INTRODUCTION:
Primary stability is a prerequisite for the success of cementless hip replacements as osseointegration is only possible if the interface-micromotion is sufficiently low (40-100µm [1, 2]). In short stemmed prostheses primary stability is difficult to achieve. Hence, extensive pre-clinical testing is required prior to clinical trials. The aim of this study was to evaluate the migration and relative motion of a new short stemmed prostheses design under dynamic loading in comparison with clinically established, successful shaft prostheses. Additionally, the effect of head offset and surface finish was investigated.

METHODS AND MATERIALS:
Four test series with 5 paired human femora each were performed. Tests 1 and 4 compared the short stemmed, high offset PROXIMA prosthesis with the cementless IPS and SUMMIT shaft prostheses, respectively (all DePuy). In test series 2 the influence of head offset and in test series 3 the influence of surface finish was investigated (Figure 1).

The distal femurs were embedded in Ureol on a XY-table and cyclic (2 Hz) sinusoidal loading, increasing from 50 to 2,100N, was applied to the prosthesis head in 10° of adduction and 10° of flexion (ISO 7206-4) for up to 100,000 cycles with an MTS 858.2 material testing machine. Relative motion between prosthesis and the greater trochanter was measured using retro reflective markers (3D optical system, Vicon 470). Output variables were total migration (permanent relative movement of the prosthesis with respect to the bone) and total relative motion (amplitude of the relative motion during one loading cycle) at 15,000 cycles. Only translational results are presented here. Failure was also recorded and categorised into early (<10,500 cycles) and late (>15,000 cycles) periods. One-way ANOVA statistical analyses were performed using SPSS (Inc., Chicago, USA).

RESULTS:
The stemmed prostheses showed higher relative motion than the PROXIMA prosthesis (Table 1). The difference was significant between the IPS and the PROXIMA (test series 1, p<0.001; Table 1) whereas only a tendency was observed for the SUMMIT (test series 4, p=0.079; Table 1). During loading, bending of the femur in the frontal plane was visually observed to have a more physiological pattern (more similar to the deformation without an implant) for the PROXIMA prosthesis than for the shaft prostheses.

The PROXIMA exhibited a higher migration than the stemmed prostheses (Table 1) but stabilised at maximum load (Figure 2). The migration of the SUMMIT was significantly smaller than for the PROXIMA (test series 4, p=0.035; Table 1). Early failure of the PROXIMA by medial cutout occurred in cases of poor bone quality or due to suboptimal implantation. The PROXIMA with the +17mm head offset failed in all cases within the early test period (test series 2, Table 1). The surface finish had no effect on the relative motion or migration pattern (test series 3, Table 1).

DISCUSSION:
The test setup presented in this study simulates a worst-case scenario, as no stabilizing muscle forces or biological effects are considered. The relative motion magnitudes cannot directly be compared to micromotion values in the literature, since the measurements between the externally mounted marker sets include the bone deformation. This limitation does not influence the comparison between prostheses or conditions.

The PROXIMA tended to migrate mostly in varus direction indicating the need for good medial bone stock and lateral support. The total migration was higher than for the shaft prostheses and lack of stabilization due to suboptimal implantation or poor bone stock led to failure by medial cutout. The importance of patient selection (bone quality) and proper implantation technique became obvious.

The use of high offset heads with short prostheses as the PROXIMA should be considered carefully due to the larger effective lever arm.

The PROXIMA displayed lower cyclic relative motions compared to the clinically successful IPS and SUMMIT stems. Since the prostheses surfaces are similar, bony ingrowth could be expected for the PROXIMA. The more physiological bending of the bone indicates more desirable proximal load transfer with this short-stemmed prosthesis which may reduce the risk of stress shielding.

REFERENCES:

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Table 1: Parameters and results of each test series.

<table>
<thead>
<tr>
<th>Test</th>
<th>Prosthesis / condition</th>
<th>Relative motion [mm]</th>
<th>Migration [mm]</th>
<th>Failure [#]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PROXIMA</td>
<td>0.29 (±0.10)</td>
<td>5.22 (±3.5)</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>IPS</td>
<td>0.66 (±0.11)</td>
<td>4.71 (±0.6)</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>(porous coat)</td>
<td>0.39 (±0.08)</td>
<td>6.97 (±2.1)</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>PROXIMA</td>
<td>0.40 (±0.04)</td>
<td>4.30 (±1.0)</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 1: (a) from left to right: PROXIMA, SUMMIT, IPS prostheses, (b) top: +17 mm head, bottom: +5 mm head, (c) top: standard Porocoeat™ surface, bottom: ZTT™ surface

Figure 2: Typical total translational migration of one femur pair (test 1).