Accuracy of Digital Templating for Non-Cemented Total Hip Arthroplasty: A Large Series by a Single Surgeon

Adam Wheeler

University of Toledo College of Medicine and Life Sciences

Ian M. Gradisar (✉ igradisar@crystalclinic.com)

Crystal Clinic Orthopaedic Center <https://orcid.org/0000-0002-8339-7992>

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Abstract

Introduction

Preoperative planning for total hip arthroplasty (THA) is an essential step taken to reduce surgical errors and improve patient outcomes. Previously, templating using acetate radiographs proved accurate and beneficial. However, digital templating of digitally acquired radiographs has become more commonplace. The purpose of this study was to quantify accuracy of digital templating for THA's performed by a single surgeon over a 4-year period and to determine if accuracy improved over time.

Materials and Methods

491 patients undergoing primary THA from 2013-2017 performed by a single surgeon were retrospectively analyzed. Digital templating was performed using ORTHOVIEW Orthopaedic Digital Templating for CARESTREAM PACS (© 2019 Carestream Health). Digitally templated acetabular and femoral component sizes were compared to actual implanted sizes to determine template percent accuracy. To investigate changes in accuracy over time, THA cases were divided in half and compared. Chi Square and Fisher's Exact Tests were used to determine statistically significant differences in percent accuracy over time.

Results

Overall percent accuracy of acetabular and femoral components was 97.4% and 87.2% respectively. When comparing the first and second half, percent accuracy of acetabular and femoral components was 98.4% versus 97.1% ($P=0.58$) and 89.4% versus 84.9% ($P=0.14$) respectively.

Conclusions

This study represents one of the largest retrospective analyses aimed at determining accuracy of digital templating in THA procedures performed by a single surgeon at a single institution. Percent accuracy was consistently high throughout time and deemed an accurate methodology for preoperative planning of cementless THA.

Introduction

Preoperative templating for total hip arthroplasty (THA) can positively impact surgical outcomes and implant longevity. Templating facilitates procedural standardization, reproducibility, and accuracy. In addition, preoperative templating has been shown to decrease intra- and post-operative complications related to improper sizing of total joint prostheses, inaccurate femoral offset, and/or failure to achieve leg length equality.(1–7) For instance, via thorough preoperative templating, intra- and postoperative fractures, accelerated wear or loosening of components, and failures of implant ingrowth are all strongly reduced in occurrence.(1–6, 8) Moreover, joint stability and range of motion are improved, and operative times are reduced.(8–10)

Previously, preoperative templating by way of superimposing acetate templates onto standard printed radiographs was an accepted and accurate method for surgical planning. However, now in the digital era, standard radiograph imaging is an increasingly antiquated technology largely replaced by digital radiography for several clinical, practical, and economical reasons.(7) In the wake of this transition to a progressively more digital workspace, various software solutions for digital templating of prostheses have emerged. Several studies have been conducted to verify the validity, accuracy, and reproducibility of this new completely digitized system. Though some studies have suggested digital templating may not be adequately accurate or reliable,(11–13) several others have found digital templating to be equally if not more accurate than acetate templating.(9, 14–26)

We sought to investigate the accuracy of digital templating used for preoperative planning of primary THA procedures performed sequentially over a four-year time period by a single surgeon (Ian M. Gradisar, IMG) at a single institution (Crystal Clinic Orthopaedic Center, CCOC). Our study goal was to determine if digital templating was in fact an accurate means for preoperative planning. We also sought to determine if accuracy improved over the four-year timespan as familiarity and experience with the technology accumulated.

Methods

Retrospective analysis included data from 491 consecutive primary cementless THA procedures, performed by either an anterior or posterior approach. All preoperative templating and subsequent procedures were performed by a single surgeon at a single institution between the years 2013 and 2017. Exclusion criteria were the following: patients younger than 18 years of age, revision or repeat same-side hip arthroplasty, and non-elective intervention. Clinical and demographic characteristics were collected from patient records in compliance with HIPAA regulations. 56% of patients were female and 44% male (275 female, 216 male). The average age of our patient cohort was 63 ± 10 years, and average BMI was 30 ± 6 kg/m².

Standard digital hip radiographs were obtained in an anterior-posterior view with 15–20° of femoral internal rotation for templating and preoperative planning. A metallic radio-opaque sphere with a standardized diameter of 25mm was centered at hip height and depth to correct for radiograph image magnification. Digital templating was performed using ORTHOVIEW Orthopaedic Digital Templating for CARESTREAM PACS (© 2019 Carestream Health). Acetabular and femoral hip stem components included: Smith & Nephew (n = 226) R3 acetabular cup and Anthology femoral stem (Andover, MA); Stryker (n = 100) Tritanium cup and Accolade II femoral stem (Kalamazoo, MI); and Exactech, Inc. (n = 165) Novation Crown acetabular cup and Alteon femoral stem (Gainesville, FL). Each hip system was templated using the appropriate manufacturer specific digital templates within the software program.

Component sizes determined by digital templating were compared to actual sizes implanted per postoperative reports. Accuracy of digital templating was defined as a perfect match ± 2 component sizes. The proportion of component sizes that fell within this definition compared to the total number of

templated procedures was used to calculate the percent accuracy of digital templating. To determine if percent accuracy improved over time, THA procedures were divided in half to create two groups. The “first half” and “second half” groups represented the first 50% (n = 246) of THA and second 50% (n = 245) of THA done. Statistical analysis was calculated with Prism 8 software by GraphPad Software, LLC. (San Diego, CA). Contingency tables were created to perform Chi Square and Fisher’s exact test to compare percent accuracy rates of digital templating over time. Statistical significance was set at *P* value < 0.05.

Results

Overall Template Reliability

491 digitally templated THA cases were reviewed to determine the overall percent accuracy of digital templating (Table 1). The exact acetabular cup size (perfect match) was predicted in 39.5% (n = 194) of all primary THA procedures. We found that 83.3% (n = 409) were accurate within ± 1 size and 97.4% (n = 478) were accurate within ± 2 sizes. Femoral stem size was exactly predicted in 29.3% (n = 144) of cases, 69.4% (n = 341) within ± 1 size, and 87.2% (n = 428) within ± 2 sizes.

Table 1
Overall Average Percent Accuracy of Digitally Templated Components in Primary Cementless THA

	<i>Acetabular Cup</i>	<i>Femoral Stem</i>
<i>Perfect Match</i>	39.5% (194)	29.3% (144)
<i>± 1 Size</i>	83.3% (409)	69.4% (341)
<i>± 2 Sizes</i>	97.4% (478)	87.2% (428)
<i>> ± 2 Sizes</i>	2.65% (13)	12.8% (63)
Number of components represented is indicated in parentheses.		

Comparing Change in Percent Accuracy Over a Four-Year Period

To determine if accuracy of digitally templating components for cementless THA improved over time, 491 consecutive procedures, representing a 4-year time period, were divided equally into “first half” (n = 246) and “second half”(n = 245) groups.

Overall percent accuracy, defined as all components templated within 0 to ± 2 sizes, for the first half versus the second half was as follows: 98.4% versus 97.1% (*P*= 0.58) for acetabular components and 89.4% versus 84.9% (*P*= 0.14) for femoral components.

Table 2 demonstrates and compares the distributions of component size agreements during the first and the second halves of the study. Acetabular components were perfectly matched in 38.2% (n = 94)

versus 40.8% (n = 100) ($P = 0.58$), within ± 1 size in 85.8% (n = 211) versus 81.2% (n = 199) ($P = 0.18$), within ± 2 sizes 98.4% (n = 242) versus 97.1% (n = 238) ($P = 0.38$), and inaccurately templated in 1.6% (n = 4) versus 2.9% (n = 7) ($P = 0.38$) during the first and second half respectively.

Table 2
Average Percent Accuracy of Digital Templating Over Time

	First Half (N = 246)	Second Half (N = 245)	P-value
<i>Acetabular Cup</i>			
<i>Perfect Match</i>	38.2	40.8	0.58
<i>± 1 Size</i>	85.8	80.8	0.18
<i>± 2 Sizes</i>	98.4	96.3	0.38
<i>Femoral Stem</i>			
<i>Perfect Match</i>	26.0	33.1	0.11
<i>± 1 Size</i>	70.3	69.0	0.70
<i>± 2 Sizes</i>	89.4	85.3	0.14

Femoral components were perfectly matched in 26.0% (n = 64) versus 32.7% (n = 80) ($P = 0.11$), within ± 1 size in 70.3% (n = 173) versus 68.6% (n = 168) ($P = 0.7$), within ± 2 sizes 89.4% (n = 220) versus 84.9% (n = 208) ($P = 0.14$), and inaccurately templated in 10.6% (n = 26) versus 15.1% (n = 37) ($P = 0.14$) during the first and second half respectively.

Table 3

Summary of Reported Average Percent Accuracies Achieved for Digitally Templated Acetabular and Femoral Components in Preoperative Planning for THA

Study	Sample Size (n)	Acetabular Cup (%)	Femoral Stem (%)
Davila et al. (2006) ¹⁵	36*	86(± 1)	96 $\pm$ 2)
The et al. (2007) ²⁹	104	81(± 1)	76(± 1)
Wedemeyer et al. (2008) ¹⁷	40	92(± 2)	95(± 1)
Iorio et al. (2008) ¹⁸	50	60(± 1)	74(± 1)
Kumar et al. (2009) ³⁰	45	100(± 2)	78(± 1)
Steinberg et al. (2010) ²⁷	73	87(± 1)	96(± 2)
Gamble et al. (2010) ³¹	117	80(± 1)	85(± 1)
Efe et al. (2011) ³²	169	77.5(± 1)	82.3(± 1)
Schmidutz et al. (2012) ²⁴	100*	93.3(± 2)	97.5(± 2)
Shaarani et al. (2013) ²⁶	100*	98(± 2)	98(± 2)
Si et al. (2015) ²⁸	90	95.56(± 2)	93.33(± 2)
Strom et al. (2018) ¹³	41	73(± 2)	90(± 2)
Holzer et al. (2019) ¹⁰	632	78(± 1)	87(± 1)
Present study (2020)	491*	97.4(± 2)	87.2(± 2)
Accuracy of acetabular and femoral components within either ± 1 or ± 2 sizes is indicated in parentheses as reported for each study. *Indicates single-surgeon study			

Discussion

Previous studies have presumed a templated acetabular cup or stem to be accurate if within ± 2 sizes of the implanted size.(26–28) In our current study of 491 THAs, we found 83.3% of acetabular templates to be accurate within ± 1 size and 97.4% to be accurate within ± 2 sizes, data that is congruent with the previous literature. When examining accuracy of femoral stem templating, 69.4% were accurate within ± 1 size and 87.2% were accurate within ± 2 sizes. Again, this data is consistent with the findings from previous studies. Table 3 illustrates a current overview of the percent accuracy achieved for acetabular and femoral templates throughout the literature.

The greater accuracy of the acetabular components among all vendors could be explained in a couple of ways. First, when templating off a 2-D X-ray, the variation in acetabular cup size is reduced by templating to the visible cortical rim demarcating the supero-lateral and infero-medial borders of the acetabulum. Therefore, estimating final cup size is more reproducible if the templating surgeon stays within these landmarks. Conversely, there are several variables that can account for errors when templating the femoral stem side. Given the cone geometry of the proximal femur and the cone shape of the femoral stem implant, there is not only medial-to-lateral fit of the stem in the bone, but also the proximal distal shift in that cone of the proximal femur. For example, what may look like a good fit on a 2-D template, may fit better in the bone if the stem was more proximal or distal in the bone.

Another variable for greater differences in the femoral stem sizing from the templated size is the femoral rotation on the X-ray. The native hip has about 15 degrees of anteversion of the femoral neck. Although the X-ray image is taken with the patient's lower extremity in 15 degrees of internal rotation to try and create an *en fosse* view of the femoral neck, this is sometimes not achievable. The inherent stiff nature of an arthritic hip joint may prevent the necessary femoral rotation for the X-ray. If the *en fosse* view of the femoral neck is not achieved, then the size of the proximal femur can appear more narrow on the X-ray, to have less offset, and can appear more valgus than reality. This inadequate profile can then lead to under-sizing of the femoral stem template.

One variable not elucidated in this study was femoral head offset and length differences when different femoral head offset sizes were used. For example, when templating the femoral stem size for "best fit" within the metaphysis, there is an ability to template different femoral head offset sizes onto the femoral neck. These different femoral head offset sizes allow the femoral head to be positioned deeper on the femoral neck, thereby reducing overall length and offset; or for the femoral head to seat more toward the tip of the femoral neck, creating more length and offset of the femur. During templating, not only is there a demand for best fit of the femoral stem within the metaphyseal bone, but consideration is equally given to the ultimate length and offset that a given femoral head and stem combination would produce. Therefore, a stem might be slightly smaller in size to achieve a better fit in the metaphyseal bone, but may require a "plus" offset on the femoral head to regain length and offset lost by the use of the smaller stem size. Conversely, a larger stem may fit better sitting higher in the femoral bone, but may need a "minus" offset head to achieve the desired length and offset.

This variability of femoral head offset sizes was not factored in to this study. Therefore, if a different stem size was used than what was templated, the length and offset may have been made up by the resulting femoral head offset, allowing for the best intra-operative fit of the femoral stem. This explains why there may be less accurate templating of the femoral stem sizes when compared to the acetabular cup sizes, as intraoperatively a different sized stem could have been used to achieve best fit.

When looking at a comparison of accuracy of templating over time, the accuracy of the first half versus the second half of the templated total hips were similar and not found to be statistically significant

(Table 2). The consistency over time, despite different total hip component vendors, may be attributed to the very short learning curve and ease of incorporating digital templating into a total hip practice.

A limitation of this study was the inability to identify the cause of the inaccurately templated acetabular cups and stems as defined by those greater than two sizes of the templated size. This inaccuracy accounted for 2.6% of the acetabular cups and 12.8% of the femoral stems. We did not compare other factors that could possibly contribute to this inaccuracy such as BMI, gender, extreme sizes, or poor scaling device placement. An additional limitation was the accuracy of templating among the three different total hip component vendors. Comparing vendors was not the focus of this study, but could be considered in future studies.

Conclusion

This study represents one of the largest retrospective analyses aimed at determining accuracy of digital templating in THA procedures performed by a single surgeon at a single institution. Achieved accuracy of templated total hip femoral stems and acetabular cups from varying vendors was consistently high over a four-year study period. In agreement with previous smaller sample size studies, we conclude that digital templating is indeed an accurate method of preoperative planning that can be utilized in the setting of cementless THA.

Abbreviations

THA, total hip arthroplasty

Declarations

Ethics approval and consent to participate

We confirm that this study has been reviewed by an appropriate ethics committee and was conducted in accordance with the ethical standards laid down in an appropriate version of the 1964 Declaration of Helsinki

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to information falling under the Health Insurance Portability and Accountability Act but are available from the corresponding author on reasonable request

Competing interests

We, the authors, have no competing interests to disclose.

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Authors' contributions

All authors have seen and approved the manuscript and have contributed significantly to the concept, design, data collection, and writing of the manuscript

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