Comparing the Accuracy of Radiographic Preoperative Digital Templating for a Second- Versus a First-generation THA Stem

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Abstract: This study assessed the accuracy of preoperative digital templating for a second-generation cementless stem compared with its first-generation design. A prospective cohort of 100 consecutive patients who had undergone a primary total hip arthroplasty using a new second-generation cementless stem was compared with the prior 100 hips that had received the first-generation stem. The authors believe that the second-generation stem may allow equal or more accurate digital templating compared with its predicate design.

The use of digital radiographs and templating software is increasing every year due to the aging population, expansion of THA indications in younger and more active patients, and improvement in the results of the procedure with a variety of pathologies. Although acetate templating is reported as the gold standard for THA and has proven reliability and accuracy, templating using digital radiographs has many potential advantages, including ease of use, ability to digitally save or transfer the files for later use, and potentially lower costs. The optimal purpose of digital templating with THAs is to improve preoperative planning by potentially matching the normal anatomy of the femoral canal, which may lead to improvements in alignment, reduction of overall operating room costs, and potentially superior clinical outcomes.

Several studies have evaluated the accuracy of digital templating in cementless THA using 2- (2-D) or 3-dimensional (3-D) techniques. Although accuracy of previously published 2-D studies have reported accuracies of 35% to 79% for digital templates to correctly predict the size of the femoral stem component. Introduction of new implant designs may raise the possibility that preoperative templating for the new stems may not be as accurate as that for the older-generation design, which may have been used for many years with good results. In such instances, prospective studies may be necessary to radiographically evaluate the new implant designs regarding stem fit and fill and preoperative templating accuracy.

The purpose of this study was to assess the accuracy of preoperative templating in predicting the actual implanted stem size for a new second-generation proximally porous-coated, tapered cementless stem compared with its first-generation design. The basis for this new femoral stem design was to offer a potentially better implant fit and improved canal fill to maximize metaphyseal engagement.

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Drs Issa, Pivec, and Boyd have no financial relationships to disclose. Dr Harwin receives royalties from Stryker and SLACK Incorporated, is on the speakers bureau for Stryker and Convatec, is a paid consultant for Stryker and Convatec, and has stock or stock options at Stryker; Mr Wuestemann and Dr Nevelos are employed by Stryker Orthopaedics; Dr Mont receives royalties from Stryker; is a consultant for Janssen, Sage Products, Inc, Salient Surgical, Stryker, OCSI, and TissueGene; receives institutional support from Stryker; and is on the speakers bureau for Sage Products, Inc.

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doi: 10.3928/01477447-20121120-03
For both groups, the authors evaluated the following questions: (1) What percentage of the time did the preoperative templates accurately predict the exact size of the implanted femoral stem?; (2) what percentage of the time did the preoperative templates accurately predict the size of implanted stem within ±1 or ±2 sizes?; and (3) did the preoperative digital templates under- or overestimate the actual size of the implanted stems?

Materials and Methods

Preoperative digital templates in a prospective cohort of 100 consecutive patients who had undergone a primary THA between January and June 2012 (after a learning curve of 10 THAs) using a second-generation cementless stem were compared with the prior 100 hips that had received the first-generation stem. All procedures were performed at a single, high-volume institution by an experienced, fellowship-trained adult reconstructive surgeon (M.A.M.). Participants were 54 women and 46 men with a mean age of 55 years (range, 21-78 years) who had received the second-generation stem and 52 men and 48 women with a mean age of 56 years (range, 23-80 years) who had received the first-generation stem. Appropriate institutional review board approval was obtained for this study (Table 1).

Anteroposterior (AP) radiographs obtained prior to each THA were used to predict a preoperative femoral stem size by using templating software (TraumaCad, Voyant Health, Petach-Tikva, Israel), which had been used at the authors’ institution for the previous 5 years (Figures 1, 2).

To obtain AP hip radiographs, patients were placed in the supine position and their lower limb was medially rotated approximately 15° ± 5° to center the femoral shaft parallel to the cassette, which was placed at the midshaft of the femur. While shielding the reproductive organs and placing the patient’s arm in a comfortable position, AP hip radiographs were obtained. Magnification of the radiographs was standardized using a calibration ball technique.24 All primary THAs in both groups were performed through an anterolateral approach with the senior author (M.A.M.) blinded to the preoperative template results. All patients had received Trident acetabular components (Stryker Orthopaedics, Mahwah, New Jersey), which were implanted using a press-fit technique with or without screws. Therefore, the only difference in the procedure between the 2 groups was the type of femoral stem component.

The older first-generation stem was the Accolade TMZF femoral component device (Stryker Orthopaedics), which is a tapered, proximally porous-coated titanium alloy cementless stem with a 50-µm hydroxyapatite nominal thickness coating. The second-generation stem was the Accolade II (Stryker Orthopaedics), which is a new stem based on the predicate design, but with a morphologic wedge and a size-specific medial curvature that was designed based on a study of 556 CT scans of cadaveric left femora.25

The bones were obtained from a diverse population of individuals based on age groups (mean, 66 years; range, 40-93 years), sex (57% male and 43% female), and ethnicities (69% Caucasian and 16% Asian). Compared with the first-generation design, the stem in the second-generation design is approximately 15 mm shorter, has a variable medial curvature, and has a distal lateral relief.

Postoperatively, implant records for all patients were obtained, and the actual femoral stem size that was implanted for each patient was recorded and compared with the preoperative template. The accuracy of preoperative templating between the 2 stem types was evaluated by comparing how many times the preoperative template and the actual stem size were identical, within ±1 stem size, within ±2 stem sizes, and within more than 2 stem sizes. All templating procedures were performed by 2 authors (K.I., B.B.), similar to reports by Ku et al26 and Steinberg et al.16 To evaluate inter- and intraobserver reliability, 25 AP hip radiographs in each group were randomly reassessed, resulting in a mean Pearson correlation coefficient of 0.84 and 0.81, respectively.

All data were recorded using an Excel spreadsheet (Microsoft Corporation, Redmond, Washington). Statistical analyses were performed using Student’s t-test and Fisher’s exact test to compare the accuracy of preoperative templating with the actual implanted stem sizes between the first- and second-generation stems. Using a 95% confidence interval (CI), a P value less than .05 was considered significant.

Results

No significant differences were found in the accuracy of first- and second-generation preoperative digital templates to correctly predict the exact size

<table>
<thead>
<tr>
<th>Parameter</th>
<th>First-generation Stem</th>
<th>Second-generation Stem</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of hips</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>No. of men:women</td>
<td>46:54</td>
<td>52:48</td>
<td>.71</td>
</tr>
<tr>
<td>Mean age (range), y</td>
<td>56 (23-80)</td>
<td>55 (19-79)</td>
<td>.74</td>
</tr>
<tr>
<td>Accuracy to predict the stem, %</td>
<td></td>
<td></td>
<td>.39</td>
</tr>
<tr>
<td>Exact size</td>
<td>52</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>±1 size</td>
<td>84</td>
<td>89</td>
<td>.3</td>
</tr>
<tr>
<td>±2 sizes</td>
<td>98</td>
<td>99</td>
<td>.57</td>
</tr>
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<td>&gt;2 sizes</td>
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<td>.57</td>
</tr>
<tr>
<td>Overall undersized, %</td>
<td>32</td>
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<td>.42</td>
</tr>
<tr>
<td>Overall oversized, %</td>
<td>12</td>
<td>11</td>
<td>.53</td>
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of the implanted femoral stem component (odds ratio [OR], 1.27; 95% CI, 0.72-2.2). The second-generation preoperative templates predicted the exact size of the femoral stems in 58% (n=58) of the cases, which was higher than 52% (n=52) in the first-generation stem; however, this difference (6% improvement in accuracy) was not statistically significant (P=.39) (Figure 3).

No significant differences were found between the first- and second-generation preoperative digital templates in accurately predicting the size of the implanted femoral stems within ±1 size (OR, 1.54; 95% CI, 0.67-3.5; P=.30), within ±2 sizes (OR, 2.02; 95% CI, 0.18-22.6; P=.57), or within more than 2 sizes. The second-generation stem digital templates predicted the stem size within ±1 size in 89% of cases, within ±2 sizes in 99% of cases, and within more than 2 stem sizes in 1% of cases. In comparison, the first-generation stem digital templates predicted the stem size within ±1 size in 84% of cases, within ±2 sizes in 98% of cases, and within more than 2 sizes in 2% of cases.

Overall, a higher number of preoperative digital templates were undersized than oversized for both templates. For the second-generation stem, of the 38 stems that did not match the actual implanted size, 27 (71%) stems were undersized and 11 (29%) were oversized. Similarly, of the 44 stems that did not match the exact implanted size for the first-generation stem, 32 (72%) stems were undersized and 12 (28%) were oversized.

**Discussion**

Total hip arthroplasty is one of the most successful and cost-effective procedures in orthopedics. Preoperative planning is an integral part of hip joint reconstruction and is thought to potentially increase surgical precision, reassure availability of component sizes, reduce operative time and the incidence of prosthetic loosening, and minimize related complications (eg, periprosthetic fracture, instability, and limb-length discrepancy).12,17,20,27-32

Müller33 and Charnley34 recommended preoperative planning during the 1970s, although a limited number of femoral stem sizes were available at that time. The goal of preoperative templating in cementless THA is to maximize the surgeon’s ability to obtain metaphyseal/medullary canal filling, which may not be as important in cemented cases.35 Advancement in technology and the introduction of new implant designs raises the possibility that preoperative templating for new designs may not be as accurate at that for older-generation designs, which have been used for many years with excellent results.

The purpose of this study was to compare the accuracy of preoperative digital templating...
in predicting actual implanted femoral size in a second-generation proximally porous-coated, tapered cementless stem with a first-generation design. The authors found equally accurate digital templating outcomes with the second-generation stem compared with the first-generation stem, with trends to potentially improved outcomes.

Several potential limitations existed for this study, including the relatively small sample size in each group. The implanted femoral stem was always assumed to be the final optimal size, which may not always be the case. Femoral rotation was difficult to analyze on plain 2-D radiographs; thus, this could have introduced some bias to the study.

Nevertheless, the authors believe that the results are valuable due to the study’s prospective design and blinded evaluations, as well as its being the first to compare the accuracy of digital templating for this new stem design. Further prospective studies with bigger sample sizes are needed to better evaluate whether the new design offers a statistically significant improvement in preoperative templating outcomes compared with its predicate design (Table 2).

The current results are in agreement with previous studies that have evaluated the accuracy of 2-D digital preoperative templating compared to implanted femoral stem sizes (Figure 4). Steinberg et al. evaluated results of preoperative templating in a series of 73 patients with a mean age of 67 years (range, 19-86 years) undergoing THA. They reported exact component size prediction in 47% of cases, within ±1 size in 87% of cases, within ±2 sizes in 96% of cases, and within more than 2 sizes in approximately 4% of cases. Shaarani et al. evaluated the accuracy of digital preoperative templating in a series of 100 consecutive cementless primary THAs compared with the actual implanted stem sizes. They reported that preoperative templating was able to predict the exact stem size in 36% of cases, within ±1 size in 75% of cases, and within ±2 sizes in 98% of cases. Similar to these studies, the current authors also found that 98% and 99%, respectively, of the preoperative templates were within ±2 stem sizes from the implanted stem sizes.

Iorio et al. compared the accuracy of acetate (250 hips) and digital (50 hips) templating for primary THA. They reported that digital templating predicted the femoral stem within 1 size in 74% of the cases (37 of 50 hips). However, digital measurements significantly underestimated the stem size (positive error values, $P<.001$). The current study similarly showed a higher ratio of preoperative template predicting an undersized femoral stem than an oversized femoral stem. One reason for this finding may be that the operator may not accurately predict how much of the femoral canal would actually be broached and reamed.

Accuracy and reliability of 2-D digital templating has been previously reported to be similar or superior to conventional analog templating. However, 3-D preoperative digital templating has also been used in primary THA with superior results reported when compared with 2-D templates. In a prospective, randomized study, Sariali et al. compared the accuracy of 3-D preoperative templating using CT scanning in 30 cementless THAs with 2-D templating in 30 patients. They reported that 100% of the implanted stems matched the preoperative size in the 3-D group compared with 43% in the 2-D group. This level of accuracy is higher than any other 2-D report in the literature; however, 3-D templating is less commonly used due to the unnecessary patient radiation exposure and the extra costs.

Contradictory reports exist regarding the influence of surgical experience, familiarity with templating software, and reliability and reproducibility of preoperative templating in primary THA. However, femoral component templating has been reported to be easier and more accurate than acetabular templating. In the current study, a good inter- and intraobserver accuracy was achieved, which is consistent with previous published reports.

Previous studies have reported excellent clinical outcomes using the first-generation cementless stem used in the current study. Casper et al. reported the outcome of 145
consecutive patients (158 hips) with a mean age of 68 years (range, 44-86 years) who had undergone a primary THA using the first-generation stem. At a mean follow-up of approximately 7.5 years (range, 5-9 years), they reported an overall 97.4% survivorship (0.6% of the failures were due to femoral component loosening). Costa et al reviewed 45 consecutive patients younger than 30 years (mean age, 20 years) who had undergone 53 primary THAs using the first-generation stem. At a mean follow-up of 5 years (range, 2-7 years), the overall survivorship was 96% with no femoral stem failures. In addition, 91% of patients had achieved a Harris Hip Score of more than 80 points and a mean University of California Los Angeles activity score of 8 at final follow-up.26

In the current study, the new second-generation stem showed a trend toward improved preoperative templating outcomes (demonstrating better fit) when compared with the first-generation stem; however, the differences were not statistically significant. Preoperative digital 2-D templates for the first- and second-generation stems accurately predicted the exact size of the implanted stem in 52% and 58% of cases, within ±1 size in 82% and 89% of cases, and within ±2 sizes in 98% and 99% of cases, respectively. For the templates that had not exactly matched the implanted stem, a higher number of the templates were undersized than oversized.

The authors believe that the second-generation stem may provide equally accurate digital templating compared with its predicate design. The authors are currently prospectively following these patients to determine whether this newer implant design has a high implant survivorship and similar excellent clinical outcomes compared with the first-generation design. 

REFERENCES


