Experimental Investigation of Screw Cup Performance during Insertion
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Introduction
The evaluation of the clinical performance of cementless screw cups in Total Hip Arthroplasty (THA) is very controversial. Although these products do not find wide acceptance in anglo-american countries they are still held in high regard in central Europe. The reason for this lies in the fact that in the United States screw cups with inferior designs and unsuitable materials produced very poor medium term results, while numerous products implanted in Europe demonstrate an extremely satisfying clinical outcome.

Decisive for the clinical success of an implant are the design (the basic cup form as well as the thread form chosen) and the material. Nowadays it is undisputed that pure titanium and titanium alloys are the materials of choice for cementless implants. A further essential requirement is the primarily stable anchorage of the implant. Therefore it is important that, after screwing the cup into position, a final check confirms that a stable fixation has been attained.

Clinical experience with the cups chosen for this study, specifically concerning their behaviour during insertion, was markedly different. While it is often difficult to achieve the correct implantation depth with pointed threads – due to premature jamming - with a purely flat thread surgeons often have the impression that the implantation procedure is too easy to complete and that at the end of the process the primary stability of the cup may be insufficient. It was therefore the goal of this investigation to objectively evaluate these perceived differences and to determine the true performance of the different thread designs during insertion under standardised test conditions, both for large and small cups.

A large and a small version of four commercially available screw cups were chosen for this study, with their outside diameters at the equator being approximately 50 mm and 58 mm respectively. The tests were conducted four times for each variant.

The main differences in the design of the cups and the screw threads is summarised in Table 1. The differences between the different thread types is shown in Figure 1 and the cross section of each of the cups tested in Figure 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Cup A</th>
<th>Cup B</th>
<th>Cup C</th>
<th>Cup D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thread type</td>
<td>Conical (I)</td>
<td>Conical (I)</td>
<td>Cylindrical (II)</td>
<td>Flat (III)</td>
</tr>
<tr>
<td>Thread height (mm)</td>
<td>≈ 3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>≈ 2.9</td>
</tr>
<tr>
<td>Thread pitch</td>
<td>≈ 5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>≈ 5.0</td>
</tr>
<tr>
<td>Tooth undercut (mm)</td>
<td>Linear, ≈ 0.2</td>
<td>Linear, 0.2</td>
<td>Radial, 0.4</td>
<td>Linear, ≈ 0.7</td>
</tr>
<tr>
<td>Cup design</td>
<td>Bi-conical</td>
<td>Conical</td>
<td>Conical</td>
<td>Parabollic</td>
</tr>
<tr>
<td></td>
<td>Flat floor</td>
<td>Flat floor</td>
<td>Spherical floor</td>
<td>Flat floor</td>
</tr>
</tbody>
</table>

Table 1: Summary of Cup and Thread Design Characteristics

Figure 1: (I) Conical, (II) Cylindrical and (III) Flat Threads
Methods
All cups were screwed into pre-machined polyurethane foam blocks (ep-DUR®, Emaform AG, Gontenschwil/Switzerland, Flexural modulus = 800 MPa) with the help of a biaxial testing machine (Instron Biaxial 8502, Instron Corp., Mass./USA) and control system (Instron 8500 plus, Instron Corp., Mass./USA) with an angular velocity of 5° per second. This PU material, with an E-Modulus of around Where possible the original surgical instrument was used to transmit the torque to the cup. Otherwise custom made adapters based on the surgical instruments were manufactured for this purpose. A torque sensor (Sensor Data M211-112, supplied by Instron Corp., Mass./USA) supplied together with appropriate software (Instron MAX version 5.21, Instron Corp., Mass./USA) was used to record the torque during the insertion process.
A minimum of 500° of angular movement, approximately 1.4 complete revolutions, was needed to screw each of the cup designs fully into place. Before the turning motion began a 150 N axial preload was applied and was held for the duration of the insertion. However, as the maximum angular movement of the machine was limited to 270° it was necessary to remove the preload, return the actuator back to the original position, re-apply the preload and continue the insertion process in order to complete the test. The test was considered complete either when the cup was fully inserted or when the upper measurement limit of the sensor, 100 Nm, was reached.

Results
Most orthopaedic surgeons using threaded cups agree that the torque required at the end of the insertion process is of particular importance. On the one hand, too high a torque could mean that the surgeon is unable to seat the cup as far down in the acetabulum as they would wish. On the other hand, too low an insertion torque may lead them to have doubts as to whether or not the implant is sufficiently well anchored. For this reason particular attention was paid to the torque towards the end of the procedure, in this case at 500°, as shown in Figure 3.
In addition, another view expressed by the clinicians asked was that the ideal cup should exhibit stable behaviour during insertion. That is, over the whole insertion process there should be no large fluctuations in the amount of torque required. For this reason the torque was plotted against the number of degrees the cup had been turned through, as shown in Figure 4.
A variance analysis using statistical software showed that both the cup size (p=0.003) and the thread design (p=0.0009) affect the insertion torque.

**Discussion**

With the exception of cup C, the insertion torque of smaller cups was markedly lower than that of large ones. Furthermore, differences between the performance of the individual designs were detectable and are caused by the different thread designs. Using this particular test configuration, Cup A exhibited an undesirable increase in insertion torque at the end of the procedure and Cup B a high but linear torque versus insertion angle pattern. The larger size of Cup D required by some distance the lowest insertion torque and could cause the surgeon to question the cups' primary stability. Cup C met the two subjective requirements expressed by the surgeons consulted better than the other designs, namely an achievable torque at the end and stable behaviour during the insertion procedure.

**References**

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