IMPACT OF TOTAL MENISECTOMY ON TIBIAL PLATEAU CONTACT FORCES, FEMORAL CARTILAGE STRESS LEVEL & CRUCIATE LIGAMENT FORCES IN PASSIVE KNEE FLEXION

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INTRODUCTION
Cartilage degeneration in the knee joint is mainly caused by elevated stress level and high contact forces resulting from total meniscectomy procedures [1]. Statistics showed that among patients who had meniscectomy surgeries, 14.1% of men & 22.8% of women over 45 years show symptoms of Osteoarthritis (OA) which treatment costs around $185.5 billion in USA annually [2]. Previous studies lacked a full comparison between fully meniscectomized and intact knee joint during passive flexion. The objective of this study is to create a validated F.E. knee joint model that mimics biological behavior in order to predict results of complex scenarios and be used to provide full comparison of the above-mentioned cases. Parameters of interest are Von Mises (VM) stress, axial contact force, contact pressure and cruciate ligaments forces, In this study, the same passive knee joint model was analyzed under two scenario conditions:(1) Menisci Intact (control), (2) Total meniscectomy;(flexion 0-60 deg.) Only tibio-femoral joint was considered.

METHODS
A Finite Element knee joint model was constructed based on MRI scans of the right knee (Male:45 yr-70 kg) which were used to extract the 3D geometry of the knee joint model. The 3D geometry of the skeletal knee was built using Mimics and Abaqus software. Articular cartilages and menisci were considered to behave as linear elastic isotropic as reported in the literature [3]. Ligaments were modeled as springs which have an elastic nonlinear behaviour [4]. Since bone stiffness is much higher than soft tissues, bones are modeled as rigid bodies represented by a reference node and meshed with tetrahedral elements. Menisci and cartilages were meshed with 8 node hexahedron elements. Frictionless non-linear contact with finite sliding was assumed in all articulations. Boundary conditions were set to fix tibia & fibula in all D.O.F. Flexion was applied to the femoral reference node to flex in range (0-60) degrees.

RESULTS AND DISCUSSION
More load-bearing was noticed on the medial compartment in intact model which agrees with previous studies [5], while it shifted to lateral compartment in meniscectomy model. Results of axial contact forces on tibial plateau in intact case (Table 1) agreed with experimental validated results reported in previous study [6]. In case of meniscectomy, model predicted results showed a substantial increase of axial contact forces on the tibial plateau compared with the menisci intact case (Figure 1). Higher VM stress level values on femoral cartilage resulted in case of meniscectomy (Figure 2), results were within range of those reported in a previous experimental and numerical validated study [7] (Table 1). At 15 degrees of flexion, minor difference was noticed, however stress level started to ramp up at 30, 45 and 60 degrees flexion (Table 1) For cruciate ligaments forces, the model results of intact case were also validated with results reported in previous studies [4], in case of meniscectomy, much higher PCL forces were noticed compared to menisci intact case (Figure 3). Model predicted results of PCL forces in meniscectomy were (42N), (144N), (250N) and (424)N at 15, 30, 45 and 60 degree flexion respectively. ACL forces in case of meniscectomy were almost twice the value of the intact model between 0 and 15 degree flexion, then both values matched at higher flexion angles (almost zero force) which agrees with ACL curve pattern reported in previous studies [4] (Figure 4).

Table 1: Axial Contact Forces on tibial plateau and VM stress on femoral cartilage vs flexion in Menisci Intact and Meniscectomy

<table>
<thead>
<tr>
<th>Flexion (Deg)</th>
<th>Axial Contact Force on Medial cartilage (N)</th>
<th>Axial Contact Force on Lateral cartilage (N)</th>
<th>VM stress on femoral cartilage (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uncovered Covered Meniscectomy Uncovered Covered Meniscectomy</td>
<td>Uncovered Covered Meniscectomy</td>
<td>Intact Meniscectomy</td>
</tr>
<tr>
<td>30</td>
<td>313 100 915</td>
<td>190 95 1360</td>
<td>1.2 1.7</td>
</tr>
<tr>
<td>45</td>
<td>365 80 1040</td>
<td>140 60 1588</td>
<td>1.3 2.2</td>
</tr>
<tr>
<td>60</td>
<td>278 40 800</td>
<td>100 45 1618</td>
<td>1.68 2.2</td>
</tr>
</tbody>
</table>
due to meniscectomy indicate higher cartilage degeneration risk, which promotes OA. Role of menisci in load bearing and shock absorption was highlighted when comparing covered, uncovered vs meniscectomy tibial cartilage axial contact force values (Figure1). It is interesting to notice that during flexion of meniscectomized model, more stress level was concentrated on the lateral compartment of femoral cartilage which shows a shift in loading than the intact model (concentrated on medial compartment), which recommends further investigation. Higher cruciate ligament forces indicate tear risk and instability of the joint. Total meniscectomy remains the most disrupting condition for the knee joint and is clinically recommended to be avoided as a fast treatment of meniscal injury.

**CONCLUSIONS**

Total meniscectomy resulted in much higher cruciate ligaments forces, higher contact pressure, stress level on femoral cartilage and higher axial contact force on tibial cartilages in all analysis processed. The elevated values of contact force and VM stress on cartilages

- Figure 1: Axial contact forces on tibial plateau: Covered (via Menisci), uncovered (via cartilage) and complete Meniscectomy vs Flexion angles
- Figure 2: VM stress on lateral (L), medial (M) femoral-compartments vs flexion (a) menisci intact. (b) meniscectomy.

Maximum contact pressure values on femoral cartilage were 3, 3.3 and 5.2 MPa (intact) versus 4.6, 6.4 and 7 MPa (meniscectomy) at 30, 45 and 60 degrees flexion respectively. Values of contact pressure were validated and agreed with experimental results of frozen cadaver knees under flexion testing as reported in study [8]

**REFERENCES**


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