The Journal of Arthroplasty 30 (2015) 622–626

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

A Patient-Specific Predictive Model Increases Preoperative Templating Accuracy in Hip Arthroplasty

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ARTICLE INFO

Article history:
Received 12 July 2014
Accepted 8 November 2014

Keywords:
hip arthroplasty
preoperative templating
Traumacad
anterior approach
digital imaging

ABSTRACT

Application of digital radiography during preoperative templating has shown potential to reduce complications in total hip arthroplasty. In this study, we aimed to further improve digital templating by using a predictive model built on patients' specific data. The model was significant in improving the accuracy of templating within ±1 size of acetabular component ($\chi^2(1, N = 468) = 19.314$, $P < 0.0001$, $\Phi = 0.604$, and odds-ratio: 7.750 (95% CI 2.740–30.220)). We successfully achieved a 99% accuracy within ±2 of templated size. Additionally, patient demographics, such as height and weight, have shown significant effects on the predictive model. The outcome of this study may help reducing the costs of health care in the long term by minimizing implant inventory costs.

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Preoperative planning in total hip arthroplasty is an essential part of the procedure [1,2] because it prepares the surgical team and significantly reduces the surgical time by minimizing potential complications [3]. The utilization of digital radiography in clinical settings has grown significantly in the past few years. This technique is being used more commonly as a financially sound alternative compared to analogue radiography, as it provides the opportunity to store an unlimited number of images while reducing the costs of film storage and the need for recycling [4]. In addition, advanced computer programs have been developed to analyze the obtained digital information [5].

Historically, templating accuracy, particularly when utilizing analog radiography, has been reported to be relatively low; recently, the literature shows that digital templating can be successful in identifying the implant size within ±2 implant sizes [3–13]. In this study, we aimed to further improve the accuracy of predicting the implant size in total hip arthroplasty by considering some anthropometric characteristics of the patient.

In today's digital world, due to the costs associated with expanding implant options and inventory management, digital templating could be of great benefit for surgical preparation and for reducing inventory in the field, thereby decreasing the overall cost of THA. Proper surgical preparation, including digital templating, can reduce surgical time and potential complications, but digital templating is rarely utilized to manage inventory flow in the field. Accurate templating requires proper patient positioning and standardized X-ray techniques to generate images of sufficient quality. A major concern with templating, particularly computer-assisted, image-processing software, is the issue of "inaccurate magnification ratio." Generally with computer-assisted templating, an initial 20% magnification of the image is assumed. This ratio can be affected by patient-related factors, such as obesity and body habitus, or technical factors, such as the distance of the X-ray tube to the joint being X-rayed. Traditional preoperative planning utilizes a tube-to-film a distance of 48 inches for X-ray imaging, resulting in an estimated magnification of 20% compared to the actual size. However, the accuracy of such magnification has been questioned and can vary widely [4]. Traditional templates provided by implant manufacturers come in different magnifications and are overlaid on standard X-rays to provide the templated implant size. A similar concept is utilized in digital radiography, in which the digital radiographs are adjusted for magnification by utilizing a magnification marker or a constant magnification ratio and software is used to create digital overlays of implant sizes to select the appropriate size and orientation of the component. Table 1 summarizes some of the recent studies conducted in different institutions representing the relationship between the preoperative templating and the actual implant sizes used for the patients. Although many of the previous studies indicated high accuracy, other studies have raised concerns about relying on the outcome of templating. Efe et al reported that, in approximately 9% (15 out of 169) of their cases, the intraoperative implant size could not be predicted, even within 2 sizes [14]. These concerns have inspired our research to find other factors that might facilitate and improve the accuracy of preoperative templating. Thus, the main goal of this study was to improve accuracy of preoperative templating by using a predictive model that includes patient-specific demographics (i.e., height, weight, body mass

The Conflict of Interest statement associated with this article can be found at http://dx.doi.org/10.1016/j.arth.2014.11.021.

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http://dx.doi.org/10.1016/j.arth.2014.11.021
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Table 1
Examples of Previous Studies Investigating the Accuracy of Preoperative Templating of Femoral and Acetabular Components.

Study		Exact Size (%)		±1 Size (%)		±2 Size (%)	
	Total	Femoral	Acetabular	Femoral	Acetabular	Femoral	Acetabular
Whiddon et al (2011) – Digital	51	61	39	90	78	96	96
Whiddon et al (2011) – Manual measurement	51	33	31	82	67	100	88
Shaarani et al (2013)	100	38	36	80	75	98	98
Maratt (2012)	20	NA	NA	75	73	93	96
Maratt (2012) – Acetate	20	NA	NA	93	63	98	86

index (BMI)). Thus, the purpose of this study was to develop a prediction model to enhance the accuracy of preoperative digital templating by considering a multitude of patient variables, such as height, age, sex, BMI, etc. We hypothesized that anthropometric variables impact the accuracy of the preoperative templating size of acetabular and femoral components.

Methods

A retrospective review of preoperative radiographs for 468 individuals (224 females/244 males) who received total hip arthroplasty was conducted. The preoperative templated sizes were compared to actual implant sizes used at the time of surgery. The data were collected from August 2012 to December 2013 at a single institution.

The average age was 59.96 ± 12.50 years, 436 diagnosed with osteoarthritis, 53 with avascular necrosis, 13 with failed THA, 2 with infection, 4 post trauma, and 13 with failed hemi arthroplasty.

All patients underwent direct anterior total hip arthroplasty. The level of the femoral osteotomy was performed based on preoperative templating. Acetabular reaming and cup impaction were performed in standard fashion. Supplemental screw fixation was utilized when needed. The final acetabular component size was selected based on the final reamer size and a quality press fit in the bleeding bone. An attempt was made to restore the native hip center of rotation in all cases. During the study period, two different implant manufacturers for the acetabular component (Stryker Orthopedics and Corin Inc.) were utilized. Acetabular reaming was performed according to the manufacturers' recommendation to achieve a solid interference fit.

All preoperative radiographs were taken with a standardized X-ray source-to-image distance of 1 m when the patients were at the standing position. All radiographs were taken by a single team of radiology technicians. However, no magnification marker was used in these radiographs for the purpose of referencing.

For THA templating in the anteroposterior view the pelvis image was centered over the pubic symphysis, while the hip was internally rotated between 10° and 15°. Fig. 1 depicts a sample of the templated joints that was used in predicting the implant size. The digital radiographs were all analyzed utilizing the TraumaCad software system (TraumaCad, BRAINLAB, Westchester, IL, USA) [15]. The initial implant model was adjusted and magnified by a factor of 120% to provide an acceptable overlay on the hip joint. All intraoperative data were collected prospectively using online, Web-based, data-entry software from an IRB-approved joint registry (IRB # HSC-GEN-09-0143), including the final implant sizes selected by the surgeon.

Statistical Model

A multiple regression model was used to develop the predictive model and to investigate the contribution of each factor to the model to predict the actual size of the implant from the preoperative measurements. These variables included, preoperative acetabular size, preoperative femoral size, body mass index (BMI), age, gender, height, and weight. In each model, a backward stepwise algorithm was used to identify the variables, resulting in significant model demonstration. This algorithm initially enters all variables into the model but systematically removes the predictors that do not have significant contribution in defining the changes in the model. In addition, we used a multiple regression model that includes all the variables of interest in this study to explore their effects as well and provide a more standardized equation for future studies. Finally, to assess the improvement in the accuracy of the templating we used a nonparametric McNemar's test to compare the binomial accuracy outcome (i.e., yes vs. no) between the templating alone method versus utilizing the model. The effect size and odds ratio of the McNemar's test were calculated for the significant differences. In the cases in which the number of cells in the McNemar's test was less than 5 we used an exact McNemar's test. A significance level of .05 was assumed in this study. The analysis was conducted by using SPSS 21.0.0 (SPSS Inc., Chicago, Illinois, USA).

Results

Table 2 includes the demographics of the individuals who participated in this study.

The Acetabular Component

The backward stepwise model has demonstrated that, for the acetabular component size, four significant predictors were achieved, which were templated acetabulum size, height, BMI, and templated femoral size. This model had the $R^2 = .0.797$ with adjusted $R^2 = .795$ with standard error of 1.726. Gender and weight were not significant factors in this model. The outcome of a full regression model is demonstrated in the acetabular model, in which gender and weight are also included in the prediction.

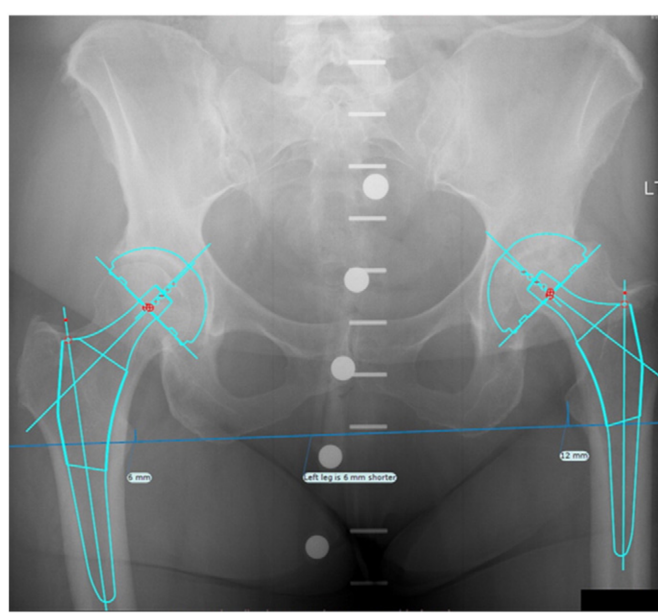

Fig. 1. A sample of templated hip joints by using TraumaCad.

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