Introduction: Meniscal debridement remains the most commonly performed orthopaedic surgery in the US, even though several clinical long-term studies have shown that total or partial meniscectomy may lead to cartilage degeneration and early onset of osteoarthritic changes. Repair should be considered depending on the type and the location of the meniscal tear. Good and excellent results have been obtained in the repair of peripheral meniscus tears in the vascularized zone (red-red-zone). Several basic research studies have evaluated the structural properties of meniscal repair constructs. Most commonly, these studies test a “worst case scenario” or distraction test where the load is applied parallel to the axis of the tested fixation device. Frequently, meniscal injuries occur secondary to a rotational force in combination with an axial load. This may pull the central part of the meniscus while the peripheral part of the meniscus is still attached to the joint capsule and thereby leading to a rupture. The force directions can be subdivided into sagittal and coronal forces. The resulting force vector is in an oblique direction thereby matching the definition of a shear force scenario. The purpose of the current study was therefore to evaluate structural properties and elongation of meniscal repair using horizontal and vertical suture techniques after being subjected to a cyclic loading protocol in a distraction and in a shear force scenario. We hypothesized, that a vertical suture technique for meniscal repair subjected to cyclic loading in a shear force scenario will result in significantly less elongation when compared to horizontal sutures.

Methods: In this study 40 fresh frozen porcine menisci were repaired using horizontal (group 1) and vertical (group 2) loop sutures using 2-0 Ethibond (Ethicon, Norderstedt, Germany) in an outside-in technique. The menisci were mounted in a custom made tissue clamp. In part one of the study, the loads were applied in line with the axis of the implants to simulate a distraction case scenario (Fig.1.a). In part two, the repair complexes were subjected to shear forces with the load applied perpendicular to the repair complex (Fig.1.b). Each meniscus-implant/suture construct was subjected to 1000 cycles of a load between 5 and 20 N and subsequently loaded to failure at a cross head speed of 12.5 mm/sec. Elongation after 100, 500, and 1000 cycles of load, ultimate failure load, mode of failure and stiffness were recorded. Data were analyzed using an ANOVA test with the level of significance set at p<0.05.

Results: In the distraction force scenario specimens of group 1 (horizontal suture) showed slightly lower total elongation when compared to group 2 (vertical sutures) (Tab.1) (p<0.05). Specimen repaired with horizontal suture technique (group 1) and vertical suture technique (group 2) showed no statistically significant difference in stiffness and yield load (p>0.05). Meniscal repair with a horizontal suture revealed maximum load to failure with a mean of 64.3 (+/-5.9) N which was statistically significant higher when compared to vertical sutures (56.9 +/-7.0) N/mm. In the shear force scenario, specimens repaired with horizontal suture technique (group 1) showed significantly less elongation when compared to vertical suture technique (group 2) (Tab.1). No statistical significant differences in stiffness, yield load and maximum load was to be found.

Discussion: Aim of the study was to evaluate structural properties and elongation during cyclic loading of meniscal repairs using horizontal and vertical suture techniques in shear force scenario and distraction force scenario. In distraction force scenario, horizontal and vertical sutures techniques showed no statistical significant difference in elongation after 1000 cycles between 5 and 20 N (p>0.05). The structural properties of horizontal sutures techniques such as stiffness and yield load showed no statistical significant difference whereas the maximum load was significantly higher when compared to vertical suture technique. In a shear force scenario however, elongation after 1000 cycles between 5 and 20 N was significantly lower for the horizontal suture technique when compared to the vertical suture technique. Biomechanical studies have shown that in distraction force tests ultimate load of vertical sutures might be higher than horizontal placed sutures for meniscal repair (Kohn et al. 1983, Rimmer et al. 1995), however others implicate no statistical significant difference between the two techniques (Søl et al. 2000, Bellemans et al. 2002). A potential reason for the different results of these studies may be different test set up such as fixation of the meniscal specimens, different cross head speeds of the material testing machines, and different fixation techniques. In part 2 of the study, we focused on application of shear forces to more closely mimic the in vivo loading condition. When being subjected to shear forces, horizontal suture techniques resulted in significantly lower elongation than vertical suture repair. Our results suggest that horizontal sutures withstand elongation due to cyclic loading more efficient when compared to vertical suture placement. A possible explanation for this could be that in a shear force scenario, horizontal suture placement might be beneficial since this suturing technique provides two points of fixation in the plane of load application. Limitations of this study include the use of porcine menisci. The use of porcine menisci however eliminates degenerative components of human cadaver menisci obtained from old body donors and many studies have shown that porcine menisci are a suitable model to study biomechanical characteristics of meniscus repair techniques.

In conclusion, the present study shows that meniscal repair using horizontal suture techniques resulted in significantly less elongation than a vertical suture repair when subjected to shear forces. These results may suggest that a horizontal suture technique is from a biomechanical point of view well justified to be used for the reconstruction of meniscal tears in the intermediate part of the meniscus.

*Department of Orthopaedic Surgery, University Schleswig-Holstein, Campus Kiel

Fig.1: Test set-up in distraction force (a) and shear force scenario (b).

Tab.1: Elongation after cyclic loading

<table>
<thead>
<tr>
<th>Shear forces</th>
<th>Cycle 100</th>
<th>Cycle 500</th>
<th>Cycle 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal suture</td>
<td>1.3 (+/-0.5) *</td>
<td>2.3 (+/-0.8) *</td>
<td>2.8 (+/-1.1) *</td>
</tr>
<tr>
<td>Vertical suture</td>
<td>2.2 (+/-1.3)</td>
<td>3.7 (+/-1.7)</td>
<td>4.6 (+/-2.0)</td>
</tr>
</tbody>
</table>

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