger than observed for the native MM (Fig. 2), but the differences were non-significant. For ML translation (Fig. 2), a significant effect of meniscal condition was found (p=0.028), but pairwise comparisons did not reveal significant differences.

Discussion: Kinematics, contact mechanics and knee stability were comparable for the implant and allograft conditions. Functioning of the native MM however, could not be reproduced by the implant nor the allograft. Differences in kinematics, mean pressure and contact area between the meniscal replacements and the native MM may arise from the difference in fixation. The implant and allograft had a point fixation (suture through tibial drill hole), while the native meniscus has a larger attachment area. This difference may cause the increased radial extrusion observed for the meniscal replacements, pushing them away from the pressure sensor area. Therefore, the radial extrusion may also influence the contact mechanics data. It should be investigated whether a more anatomical-like fixation of the implant could improve these outcomes. In conclusion, biomechanical performance of the PCU total meniscus replacement was similar to allograft functioning. Allografts are considered to be an effective treatment to relieve pain and resume activity for total Mx patients [6], even though they have been shown not to be capable of restoring contact mechanics to native meniscus levels [4,5]. Taking this together, our implant has the potential to become a successful alternative to allograft menisci.

Significance: This study demonstrates the biomechanical potential of a PCU anatomically shaped implant for total meniscus replacement, that can serve as an alternative to meniscal allografts.

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Figure 1: PCU, anatomically shaped, total meniscus implant.
Figure 2: Contact mechanics results. (A) Peak pressure, (B) Mean pressure, (C) Contact area. All data in mean ± SEM. * refers to p<0.05.
**Figure 3:** Meniscal translations (mean ± SEM) in AP and ML direction for the native meniscus, implant and allograft.

<table>
<thead>
<tr>
<th>Knee angle</th>
<th>Anterior translation of tibia (mm)</th>
<th>Native</th>
<th>Implant</th>
<th>Mx</th>
<th>Allograft</th>
</tr>
</thead>
<tbody>
<tr>
<td>30°</td>
<td>1.81±0.47</td>
<td>3.14±0.70</td>
<td>3.42±0.77</td>
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<tr>
<td>90°</td>
<td>4.61±0.84</td>
<td>5.47±1.03</td>
<td>6.45±1.14</td>
<td>6.39±1.13</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1:** AP laxity (mean ± SEM) in 30° and 90° flexion