Loose Cementless Stems: Effect of Axial Loading on Rotational Stability and Risk of Periprosthetic Fracture

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Introduction: Cementless femoral stems are designed for press fit initial fixation in the femoral canal and have become the standard option in total hip arthroplasty in the United States[1]. Cementless stems allow for biological fixation and have been shown to have a better 20-year survival rate as compared to cemented stems [2]. However, micromotion between the stem and adjacent bone may lead to failure of osteointegration [3]. Loose cemented stems have been shown to have a higher risk of periprosthetic fracture than well fixed cemented stems [4, 5]. Our goal was to determine if loose cementless stems have the same increased risk. This study examined the effect of axial loading on the rotational stability of loose cementless stems, and assessed loose cementless stems as a risk factor for periprosthetic fracture.

Methods: Ten matched-pairs of cadaveric femora were evaluated by DEXA scan to ensure comparable bone mineral density between the femora of each pair. One femur from each pair was prepared to accept a press-fit anatomic tapered femoral stem (ABG™II, Stryker Inc, NJ, USA) while the other was prepared to accept a loose femoral stem of the same design. Each femur was serially reamed and broached until the broach had rotational stability when 6.8N-m (60in-lbf) was applied to it via a torque wrench. Alternating right vs. left from pair to pair, a femur was then implanted with a well-fixed stem that was the same size as the last broach while the contralateral femur was gently implanted with a stem one size smaller than the last broach to represent a loose stem. Each femur was mounted in 25 deg of adduction on an Instron 1321 biaxial servohydraulic test machine (Instron Corp., Canton MA) retrofitted with MTS TestStar™ II digital controller (MTS Corp., Eden Prairie MN), to simulate single leg weight bearing (Figure 1). While maintaining 0N of axial load, rotational stability of the specimen was assessed by rotating the specimen at 0.5 deg/s until experiencing a 2 N-m torque three times each in clockwise and counterclockwise directions. Axial displacement was recorded concurrently. The toggle measurement was repeated at 250N and 500N of axial load. While still at an axial load of 500N, each specimen was then rotated at 90 deg/s to simulate external rotation on a planted foot. Torque and rotation to failure were recorded. Toggle data was analyzed via mixed model ANOVA followed by Tukey-Kramer post-hoc pairwise comparisons. Failure data was analyzed via paired t-tests. P values less than 0.05 were considered statistically significant.

Results: One osteoporotic femur developed a calcar split at the time of stem insertion and the entire pair was excluded, leaving nine pairs of femora for the analysis. The mean toggle for the loose stems was statistically higher than well-fixed stems at 0N load (p<0.0001) while no significant difference was detected between well-fixed and loose stems in the mean toggle at 250N (p=0.7019) or 500N (p=0.9229) (Table 1). The difference in toggle between load levels 0N, 250N, and 500N for the well-fixed stems was not found to be statistically significant (p=1.0). However, the toggle for the loose stems was significantly reduced relative to 0N for both 250N (p=0.009) and 500N (p=0.003). No significant difference was detected between 250N and 500N for toggle of loose stems (p=0.9229). The loose stems subsided significantly from 0N of axial load to 250N and 500N with the subsidence at 500N also being significantly more than at 250N (p<0.0001). In contrast, the well-fixed stems did not show a statistically significant subsidence with axial load up to 500 N (p=0.1621). The well-fixed construct had greater stiffness as compared to the loose stems (p=0.003). (Figure 2) However, no significant difference was detected between loose and well-fixed stems for the torque at failure (p=0.7568) or the rotation to failure (p=0.2629).

Discussion: We explored whether cementless stems that are loose at implantation are rotationally unstable under axial loading conditions and therefore predisposed to periprosthetic femoral fracture. With axial loading, loose cementless stems demonstrated a tendency to subside and become more rotationally stable, while the rotational stability of well-fixed stems did not change with axial load. Our results support the concept of secondary stabilization of cementless stems, consistent with prior Roentgen stereophotogrammetric analysis based studies [6]. There was no difference in torque at failure and rotation to failure between loose and well-fixed stems. Loose cementless stems did not increase the risk of periprosthetic fracture, likely secondary to attainment of rotational stability with axial loading. This is in contrast to the known higher risk of periprosthetic fracture with loose cemented stems [4, 5]. This suggests that early postoperative femoral fractures with cementless tapered stems are more likely to result from insertional cracks unnoticed at the time of surgery, rather than from loose femoral stems.

Significance: Tapered femoral hip stems that are rotationally unstable at implantation subside and become rotationally stable...
with axial loading. Cementless stems inserted with moderate torsional instability do not increase the risk of early postoperative periprosthetic fracture.

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**References:**

**Figure 1:** Femur in 25 degrees of adduction to the direction of axial loading. Axis of rotation aligned with estimated center of femoral head.
Figure 2: a) Stiffness of the constructs from 5N-m to 40N-m of torque, b) torque at failure, and c) degrees of rotation to failure for well-fixed and loose stems. Statistical significance denoted by * for p=0.0033.

Table 1: Toggle (degrees) and subsidence (mm) relative to 0N before toggle for loose and well-fixed stems at different levels of axial load. Values reported as mean (sd).

<table>
<thead>
<tr>
<th></th>
<th>0N</th>
<th>250N</th>
<th>500N</th>
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<tbody>
<tr>
<td><strong>Toggle</strong></td>
<td><strong>Well-fixed</strong></td>
<td><strong>0.18(0.04)</strong></td>
<td><strong>0.18(0.04)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Loose</strong></td>
<td><strong>1.93(1.01)</strong></td>
<td><strong>0.45(0.13)</strong></td>
</tr>
<tr>
<td><strong>Subsidence before toggle</strong></td>
<td><strong>Well-fixed</strong></td>
<td><strong>0</strong></td>
<td><strong>-0.22(0.09)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Loose</strong></td>
<td><strong>0</strong></td>
<td><strong>-1.11(0.96)</strong></td>
</tr>
<tr>
<td><strong>Subsidence after toggle</strong></td>
<td><strong>Well-fixed</strong></td>
<td><strong>0.00(0.003)</strong></td>
<td><strong>-0.22(0.08)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Loose</strong></td>
<td><strong>0.50(0.36)</strong></td>
<td><strong>-1.64(1.24)</strong></td>
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