THE EFFECT OF REAMING ON THE TORSIONAL STRENGTH OF THE HUMERUS

*Choo, A MT; *Hawkins, R H (A-DePuy Canada); *Goertzen, D J; *Kwon, B; **Oxland, T R (A-DePuy Canada)
+*Department of Orthopaedics, University of British Columbia, Vancouver, BC, Canada. 910 West 10th Avenue, 3rd floor, Vancouver, BC, Canada, V5Z 4E3, 604-875-5475, Fax: 604-875-4677, toxland@interchange.ubc.ca

Introduction
Periprosthetic humeral fractures after shoulder arthroplasty are reported to have a 1% to 3% incidence.1,2 Although low, this accounts for roughly 20% of all complications related to shoulder arthroplasty.1 The majority of these fractures occur intraoperatively and the spiral or long oblique fracture pattern suggests that external rotation or torsion is a primary injury mechanism.1 There are several possible factors which increase fracture risk, including poor bone stock, excessive manipulation of the arm, endosteal defects introduced during the reaming process, or inappropriate selection of implant diameter resulting in high hoop stresses. The focus of the current investigation was to address the effect of reaming on humeral torsional strength. The specific objectives of this study were:

i) to determine whether reaming to a clinically relevant diameter significantly reduces the torsional strength of the humerus;
ii) to determine if a relationship exists between the increase in diaphyseal strain during reaming and the ratio of reamer diameter to intramedullary canal diameter. Our motivation here was to determine if such a ratio could be used as a clinically practical indicator of fracture risk.

Methods
Four uniaxial strain gauges (PA06-125AA-350-1R EN, JP Technologies, San Bernardino, CA) were mounted at 45° to the longitudinal axis of the humerus onto the distal diaphysis (lateral, anterior, medial, posterior), one cm proximal to the maximum anticipated reaming depth. Nine humeri were tested, but three of the specimens were excluded from statistical analysis because of either inconsistent gauge positioning or incomplete data due to gauge failure during the experiment. The humeri were x-rayed from both anterior-posterior (A-P) and medio-lateral (M-L) directions. From the radiographs, the outer and inner diameters were measured with vernier calipers. Each humerus was mounted in a fixture and a constant torque of 35Nm was applied and maintained during all reaming steps. This torque magnitude was used to guarantee good strain signal quality. The strain data were recorded continuously at 25 Hz via a 16-bit A/D card (Labtronic 8800-233 Data Acquisition Unit, Instron Shenck Testing Systems, Canton, MA) and appropriate signal conditioning was used (Vishay 2120, Measurements Group, Raleigh, NC). The humeri were reamed with rigid intramedullary reamers from a commercial shoulder arthroplasty system (Global Total Shoulder system, DePuy, Warsaw, IN). Successively larger reamer diameters were used from a minimum of six mm to a maximum of sixteen mm in two mm increments. In some specimens, the largest reamer diameter was less than sixteen mm due to fracture of the specimen. All reaming was conducted by an experienced shoulder surgeon (RHH) who identified the reamer diameter which would have been used clinically. This is referred to as the Clinical Diameter. Throughout the reaming process, the surgeon was blinded to the recorded strain data. Under a constant torque, an increase in strain indicates an increase in stress and consequently, a reduction in torsional strength. To address the first objective of the study, a repeated measures one-way MANOVA was used to compare the percent change in strain at one reamer size below the clinical diameter and at the clinical diameter. The four dependencies at each level were lateral, anterior, medial, and posterior change in strains. Post-hoc SNK tests were used to compare the changes at each strain gauge location and significance was assumed to be at a 95% level. To address the second objective, the relationship between the change in strain and the ratio of reamer diameter to intramedullary canal diameter was desired. Since the relationship was assumed to be non-linear, an exponential curve was fit through the data for the four gauge locations. For the anterior and posterior gauges, the medio-lateral diameter was used and for the medial and lateral gauges, the antero-posterior diameter was used. A correlation coefficient was calculated to provide an indication of the strength of the relationship.

Results
For all locations on all specimens, the percent change in strain relative to the initial strain remained below 20% at six, eight, and ten mm diameter reamers. At the clinically reamed diameter, the change in strain ranged from 3% to 142%, with four specimens undergoing an increase of over 50%. Strain increases of 50% and 142% indicate reductions in torque strength of 33% and 58.7%. Three of the nine specimens fractured when they were reamed one size beyond the clinical diameter. Statistical analysis showed a significant difference was found by reaming to the clinical diameter on the lateral and posterior aspects of the humeri. (Table 1).

Table 1: Percent strain changes from one reamer size below to the clinical diameter [mean(sd)]

<table>
<thead>
<tr>
<th>Position</th>
<th>Below</th>
<th>Clinical Diameter</th>
<th>SNK test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral</td>
<td>-0.3 (11.1)</td>
<td>10.8 (15.3)</td>
<td>p = 0.0106 *</td>
</tr>
<tr>
<td>Anterior</td>
<td>4.1 (6.2)</td>
<td>41.1 (50.6)</td>
<td>p = 0.1011</td>
</tr>
<tr>
<td>Medial</td>
<td>3.7 (9.3)</td>
<td>11.4 (14.1)</td>
<td>p = 0.0549</td>
</tr>
<tr>
<td>Posterior</td>
<td>7.4 (8.1)</td>
<td>41.4 (30.8)</td>
<td>p = 0.0155 *</td>
</tr>
</tbody>
</table>

The relationships between the strain changes and the ratio of reamer to intramedullary canal diameter were variable when using an exponential curve fit. The correlation coefficients for the lateral, anterior, medial, and posterior gauge locations were 0.43, 0.13, 0.29, and 0.70 respectively. The posterior relation is shown in Figure 1. There is essentially no change in strain when the ratio is below 0.7 and a distinct strain increase above a ratio of 1.0.

Discussion
This simple biomechanical study demonstrated that the surgical decision to advance to a reamer size which engages the endosteal surface has the potential to significantly compromise the torsional strength of the humerus. The longitudinal curvature of the humerus may be a useful indicator of eccentric reaming but was not addressed. The ratio of reamer diameter to intramedullary canal diameter may have utility in determining how close the humerus is to fracture, although our findings were not definitive. In particular, some of the exponential fits were rather poor. It is important to note that there was a modest reduction in torsional strength at a reamer to canal diameter above 0.7 and a steep strength reduction above a ratio of 1.0. Further to be investigated is the effect of inserting a 1mm oversized stem which may have a greater impact on torsional strength than reaming.

References

Acknowledgements
This study was supported by DePuy Canada. Thanks to Dr. D.P. Romilly for his contribution of invaluable instrumentation.