STEM-CEMENT INTERFACE SHEAR STRENGTH IS INFLUENCED BY STEM SURFACE FINISH BUT NOT CEMENT INTERFACE POROSITY

+*Wang J-S, Flivik G, Taylor M, Lidgren L. Dept. of Orthopaedics, Lund University Hospital, S-221 85 Lund, Sweden, Phone:+46-46 177164, Fax:+46 46 177167, E-mail Jian-sheng.wang@ort.lu.se

Introduction
Some studies have indicated that mechanical loosening of cemented implants begins at the stem-cement interface (1,2). The mechanical strength of the stem-cement interface may be related to porosity at the interface. Previous studies have shown that pretreating the stem surface, for example by polishing or preheating the stem, reduced the interface porosity (3,4). However, it is uncertain if pretreating the stem increases the stem-cement interface strength. The purpose of this study was to determine if a relationship existed between porosity and static shear strength for stems with either a matt or a polished surface finish. The tests were made with stems either preheated or room temperature.

Materials and Methods
Thirty six stainless steel rods (10 mm in diameter and 37 mm length) were fabricated. Eighteen of the rods were polished and the rest were grit-blasted. The surface roughness (Ra) was 0.05±0.01 µm and 0.88±0.15 µm for the polished and matt surfaces respectively. Nine polished and 9 matt stems were preheated to 44 °C in an oven, while the rest were kept at room temperature. The stems were cemented into an aluminium cylindrical holder using a custom made alignment jig which ensured accurate axial alignment of the stem within the cement mantle. The aluminium holder was 16mm in diameter and had an internal depth of 20 mm. The base of the holder had a 11 mm diameter hole to allow for the stem to be pushed out in subsequent testing. During delivery of the cement and insertion of the stem the hole was capped with a silicone stopper. Six stems were cemented per mix of polymethylmethacrylate. Prechilled (4°C) Palacos R bone cement was mixed under vacuum for 30 seconds and injected into the cylinder with a delivery nozzle in a retrograde manner 2 minutes after the start of mixing. The stems were inserted 4 minutes after the start of mixing. After curing, the specimens were kept at 37°C in a water bath for 72 hours.

Mechanical testing was employed using an Instron 8511 testing machine. All tests were performed in a room temperature of 22°C. The specimens were supported on a custom made fixture, which allowed free axial movement of the stem. The stem was displaced at a constant rate, 2 mm/min, and the resultant force-displacement curve recorded to a data file. Interfacial failure was assumed to occur at the first peak in the force-displacement curve. The shear strength was calculated by dividing the peak force by the surface area of the interface. The interface shear strengths from the various groups were statistically analyzed using a Student’ t-test.

After the push-out test, the specimens were cut longitudinally into four even sections. The surfaces of the specimens were stained using a black oil polish and measured using a direct light microscope which connected to a computerised video digital system (Videoplan TM, Zeiss) at a magnification of 40 x. Each measuring area was 15 mm². There were 4 measuring areas in each section. The measurement was done blindly in a random order. The pore area on the surface was measured. The percentage of pore area was calculated by dividing the area of pores on the surface by the total area and multiplying by 100. The mean value of the four sections from each specimen was calculated and analyzed by Student’ t-test.

Results
Table 1 shows the interfacial shear strength and the percentage porosity for the four groups of stems. The shear strength of the matt stems was approximately 5 times greater at room temperature and 4 times greater when preheated than that of the polished stems. There was no difference in the shear strength between 23 °C and 44 °C for either the matt groups or polished groups. The percentage of pores was significantly lower in the polished groups compared with the matt groups (p<0.01). Preheating the stem also reduced the porosity (p<0.0001). However, the reduction of surface porosity by preheating the stem did not change the static shear strength.

Table 1. Interface shear strength (MPa) and percentage of pore area, that is the mean values of each sample. Each treatment group consists of 9 samples (Mean±sd).

<table>
<thead>
<tr>
<th>Stem treatment</th>
<th>Stem Temp.</th>
<th>Shear strength (MPa)</th>
<th>Porosity %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matt</td>
<td>23°C</td>
<td>2.65±0.33</td>
<td>11.88±5.49</td>
</tr>
<tr>
<td>Matt</td>
<td>44°C</td>
<td>2.33±0.52</td>
<td>2.35±2.68</td>
</tr>
<tr>
<td>Polish</td>
<td>23°C</td>
<td>0.53±0.26</td>
<td>4.38±2.69</td>
</tr>
<tr>
<td>Polish</td>
<td>44°C</td>
<td>0.60±0.25</td>
<td>0.94±1.19</td>
</tr>
</tbody>
</table>

Discussion
The present work suggests that matt stems have a stronger static interfacial shear strength than polished stems. A reduction of porosity on the surface does not, however, significantly increase the interface strength. The interface static shear strength is thus more dependent on the surface finish of the stem.

This study shows similar findings as previous works (3,4), namely, that standard methods of cemented implantation causes porosity at the stem-cement interface. Interface porosity can be reduced by stem surface pretreatment, i.e., polishing and pre-heating the stem. Even though the reduction of porosity does not increase the interface strength, such a surface is likely to better avoid the generation of cement debris after interface debonding.

References:

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