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ORIGINAL ARTICLE

Use of Acetate Templates Over Digital Radiographs for Templating in Total Hip Arthroplasty: Technique and Its Validation

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Abstract

Purpose Acetate templates were commonly used for templating for total hip arthroplasty. With digital radiographs having replaced conventional analogue radiographs, newer techniques are required. We describe a method for templating images of digital radiographs using conventional acetate templates, which is independent of a magnification marker or PACS system.

Methods Fifty-one patients (64 hips) who were treated with primary THA were prospectively evaluated. Templating was done by keeping the acetate template directly over the digital image of the radiograph on a liquid crystal display (LCD) monitor, after calibrating the linear scale generated by the digital radiography machine. The size of prosthesis predicted on this templating technique was compared with the actual sizes used during the surgery. Inter-observer and intra-observer reliabilities were assessed. Our calibration method was further validated by comparing the size of the cup calculated on postoperative radiograph using digital templating software (mediCAD Hectec GmbH) and the actual size used during surgery.

Results Accurate size was predicted for 36.7% of the acetabular cup and 35.9% of femoral stems. The accuracy within ± one size was 89.9% for acetabular cups and 91.4% for femoral stems. Excellent inter-observer and intra-observer reliability were seen for both femoral and acetabular components.

Conclusion The method described provides an accurate, reproducible, convenient and low-cost technique of preoperative templating. It combines the ease of using acetate templates with the convenience of being able to use digital images, without the need for expensive software.

Keywords Digital radiograph · Templating · Total hip arthroplasty

Introduction

Total hip arthroplasty (THA) is a common procedure for relieving pain and improving function in patients having significant hip arthritis. Complications like peri-prosthetic fractures, prosthetic loosening, loss of bone stock and impingement can occur if components are incorrectly sized [1–3]. Preoperative templating using radiographs could avoid such complications [4–7].

Another important purpose of templating is to get a fair idea regarding the acetabular cup and femoral stem size in advance and anticipating the need for uncommon components that may not be readily available. Restoration of offset and correction of leg length discrepancy (LLD) can also be planned. Traditionally, preoperative templating was done using the standard acetate templates from the manufacturer over an analog radiograph. These radiographs generally have a magnification of 15–20%, which is accounted for in the templates [8]. Now digital radiography (DR) has almost

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replaced the analog radiographs. They do not have a constant magnification and cannot ordinarily be used with acetate templates.

The introduction of picture archiving and communication system (PACS) has encouraged the use of 'digital templating'. Available literature suggests that digital templating has good reliability and validity [5, 9]. Digital templating requires templating softwares that carry information on different prosthesis systems. However, it has limitations like cost and training.

Digital radiography machine generates a magnification scale based on source and cassette distance. The magnification scale on the digital radiographs can be used as a reference for magnification on standard acetate templates. We are presenting a method of templating that would be cost-effective and easy to perform. The method is independent of PACS and external magnification marker and uses routine acetate templates over digital images of the radiographs projected on a liquid crystal display (LCD) monitor. In this study, we aim to find the accuracy of this method of templating in the preoperative planning of THA as it would be a cost-effective easily reproducible method of templating.

Materials and Methods

This was a prospective study conducted in a tertiary care institute, from October 2018 to September 2019. Before starting the study, ethical clearance was obtained from the institutional ethics committee. A total of 51 patients undergoing uncemented primary total hip arthroplasty were enrolled in the study. We excluded revision hip arthroplasties, surgically intervened hips, protrusio acetabuli, or severe deformity where standard radiographs could not be obtained for templating. Two implant systems were used for this study. In 32 hips (27 patients) Trilogy acetabular system and Versys fiber metal taper stem prosthesis (Zimmer®) were used. Pinnacle acetabular cups with Corail stems (DePuy®) were used in another 32 hips (24 patients). Preoperative acetate templating was done for all patients on digital radiographs using the technique mentioned below.

During our study tools used for templating were standard anteroposterior (AP) radiograph of pelvis with bilateral hip, LCD monitor, acetate template. Study method included following steps.

- Digitalization of standard radiograph:
  Standard anteroposterior radiographs of the bilateral hip with thigh in 15–20 degrees of internal rotation of legs were taken preoperatively. The gantry was placed at a distance of 1 m from the plate in all the patients. Digital Diagnost (Philips Ltd) digital radiography machine was used for imaging. Photograph of the digital radiograph was saved in a joint photographic expert group (JPEG) format and transferred to LCD monitor.
- Manual templating on digital radiograph:
  - Manual templating was done with the company provided acetate templates using the following steps [10, 11]. Calibration of digital radiograph was done by serial zooming till it matched the magnification scale of the given acetate template i.e., 1.15 with DePuy and 1.20 with Zimmer (Fig. 1). This was done using a digital line method similar to the one used by Oddy et al. [12]. The images saved from the DR machine have a linear scale according to the calibration of the machine. A line of 50 mm on this scale on the digital image was taken as a reference and the size of the image was adjusted till this 50 mm line equalled a distance of 50 mm on the scale on the acetate template.
  - Keeping the digital radiograph at this fixed magnification, templating was done to determine acetabular cup size and femoral stem size.
  - The acetabular cup size was determined in 40–45 degrees of inclination, at a position just lateral to teardrop and above obturator foramen (Fig. 2).

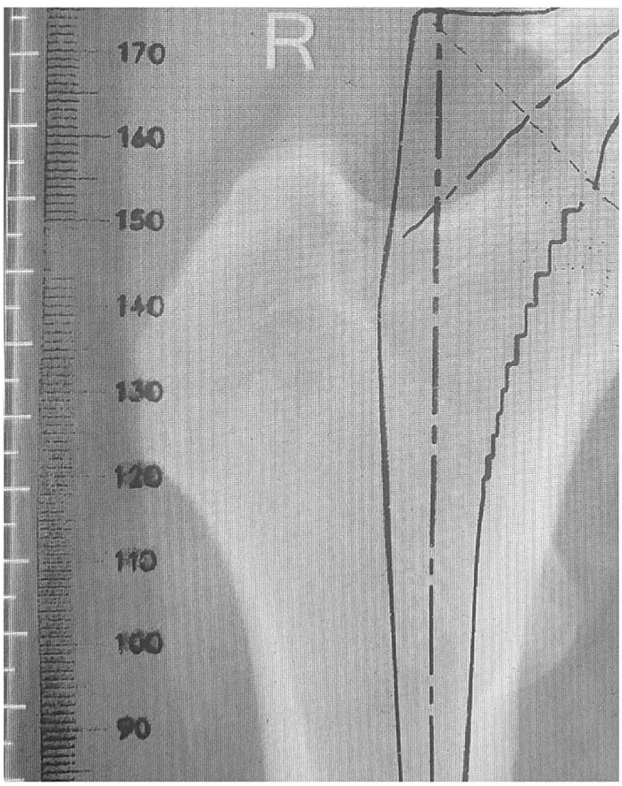

Fig. 1 Calibration of the digital image using a liner magnification marker to correspond with the acetate template

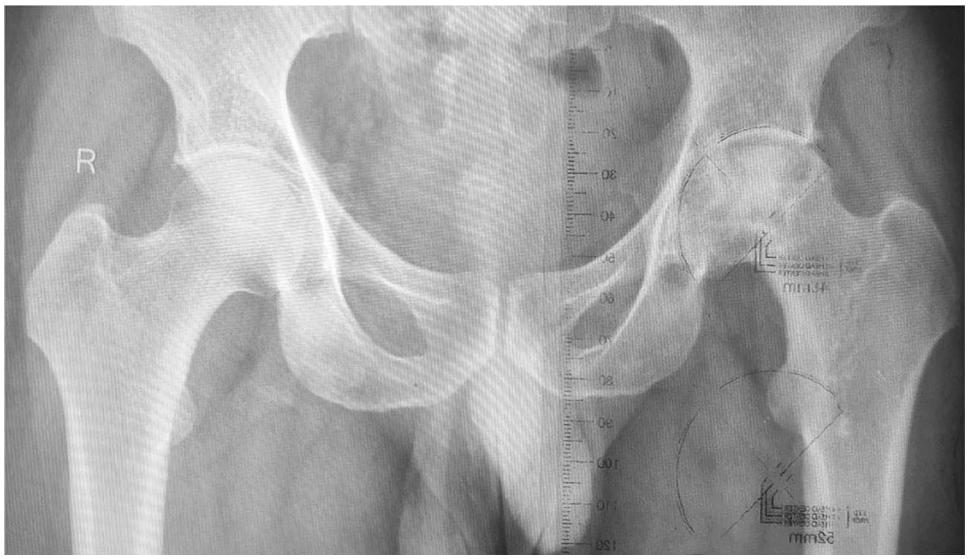

Fig. 2 Overlaying an acetate template over the image of a digital radiograph for templating of the acetabulum

- The femoral stem size was determined by fitting the proximal coated part of prosthesis compactly in the proximal femoral metaphysis (Fig. 3).

Validation of templating with actual data:

All the surgeries were performed by the single arthroplasty surgeon (TG). The surgeon was blinded for templating data to reduce bias. The final size of the prosthesis for implantation was determined intra-operatively based on surgeons' judgement of best-fit. Data obtained from preoperative templating were compared with actual component sizes used during the surgery. The study was performed by two investigators (SS and SA) separately for all the hips to evaluate inter-observer variability. The same procedure was repeated by both the investigators after 2 weeks to measure intra-observer reliability. We compared acetabulum cup size calculated from post-operative radiographs to the size of the implants used during the surgery [13]. This was done by a separate investigator (SP), who was not involved in the surgery, pre-operative templating or patient care. The size of the acetabular cup was derived from post-operative images using digital templating software (mediCAD Hectec GmbH). Images were scaled using the linear scale from the DR machine. The relation between the size of the

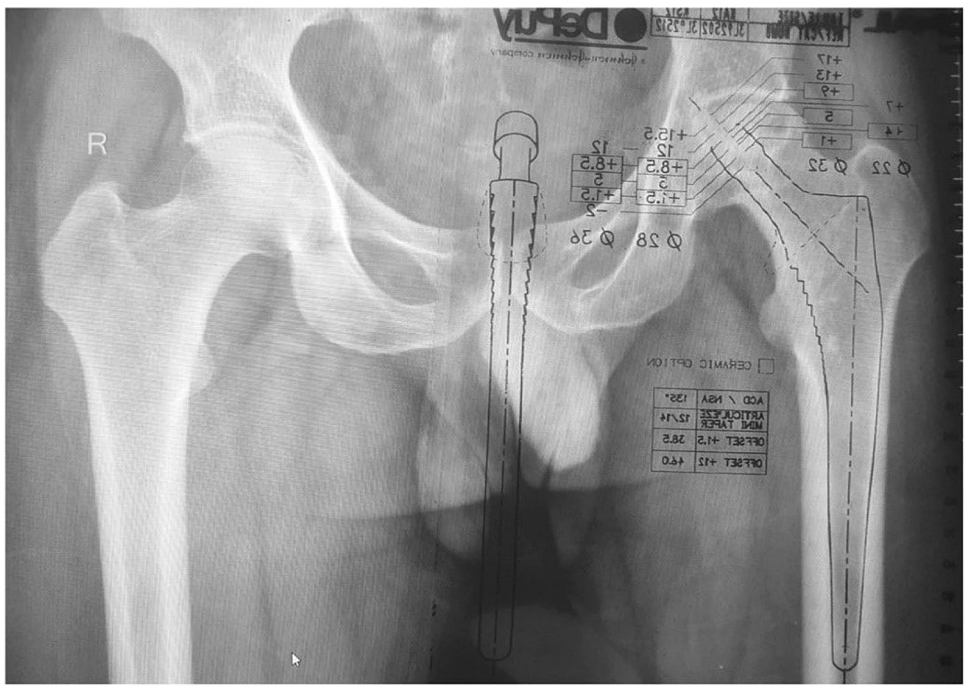

Fig. 3 Overlaying an acetate template over the image of a digital radiograph for templating of the femur

Table 1 Distribution of acetabular component errors

Component size	Investigator 1 *N* (%)	Investigator 2 *N* (%)	Average *N* (%)
− 2	0 (0)	1 (1.5)	1 (0.7)
− 1	11 (17.1)	19 (29.6)	30 (23.4)
0	28 (43.75)	19 (29.6)	47 (36.7)
+ 1	20 (31.2)	17 (26.5)	37 (28.9)
+ 2	5 (7.8)	8 (12.5)	13 (10.1)
Accurate within ± one size	59 (92.1)	55 (85.9)	114 (89.0)

Table 2 Distribution of femoral stem component errors

Component size	Investigator 1 *N* (%)	Investigator 2 *N* (%)	Average *N* (%)
− 2	1 (1.5)	1 (1.5)	2 (1.5)
− 1	18 (28.1)	23 (35.9)	41 (32)
0	25 (39)	21 (32.8)	46 (35.9)
+ 1	17 (26.5)	13 (20.3)	30 (23.4)
+ 2	3 (4.6)	6 (9.3)	9 (7.0)
Accurate within ± one size	60 (93.7)	57 (89.0)	117 (91.4)

cup calculated from the software and the actual size that was used during the surgery was studied.

Statistical Analysis

Statistical analysis was done using SPSS 21.0 software. Continuous variables were depicted as mean ± standard deviation. Inter-observer and intra-observer measurements were done using the intraclass correlation coefficient (ICC).

Result

A total of 51 patients (64 hips) were included in the study. There were 31 males and 20 females. The mean age was 41.84 ± 16.35 (in years ± 2SD). Accurate size was predicted for 36.7% of the acetabular cups and 35.9% of femoral stems. Accuracy within ± one size difference was seen for 89.9% acetabular cups and 91.4% femoral stems (Tables 1, 2). Excellent inter-observer and intra-observer reliability were seen for both femoral and acetabular components. ICC values are summarised in Table 3.

In 62 out of 64 acetabular cups, size calculated from the digital templating software was the same as the size used during the surgery. It was 2 mm more than the actual size in the remaining two cases.

Table 3 The intra-class correlation coefficient for intra-observer and inter-observer variability

	ICC value	95% confidence interval	
		Lower	Upper
Inter-observer variability			
Acetabulum	0.884	0.809	0.929
Femoral stem	0.972	0.954	0.983
Intra-observer variability			
Investigator 1			
Acetabulum	0.972	0.954	0.983
Femoral stem	0.958	0.93	0.974
Investigator 2			
Acetabulum	0.965	0.942	0.978
Femoral stem	0.971	0.952	0.982

Discussion

Good pre-operative planning is the first step for successful outcomes in total hip arthroplasty (THA). Although templating may not predict exact sizes in all the cases, it gives a fair idea about what size of implant would be required, and may avoid errors and complications.

Acetate templates by manufacturers are based on drawings of implants on transparencies with a fixed magnification. They can be used on prints of radiographs with the same magnification [12]. Digital radiographs are more common nowadays as it reduces radiation exposure, reduces wastage due to unsatisfactory films and gives better-quality images. Prints of these images have no fixed magnification and it can easily be changed by the user. Thus, for using acetate templates, the digital images have to be magnified to the scale provided on the templates. Different methods have been described to scale digital radiographs [12], such

Table 4 Table showing advantages and disadvantages of different templating methods

Available methods	Requirements	Advantages	Disadvantages
Manual templating	Radiograph Acetate template Scaling of radiograph	Low cost	Requires scaling during radiography Reproducibility id questionable
Digital templating	Digital templating software/PACS	Easy reproducibility	High cost Training
Hybrid templating	Radiograph Acetate template	Same effectiveness as digital templating Low cost	Not validated method till now

as a disc or a sphere of a known size placed in the plane of the hip joint by taping it to the skin on lateral side of the greater trochanter [14, 15] or embedding it in a plastic block and placing it between the thighs [16, 17]. These methods are operator dependent, increase our reliance on technical staff and may be flawed if the marker is not positioned in the exact plane of the hip joint. They add an extra step in the process of radiography and may not be complied well in a busy radiology department. Positioning of the marker may be difficult when landmarks cannot be palpated, for example in an obese patient.

Most DR machines also provide an in-built magnification scale, which is based on object-source distance. It is calibrated by the software of the machine and the print of the radiograph will also have this linear scale printed on it. It has been used by Oddy et al. [12] and was found to be as consistent as an external magnification marker. Brew et al. [11] in their study manually templated on digital X-rays on the PACS system using acetate templates without using any external calibration marker. Scaling digital images with external calibration markers may not increase the accuracy of templating when compared with the fixed magnification of traditional analog technique [18]. We did not use PACS while templating as the digital image of the radiograph carried the linear magnification line.

Many authors have used an external magnification marker for this purpose. Petretta et al. [19] studied digital radiographs of 52 THAs using a magnification marker, on LCD monitor for acetate on-lay templating. It was found to be a suitable alternative to digital templating using specialised software. The study used a 25 mm magnification marker placed at the level of the hip joint [8]. Krishnamoorthy et al. [20] studied the accuracy and reliability of templating the acetabular cup size using conventional acetate templates on digital radiographs. They reported a 90% prediction rate for the acetabular cup size within ± 1 size. The study only considered the acetabular component and did not take into account the femoral templating. Similar findings were also seen by Shin et al. [10] using a magnification marker for templating using acetate templates.

It is not clear in literature if digital templating is superior to acetate templating. There are studies that favour digital templating over acetate templating [16, 21, 22]. At the same time, several studies have found both methods to be comparable [9, 23]. Digital templating also uses a magnification scale on the digital radiograph, whether it is a magnification marker or a calibrated linear scale by the imaging system. Inaccuracies in image acquisition because of variation in distance of the object (hip joint) from X-ray source or the cassette will affect the accuracy of templating in both the methods.

We calibrated our digital images using a magnification scale provided by the DR console. Excellent predictability of intra-operative prosthesis size was seen. Our findings support the use of this method for templating. Results similar to the studies using a magnification marker on digital films [11, 19] were found in the present study. Our results were further validated by repeating the exercise on the postoperative radiographs. 62 out of 64 acetabulum cups used during the surgery had the same size as calculated on post-operative radiographs by digital templating using a linear scale calibrated by the DR machine.

The advantages of our method are that it is convenient, low-cost and independent of the PACS system or external calibration marker. It is very suitable for use in resource-constrained settings. Jeyaseelan et al. [24] wrote that people have stopped using templating due to the non-availability of the analogue films and the complexity of the templating software for digital radiographs. The advantages and disadvantages of different templating methods have been summarized in Table 4.

Strength of the present study include its prospective nature, prosthesis systems from two different companies were tested and both acetabular and femoral component were taken into account. The study has several limitations. The magnification scale provided by different companies may be different. Inherent magnification of the radiograph during acquisition of the image and the magnification of the acetate templates may not coincide. These variations should be studied in detail before templating is planned.

Conclusion

The method described provides an accurate, reproducible, convenient and low-cost technique of preoperative templating. It combines the ease of using acetate templates with the convenience of being able to use digital images, without the need for expensive softwares and complex techniques.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical standard statement This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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