Reproducibility of Femoral Offset Following Short Stem and Straight Stem Total Hip Arthroplasty

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abstract

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Bone stock–preserving short stem prostheses have gained importance in total hip arthroplasty (THA) with the use of minimally invasive surgical procedures. Because of their metaphyseal fixation and their dependency on the calcar radius, it is unknown whether the femoral offset can be reproduced with the same accuracy following short stem vs standard stem THA. This study clarifies whether it is possible to restore the femoral offset using a short stem prosthesis (Fitmore; Zimmer, Warsaw, Indiana) compared with a conventional straight stem prosthesis (CLS; Zimmer) following minimally invasive implantation using an anterolateral approach. In a prospective, randomized, double-blinded study, 80 patients underwent THA using a short stem (SS group; n=40) or CLS implant (control group; n=40). Follow-up examinations were conducted 6 weeks postoperatively. Radiological and functional outcomes were measured. Subjective assessment of quality of life was evaluated using the Harris Hip Score (HHS), the Short Form 36-item health survey (SF-36), and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Pre- and postoperative comparison of the groups’ change in offset showed no significant differences (SS group difference from pre- to postoperative, 6.1±6.5 mm; control group difference from pre- to postoperative, 6.5±7.1 mm; P=.93). Group comparison after 6 weeks revealed no significant differences in HHS, SF-36, or WOMAC. Based on these data, an equivalent reproducibility of the femoral offset was demonstrated following short stem and straight stem THA using a minimally invasive anterolateral approach. If the long-term results of short stems show a comparable survival, they represent a sensible alternative to standard stems.

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The use of short stem prostheses has gained in popularity with the increasing interest in minimally invasive approaches and bone-preserving implantation. In the setting of bone stock–dependent results after revision of total hip arthroplasty (THA), bone stock–preserving short stems could be an alternative for primary THA in young patients because this group has a high probability of undergoing revision surgery.

In principle, the minimization of perioperative soft tissue damage through minimally invasive approaches, reconstruction of hip joint geometry, and engagement of the components in vital bone stock are considered crucial for the optimization of results after THA.

Hube et al described improved early functional results with the Mayo short stem prosthesis (Zimmer, Warsaw, Indiana) compared with a standard stem implant (AGB; Stryker Howmedica Inc, Rutherford, New Jersey). Potential causes were the longer medial preparation of the femur and the associated preservation of gluteal muscle insertions in the region of the greater trochanter to implant the standard stem vs the short stem. In the setting of an individual correlation between the hip abductor muscles and hip joint geometry, the correct restoration of that geometry should be sought.

Compared with straight stems, short stems, which are engaged diaphyseally, are fixated metaphysically and are therefore susceptible to implantation in a varus position with a consecutive change of hip joint geometry through a variation of femoral offset. Due to the missing diaphyseal part, the area of fixation is reduced in short stem systems compared with a standard stem. Because the proximal part of a short stem has no endosteal cortex fixiation in the greater trochanter, the bony engagement of these stems must be realized via the calcar and the mediolateral endosteal surface in the metaphyseal-to-diaphyseal femoral portion. According to Gustke, there is a correlation between the calcar curve radius and the offset: the larger the calcar curve radius, the smaller the offset. Therefore, a valgus femur has a smaller offset, and varus femurs—with a smaller calcar curve radius—have a larger offset. The average femur shape lies between these 2 extremes, with male patients displaying a larger offset. The Fitmore stem (Zimmer) used for the current study was developed on the basis of these facts. There are 3 different stem variants: The A stem has the largest calcar curve radius with the smallest offset, the B stem is suitable for middle-range calcar curve radii, and the C stem has the smallest calcar curve radius and the largest offset.

Subsequently, this short stem system offers the possibility to respond to anatomical variabiliy, reduce perioperative bone loss, and provide muscle-sparing implantation. However, the current literature shows limited knowledge of postoperative results in terms of the reproducibility of femoral offset and functional outcomes in short stem THA. Therefore, the purpose of the current study was to show that the radiological and functional results following implantation of a Fitmore short stem using a minimally invasive approach are comparable with those following implantation of a CLS straight stem (Zimmer) via the same approach.

**Materials and Methods**

Eighty patients were included in a prospective, randomized study that comprised a short stem prosthesis group (SS group; n=40) who received the Fitmore stem and a control group (n=40) who received the CLS straight stem. The study was conducted from June 2010 to May 2011 and was examined and approved by the appropriate ethics committee. There was no selection of patients by age or body mass index (BMI). Patients with serious systemic internal diseases, connective tissue disease, or neurological conditions, as well as patients with joint infection, were excluded. Planning for the femoral component was performed for each patient according to the manufacturer guidelines for his or her respective stem type. Matching the preoperatively measured center column diaphysis (CCD) angle, the planning for the femoral component was created for the CLS stem (CCD angles: 125°, 135°, and 145°; stem size, 5-20 mm). According to the calcar curve radius, the family (A, B, or C) and the measured size (1-7) of the Fitmore stem were chosen (stem family: A [140°], B [137° or with extended offset 129°], and C [127°]; stem size: 1-7).

Patients were assigned to the 2 branches of the study at the start of the operation by opening a sealed envelope. General or spinal anesthesia was used. Mean operative time was 51.75±1.7 minutes for the control group and 50.43±1.7 minutes for the SS group (P=.6).

Follow-up treatment for both groups was standardized, with pain-oriented full weight bearing on the affected limb. Physiotherapy started on postoperative day one, with respiratory therapy, gait training in 3-point gait using crutches, and exercises for active thrombosis prevention. In addition, active and passive mobilization was introduced depending on tolerance.

For the purposes of this study, the patients were examined preoperatively and 6 weeks postoperatively. Radiological and clinical monitoring were conducted, and examination forms and questionnaires were completed. Harris Hip Score (HHS), Short Form 36-item health survey (SF-36), and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) results were recorded. A blinded investigator (F.Z.) conducted the examinations. The patients included were told which implant had been used only when the study had ended.

Preoperative diagnostic radiography included images of the hip joint in 2 planes. Radiological images in 2 planes were also taken 6 weeks postoperatively. The images were examined for implant position, loosening, and migration. Offset was measured as depicted in Figure 1.
To measure the difference in leg length, a reference line between the acetabular teardrop figures was drawn. The distance between the reference line and the lesser trochanter on both sides was defined as the difference in leg length.

A power analysis indicated a group size of 40 patients per group. The data were recorded, presented, and evaluated with the aid of SPSS version 15 statistical software (SPSS Inc, Chicago, Illinois). The data are presented as mean±SD. Group differences for parameters were assessed using the Mann-Whitney U test. Pre- vs postoperative pairwise comparison was assessed using the Wilcoxon test. A P value of .05 or less was considered significant.

Surgical Technique

Preoperative estimation of the size of the femoral component for an exact restoration of the femoral offset was assessed according to the manufacturers’ guidelines. A minimally invasive anterolateral approach with the patient in a lateral position was used in both groups.\(^{14,15}\)

The incision was made from the anterior greater trochanter in the direction of the anterior superior iliac spine. The fascia was cut parallel to the skin incision. The intermuscular interval was opened bluntly. The hip joint capsule was exposed and opened to implant the THA. The surgical procedure was conducted by a single surgeon (R.H.). Patients in the SS group were implanted unilaterally with a Fitmore prosthesis, and patients in the control group were implanted with a CLS prosthesis. For the acetabular component, the Allofit cup (Zimmer) was used. No complications were observed in the study cohort.

Results

Eighty patients (42 women and 38 men) were included in this study. Demographic data are shown in Table 1.

Radiological Data

No signs of loosening or migration were found in either group. Preoperatively, the SS group had a mean offset of 52.7±6.6 mm and the control group had a mean offset of 51.1±7.1 mm (P=.28). Six weeks postoperatively, the SS group had an offset of 57.5±9.7 mm and the control group had an offset of 57.6±6.5 mm (P=.41). Pre- and postoperative comparison of the groups’ change in offset showed no significant differences (SS group difference from pre- to postoperative, 6.1±6.5 mm; control group difference from pre- to postoperative, 6.5±7.1 mm; P=.93; Figure 2).

Leg lengths in the 2 groups were compared preoperatively (SS group, 0.1±3.7 mm; control group, -1.3±4.6 mm; P=.2). Six weeks postoperatively, leg-length discrepancy was -0.7±4.0 mm in the SS group and -2.9±3.5 mm in the control group (P=.01). Pre- and postoperative comparison of the groups’ change in leg length showed no significant differences (SS group difference from pre- to postoperative, 2.7±2.1 mm; control group difference from pre- to postoperative, 3.5±2.5 mm; P=.17).

Harris Hip Score

The Harris Hip Score showed a uniform distribution preoperatively (Table 2). Mean preoperative HHS was 63.3±13.3 points in the SS group and 64.8±14.8 points in the control group (P=.95). Six weeks postoperatively, mean HHS was 83.4±12.4 points in the SS group (pre- vs postoperative, P>.0001) and 84.75±13.9 points in the control group (pre- vs postoperative, P>.0001). Comparison of the mean postoperative total HHS in the SS group vs the control group showed no significant difference (P=.49). Figure 3
shows the assessment of HHS preoperatively and 6 weeks postoperatively.

Mean flexion in the SS group was 97.0°±16.9° preoperatively and 98.0°±9.8° at final follow-up (P=.81). Mean flexion in the control group was 95.3°±13.1° preoperatively and 94.2°±10.9° at final follow-up (P=.67). No significant difference was found between the SS and control groups (SS group vs control group 6 weeks postoperatively, P=.08). Mean external rotation in the SS group was 18.5°±9.8° preoperatively and 22.6°±5.8° at final follow-up (P=.02). Mean external rotation in the control group was 17.1°±9.2° preoperatively and 20.2°±9.4° at final follow-up (P=.06). Comparison of external rotation in the SS group vs the control group showed a significant difference (SS group, 22.6°±5.8° vs control group, 20.2°±9.4° six weeks postoperatively; P=.04).

Short Form 36-Item Health Survey

Preoperatively, there were no statistically significant differences between the study groups in the SF-36 scale values (physical functioning: SS group, 39.5±20.3 vs control group, 41.5±22.5; P=.7). Postoperatively, there was a significant increase in the SF-36 score in both groups (physical functioning: SS group, 59.8±21.2 [P<.0001] vs control group, 62.4±21.5 [P<.0001]). Comparison of the scale values between the groups showed no significant difference postoperatively (physical functioning: SS group vs control group, P=.48). Further scale values are shown in Table 3.

Western Ontario and McMaster Universities Osteoarthritis Index

Mean preoperative WOMAC score was 160.2±52.4 points in the SS group and 151.2±67.2 in the control group (P=.7). Six weeks postoperatively, mean WOMAC score was 72.9±40.6 points in the SS group and 66.6±39.5 in the control group (P=.46; SS group pre- vs postoperative, P=.0001; control group pre- vs postoperative, P=.0001; Table 4).

DISCUSSION

A potential advantage of short stem prostheses is the more muscle-preserving insertion of the femoral components, offering a bone stock–sparing option essential for younger patients.16 The fixation of short stems relies on maximizing the bony contact in the calcar area. The radius of the calcar has a direct influence on the femoral offset.1 The purpose of this study was to investigate whether the femoral offset is reproducible using a short stem prosthesis vs a straight stem prosthesis when a minimally invasive anterolateral approach is used. Based on the data obtained, the short stem prosthesis offers the possibility to reproduce the femoral offset with the same accuracy as the straight stem prosthesis. No differences were observed between the 2 groups in terms of HHS, SF-36, or WOMAC scores.

The offset was measured as described by Brown et al (Figure 1).13 Ettinger et al17 measured the femoral offset following short stem prosthesis implantation based on the distance between the lateral wall of the foramen obturatorium and the lateral point of the trochanter major. An abducted or adducted femur will result in an incorrect femoral offset measurement. The method of Brown et al13 overcomes this problem by measuring the distance between the center of the medullary canal of the femur and a par-

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Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control Group</th>
<th>SS Group</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>19.4±10.5</td>
<td>17.6±9.5</td>
<td>.38</td>
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<tr>
<td>Function</td>
<td>37.3±6.5</td>
<td>38.2±6.1</td>
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</tr>
<tr>
<td>Deformity</td>
<td>3.4±1.45</td>
<td>2.8±1.8</td>
<td>.13</td>
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<td>Range of motion</td>
<td>4.6±0.47</td>
<td>4.7±0.5</td>
<td>.62</td>
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<tr>
<td>Overall</td>
<td>64.8±14.8</td>
<td>63.4±13.3</td>
<td>.95</td>
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<tr>
<td>6 wk postop</td>
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<tr>
<td>Pain</td>
<td>37.1±8.04</td>
<td>34.8±9.08</td>
<td>.22</td>
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<tr>
<td>Function</td>
<td>38.8±9.4</td>
<td>39.65±5.6</td>
<td>.63</td>
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<tr>
<td>Deformity</td>
<td>3.9±0.15</td>
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<td>.57</td>
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<tr>
<td>Range of motion</td>
<td>4.8±0.36</td>
<td>4.9±0.3</td>
<td>.32</td>
</tr>
<tr>
<td>Overall</td>
<td>84.7±13.9</td>
<td>83.4±12.4</td>
<td>.49</td>
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</table>

Abbreviations: HHS, Harris Hip Score; postop, postoperative; preop, preoperative; SS, short stem.
Parallel line through the rotational center of the femoral head.

Radiological analysis showed no significant increase in femoral offset following short stem implantation. Implantation of the straight stem led to an almost identical increase in offset. The largest investigation conducted to date of 500 short stem prostheses of the type also used in the current study contains no data on postoperative offset. The largest investigation conducted to date of 500 short stem prostheses of the type also used in the current study contains no data on postoperative offset.

In the current study, the SS group had a significantly smaller postoperative leg-length discrepancy than the control group (-0.7 vs -2.95 mm, respectively; P=.013). This leads to the conclusion that leg lengths were reconstructed more accurately on average with the Fitmore stems. In terms of pre- vs postoperative leg-length discrepancy, there was no difference between stem types. The figures are comparable with those in the literature. Jerosch et al18 reported a postoperative leg-length discrepancy of 0.09±0.36 mm with the MiniHip short stem prosthesis. Benedetti et al22 concluded that a change in leg length within the range of 20 mm does not affect the symmetry of time-distance parameters and hip motion. According to Benedetti et al,25 the leg-length change observed in the current study does not affect the function of the THA.

Mean operative time was similar for the groups in the current study (approximately 50 minutes) and agreed with information in the literature.26

Pre- and postoperative HHS scores were comparable with those published in the literature.27,28 In their study, Hube et al8 demonstrated a significantly better HHS score following implantation of the Mayo short stem prosthesis compared with a standard AGB stem using a translhumeral approach. In the current study, a minimally invasive anterolateral approach was used. The fact that this study did not identify a functional difference between the 2 stem systems may be due to the more muscle-preserving preparation of the pelvitrochanteric musculature. The short stem requires a smaller operating field for implantation, but the minimally invasive anterolateral approach appears to have the potential for implanting a significantly larger stem with a similarly low degree of muscle trauma. Using this

<p>| Table 3 |
| SF-36 Scores at Final Follow-up |
| Mean±SD SF-36 Score |</p>
<table>
<thead>
<tr>
<th>Domain</th>
<th>Control Group</th>
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<th>P</th>
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<tbody>
<tr>
<td>PF</td>
<td>62.4±21.5</td>
<td>59.8±21.2</td>
<td>.48</td>
</tr>
<tr>
<td>RP</td>
<td>68.1±43.1</td>
<td>55.4±47.8</td>
<td>.23</td>
</tr>
<tr>
<td>BP</td>
<td>67.2±21.7</td>
<td>58.5±20.6</td>
<td>.09</td>
</tr>
<tr>
<td>GH</td>
<td>79.0±17.1</td>
<td>75.8±15.8</td>
<td>.39</td>
</tr>
<tr>
<td>VT</td>
<td>70.9±15.3</td>
<td>64.4±15.4</td>
<td>.09</td>
</tr>
<tr>
<td>SF</td>
<td>88.4±15.6</td>
<td>81.6±21.7</td>
<td>.14</td>
</tr>
<tr>
<td>RE</td>
<td>94.2±22.5</td>
<td>89.2±26.6</td>
<td>.38</td>
</tr>
<tr>
<td>MH</td>
<td>81.2±14.4</td>
<td>80.1±14.6</td>
<td>.73</td>
</tr>
</tbody>
</table>

Abbreviations: BP, bodily pain; GH, general health; MH, mental health; PF, physical functioning; RE, role emotional; RP, role limitations due to physical health; SF, social functioning; SS, short stem; VT, energy/fit and fatigue.

<p>| Table 4 |
| WOMAC Scores at Final Follow-up |
| Mean±SD WOMAC Score |</p>
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control Group</th>
<th>SS Group</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>9.3±8.3</td>
<td>11.1±8.9</td>
<td>.37</td>
</tr>
<tr>
<td>Stiffness</td>
<td>8.7±5.4</td>
<td>7.4±5.2</td>
<td>.65</td>
</tr>
<tr>
<td>Function</td>
<td>49.3±30.9</td>
<td>54.4±29.7</td>
<td>.46</td>
</tr>
<tr>
<td>Overall</td>
<td>66.6±39.5</td>
<td>72.9±60.6</td>
<td>.46</td>
</tr>
</tbody>
</table>

Abbreviations: SS, short stem; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

Charles et al19 and Bourne and Rorabeck20 reported that femoral offset is correctly reconstructed in only 40% of cases after THA. The change in offset after THA is a matter of controversy in the literature. An increased offset leads to improved muscle strength and a greater range of motion. In their study, Sakalkale et al21 showed that a larger offset is associated with a lower wear rate. Conversely, Little et al22 reported an increased wear rate, although it should be noted that the wear rates depend not only on the joint contact forces influenced by the offset but also on the level of activity and the bearing used. Adverse micromovements were not detected following an increase in offset.23 Disadvantages of increased offset are the increase in medial bending load and loading of the distal portion of the prosthesis.18,22-24 Moreover, an increased offset can lead to an increased risk of trochanteric pain.20 Several authors described the biomechanical advantages of an anatomical reconstruction of the physiological femoral offset.10,17,18,20
approach, it appears possible to preserve the musculature independently of the stem system and, as a result, to achieve an equivalent postoperative functional result. Lombardi et al.\textsuperscript{27} described similar figures for 591 patients. A total of 640 Taperloc short stems (Biomet, Warsaw, Indiana) were implanted. On average, total HHS improved from 50 to 80 points after 7.3 months.\textsuperscript{27} Lazovic and Zigan\textsuperscript{29} performed short stem implants in 55 patients.

In the current study, the examination of mobility showed significantly better external rotation following implantation of a short stem prosthesis. However, in the authors’ opinion, a 2\textdegree{} difference in external rotation must be regarded as clinically irrelevant. The majority of studies published to date have a retrospective study design or lack a control group.\textsuperscript{1,18,27,29,30}

The SF-36 showed no significant differences between the short and standard stem. The scores on the individual subscales were comparable with those in the literature, and the groups did not differ significantly either pre- or postoperatively.\textsuperscript{31-34}

The predictive power of this study is limited by the short follow-up interval. As a consequence, the results allow an assessment of only a limited time period shortly after implantation of the prosthesis. Despite the small number of cases (n=80), significant differences (eg, leg length, range of motion) were demonstrated, so it is possible to draw conclusions with regard to group differences.

**CONCLUSION**

This study shows that the Fitmore short stem prosthesis, compared with the conventional CLS prosthesis, shows an equivalent reproducibility of the femoral offset and functional results. The authors believe that the reason for the functionally equivalent results lies in the use of a minimally invasive implantation procedure, which is apparently independent of the stem system. The bone stock–preserving aspect can be counted as an advantage for young patients likely to undergo revision surgery.

**REFERENCES**


