IN-VIVO LOADING OF A SHOULDER IMPLANT – FIRST POSTOPERATIVE DATA

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Introduction
Existing knowledge of the loads acting in the shoulder joint has never been validated by in-vivo data. Simple mechanical calculations delivered force magnitudes about 90% of the body weight (%BW) during arm abduction [4]. Complex muscle models supplied additional information about load directions [2, 5]. Such models have to be validated and possibly improved by real data from patients. An instrumented shoulder implant was therefore developed for telemetric measurements of shoulder loading.

Methods
A Bio-Modular shoulder implant (Biomet) was modified (Fig.1). Inside its short neck an inductively powered telemetry and 6 strain gauges measure six force and moment components acting at the head of the implant. All load components were measured with an average accuracy of about 1%, except the torque around the neck axis (2%). Telemetry and external devices are described elsewhere [1, 3]. The first patient (69 years) with omarthrosis obtained a humeral component without glenoid replacement in May 2005. Selected measurements during physiotherapy within the first 2 months are reported here, when the patient’s shoulder function wasn’t yet fully restored. The coordinate axes are defined relative to the humerus: x points forwards, y upwards, z outwards. ForcesFx, Fy, Fz act in axes directions, F is the resultant force. Moments Mx, My, Mz act clockwise around axes. During exercises against resistance the external force Fext was additionally measured (Fig.2).

Results
From the 2nd postoperative (po) day on and during the first 2 po months (mpo) typical joint contact forces during various activities reached 300N. Occasionally even 450N were measured. At 0.6 mpo a force of 300N and a moment of 1.3Nm was observed during assisted arm elevation in supine position (Tables, activity #1). 0.6 mpo forces up to 450N and moments of 0.6Nm were observed during outer rotation against resistance (#2, Figs.2, 3). 1.9 mpo the forces were lower but the moments higher for the same activity (#3). The forces during inner rotation (#4) were lower than during outer rotation but the force directions were similar. During assisted abduction in a sitting position a force of 285N was measured. When sliding the hand forward and backwards while sitting at a table, up to 280N acted in the joint (#6, Fig.4). It was a frequent observation that the moments varied much and even changed their sign when repeating exercises.

Discussion
A general load decrease with the postoperative time for the same exercise could not be observed. Non-zero moments indicate that, due to friction, the resultant force doesn’t act exactly through the joint center. A moment of 1.5Nm and a simultaneous force of 300N, for example, indicate an eccentricity of 5mm. Large variations of moments during the same activities proved that muscular balancing was still imperfect. During some activities the biceps tendon suddenly jumped to a new position. Fig.4 illuminates this mechanism: The moments rise, but after 17s suddenly fall without marked force changes. At this instant the tendon jumps and the humeral head is re-centered in the glenoid.

# Activity
1 Supine position, elevation of arm, supported
2 Supine, isometric outer rotation, elbow flexed, external resistance
3 Same activity as #2
4 Supine, isometric inner rotation, elbow flexed, external resistance
5 Sitting, assisted abduction
6 Sitting, sliding hand for- and backwards on table

# Loads: Forces [N] and Moments [Nm]

<table>
<thead>
<tr>
<th>Months po.</th>
<th>Activity</th>
<th>Forces [N]</th>
<th>Moments [Nm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>#1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.9</td>
<td>#2</td>
<td>10, 450</td>
<td>-300, Mx = 0.6, Mz = +0.6</td>
</tr>
<tr>
<td>1.9</td>
<td>#3</td>
<td>11, 280, 250</td>
<td>-0.45, Mz = +1.0</td>
</tr>
<tr>
<td>0.6</td>
<td>#4</td>
<td>12, 110, 0</td>
<td>-0.7, Mz = +0.7</td>
</tr>
<tr>
<td>0.6</td>
<td>#5</td>
<td>0, 285, -275</td>
<td>-0.9, Mz = +0.9</td>
</tr>
<tr>
<td>1.9</td>
<td>#6</td>
<td>0, 280, 265</td>
<td>+1.35, Mz = -1.5</td>
</tr>
</tbody>
</table>

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References