The short stem

PROMISES AND PITFALLS

Conventional uncemented femoral implants provide dependable long-term fixation in patients with a wide range of functional requirements. Yet challenges associated with proximal-distal femoral dimensional mismatch, preservation of bone stock, and minimally invasive approaches have led to exploration into alternative implant designs. Short stem designs focusing on a stable metaphyseal fit have emerged to address these issues in total hip replacement (THR). Uncemented metaphyseal-engaging short stem implants are stable and are associated with proximal bone remodeling closer to the metaphysis when compared with conventional stems and they also have comparable clinical performances. Short stem metaphyseal-engaging implants can meet the goals of a successful THR, including tolerating a high level of patient function, as well as durable fixation.

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Uncemented total hip replacement (THR) has proven to be clinically, functionally and radiologically successful in the treatment of end-stage arthritis of the hip.1-8 Because of the success of uncemented designs, THR is increasingly being performed in patients who are more active, younger and larger. These issues present particular challenges in uncemented THR, including the assurance of optimal load transfer to the proximal femur, the elimination of proximal/distal stem dimensional mismatch, the ease of removal for revision and the facilitation of minimally invasive approaches.9 Short stem uncemented femoral implants have gained popularity in addressing some of these challenges, while maintaining the current level of success experienced with uncemented implants of conventional length.

Short stem implants have been defined as those < 120 mm in length, which typically coincides with the metaphyseal–diaphyseal junction.10 A finite element analysis showed that reducing stem length to < 105 mm did not reduce the stability of implants.11 The stability of these shorter stems depends upon their stable metaphyseal fixation; a requirement for optimal proximal load transfer (Fig. 1).9,12-15 Biomechanical studies have shown that optimizing proximal load transfer can lead to the best chance of bone preservation. Arno et al,16 in a cadaveric study, evaluated changes in femoral strain based on stem length. Longer stem lengths were associated with decreased proximal femoral strain, and theoretically therefore, would be more likely to cause stress shielding.16 Chen et al12 investigated the bone stock in patients who had undergone THR with the Mayo short stem (Zimmer International, Warsaw, Indiana). Through dual energy X-ray absorptiometry (DEXA) analysis they found only a mean bone loss of 3.3% in patients with short stems, compared with the literature standard of 20% with conventional length implants17-21.

Another current challenge in THR is proximal/distal dimensional mismatch. The use of implants of conventional length can make some patients with femoral deformity difficult to treat (Fig. 2). A much more clinically relevant subset of proximal distal stem dimensional mismatch occurs in patients with thick Dorr A diaphyseal bone,22 and therefore a small internal diameter and a relatively broad metaphysis. The use of a conventional length implant may not fit safely in this type of bone. Elimination of proximal distal mismatch may reduce the rate of peri-prosthetic fractures in uncemented THR.23

Well-fixed components need occasionally to be removed. Care must be taken to extract them safely while preserving bone stock, which can be difficult in conventional length implants. Radiographs in Figure 3 demonstrate two different femoral implants that caused an adverse local soft-tissue reaction from metallic corrosion at the modular neck–stem junction.24 During revision surgery it was relatively easy to remove a well-fixed uncemented short stem.
and replace it with a non-modular short stem. The conventional length implant required an extended trochanteric osteotomy, revision to an extensively coated long-stem implant and cable and plate fixation.

Minimally invasive surgical and muscle sparing approaches, such as the direct anterior approach, often limit the view of the femur, increasing the risk of fracture with longer length stems. As stated previously, short stem implants must attain a level of efficacy similar to conventional length devices and must be implanted safely in patients of all ages and bone quality.

The authors have posed the following questions:

1) Do short stem implants achieve clinical and radiological results similar to conventional length implants?
2) Is an off-the-shelf short stem implant appropriate in patients with osteoporotic bone?
3) Does varus alignment in short stem implants affect clinical outcome?

Patients, Methods and Results

The authors initiated a prospective clinical evaluation of custom short stems designed to obtain extensive metaphyseal contact. The pilot study looked at the minimum two-year (mean 32 months; 24 to 44) clinical and radiological results from 65 hips in 60 patients who were fitted with a CT design-based customised short stem femoral implant (Biomet, Warsaw, Indiana).\(^9\) Patients aged \(> 70\) years were excluded. The mean age was 56 years (16 to 69) and the mean stem length was 90 mm (70 to 125) (Fig. 4). In 65\(^5\) THRs, the mean Harris hip score (HHS)\(^25\) improved from 49 (23 to 68) pre-operatively to 93 (73 to 100) at minimum two-year follow-up.

The clinical and radiological results from the CT-based stems inspired the development of a short ‘off-the-shelf’ stem with similar fit-and-fill characteristics. Unlike the custom cohort, there was no age restriction with this implant. While this prospective study began we continued to follow the custom cohort with up to seven years follow-up.\(^26\) In the custom group, 69 hips in 61 patients completed minimum five-year follow-up (mean 66 months (60 to 81)), the mean HHS was mean 55 (20 to 90) pre-operatively and 96 (55 to 100) post-operatively. The mean Western Ontario and McMaster Universities osteoarthritis index (WOMAC) scores\(^27\) were 51 (13 to 80) pre-operatively and 3 (0 to 35) post-operatively. All implants had radiological evidence of bony in-growth as seen by bone bridging and endosteal condensation in the proximal Gruen zones.\(^28\)

The off-the-shelf implant cohort comprised 148 hips in 139 consecutive patients treated with an uncemented short stem (Citation, Stryker, Mahwah, New Jersey) (91 mm to 105 mm) that were a close fit against the endosteal metaphyseal bone along its anterior aspect, medial calcar, posterior femoral neck, and metaphyseal flare at the bottom of the greater trochanter (Fig. 5). At a mean follow-up of 67 months (44 to 96), the mean HHS and WOMAC scores for the off-the-shelf cohort were 94 (55 to 100) and 3.3 (0 to 27), respectively. In comparison with the custom implant group, there was no difference in post-operative HHS or WOMAC scores (\(p = 0.2734\) and \(p = 0.8736\), respectively). One off-the-shelf implant subsided by \(> 2\) mm (migration of the distal tip of the stem in the femur) post-operatively. The patient was asymptomatic and the implant was stable on all subsequent follow-up. There was also one intra-operative non-displaced fracture in a patient with a...
Dorr type C femur. The fracture was treated with cerclage wires, and was stable at long-term follow-up. Bone remodelling was similar to the custom implant (Fig. 6). Of note, 40 implants (27%) were found to be placed in varus (5.2° to 10°) in the off-the-shelf cohort. No stems were placed in varus in the custom cohort. The 40 patients with off-the-shelf implants that had > 5° (5.2° to 10°) of varus alignment had no difference in clinical outcome scores compared with implants placed in neutral or valgus alignment.

As the custom short stem implant was initially restricted to patients aged < 70 years, we wanted to evaluate the performance of short stem implants in more osteoporotic
bone. In the off-the-shelf group there were 60 patients aged >70 years. Two-year follow-up of these 60 patients (65 hips) 70 years and older (mean 75 years (70 to 86)) with the off-the-shelf short stem had a mean HHS of 88 (70 to 100) and WOMAC score of 6 (0 to 43), both of which were statistically similar to the rest of the cohort.

**Discussion**

Short stem metaphyseal engaging implants provide reliable and secure fixation up to eight years following surgery. Our clinical and radiological results are achievable in patients of all ages and bone quality and short stem femoral implants are associated with positive bone remodelling in the metaphysis. Also, varus alignment after implantation with short stems does not appear to affect clinical and functional outcomes negatively. And lastly, these implants can be inserted using familiar surgical techniques.

Another institution familiar with short stem femoral implants compared a large cohort of conventional length femoral implants (Mallory-Head Porous (MHP); Biomet, Warsaw, Indiana) and short stem femoral implants (TaperLoc Microplasty; Biomet). They found equivalent clinical and functional scores between 389 conventional length stems and 269 short stems at a mean follow-up of 29 months (0.8 to 62.2). They also found a decreased complication rate (0.4%) in the short stem group compared with the conventional length group (3.1%) (p = 0.013). Santori and Santori reported reliable clinical and radiographic results in 129 custom-made uncemented high-femoral neck resection short stem implants up to eight years. The indications for the use of this stem in this cohort were...
Table I. A comparison of short stem implants of various designs, as well as un cemented conventional length implants displaying Harris hip score (HHS) and rate of failure (HA, hydroxyapatite)

<table>
<thead>
<tr>
<th>Study</th>
<th>Implant design</th>
<th>Stem fixation type</th>
<th>Hips (n)</th>
<th>Mean post-op HHS</th>
<th>Mean age (yrs)</th>
<th>Mean follow-up (yrs)</th>
<th>Stem revision for aseptic loosening (n, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stulberg and Dolan1</td>
<td>Anatomic custom short stem</td>
<td>Uncemented w/ HA</td>
<td>65</td>
<td>93</td>
<td>56</td>
<td>2</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Morrey35</td>
<td>Short stem w/ high valgus neck</td>
<td>Uncemented</td>
<td>20</td>
<td>98</td>
<td>n/a</td>
<td>2</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Pipino et al33</td>
<td>Anatomic femoral neck sparing w/ collar</td>
<td>Uncemented</td>
<td>44</td>
<td>37% Excellent</td>
<td>62.5</td>
<td>13 to 17</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Santori and Santori31</td>
<td>Custom high-neck resection short stem</td>
<td>Uncemented w/ HA</td>
<td>129</td>
<td>95</td>
<td>51</td>
<td>8</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Morrey et al32</td>
<td>Double tapered short stem modular neck</td>
<td>Uncemented</td>
<td>159</td>
<td>90.4</td>
<td>51</td>
<td>6</td>
<td>3 (1.8)</td>
</tr>
<tr>
<td>Meding et al7</td>
<td>Conventional</td>
<td>Uncemented w/ HA</td>
<td>105</td>
<td>92</td>
<td>56</td>
<td>10</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Berend et al1</td>
<td>Conventional</td>
<td>Uncemented</td>
<td>49</td>
<td>84</td>
<td>79</td>
<td>5</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Kelly et al34</td>
<td>Conventional</td>
<td>Uncemented w/ HA</td>
<td>15</td>
<td>94.5 (median)</td>
<td>54</td>
<td>11.5</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Patel et al26</td>
<td>Anatomic custom short stem</td>
<td>Uncemented w/ HA</td>
<td>69</td>
<td>96</td>
<td>56</td>
<td>5.5</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>


age of < 60 years and good bone stock. In comparison to short stem implants of other designs as well as un cemented conventional length implants, our studies show similar outcome scores and rate of failure (Table I).1,7,32–35

Conclusion
The higher rate of varus alignment has been raised as a particular concern with short stem implants. The shortened stem lacks extension into the diaphysis and therefore is unable to facilitate the overall directional placement of the implant. Nevertheless, varus placement in these short un cemented femoral components has not been proven to be detrimental in terms of clinical function. Nevertheless, looking ahead, there will need to be improved instrumentation with use of short stem implants, particularly to avoid varus alignment. Uncemented short stems are not immune from other complications, including subsidence and peri-prosthetic fractures. While these complications occur in un cemented implants of all types, further investigation into the prevalence and aetiology of those complications specific to short stem metaphyseal engaging implants is required. Also, the extent and type of optimum porous coating remains unknown. Lastly, continued follow-up is needed to evaluate the rate of long-term survivorship.

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References