An Original Study

Accuracy of Digital Templating in Total Hip Arthroplasty

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Abstract

Digital radiography is becoming the standard of care for many hospitals and clinics worldwide. The introduction of this new standard has led to the development of arthroplasty templating software. We sought to compare our results using the standard acetate method with the new software method. Our digital preoperative plan was accurate to within 1 size in 78% of the acetabular components and 90% of the femoral components. The manually templated plan was accurate to within 1 size in 67% of the acetabular components and 82% of the femoral components. There did not appear to be any correlation between body mass index and inaccuracies in the preoperative template.

Digital templating is an accurate tool to preoperatively plan total hip arthroplasty. The accuracy demonstrated in this study should be achieved easily with any digital templating software. The benefit comes from the ability to scale the templates to the actual x-ray magnification. We expect that this improved accuracy over traditional acetate templating will enhance our ability to restore normal hip biomechanics.

Preoperative planning is an essential and important step in total hip arthroplasty (THA).[1,2] The emergence and implementation of digital radiography have necessitated changes in the way surgeons plan THA. Preoperative templating permits assessment of bone stock and deformity, which may require special implants or techniques. Proper placement of appropriately sized implants allows restoration of proper leg length and offset. When this plan is executed in the operating room, the biomechanics of the hip are restored.

Digital templating software has been developed for preoperative planning of THA in an entirely digital environment. With a scaling marker placed at bone level, the digital radiograph can be scaled appropriately, thereby eliminating the planning errors that result from major discrepancies in radiographic magnification. Digital templating algorithms have been developed and implemented with good results.[3] Each software manufacturer offers proprietary user interfaces and "wizards" to streamline the process, but the basic steps are applicable across all platforms (Figure 1).

The goal of this study was to evaluate the accuracy of our early digital templating experience and to compare it with that of our conventional technique.

Methods

Newly acquired digital templating software was made available to arthroplasty fellows at a specialty orthopedic surgery hospital in October 2006. One hundred twenty-one consecutive primary THAs performed by 3 attending surgeons around this time period were retrospectively evaluated to identify which patients had been templated with the new digital templating software before undergoing surgery. We identified 51 patients, and this group represents our early experience with digital templating.

The arthroplasty fellows used Impax digital templating software (Agfa, Mortsel, Belgium)[4] to template the digital radiographs. The goal of templating the hip was to prepare a preoperative plan to restore equal leg length and anatomical offset.[3] One cementless acetabu-

1) Determine the magnification of the radiograph.
2) Determine the orientation of the pelvic axis by drawing a line between the acetabular teardrops.
3) Determine whether a limb-length discrepancy is present.
4) Position the acetabular component to establish the new center of rotation of the hip joint.
5) Determine the size of the femoral component needed to best recreate leg length and offset.
6) Position the femoral component within the bone so that the center of rotation of the femur overlays the center of rotation of the acetabular component or at the appropriate level to restore leg length.
7) Measure and record the level of the femoral neck resection and other intraoperative measurements such as the distance between the lesser trochanter to the center of rotation of the head.

Figure 1. Digital templating steps.

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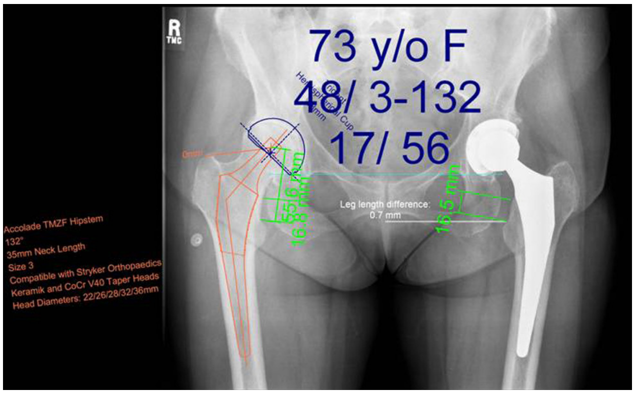
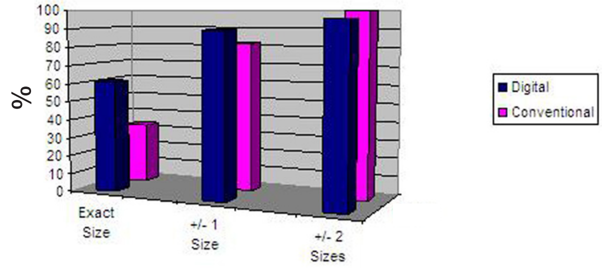


Figure 2. Sample digital template.



	Exact Size, %	+/- 1 Size, %	+/- 2 Size, %
Digital	61	90	96
Conventional	33	82	100

Figure 3. Accuracy of stem size predictions.

lar component, Trident (Stryker, Mahwah, New Jersey), and 2 cementless femoral components, Secur-Fit Max or Accolade (Stryker), were used. The preoperative templated sizes for cup and stem were recorded. The digital template was saved and used during the operative case (Figure 2).

For the purposes of the study, printed films of the same radiographs for all 51 patients were also made. These radiographs were templated using the standard acetate overlays provided by the implant manufacturer. Standard magnification of 20% was used. Planned sizes for cup and stem were recorded.

Preoperative radiographs were obtained with 1 of 2 systems available in the hospital: Agfa CR (Mortsel, Belgium) and Swissray DR (Hochdorf, Switzerland). Images were acquired on a 14×17-in cassette with a 40-in tube-to-cassette distance and standard resolution of 6 pixels/mm on the Agfa system and 3.5 lp/mm (lines per millimeter) spatial resolution on the Swissray system. All radiographs were obtained with radiographic scaling markers placed at bone level. The known dimensions of the marker were entered into the software. The digital templating software automatically calibrates the image and template overlays according to the known size of the marker. For the printed images, the marker was measured, and percentage magnification was estimated with the formula: Measured Diameter of Radiopaque Marker / Actual Diameter of Radiopaque Marker × 100. Patient height and weight were recorded from the medical record, and body mass index (BMI) was calculated.

Table I. Characteristics of Patients (n=51)

Characteristic	Summary
Mean (SD) age, y	59.9 (11.5)
Mean (SD) height, in	67.2 (4.1)
Mean (SD) weight, kg	81.3 (21.2)
Mean (SD) body mass index, kg/m^2	27.7 (5.8)
No. (%) of patients with body mass index >30	12 (23.5)

Statistical Analysis

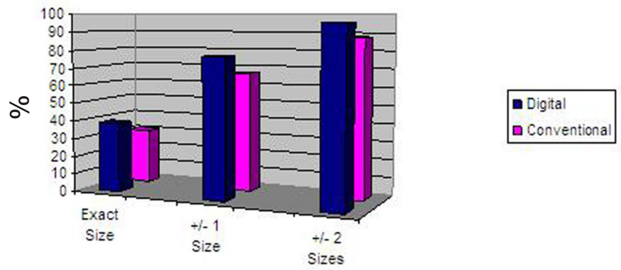
All data were entered into an Excel spreadsheet (Microsoft, Redmond, Washington). Agreement between templated cup and stem sizes and actual cup and stem sizes was computed for the digital and manual methods using a weighted κ analysis. Weighted κ values are appropriate when the data are ordinal, such that a 2-size disagreement is considered more incorrect than a 1-size disagreement. The effect of BMI was examined by stratifying the group into patients with BMI greater than 30 kg/m^2 and patients with BMI of 30 kg/m^2 or less. These strata were compared using the Fischer exact test for comparison of categorical variables. All computations were performed with SAS Version 9 (SAS, Cary, North Carolina).

Results

Table I lists the descriptive statistics. Mean (SD) magnification of the conventional radiographs was 119% (6.3%).

The digital and manually templated plans for both stem and cup were highly correlated (Figures 3, 4). The digitally templated stem was within 1 size of the actual stem in 90% of the cases. The manually templated stem was within 1 size in 82% of the cases. Similarly, the digital plan for the acetabular component was within 1 size in 78% of the cases and within 2 sizes in 96% of the cases. Using the manual method, the cup was within 1 size in 67% of the cases and within 2 sizes in 88% of the cases.

There were more outliers in the manual group, with 6 patients having a cup size that was more than 2 sizes different from the templated cup size. In all cases, the templated cup size was smaller than the actual implanted cup size. All stems were within 2 sizes of the manually templated sizes. Outliers occurred in the digitally templated group as well, with 2 patients having a stem size more than 2 sizes different from the digitally templated size. One of the stems was larger than the templated size and 1 was smaller. Two patients had a cup size that was more than 2 sizes different from the digitally templated size. As with the manually templated cups, these differences were all in patients who were templated for a size smaller than what was actually implanted.



	Exact Size, %	+/- 1 Size, %	+/- 2 Size, %
Digital	39	78	96
Conventional	31	67	88

Figure 4. Accuracy of cup size predictions.

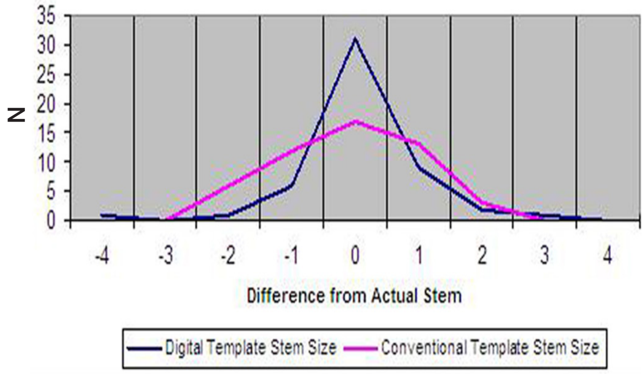


Figure 5. Distribution of stem sizes.

The statistical analysis showing the κ agreement between the templating methods, and the actual sizes of the stems and cups used is shown in Table II.

For the stem, there was high agreement between the digital templating method (weighted κ, 0.88; 95% confidence interval [CI], 0.82-0.94) and the manual templating method (weighted κ, 0.81; 95% CI, 0.76-0.87). With the numbers available, the Fisher exact test did not detect any significant difference between the κ values for patients with BMI of more than 30 kg/m^2 (digital, P = .50; manual, P = .29).

For the cup, there was lower agreement between the digital method (weighted κ, 0.56; 95% CI, 0.44-0.69) and the manual method (weighted κ, 0.43; 95% CI, 0.30-0.55). Again, the Fisher exact test did not detect any differences in the κ agreement between BMI strata.

Discussion

Many hospitals have sought to reduce costs associated with radiographic film printing and storage with implementation of Picture Archiving and Communication Systems technology. Light boxes are replaced with computer monitors. Instead of receiving film jackets, patients are given optical disks that include their radiographs. In response to this challenge, manufacturers have developed software that can be used to manipulate these digital images for the planning of orthopedic procedures, including THAs. This development has provided a valuable opportunity to correct for some of the shortcomings in traditional acetate overlays but, as with any new technology, its accuracy and reliability must be evaluated. Theoretically, digital templating should allow for improved accuracy because template overlays can be scaled to the known magnification of the radiograph. In traditional templating, hip implant manufacturers provide an acetate overlay of a fixed magnification, usually 15% to 20%. The appropriately sized implant is traced on the printed film, and the size is recorded. To save on costs, however, many hospitals have stopped routinely providing printed films. Furthermore, when digital images are printed, there is potential for the image to be rescaled to fit the radiographic paper, which could result in a magnification that is substantially different from the magnification of the acetate overlay.

Agreement between stem templates and actual implants was high for both digital and manual templating. There was a normal distribution of stem sizes (Figure 5). With respect to the acetabular component, we tended to upsize it during surgery (Figure 6), using both conventional and digital methods. In some cases, this represented an upsizing of the component to place

Table II. Agreement Between Templating Methods

	Digital vs Actual				Manual vs Actual			
	Wgt κ	Lower 95% CI for κ	Upper 95% CI for κ	% Agreement	Wgt κ	Lower 95% CI for κ	Upper 95% CI for κ	% Agreement
Stem								
Unadjusted (n = 51)	0.88	0.82	0.94	60.8% (46.1%, 74.2%)	0.81	0.76	0.87	33.3% (20.8%, 47.9%)
BMI ≤30 (n = 39)	0.90	0.85	0.95	64.1% (47.2%, 78.8%)	0.84	0.79	0.90	38.5% (23.4%, 55.4%)
BMI >30 (n = 12)	0.82	0.65	0.99	50% (21.1%, 78.9%)	0.71	0.58	0.84	16.7% (2.1%, 48.4%)
				Fisher exact test, P = .50				Fisher exact test, P =.29
Cup								
Unadjusted (n = 51)	0.56	0.44	0.69	39.2% (25.8%, 53.9%)	0.43	0.30	0.55	31.4% (19.1%, 45.9%)
BMI ≤30 (n = 39)	0.58	0.44	0.72	41% (25.6%, 57.9%)	0.44	0.30	0.59	30.8% (17%, 47.6%)
BMI >30 (n = 12)	0.48	0.16	0.81	33.3% (9.9%, 65.1%)	0.29	0.08	0.50	33.3% (9.9%, 65.1%)
				Fisher exact test, P = .74				Fisher exact test, P = 1.00

Abbreviations: BMI, body mass index; CI, confidence interval; Wgt, weighted.

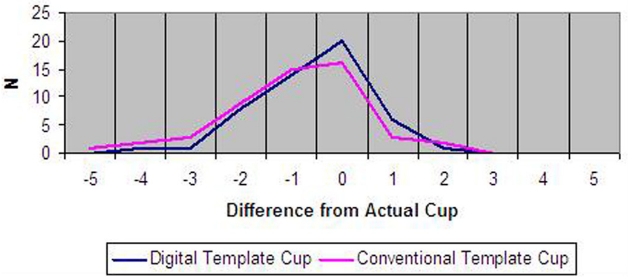


Figure 6. Distribution of cup sizes.

a ceramic liner that was available only at a larger cup size. In other cases, the surgeon upsized the component to provide the option for a larger head ball to reduce the risk for dislocation.

Our results compare favorably with those in similar studies. Iorio and colleagues[5] compared conventional and digital templating. Two attending surgeons and 4 arthroplasty fellows planned 50 operations. For the acetabular component, they found that the digital plan was within 1 size of the actual component in 60% of the cases, as compared with 78% for the conventional plan. The femoral component was predicted within 1 size in 74% of the cases templated digitally and in 77% of the cases templated conventionally. A significant difference between the digital and conventional methods could not be detected. In contrast to our data, there was a significant tendency for the digital plan to upsize the acetabular component and undersize the femoral component.

In spite of using cementless femoral components, we demonstrated almost perfect agreement of the digital and conventional plans in predicting femoral component size.

In 2005, The and colleagues[6] found that digital planning was less frequently correct than analog methods. In contrast to our study, however, the author who performed the digital templating was not involved in the operation. Involving the operating surgeon in preoperative planning is crucial. In particular for cemented stems, there is usually a range of stems that could be used to restore the proper biomechanics of the joint when placed at the proper depth within the bone.

González Della Valle and colleagues[7] found a significant difference in the acetabular component sizes predicted by digital and analog templating that favored the analog method. With the numbers available, they were unable to establish a link between magnification errors and component oversizing in the digital plan. We found that both preoperative planning methods tended to undersize the component. In practice, an undersized component would not obtain stable fixation. On the other hand, if the template indicated a much larger size because of magnification errors, the likelihood of reaming away too much bone would be higher. Both errors are undesirable, but the latter is difficult to reverse.

In conclusion, this study of our early experience with digital templating demonstrated equivalent results for the conventional acetate method of templating and the new digital method of templating. Neither conventional nor digital templating is perfect. Preoperative planning of a THA enhances our ability to recreate the biomechanics of the hip and should lead to better long-term outcomes.

Authors' Disclosure Statement

Dr. Bono wishes to report being a paid consultant for Sectra, a manufacturer of digital templating software. The other authors report no actual or potential conflicts of interest in relation to this article.

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Erratum

In the article entitled, "Posterior Remodeling of Medial Clavicle Causing Superior Vena Cava Impingement" by Peter Carbone, MD, MC, USN, Matthew Rose, MD, MC, USN, Joseph A. O'Daniel, MD, MC, USN, William C. Doukas, MD, MC, USA (Ret), Robert V. O'Toole, MD, and Romney C. Andersen, MD, MC, USA, published in Am J Orthop. 2011;40(6):297-300, Dr. Andersen's name was misspelled in the author affiliations section of the article. The correct spelling of his name is Romney C. Andersen, MD, MC, USA.