

Digital versus conventional templating techniques in preoperative planning for total hip arthroplasty

Yona Kosashvili, MD, MHA*
 Nadav Shasha, MD*
 Eli Olschewski, BSc, MD*
 Oleg Safir, MD*
 Larry White, MD†
 Allan Gross MD*
 David Backstein MD, MEd*

From the *Division of Orthopaedic Surgery and the †Medical Imaging Department, Mount Sinai Hospital, University of Toronto, Toronto, Ont.

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Correspondence to:

Dr. D.J. Backstein
 600 University Ave., Rm. 476D
 Toronto ON M5G 1X5
 fax 416 586-8678
 david.backstein@utoronto.ca

Background: The purpose of our investigation was to compare a digital templating system to conventional templating techniques when preoperatively planning for total hip arthroplasty.

Methods: We included 18 consecutive patients with primary osteoarthritis undergoing uncemented total hip arthroplasty in our study. At separate sittings, we independently conducted preoperative templating. They performed the templating using hard-copy radiographic films and traditional hard-copy prosthetic overlays on a radiograph view box. They then repeated templating using a digital technique at a computer workstation with specially developed software. We used kappa statistical analysis to evaluate intra- and interobserver variability of both techniques. We also examined correlation of template measurements with final component selection.

Results: Intra- and interobserver variability was satisfactory for both templating techniques. There was no significant difference in the performance of the 2 techniques in predicting final component selection during surgery.

Conclusion: Digital preoperative templating is as reliable as conventional templating techniques.

Contexte : Le but de notre étude était de comparer un système de gabarits numériques aux techniques de gabarits classiques lors de la planification préopératoire d'une arthroplastie pour prothèse totale de la hanche.

Méthodes : Notre étude a regroupé 18 patients consécutifs souffrant d'arthrose primaire et devant subir une arthroplastie pour prothèse totale de la hanche non cimentée. Nous avons conçu indépendamment nos gabarits préopératoires. Nous avons préparé nos gabarits à l'aide de clichés radiographiques auxquels nous avons surimposé des calques de prothèses sur un négatoscope. Nous avons ensuite refait les gabarits à l'aide d'une technique numérique à l'ordinateur, au moyen d'un logiciel spécialisé. Nous avons utilisé une analyse statistique kappa pour évaluer la variabilité intra et interobservateur des 2 techniques. Nous avons également vérifié la corrélation entre les mesures des gabarits et la sélection des composantes finales.

Résultats : La variabilité intra- et interobservateur s'est révélée satisfaisante pour les 2 techniques de gabarits. On n'a noté aucune différence significative quant au rendement des 2 techniques pour ce qui est de prédire la sélection des composantes finales durant la chirurgie.

Conclusion : Les gabarits préopératoires numériques sont aussi fiables que les techniques de gabarits classiques.

Preoperative planning is an important part of total hip arthroplasty surgery. Templating helps selection of the correct implant size,¹ lowers the risk of periprosthetic fracture,² helps restore femoral offset³ and leg length in hip arthroplasty,^{1,4,5} facilitates optimization of alignment and ensures the required implants are available while minimizing the costs associated with a superfluous inventory. Digital image acquisition and review with computed radiography and direct digital radiography is quickly replacing standard techniques of conventional film screen radiography in orthopedic imaging. This change has had a substantial impact on preoperative assessment of total hip arthroplasty, particularly preoperative templating. Until recently, templating has been performed with drawings on transparencies of appropriately magnified implants (typically provided by the prosthesis manufacturer). These

transparencies are lined up on preoperative radiographs in the desired orientation to identify the appropriate size of implant. This conventional technique of preoperative templating has become impractical with the implementation of digital image acquisition techniques and digital image review, because hard-copy film-based radiographs may no longer exist at many institutions.

Computerized templating using preoperative radiographs has been used to compare the proximal fit and fill of alternative femoral prostheses.⁶ Computed tomography-based digital preoperative templating has been compared with manual radiograph and template methods.⁷ However, the accuracy and reliability of digital preoperative templating has not been compared with conventional templating techniques. In this study, we compared conventional templating with a digital templating system, developed by eFilm Medical (Merge Healthcare) in conjunction with Zimmer, specifically looking at planning size selection and femoral neck cut level in hip arthroplasty.

METHODS

We approached 18 consecutive patients with primary osteoarthritis before they underwent total hip arthroplasty at Mount Sinai Hospital in Toronto, Ontario. We obtained informed consent before acquiring standard hard-copy film-screened radiographs (conventional radiographs) and digital radiographs for each patient. We obtained an anteroposterior view of the pelvis as well as anteroposterior and lateral views of the affected hip for all patients at the same preoperative assessment. We standardized patient positioning, source-to-image and source-

to-object distances, and radiographic acquisition parameters (KVp, MAs) for both conventional and digital radiographic imaging.

At separate sittings, 2 fellowship-trained arthroplasty surgeons (N.S. and D.B.) independently conducted preoperative templating. In all cases, templating was performed for only 1 type of acetabular and femoral prosthesis (Trilogy acetabular cup prosthesis, VerSys Fibre Metal Taper femoral prosthesis; Zimmer). We viewed all radiographs in a blinded randomized fashion. The surgeons performed conventional templating using hard-copy radiographic films and traditional hard-copy prosthetic overlays (Zimmer) on a radiograph view box. The surgeons used an anteroposterior radiograph of the pelvis, which included the proximal third of both femora, and anteroposterior and lateral radiographs of the affected hip. All sizes of the prostheses (for the acetabulum and femur) were available as individual drawings on transparencies with a standard magnification of 1.15. The planning technique had 3 basic steps: templating the acetabulum, selecting the femoral component and determining the neck cut.

We began our templating with the acetabulum. Various transparencies were placed overlying the radiograph such that the drawn acetabular component fit into the bony acetabulum of the radiograph. We selected the size of the drawn transparency that best fit the acetabulum. A hole in the transparency at the centre of the acetabulum allowed us to mark the hard-copy film to facilitate our femoral component selection. We made this mark with the acetabular template placed over the bony acetabulum of the radiograph. The mark represented where the centre of the femoral head would lie on completion of the surgery.

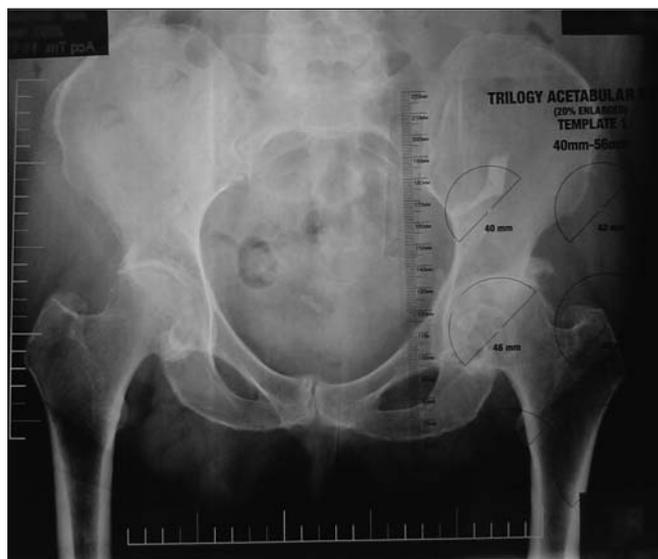


Fig. 1. Conventional templating: anteroposterior view of the pelvis, templating the acetabulum.

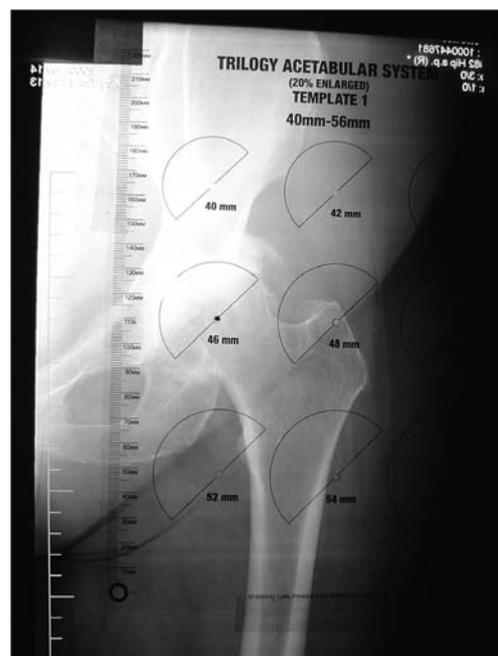


Fig. 2. Conventional templating: anteroposterior view of the hip, templating the acetabulum.

The femoral templates had images of the prosthesis with markings indicating the location of the centre of the femoral head for the various neck lengths available for the prosthesis. We placed the templates over the radiograph such that the optimal fill of both the intramedullary canal and the proximal femoral metaphysis was achieved, while the centre of the femoral head was positioned over the mark made during acetabular templating. We selected the size of the prosthetic template that best fit the described criteria. Finally the template had a cut out that allowed the femoral neck cut to be marked and measured with a ruler (also with magnification of 1.15). We then repeated these steps using the lateral radiographs (Fig. 1, Fig. 2, Fig. 3, Fig. 4).

We performed digital templating using digital radiographic images and digital templates produced from conventional template overlay data (Merge Healthcare) on a PC-based image review workstation. The technique used for the digital templating had the same steps as the conventional techniques. The computer software allowed placement of prosthetic templates over the radiographic images. We adjusted the magnification of the templates with the software to match that of the radiographs. We templated the acetabulum first, allowing the position of the desired centre of the femoral head to be determined. With the

centre identified and marked, we selected the femoral component by placing digital overlays over the radiograph. Again, fit and fill of the overlay with the radiographic intramedullary canal and metaphysis was optimized, while placing the centre of the femoral head at the desired level. The digital femoral template allowed identification of the level of the femoral cut and this was then digitally measured. We then repeated these steps using the lateral radiographs (Fig. 5, Fig. 6, Fig. 7, Fig. 8).

When we encountered a preoperative leg length discrepancy, the surgeons performed templating to equalize leg length. For instance, when the leg requiring surgery was shorter by 1 cm, the femoral templating was performed to result 1 cm above the marked acetabular centre to ensure appropriate neck cut, allowing leg length restoration. If the leg was 1 cm longer, then femoral templating was performed to result 1 cm lower than the acetabular centre.

Conventional templating for each patient occurred about 1 week before digital templating. One surgeon (N.S.) repeated all measurements a third time 3 weeks later for both the conventional and digital techniques. Measurements included size of the acetabular component, size of the femoral component and length of neck cut. We compared the final components selected intraoperatively and

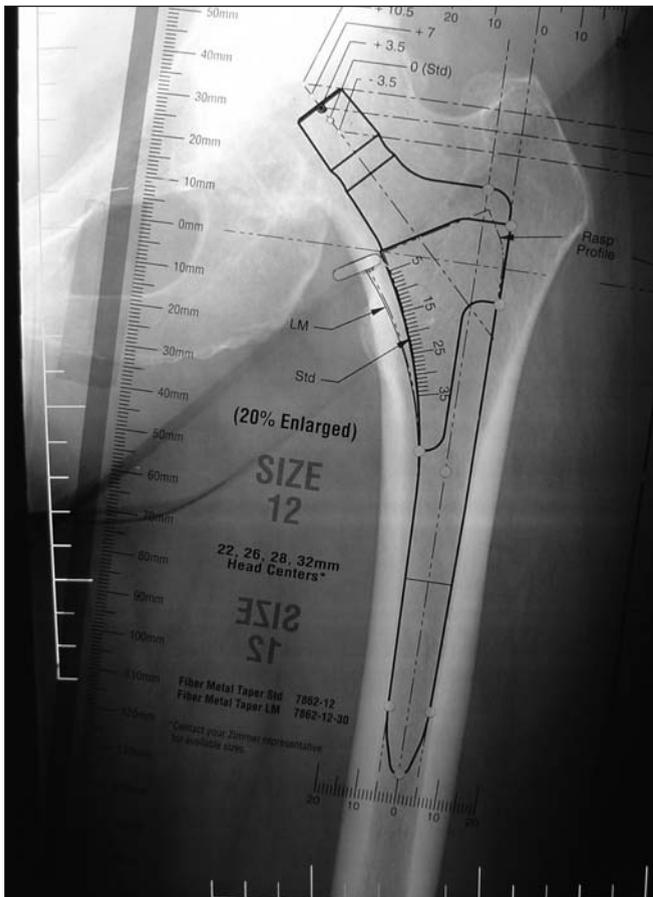


Fig. 3. Conventional templating: anteroposterior view of the hip, templating the femur.

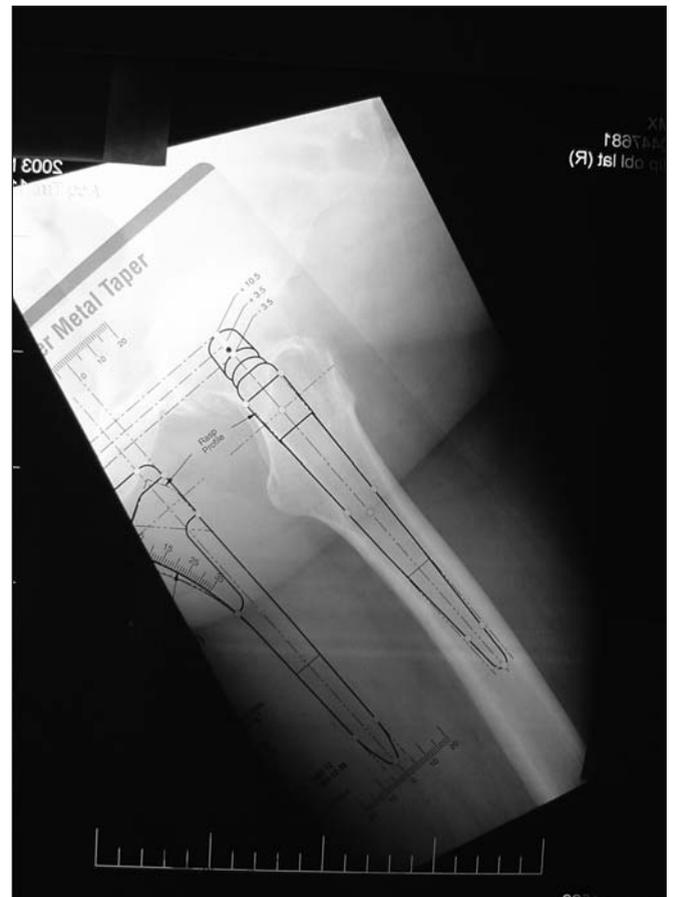


Fig. 4. Conventional templating: lateral view of the hip, templating the femur.



Fig. 5. Digital templating: anteroposterior view of the pelvis, templating the acetabulum and femur.



Fig. 6. Digital templating: anteroposterior view of the hip, templating the acetabulum.



Fig. 7. Digital templating: anteroposterior view of the hip, templating the femur.



Fig. 8. Digital templating: lateral view of the hip, templating the femur and acetabulum.

the length of the actual femoral neck cut made with the preoperative measurements of each method. The intraoperative decisions were made by a surgeon not involved in the templating (A.G.). The surgeon was blinded to these templating results, and he used independent, conventional templating techniques to plan his surgery. We defined agreement of measurement as acetabulum within ± 2 mm, stem ± 1 mm, neck cut ± 3 mm.

Statistical analysis

We calculated intraobserver and interobserver variability using kappa statistical analysis comparing the measurements from both conventional and digital templating techniques. We correlated measurements from both conventional and digital techniques with the actual components chosen during surgery by classifying each measurement as “correct” (agreed) or “incorrect” (not agreed), with respect to the surgical result.

We compared *t* test results for 2 independent groups with common variance for rate comparison using Minitab statistical analysis software (State College, Pennsylvania). According to this analysis, a number of 18 patients would provide a study with a power of 80% for the femoral stem and acetabulum comparison and 90% for the femoral neck cut comparison. For all statistical tests, we considered *p* < 0.05 to be significant.

RESULTS

Intraobserver variability for conventional templating was 0.60 for the acetabulum, 0.92 for the femoral stem and 0.35 for the femoral neck cut. For digital templating the intraobserver variability was 0.77 for the acetabulum, 1.00 for the femoral stem and 0.53 for the femoral neck cut (Table 1). Interobserver agreement for conventional tem-

plating was 0.36 for the acetabulum, 1.00 for the femoral stem and 0.62 for the femoral neck cut. For digital templating the interobserver agreement was 0.45 for the acetabulum, 1.00 for the femoral stem and 0.45 for the femoral neck cut. For Reader 1/Reader 2, the agreement between conventional templating results and the actual implants used was 0.58/0.33 for the acetabulum, 0.74/0.65 for the femoral stem and 0.64/0.48 for the femoral neck cut. For digital templating compared with the surgical results, the agreement was 0.83/0.19 for the acetabulum, 0.83/0.41 for the femoral component and 0.52/0.32 for the neck cut. There was no statistically significant difference between conventional and digital templating techniques in predicting the intraoperative component selection and femoral neck cut (*p* values 0.37–1.00) (Table 2).

DISCUSSION

In order to use any tool, it must be reliable. In this investigation, we analyzed inter- and intraobserver agreement using the kappa statistic, where a value of 1 represents complete agreement, 0 represents no agreement and -1 represents complete disagreement. A more detailed description of the kappa statistic can be found in Box 1. Our intraobserver agreement for conventional and digital templating techniques was excellent for the femoral component ($\kappa = 0.92/1.0$), very good for the acetabular component ($\kappa = 0.60/0.77$) and fair to moderate for the neck cut ($\kappa = 0.35/0.53$). Interobserver agreement for conventional and digital techniques was excellent for the femoral component ($\kappa = 1.0/1.0$), fair to moderate for the acetabular component ($\kappa = 0.36/0.45$) and moderate for the neck cut ($\kappa = 0.62/0.45$). These results indicate that both templating techniques are reliable.

We found a high level of agreement for both the conventional and the digital assessments when we looked at actual cup size, stem size and neck cut length determined during surgery (conventional/digital: reader 1 cup $\kappa = 0.58/0.84$, stem $\kappa = 0.74/0.83$, neck cut $\kappa = 0.64/0.52$; reader 2 cup $\kappa = 0.33/0.19$, stem $\kappa = 0.65/0.41$ neck cut $\kappa = 0.48/0.32$). There was no statistically significant difference between conventional and digital templating measurements with regards to accurately predicting intraoperative component selection or surgical neck cut length (*p* = 0.375–1.0). These results indicate that both con-

Table 1. Intra- and interobserver variability

Templating	Intraobserver variability		Interobserver variability	
	Conventional*	Digital*	Conventional*	Digital*
Cup	0.60	0.77	0.36	0.45
Stem	0.92	1.00	1.00	1.00
Neck cut	0.35	0.53	0.62	0.45

*Kappa statistics.

Table 2. Agreement of templating with intraoperative selection

Templating	Reader 1			Reader 2		
	Conventional*	Digital*	<i>p</i> value	Conventional*	Digital*	<i>p</i> value
Cup	0.58	0.84	0.37	0.33	0.19	0.62
Stem	0.74	0.83	1.00	0.65	0.41	0.37
Neck cut	0.64	0.52	0.69	0.48	0.32	1.00

*Kappa statistics.

Box 1. Kappa value and level of agreement

Kappa value	Level of agreement
0	Poor
0.01–0.20	Slight
0.21–0.40	Fair
0.41–0.60	Moderate
0.61–0.80	Very good
0.81–1.00	Almost perfect

ventional and digital templating techniques are valid tools to facilitate preoperative planning in total hip arthroplasty.

Preoperative planning for total hip arthroplasty has been accepted as an essential step to facilitate the surgical process.^{1,8,9} The digital radiograph format is becoming a more prevalent form of radiography. Digital radiographs have advantages over standard imaging, including reduced radiation exposure, fewer instances of over and under-exposure and reduced rates of unsatisfactory films.¹⁰ Given the benefits and increasing prevalence of digital radiography, it will become necessary to use digital templating techniques compatible with this format at many institutions. Our study demonstrated that digital templating software can be as accurate and reliable as conventional templating techniques.

Although some authors have been able to plan component size correctly in up to 92% of their cases,¹ they have used cemented prostheses, whereas uncemented prostheses are more difficult to plan.¹¹ In our study, conventional and digital templating was performed for uncemented prostheses, and our results were similar to other studies that, when studying the accuracy of preoperative templating of uncemented femoral prostheses, found the templated size corresponded to the femoral implant used in about 50% of cases.^{12,13} When Carter and colleagues¹² considered implanted femoral components within 1 size of the templated size to be correct, accuracy improved to up to 95%. When magnification was accounted for, Conn and colleagues¹³ found that the accuracy of templating increased to 68.8%. In our study, we standardized radiographic acquisition parameters, including source-to-image and source-to-object distances; however, magnification was not specifically addressed for the individual films, and we assumed a standard value of 15%. This replicates the setting of many centres and provides a real world scenario. Although not accounting for magnification may have affected the accuracy of the templating techniques, the inter- and intraobserver reliability was not affected by this omission. It must also be noted that we defined agreement as within 1 mm for the femoral component, 2 mm for the acetabular component and 3 mm for the neck cut. Undersizing uncemented femoral components can lead to a poor interference fit and instability of the prosthesis. Using femoral prostheses 1 size (1.0 mm) larger than that determined to be optimum has been shown to increase assembly strains on the femur by up to 6 times and produce longitudinal linear fractures in the femoral cortex in cadavers.¹⁴ This illustrates the importance of accuracy when selecting the femoral component size.

Patients with osteoarthritis commonly have external rotation contractures. Rotation of the hip can affect the appearance of the proximal femur on radiographs,¹¹ and this has been shown to be a cause of error in preoperative templating.¹¹ We did not specifically address this factor; however, rotation of the hip would have had the same effect on

conventional and digital templating. Therefore, this factor would have affected accuracy but not reliability.

We examined a specific digitalized templating system with conventional templating for a specific stem and cup. Although it is reasonable to believe that the result would be similar for other systems, additional studies may be required.

In conclusion, digital preoperative templating can be a tool that is as reliable as conventional templating techniques. However, although templating is useful, there is an ongoing risk of producing a fracture when inserting components selected based solely on preoperative templating, and there is a need for ongoing improvement of templating accuracy.

Competing interests: None declared.

Contributors: Drs. Safir, Gross and Backstein designed the study. Drs. Shasha, Olschewski, White and Backstein acquired the data, which Drs. Kosashvili, Gross and Backstein analyzed. Drs. Kosashvili and Backstein wrote the article, which Drs. Shasha, Olschewski, Safir, White and Gross reviewed. All authors approved final publication.

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