Improving Accuracy of Total Hip Arthroplasty Templating Considering Differences in Magnification of Preoperative X-rays

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Funding The authors received no financial support for the research, authorship, or publication of this article.

Conflict of Interest The authors report no conflicts of interest.

ABSTRACT

Background: The authors present a novel technical strategy in preoperative planning for templating total hip arthroplasty (THA), which involves the intraoperative measurement of the native femoral head as a guide for component sizing at different preoperative templating magnifications.

Methods: Sixty-nine hips were templated using a magnification of 105.0%, 110.0%, and 115.0%. The native femoral head size was then measured intraoperatively and matched to the correlated head size at the specified preoperative templated magnification. Based on the specified magnification, the corresponding implants were then used as a starting point for component placement.

Results: The authors found that measurement of the femoral head intraoperatively corresponded most with a preoperative templated magnification of 110.0% (n = 35) followed by 115.0% (n = 24) and 105.0% (n = 10). The frequency of predicting component sizing within ±1 for the acetabular cup, neck, and stem components was 98.0%, 92.5%, and 98.0%, respectively.

Conclusion: This method of preoperative templating with different magnifications could enhance accuracy of THA templating and may be a more reliable method when compared to conventional templating techniques.

Keywords: Total hip arthroplasty; Hip joint; Hip osteoarthritis

INTRODUCTION

Digital radiography has become the standard of care for preoperative templating for total hip arthroplasty (THA). The development of templating software has aided surgeons in determining proper implant size and positioning to maintain or restore proper biomechanics.[1-3] In addition to restoring biomechanics, proper templating can help mitigate intraoperative (e.g. fracture) and post-operative (e.g. dislocation) complications.

Even though digital templating has shown to be beneficial, factors that can be controlled and those that cannot must be considered when determining its accuracy. Patient factors, such as body mass index (BMI), have been shown to influence accuracy of templating the femoral implant size.[4] Level of experience of the individual templating has also been shown to play a significant role in accuracy of templating.[3,4] Finally, technical factors such as placement of the calibration marker affect magnification of x-rays and ultimately the accuracy of templating.[5-10] Differences in the actual magnification of the hip (by using the femoral head of a previously placed hip arthroplasty prosthesis to calibrate the magnification) have led to mean discrepancy of 7.0%.[7]

Although use of digital radiography for templating has become standard practice for THA, no consensus has been made on the best templating procedure. The goal of this study is to develop a novel THA templating strategy to improve accuracy of plain film preoperative templating. The authors hypothesize that using x-ray magnifications of 105.0%, 110.0%, and 115.0% and measuring the size of the femoral head while templating will result in improving accuracy in choosing the appropriate template and the corresponding implant sizes intraoperatively for each patient undergoing THA.

METHODS

Institutional Review Board approval was obtained and retrospective chart review was performed on all patients undergoing THA performed by a single surgeon (R.H.) at the Veterans Affairs Southern Nevada Healthcare System from October 2017 through February

2020. Electronic medical records were reviewed to identify patient demographics including age, sex, BMI, and laterality of procedure.

Preoperative digital anteroposterior (AP) pelvic radiographs were obtained with a 25 mm calibration marker placed at the level of the greater trochanter on the operative side. A standardized THA templating protocol for obtaining radiographs consisted of a standard distance of 42 inches between the x-ray source and the cassette. Preoperative x-rays were evaluated for: femoral head size, distance from the lesser trochanter (i.e., distance from the medial femoral neck/stem junction to the superior aspect of the lesser trochanter), acetabulum cup size, femoral implant size, and size of calibration marker. Preoperative digital templating was performed by a single surgeon (R.H.) using OrthoView™ (Meridian Technique Ltd., Hampshire, UK). Three different magnifications (105.0%, 110.0%, and 115.0%) were used to account for inherent discrepancies that exist with calibration marker technique. The measured femoral head size, distance from the lesser trochanter, acetabulum cup size, femoral implant size, and size of calibration marker were recorded for each of the three percentage magnifications to be used for comparison in the operating room. Planned neck angle (i.e., standard vs high offset) was chosen based on pre-operative radiographs at the time of templating.

THA was performed by a single surgeon (R.H.) using the posterior approach with a single vendor (DePuy Synthes PINNACLE® and SUMMIT® Tapered Hip System, Raynham, MA, US). Intraoperatively, measurement of subchondral bone of the femoral head without removal of native cartilage was taken at the largest possible diameter in the cranial-caudal direction to best correspond to the preoperative measurement made on AP radiographs. Intraoperative femoral head size (Figure 1) was compared to the templated femoral head size at each magnification. Based on intraoperative femoral head size, the corresponding preoperative templating magnification sizes were then chosen. Operative reports and postoperative digital radiographs were evaluated to assess accuracy and reliability of preoperative templating. Patients who underwent THA on the contralateral side did not have the second contralateral surgery included from the previous surgery.

RESULTS

A total of 69 total hip arthroplasties were performed during the study time period. Of the 69 surgeries performed, 24 were performed on the left hip and 45 on the right hip. Sixty-six surgeries were performed on male patients, and average patient age and BMI were 65.7 years and 31.4 kg/m^2, respectively.

After determining femoral head size intraoperatively, the most frequently used preoperative templating magnification with the corresponding femoral head size was 110.0% (n = 35, 50.7%) followed by 115.0% (n = 24, 34.8%) and 105.0% (n = 10, 14.5%) (Figure 2).

Frequency of templated versus actual acetabular

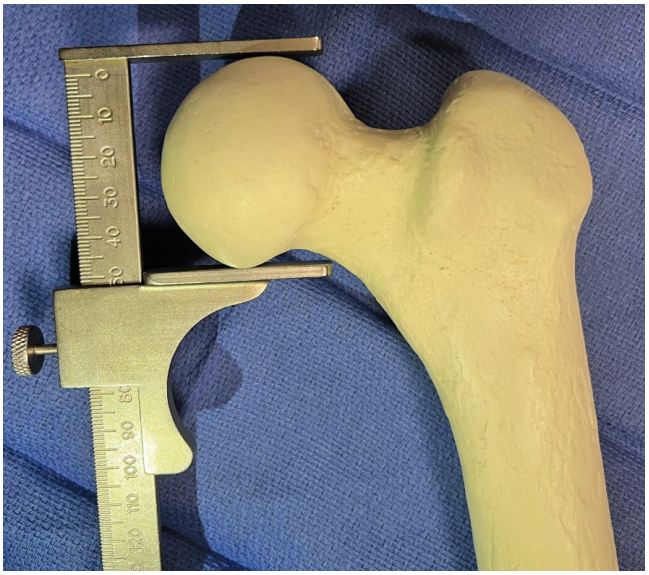

Figure 1. *Depiction of how intraoperative measurement of femoral head is performed in the cranial-caudal direction.*

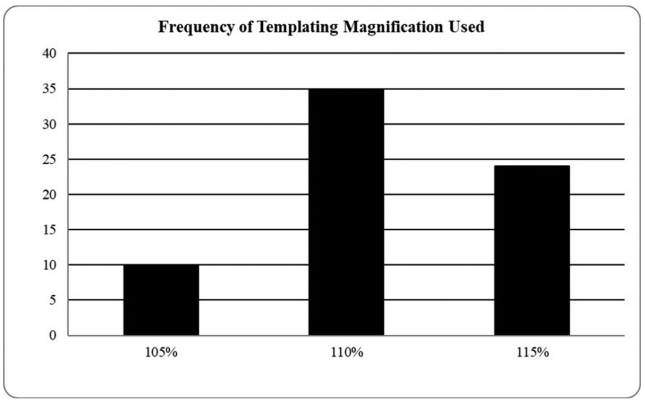

Figure 2. *105.0%, 110.0%, and 115.0% correspond to percentage magnification used for templating, respectively.*

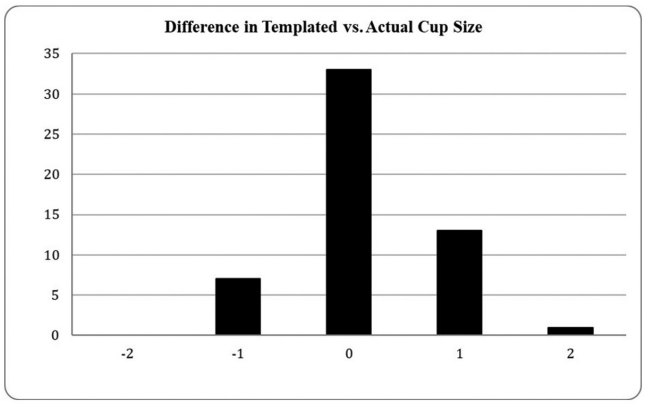

Figure 3. *0: Actual cup size same as templated, negative: Actual cup size smaller than templated, positive: Actual cup size larger than templated.*

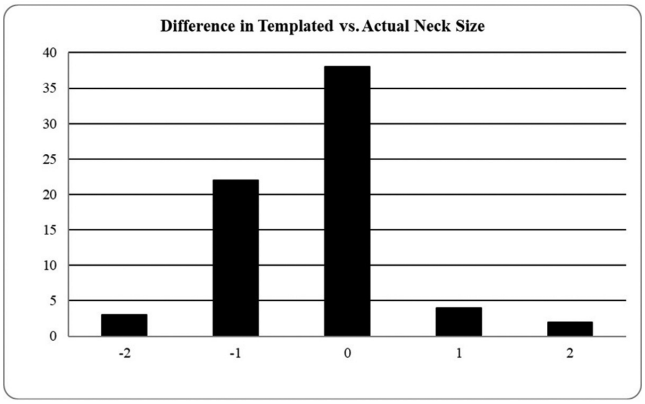

Figure 4. *0: Actual neck size same as templated, negative: Actual neck size smaller than templated, positive: Actual neck size larger than templated.*

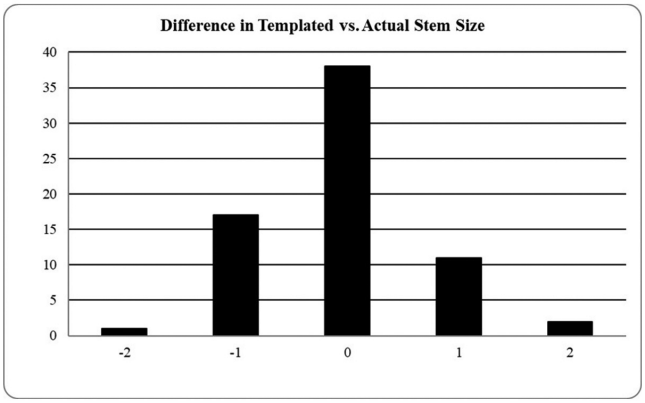

Figure 5. 0: Actual stem size same as templated, negative: Actual stem size smaller than templated, positive: Actual stem size larger than templated.

cup size (Figure 3), femoral neck size (Figure 4), and femoral stem size (Figure 5) was compared. No change in size between templated and actual size used for the acetabular cup, femoral neck, and femoral stem occurred in 40 (58.0%), 38 (55.1%), and 38 (55.1%) surgeries, respectively. Difference in templated and actual size used within ±1 size for the acetabular cup, femoral neck, and femoral stem occurred in 67 (97.1%), 64 (92.8%), and 66 (95.7%) surgeries, respectively. A negative value for acetabular cup size, femoral neck size, and femoral stem size signified a smaller size used than templated.

DISCUSSION

There has been no general consensus on the magnification that occurs in THA templating. Several studies have been carried out with regards to magnification that have documented on a wide range of averages for magnification.[3,13,14] This discrepancy further highlights the need for a more robust scaling method. Sinclair et al.[5] reported on a mean of 6.8% when templating in terms of size of the femoral head. Bayne et al.[13] reported on the accuracy of radio-opaque scaling markers based on position on radiographs and found a mean error of 8.9% with a standard deviation of 8.0%. Similar results were found in a study by Franken et al.[14] who reported on a mean error of a medially placed ball to be 2.0% with a maximum of 6.8%. The mean error reported from previous studies were the primary driver in the application of the magnification values that were used in the present study.

An integral part of THA, preoperative planning, has evolved over the last 30 years and was previously completed to mitigate leg-length discrepancies. However, today it is an important exercise in restoration of the normal mechanics of the hip joint, specifically in determining the anatomical center of the acetabulum and in normalizing the relationship between the femur and pelvic bone.[11] Several studies have investigated the effects of magnification in THA templating using standard acetate templating and with digital radiographs. Digital templating is routinely used today and has become the gold standard. Hossain et al.[15] demonstrated improved accuracy with use of digital templating in THA when compared to analogue templating. This was further strengthened by Specht et al.[12] who found similar results with regards to accuracy in digital templating of THA when compared to standard acetate templating.

In this study, the authors propose a novel technical strategy that correlates the intraoperative size of the native femoral head to the preoperative templated femoral head size measured based at magnifications of 105.0%, 110.0%, and 115.0%. The size of the native femoral head was then matched to the corresponding templated femoral head at a given magnification. Intraoperative measurement of femoral head size has been shown to correlate with the outer diameter of the implanted cup.[16] The authors found that there was greatest correlation between the femoral head size measured intraoperatively with magnification templated at 110.0% (50.7%) followed by a templated magnification of 115.0% (34.8%). This technique was able to predict actual size used within ±1 size for the acetabular cup, femoral neck, and femoral stem in 67 (97.1%), 64 (92.8%), and 66 (95.7%) surgeries, respectively. Furthermore, the present technique was able to predict exact component sizing for the acetabular cup, neck, and stem components in 40 (58.0%), 38 (55.1%), and 38 (55.1%) surgeries, respectively.

Previous studies have reported on predicting sizing for THA using templating. Gamble et al.[17] found that conventional digital templating predicted within one size for the acetabular component 80.0% of the time. Similar results were found by Steinberg et al.[18], who completed a retrospective study on 73 hips where the predicted acetabular sizing was within one size in 89.0% of the acetabular components placed. The results gathered from the present study demonstrate improvement in predicting component sizing when compared to previous studies using conventional digital templating methods. These results suggest that templating for THA within a broad spectrum of magnification (i.e., 105.0% to 115.0%) may minimize error in sizing when placing THA components

intraoperatively. In addition, this technique may be useful in templating for hip hemiarthroplasties where appropriate positioning and distance from the x-ray source can be even more variable. Measuring the femoral head size intraoperatively would determine the appropriate magnification, and therefore the correct stem size.

There are several limitations of this study. First, the percentage of males included was significantly higher than the percentage of females. This discrepancy is inherent in the patient population presenting to the Veterans Affairs Southern Nevada Healthcare System. Second, preoperative templating and THA was performed by a single surgeon using a single implant vendor. Finally, intraoperative measurement of femoral head diameter was performed without removal of remaining cartilage. Removal of cartilage could result in improvement of correlation between preoperative, radiograph-based templating and intraoperative measurement.

This study presents a novel technique for THA templating that involves measurement of the native femoral head intraoperatively and matching components to the correlated preoperative templated magnification. The study also demonstrates improvement in predicting THA components sizing when compared to conventional templating technique and may be a more reliable method when templating for THA.

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