INTRODUCTION

Total hip arthroplasty implant components are commonly implanted by impact loads applied by a surgical mallet through an intermediary insertion instrument. The quantity (per surgical procedure) and magnitude of these impact forces are of engineering interest in regards to development and testing of both implant components and surgical instruments. Maximum and average impact force magnitudes and average impacts per surgical procedure were recorded during this investigation for insertion of acetabular cups and liners (ceramic, metal and polyethylene), and femoral rasping.

METHODS AND PROCEDURES

Impact forces for several surgical procedures performed by eight Orthopaedic surgeons were measured during a cadaveric study (Zimmer, Inc.). Surgical procedures included acetabular cup insertion, femoral rasping and insertion of liners of various materials. Measurements were taken on size 48 mm, 50 mm, 52 mm and 60 mm hemispherical acetabular cups and corresponding sized liners from several Zimmer acetabular implant systems. The acetabulum in all cases was reamed undersized by 1 mm or 2 mm increments relative to the cup size for a perfect hemispherical press fit. Impact forces applied to Zimmer M/L Taper rasps size 6mm, 7.5mm, 8mm, 9mm, 11mm and 12.5mm during femur preparation were also recorded.

The impact forces were measured with two instrumented mallets (standard 907 gram surgical mallets with piezoelectric load cell transducers rigidly fastened to the strike zone). The conditioned output signal was recorded with two National Instruments modular data acquisition systems.

The output voltage file was post-processed by a software routine in LabVIEW 8.5 (National Instruments, Austin, TX). The “Peak Detector.vi” Virtual Instrument (supplied with LabVIEW) was used to detect the impacts in the file and the data point address. The data point address combined with the sampling frequency was used to determine the time between impacts.

RESULTS

The influence of particular surgeons was not analyzed due to the lack of repetitive data per surgeon per technique. Figure 1 shows the average peak impact force per surgical procedure. The total number of each procedure in which measurements were recorded, the max peak impact force, and average number of impacts per procedure are listed in Table 1.

![Figure 1: Average peak impact force magnitudes recorded per surgical procedure](image-url)
**Table 1:** Impact force data measured per procedure and total number of each procedure recorded

<table>
<thead>
<tr>
<th>Surgical Procedure</th>
<th>No. of Procedures</th>
<th>Max Peak Force (N)</th>
<th>Average Peak Force (N)</th>
<th>Avg No. of Impacts Per Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cup Insertion</td>
<td>10</td>
<td>27490</td>
<td>16750 (7270)</td>
<td>5 (2)</td>
</tr>
<tr>
<td>Femoral Rasping</td>
<td>10</td>
<td>22090</td>
<td>15380 (3400)</td>
<td>12 (9)</td>
</tr>
<tr>
<td>Poly Liner Insertion</td>
<td>7</td>
<td>11710</td>
<td>9515 (1910)</td>
<td>4 (2)</td>
</tr>
<tr>
<td>Metal Liner Insertion</td>
<td>10</td>
<td>15660</td>
<td>8940 (3450)</td>
<td>4 (1)</td>
</tr>
<tr>
<td>Ceramic Liner Insertion</td>
<td>20</td>
<td>12950</td>
<td>6335 (2500)</td>
<td>5 (3)</td>
</tr>
</tbody>
</table>

On average, the time between impacts was 0.429 (0.165) seconds or approximately 2.3 Hz excluding procedures where significant surgical delay occurred. No significant differences in the average number of impacts per procedure with consideration of standard deviation and number of procedures performed were observed.

**DISCUSSION**

The measured mean peak impact forces for cup insertion and femoral rasping were greater in magnitude compared to those measured for liner insertion (regardless of liner type). The number of impacts per procedure was greatest for the rasping procedure. However, no significant difference in impact force magnitude can be drawn between surgical procedures due to the large standard deviations for both the force and number of impacts per procedure.

The maximum and average peak rasping impact forces measured are comparable to values obtained during a prior cadaveric study on rasp and tamp instruments (Kold S et al.). In addition, an intra-operative study recorded mean peak impact broaching forces during total hip arthroplasty ranging from 20,551 to 29,919 N which correspond to the rasping measurements of this investigation (Markel D et al.).

**SUMMARY**

Mean peak impact forces recorded for acetabular cup insertion and femoral rasping were approximately 17,750 (7270) N and 15,380 (3400) N respectively. These values were greater in magnitude than those recorded for liner insertion. Liner insertion mean peak forces ranged from 9,515 (1910) N to 6,335 (2500) N depending on liner type.

Overall, the average number of impacts measured for cup insertion, femoral rasping and liner insertion (all types) were 5, 12 and 4 respectively.

**REFERENCES**