Editorial Manager(tm) for Journal of Bone and Joint Surgery
Manuscript Draft

Manuscript Number:

Title: Accuracy of digital (Filmless) Templating in Total Hip Replacement

Article Type: Clinical

Section/Category:

Keywords: Total Hip Templating; comparision of digital vs accetate templating; preoperative planning in total hip arthroplasty, presurgical planning; templating

Corresponding Author: Mr Zeev Glozman,

Corresponding Author's Institution: Ben Gurion Faculty of Medicine

First Author: William Murzic, MD

Order of Authors: William Murzic, MD; Priya Hirway, MS; Paula Lowe , RN; Zeev Glozman

Manuscript Region of Origin:

Abstract: Background: Preoperative templating has been useful to determine the correct size prosthesis in cementless total hip replacement. Typically this has been accomplished using acetate overlays on plain radiographs with good success. With the advent of digital x-ray and PACS, software has been developed that incorporates the templates of many different vendors into a program that enables the surgeon to measure without radiographs, the size of the intended femoral and acetabular components. We compared the two techniques to assess the relative accuracy of digital templating.

Methods: A total of 40 cases were analyzed comparing the preoperative templated sizes with the actual size prosthesis implanted at surgery. Both acetabular and femoral component sizes were reviewed. Magnification markers were used in all cases and all templating and surgery was performed by one surgeon. Twenty hips that were templated using radiographs were compared to twenty hips that were done using digital templating software on a pacs workstation (TraumaCad, Novapacs, Salt Lake City UT) A synergy femoral component and a Reflection cup (Smith and Nephew, Memphis TN) were used in all cases. Preoperative templating data was compared to prosthesis size on operative notes.

Results: Using standard templating, thirty percent of implanted stems were the same size as templated, 65 percent were within one size, and 5 percent were within 2 sizes. With digital templating 60 percent were the same size, 35 percent were within one size, and 5 percent were within 2 sizes. For acetabular components using acetate overlays, 50 percent of implanted cups were the same size as templated, 45 percent were within 2 mm, and 5 percent within 4 mm. Digitally, 45 percent were the identical size, 35 percent were within 2 mm, and 20 percent within 4mm. All postoperative films show good fit of the components and there were no intraoperative or postoperative fractures.

Conclusions: This preliminary study, using recently developed digital templating software, showed no significant differences when compared to the standard technique using magnified radiographic overlays. Use of this templating software was safe and effective.

Clinical Relevance: In total hip replacement, preoperative templating provides valuable information about anatomy and appropriate implant size. Having the information prior to surgery provides surgical accuracy, reduces fractures, and decreases operative time. With the increasing demand for digital imaging/pacs, digital templating will become more prevalent.

* Unblinded Title Page

The Accuracy of Digital (Filmless) Templating in Total Hip Replacement

William J. Murzic M.D*.

Priya Hirway M.S.

Paula Lowe R.N*.

Zeev Glozman B.S**.

Correspondent Author
** Zeev Glozman
Bar Kohva 34/3
Tel Aviv, Israel, 99686
Work: +(972) 54 4389 – 313
Fax: +(972) 3923 6416

* The Musculoskeletal Center
4 Centennial Drive
Peabody, MA 01960
USA,
9785310800

Background: Preoperative templating has been useful to determine the correct size prosthesis in cementless total hip replacement. Typically this has been accomplished using acetate overlays on plain radiographs with good success. With the advent of digital x-ray and PACS, software has been developed that incorporates the templates of many different vendors into a program that enables the surgeon to measure, without radiographs, the size of the intended femoral and acetabular components. We compared the two techniques to assess the relative accuracy of digital templating.

Methods: A total of 40 cases were analyzed comparing the preoperative templated sizes with the actual size prosthesis implanted at surgery. Both acetabular and femoral component sizes were reviewed. Magnification markers were used in all cases and all templating and surgery was performed by one surgeon. Twenty hips that were templated using radiographs were compared to twenty hips that were done using digital templating software on a pacs workstation (TraumaCad, Novapacs, Salt Lake City UT) A synergy femoral component and a Reflection cup (Smith and Nephew, Memphis TN) were used in all cases. Preoperative templating data was compared to prosthesis size on operative notes.

Results: Using standard templating, thirty percent of implanted stems were the same size as templated, 65 percent were within one size, and 5 percent were within 2 sizes. With digital templating 60 percent were the same size, 35 percent were within one size, and 5 percent were within 2 sizes. For acetabular components using acetate overlays, 50 percent of implanted cups were the same size as templated, 45 percent were within 2 mm, and 5 percent within 4 mm. Digitally, 45 percent were the identical size, 35 percent were within 2 mm, and 20 percent within 4mm. All postoperative films show good fit of the components and there were no intraoperative or postoperative fractures.

Conclusions: This preliminary study, using recently developed digital templating software, showed no significant differences when compared to the standard technique using magnified radiographic overlays. Use of this templating software was safe and effective.

Clinical Relevance: In total hip replacement, preoperative templating provides valuable information about anatomy and appropriate implant size. Having the information prior to surgery enhances surgical accuracy, reduces fractures, and decreases operative time. With the increasing demand for digital imaging/pacs, digital templating will become more prevalent.

Introduction

Preoperative planning is helpful in achieving a successful result in total joint replacement. Most reconstructive surgeons routinely template radiographs prior to performing total hip arthroplasty. Having preoperative information on appropriate implant size and position improves operative efficiency and facilitates the desired result. Preoperative templating in total hip replacement helps familiarize the surgeon with the bony anatomy prior to surgery, reducing surgical time as well as complications. Typically most reconstructive surgeons have used acetate overlays and radiographs to determine appropriate implant size. This method has been reasonably accurate in hip arthroplasty even though radiographs have varied magnifications due to differences in technique and soft tissue mass which do not always match the given magnification of overlays. Improvements in technology have produced digital imaging and picture archiving and communication systems (PACS) which are now prevalent and are being used by an increasing number of hospitals and clinics. The trends driving PACS are the same ones pushing general radiography toward digitization. (1) With digital radiography and computed radiography, a DICOM archive is generated for either a standalone PACS network or a web based PACS functionality. Digital images replace radiographs which can no longer be lost or misplaced in a completely filmless system. X-ray images are viewed on a diagnostic grade monitor, rendering prosthetic overlays useless. Digital templating software is now available which can be used with various digital x-ray servers. The incorporation of the various templates into the software in terms of the “magnification factor” is essential for accurate preoperative templating and planning.

The present study was performed to evaluate the accuracy of a specific templating software (with emphasis on femoral component fit) and compare it to the traditional technique using standard radiographs.

Materials and Methods

A total of 40 hips in 39 patients were studied retrospectively. All preoperative templating information was recorded and compared to operative reports and vendor labels. All surgery and preoperative templating was performed by one surgeon (***Blinded by JBJS***). All radiographs were templated with standard overlays which were 120% magnified. All x-rays (except the pelvis view) were taken with a ten centimeter magnification marker which is an acrylic stick with a metallic bead imbedded at each end. Magnification was determined by a calibration tool in the software, which then automatically adjusted the digital template accordingly. For radiographs the magnification marker was measured by hand with a ruler to establish the magnification. All digital templating was performed on the same PACS workstation using the same templating software (Fig.1) (Traumacad, Tel Aviv, Israel)

An uncemented Synergy femoral component (Smith and Nephew, Memphis TN) and Reflection cup were used in all hips. The femoral implant is a tapered titanium alloy stem with proximal porous coating. The cup is a porous coated titanium shell with a proportionally expanded rim.

The study group was comprised of patients that had surgery performed just before and after our institution acquired the software. Twenty consecutive hips using radiographs (just prior to acquiring a PACS) were compared to 20 consecutive hips that were templated digitally after the software was obtained. Digital templating and surgery was performed without allowing for learning curves. All patients had Dorr type A or B bone (4) and the use of this particular femoral component was considered appropriate. There were no unusual deformities or bone deficiencies in all 40 hips.

All charts were reviewed and surgery date, age, sex, and diagnosis were recorded. (Table 4)

There were 37 hips with osteoarthritis and three with avascular necrosis. All patients had standard AP, (Lauenstein) lateral, and pelvis x-rays preoperatively and AP and lateral x-rays at 6 weeks, three months, and six months postoperatively. All x-rays were performed by two radiology technicians using a Eureka Linear MC150 collimator using a 40 inch tube to film distance. A ten centimeter magnification marker was taped to the skin laterally over the greater trochanter for the AP view and taped anteriorly at the proximal femur for the lateral view. Digital images were produced by computed radiography (Konica-Minolta, Wayne NJ) and stored on a PACS server (Novapacs, American Fork, UT). Magnification was determined on radiographs by measuring the magnification marker by hand and using this information when choosing an appropriate size template. Standard proprietary acetate overlays were used which were one hundred and twenty percent magnified. When choosing between sizes, if the radiographic magnification was less than one hundred twenty percent, the larger size (template) was chosen; if the magnification was greater than one hundred twenty percent, the smaller size template was chosen. Digitally, a calibration tool in the software was utilized to determine the magnification of each image, and the magnification of the digital template was automatically adjusted. The magnification range was one hundred sixteen percent to one hundred twenty four percent. The template files were acquired digitally from the each manufacturer, and incorporated into the software in DXF file format.

In all cases the surgeon was aware of the preoperative templated data at the time of surgery. Radiographs and digital images were templated utilizing common objectives of canal filling and fit. Optimal femoral neck resection was around 1-1.5 cm above the lesser trochanter and was estimated from the templated image or radiograph. Offset and radiographic leg length measurements were estimated but not recorded or analyzed.

Thirty eight hips were performed through a mini incision posterior approach and a standard posterior approach was used in two hips. Surgical technique was similar in all cases with the intent of optimal fit, fill, and femoral component stability within the femur. The endosteal canal was conically reamed by hand in incremental sizes until the proximal isthmus was engaged, and then the femur was broached to that size. If the broach was felt to be axially or torsionally unstable (under sized), distal reaming was increased by one or two sizes until optimal fit of the broach was obtained.

Post operative x-rays were followed to a minimum of 6 months and examined for fractures or subsidence.

The study group included 17 (44%) males and 22 (56%) females. Patient ages ranged from 41 to 82 years (mean age 67 years). One female patient had bilateral surgery. There were 20 left hips and 20 right hips. All patients underwent total hip arthroplasty using the same components. A cross linked polyethylene liner was used in all cases. A chrome cobalt femoral head was used in 37 hips and oxinium used in three. All except three acetabular components were inserted without screw fixation. Typically the acetabulum was under reamed by one millimeter or reamed line to line with the cup size which has a flared rim. There were no cases with atypical femoral anatomy or acetabular protrusio.

Postoperative x-rays were analyzed for femoral component fit using Callaghan's criteria (2) which was modified to account for this stem geometry. The fit was considered excellent if the stem was in contact or within 1 millimeter of cortical bone at some point on both the medial and lateral stem surface (or anterior posterior surface) on either the anterior posterior or lateral x-ray. The midportion of the stem was consistently analyzed starting at the distal edge of the porous coating to a point 5 centimeters distal (before the stem tip tapers off). The fit was considered to be good if the stem was within two millimeters at some point on the medial and lateral (or anterior posterior) stem surface on either the anterior posterior or lateral x-ray. The fit was considered to be poor if there was no less than three to four millimeters between the stem surface and cortical bone at any point on both the anterior posterior and lateral x-ray. The distance between the calcar resection level and the top edge of the porous coating was measured on the immediate postop and six week and three month x-ray. A change of greater than three millimeters was considered subsidence.

Results

Hospital records and operative notes were reviewed on all patients. There were no intraoperative fractures or complications. There were two postoperative complications. One patient sustained a single postoperative dislocation treated closed successfully, and a second patient with early dementia developed recurrent instability treated with acetabular revision using a constrained liner with a satisfactory result. Clinically, there were no significant differences between the two groups. (Table 1.) Two patients in each group had mild thigh pain.

The actual size implant used for each patient was compared to the preoperative templated size. (Table 2.) Using radiographs and overlays 6 hips (30%) were the same size as templated, 13 were different by one size (65%), and one hip (5%) was two sizes different. With the templating software and PACS images, 12 hips (60%) were the same size as templated preoperatively, 7 hips (35%) were different by one size, and one (5%) was different by 2 sizes. For both groups one hundred percent were within two sizes and 95% were within one size; in the PACS group a larger percentage were the same size as planned.

For femoral components that were not the same size as planned, with digital templating 75% of hips were underestimated in terms of size (5 by one size and one by two sizes) and 25% were overestimated by one size. With film 64% were underestimated (8 by one size and one by two sizes) and 36% were overestimated by one size.

Cup size was also examined. In radiographs cup size was the same as templated in 10 (50%) hips. In 9 hips (45%) acetabular size was different by 2 millimeters, and one cup (5%) was different by 4 millimeters. Eighty percent of these acetabular components were underestimated in size and 20 percent overestimated. With digital images nine hips (45%) were the same size, seven (35%) differed by 2 millimeters and four (20%) differed by 4 millimeters. Among these eleven hips, eighty two percent were underestimated in size and twelve percent were overestimated. Comparing radiographs to digital, cup size was within 2mm of the planned size in 95 percent and 80 percent respectively.

Statistical analysis to examine difference between templated and actual implant size were conducted using STATA v.8. Differences were tested for using chi square and 1-tailed Fisher's exact test (where appropriate) for categorical data and t-tests for continuous data.

Postoperative x-rays to six months showed no subsidence or changes in femoral (or acetabular) component position in all hips. There were no significant differences in stem fit between the two groups. In hips using the standard technique stem fit was excellent in seventy percent and good in thirty percent. In the digital group stem fit was excellent in seventy five percent and good in twenty five percent. There were no stems with poor fit.

Discussion

Many hip surgeons routinely practice preoperative planning in joint replacement surgery. Planning entails several variables and considerations such as bone quality, patient activity level, choice of implant, leg length, offset, mode of fixation, bony deformity or deficiency, bearing surfaces, and economic issues. Preoperative templating for appropriate size, fit and position of the implants addresses many of these variables before surgery is performed. The templating process optimizes surgical accuracy and reduces operative time and should lead to a more durable result with fewer complications, particularly in uncemented femoral components. Unanticipated problems; issues with leg length inequality, intraoperative fracture, and instability may be avoided. Problems with implant inventory are avoided when this information is communicated with hospital operating rooms prior to surgery.

This preliminary study examines the accuracy and usability of digital templating as compared to the standard method using radiographs. Cementless components were chosen as more precision is required in the preoperative planning process. Some of the immediate major goals in uncemented hip replacement surgery are the avoidance of under sizing (preventing problems of subsidence and loosening) as well as over sizing (problems with fracture, offset, and leg length). We conducted this study to investigate whether digital templating is as effective and accurate as the standard technique. Clearly the digital technique was used effectively and safely in this set of patients. The potential advantages of digital templating are the improved method of determining x-ray magnification and the ability of the software to adjust the template magnification accordingly. The findings of this study suggest that, for uncemented femoral components, the digital technique yields a more accurate estimate of implant size; however the small sample size of the study groups is a limitation. A larger study group would increase the power of the study, and is planned for the future.

We began using this “first generation” software immediately after acquiring it and the twenty hips reviewed here were the first twenty performed without any “practice hips”. Such software programs must be surgeon friendly and easy to navigate through to find the desired implant and size. Their effectiveness depends on several factors including magnification accuracy, ease of use, and expandable implant inventory. These programs have many other applications and can be used for knee replacement, revision surgery, osteotomies, and fracture fixation. In hip arthroplasty, leg length and offset can be measured and incorporated into the templating process.

Digital imaging systems provide several advantages for orthopaedic surgery. X-ray film is no longer necessary. There are no radiographs to store, lose, or misplace. Over time this results in a cost savings as film and developing supplies are no longer needed. There is no need to transport x-rays to the operating room. Disadvantages include the initial cost of outfitting the technology and the fact that images are slightly smaller as compared to standard hip radiographs, however image size and contrast, as well as many other variables, can be adjusted by using the software included in a PACS workstation as well as the templating program.

As digital technology improves and becomes more accessible to the health care industry, digital radiography and PACS will be used by an increasing number of hospitals and orthopaedic practices. More practices will become filmless and software programs will be necessary for successful reconstructive planning and templating.

References

1. **Digital Templating in Total Hip Arthroplasty** J. Bone Joint Surg. Am., Dec 2004; 86: 118 - 122.

2. Bruce, R, C.R. vs. D.R., What are the options? Aunt Minnie.com July 2003

3. Callaghan, J.J., Dysart, S.H.; and Savory, C.G., The Uncemented Porous-Coated Anatomic Total Hip Prosthesis. J. Bone and Joint Surgery. Eveny-A, 337-346, Mar 1988.

4. Carter, L.W., Stovall, D.O.; and Young, T.R., Determination of Accuracy of Preoperative Templating of Non Cemented Femoral Protheses. J. Arthroplasty 10:507-513, Aug.1995

5. Dorr, L.D., Faugere, M. Mackel, A.M., Gruen, T.A. Bognar, B.; and Malluche, H. H., Structure and Cellular Assessment of Bone Quality of Proximal Femur. Bone., 14:231-242, 1993

6. Dorr, L.D.; Wan,Z.; and Gruen, T.: Functional Results in Total Hip Replacement in Patients 65 Years and Older. Clin. Orthop., 336: 143-151, 1997

7. Knight, J. L.; and Atwater, R.D.: Preoperative Planning for Total Hip Arthroplasty. J. Arthroplasty, 7: 43-409, 1992

8. Lattanzi, R.; Viceconti, M.; Zannoni, C. Quadrani, P. and Toni, A: Hip Op: An Innovative Software to Plan Total Hip Replacement Surgery. Med. Infrom., 27: 71-83, 2002

9. Peters, L.E.; Sheth, N.; Bostrom, M.E.; Pellicci, P.M.; and Sculco, T.P.: Preoperative Planning for Revision Total Hip Arthroplasty. Tech in Orthopaedics, 16: 205-221, 2001

Figure Legend

Figure 1: Typical Planning Picture

Table 1

TABLE 1. CLINICAL CHARACTERISTICS OF PATIENTS BY TECHNIQUE

Characteristics	Radiograph (n=20)	Digital Imaging (n=20)	p-value
Gender (n, % Female)	8, 40%	10, 50%	0.751
Mean Age, mean ± SD	64 ± 11 years	67 ± 12 years	0.419
Etiology (n, %)			
Osteoarthritis	18, 90%	19, 95%	
Avascular necrosis	2, 10% (2)	1, 5%	1.00
Site (n, % Right Hip)	11, 55%	9, 45%	0.752

Stem template size compared to actual implant size

Table 2

Table 2. TEMPLATED VERSUS ACTUAL IMPLANTED SIZE, BY COMPONENT TYPE

Component Type						p-value
Femoral Component (Film)			Femoral Component (Digital)			
Same size	6 Hips	30%	Same size	12 Hips	60%	0.0565
1 Size different	13 Hips	65%	1 Size different	7 Hips	35%	0.0578
2 Sizes different	1 Hip	5%	2 Sizes different	1 Hip	5%	1.00

Component Type						p-value
Acetabular Component (Film)			Acetabular Component (Digital)			
Same size	10 Hips	50%	Same size	9 Hips	45%	0.752
2 mm different	9 Hips	45%	2 mm different	7 Hips	35%	0.519
4 mm different	1 Hip	5%	4 mm different	4 Hips	20%	0.152

Table 3. FILM

FILM							
Name	Age/Gender	DX	Site	Pre-Op Stem	Post-Op Stem	Pre-Op Cup	Post-Op Cup
BC	61 YR/M	OA	R	10	11	52	52
RD	80 YR/F	OA	R	13	13	52	54
EL	60 YR/F	OA	R	12	13	52	52
		OA	L	13	13	52	52
EW	65 YR/F	OA	R	12	12	56	52
JC	80 YR/F	OA	L	12	13	50	52
ME	59 YR/M	OA	L	15	14	56	58
RD	46 YR/M	OA	L	17	16	58	60
EG	74 YR/F	OA	R	13	13	50	50
KA	54 YR/F	OA	L	13	14	54	54
JF	61 YR/F	OA	R	11	10	50	50
LW	61 YR/F	OA	L	13	12	50	52
EP	68 YR/M	OA	R	15	17	64	64
JD	49 YR/M	AVN	L	15	14	58	58
JM	41 YR/F	AVN	L	9	10	48	50
LG	70 YR/F	OA	R	14	15	54	52
AD	67 YR/F	OA	R	10	11	52	52
JP	79 YR/F	OA	L	9	10	54	54
WB	78 YR/M	OA	R	14	14	52	54
RD	67 YR/M	OA	R	15	15	56	58

Table 4. DIGITAL

DIGITAL							
Name	Age/Gender	DX	Site	Pre-Op Stem	Post-Op Stem	Pre-Op Cup	Post-Op Cup
PA	57 YR/F	OA	R	10	9	50	50
DF	47 YR/M	AVN	R	13	13	58	58
BB	82 YR/F	OA	R	12	12	50	50
MT	76 YR/F	OA	L	13	13	54	56
LT	64 YR/M	OA	L	14	13	52	54
PG	78 YR/M	OA	L	13	13	52	56
MT	75 YR/F	OA	L	13	14	50	50
SB	51 YR/F	OA	L	14	15	54	54
WR	59 YR/M	OA	R	14	14	54	56
JN	48 YR/M	OA	L	14	14	54	54
GF	62 YR/F	OA	L	11	12	50	52
PJ	77 YR/F	OA	R	13	13	56	52
JB	81 YR/M	OA	R	12	12	52	52
JW	61 YR/M	OA	L	14	14	54	56
RW	68 YR/F	OA	L	12	13	52	50
PG	78 YR/M	OA	L	13	13	52	56
RG	74 YR/M	OA	R	13	15	56	60
KM	50 YR/F	OA	R	13	13	52	52
AD	81 YR/F	OA	L	12	13	52	52
RB	71 YR/M	OA	R	13	13	52	54

Figure 1
Click here to download high resolution image

*** Copyright**

This piece of the submission is being sent via mail.

*** Conflict of Interest**

This piece of the submission is being sent via mail.

*** IRB Approval (clinical)**

This piece of the submission is being sent via mail.