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Original Article

Accuracy of Predicting Implant Head Size by Digital Templating with and without Radiographic Marker in Hip Hemiarthroplasty: A One Year Retrospective Record Review

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Abstract

Background *Preoperative templating has paramount importance for both Total Hip Arthroplasty and hemiarthroplasty. The objective of this study was to assess accuracy of predicting implant head size by digital templating with and without an external radiographic marker in hip hemi-arthroplasty.*

Methods: *A retrospective record review was conducted. Two blinded observers used digital software (Radiant Dicom viewer) to template the femur head size of 35 individuals who had undergone hip hemi-arthroplasty in Tikur Anbessa Specialized Hospital (TASH) from September 2022 to September 2023 using two different methods, i.e., external radiographic marker and fixed magnification factor. The templated head size values were then compared to the head size of actual implants used intra-operatively to assess the accuracy of each method. Cohen's kappa value was used to calculate inter-observer variability.*

Result: *The accuracy of predicting implant head size in hip hemi-arthroplasty using both methods was similar with a mean relative error of method 1 (2.8 & 3.1% for observers A & B, respectively) and method 2 (3.3 & 3.4% for observers A & B, respectively), p-value for both observers A & B is 0.46 & 0.59, respectively with 95% CI. Inter-observer agreement for both method 1 & 2 was excellent when a precision scale of 1 size was used with a kappa value of 0.84 and 0.93 respectively.*

Conclusion*: Digital templating of hip hemiarthroplasty using a fixed magnification factor is as accurate as the radiographic marker method in predicting implant head size with excellent Inter-observer reliability.*

Keywords*: Hemiarthroplasty, templating, femur head size, external radiographic marker, fixed magnification factor*

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Introduction

Hip fractures are the most common ones among fragility fractures. Approximately 2 million people sustain hip fractures yearly and femur neck fracture accounts for 50% [1]. By the year 2050, it is expected that the incidence will be doubled [2]. Among patients with hip fractures, 75% are women [3].

Arthroplasty is the mainstay of treatment for older individuals with a displaced femoral neck fracture. For several reasons, Total Hip Arthroplasty (THA) is the main treatment choice for older, active patients (less than 75 years of age) [4][5]. Hemiarthroplasty (HA) is reserved for elderly fragile patients and those with higher dislocation risk. However, in countries like Ethiopia most patients are managed with HA since the practice of THA is not well expanded. A variety of HA implant options are available, such as fixed and modular neck, unipolar and bipolar head, and cemented and uncemented stem. The current choice of implant is cemented modular bipolar HA [6] [7].

There have been many reports on pre-operative digital templating in THA. It helps the surgeon predict the proper implant size and levels of bone resection so that, it decreases surgical time and complications of both intraoperative and postoperative procedures [8][9]. It has also been recently shown to be a helpful tool in

hip HA preoperative planning.[10]

Although intraoperative direct measurement of the native femur head dictates the final femur head size, estimating the possible size preoperatively will help the surgeon check the availability of the size in the operation theatre stoke. The discrepancy between the femoral head size and acetabulum has been identified as a contributing factor to accelerated acetabular erosion and protrusion, which may increase the likelihood of requiring revision surgery. [11]. Various reports showed that a size difference between the native and prosthetic femur head size beyond 1.5 to 3.2 mm will result in significant acetabular erosion [12][13][14].

There are several methods for determining the magnification factor (MF) while templating. The pervious studies showed that, digital templating using a set MF has better or equal accuracy to the external radiographic marker method (ERM) [15][16]. The lower accuracy of ERM method may be due to technical difficulty in finding the center of Greater Trochanter (GT), particularly in obese patients which in turn affects the accuracy of this technique. According to study conducted in the united kingdom, there is an average 6.8% error in accuracy regarding femoral head size due to the position of ERM [17].

Though previous study showed that the ERM technique is inferior, it is still used as the mainstay of templating technique in TASH. Furthermore, this method incurs additional costs and radiation exposure by increasing the number as well as the filed of X-ray in order to incorporate the marker over the GT. This study assessed the predictive accuracy of digital templating for femur head size in hip HA with and without a radiographic marker.

Methodology

Materials and Method

A retrospective study was conducted in all patients who had undergone hip HA for the indication of femur neck fracture at TASH from Sept 2022 to Sept 2023 and fulfilled the eligibility criteria. Patients with a Adequate preoperative pelvic AP x-ray with ERM placed over the GT and documented actual implant head size in the medical chart were included in this study. Patients with contralateral hip HA were excluded from the study. Adequacy of the pelvic x-ray was assessed using the following parameters: well centered, no significant rotation of the pelvis, and the lesser trochanter of the uninjured femur shouldn't be seen in full profile. Data were collected using a checklist which consisted of sociodemographic factors (age and sex), implant related factors (size and type of implant), and templated values. Age, sex, size, and type of implant used were retrieved from their respective medical record.

Preoperative templating of femur head size:

The radiant Dicom viewer was used to template the femur head size from the uninjured side of the hip. Templating was done by two observers (A & B) who were blinded to the size of definitive implant used and each other's measurements. The widest diameter of the femur head from the uninjured hip was measured to determine the femur head size. Then the direct X-ray measurement was calibrated using 2 different methods; Method 1 – external radiographic marker & method 2 - fixed magnification factor. (figures 1 & 2)

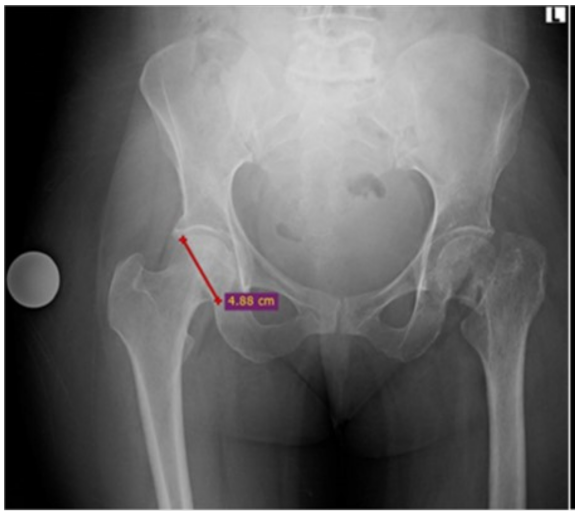

Fig. 1 direct X-ray measurement of femur head

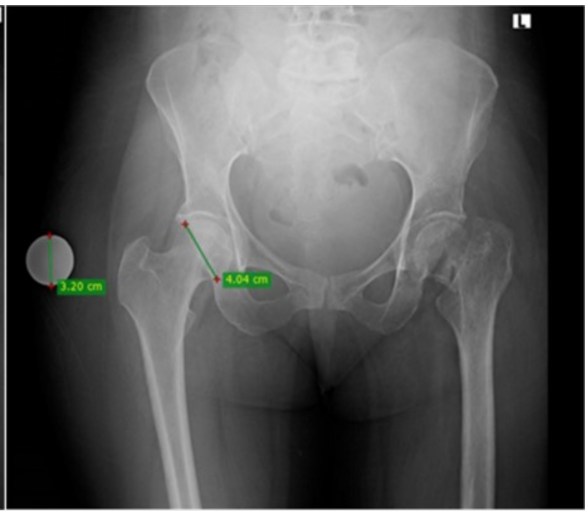

Fig.2 calibrated femur head size

The magnification factor of our digital X-ray was determined from 15 pilot pelvic AP X-rays with a 32mm sphere over the GT. Each radiograph magnification factor was obtained using the following formula and the mean magnification factor was calculated to be 118%.

$$\textbf{MF} = \frac{\text{Actual sphere size}}{\text{Templated sphere size}} \times 100$$

The femur head size was calculated using a set MF of 118 by the following formula:

$$\frac{\text{Direct x-ray measurement femur head}}{\text{Fixe magnification factor (118)}} \times 100$$

eg. Femur head size calculation for the x-ray on fig. 1 will be, $4.88/118 \times 100 = 4.13\text{CM}$.

Data processing and analysis:
Once the data ware collected and checked for completeness, analyses were done using IBM SPSSversion 29 software. The template and actual implant head sizes were compared and thedifference was computed.

The accuracy of each technique was expressed using percentages. Mean relative error for both methods & observers was calculated & compared using an independent student t-test. Cohen's kappa value (k) was used to assess inter-observer reliability.

Result
One hundred and two 102 hip hemiarthroplasties were done for an indication of femur neck fracture at TASH from September 2022 to September 2023. Out of these participants, 35 (12 males and 23 females) met the eligibility criteria. The average age was 67 (50-95 years). 8 patients underwent cemented HA and the remaining 27 were uncemented. In terms of implants 7 bipolar and 28 unipolar heads were used. The average implant head size we used was 42mm in females & 47mm in males soft tissue and joint spaces.
Fig. 3 & 4: show age and sex frequency distribution

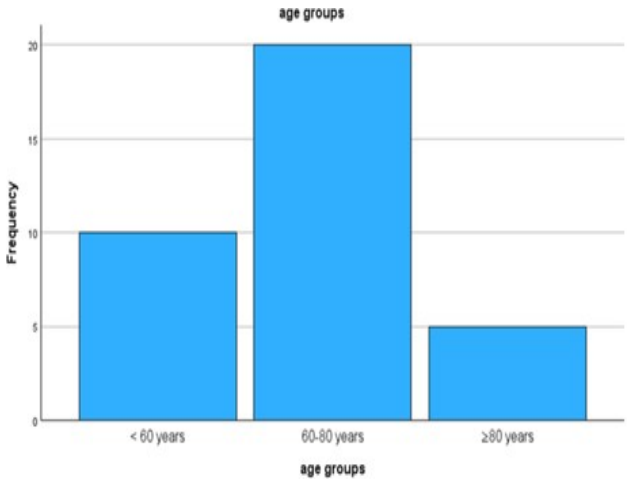

Fig.3: age frequency distribution

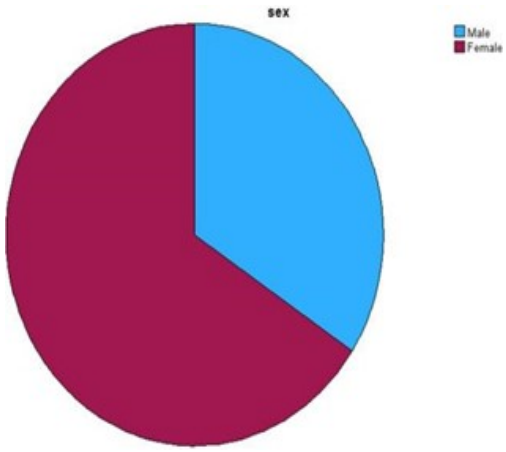

Fig.4: sex frequency distribution

Accuracy:
Observer A predicted the exact femur head size in 11 hips (31%) & 8 hips (23%) using method 1 & 2 respectively. The accuracy increased to 85% (30 hips) & 80% (28 hips) when the precision level was increased to within 2mm. Observer B predicted the exact femur head size in 9 hips (26%) & 7hips (20%) using methods 1 & 2 respectively. When the precision level is increased to within 2mm, femoral head size was predicted correctly in 27 hips (77%) using both techniques. (table1)

The mean relative error of method 1 was (2.8 & 3.1% for observers A & B, respectively) lower than method 2 (3.3 & 3.4% for observers A & B, respectively) however it was not statistically significant (p- value for both observers A & B was 0.46 & 0.59 with 95% CI). (table 2)

Inter-observers agreement:
Kappa value for the exact measurement agreement using method 1 & 2 was 0.36 and 0.52 respectively. When the precision scale of 1 size (1mm) was used, kappa value increased to 0.84 and 0.93 for method 1 & 2, respectively showing excellent inter-observer agreement.

Table 1: The difference between templated & actual head size of both observers using the two methods. A1 (observer A with method 1), A2 (observer A with method 2), B1 (observer B with method 1), B2 (observer B with method 2)

Difference between template & actual head size	No. of hips			
	A1	A2	B1	B2
-4	1	1	0	1
-3	2	5	6	5
-2	5	2	3	5
-1	3	10	6	9
0	11	8	9	7
1	8	3	7	5
2	3	5	2	1
3	2	1	2	2
4	0	0	0	0
Exact agreement	11/35	8/35	9/35	7/35
	31%	23%	25%	20%
-1+1 agreement	22/35	21/35	22/35	21/35
	63%	60%	63%	60%
-2+2 agreement	30/35	28/35	27/35	27/35
	85%	80%	77%	77%

Table 2: Mean relative error of both methods by both observer. A1 (observer A with method 1), A2 (observer A with method 2), B1 (observer B with method 1), B2 (observer B with method 2)

	A1	**A2**	**B1**	**B2**
Mean relative error in percentage	2.8 (SD 2.6; 0-9.1)	3.3 (SD 2.7; 0-9.1)	3.1 (SD 2.6; 0-7.6)	3.4 (SD 2.7; 0-9.1)

Discussion

Determination of the radiograph magnification is critical for proper templating. Various methods such as distance method, external radiographic marker, and fixed magnification factor available to determine magnification.

A study conducted to assess the comparison of systems for calibration when templating for total hip replacement with digital radiography showed that a set magnification factor was as accurate as the distance method and significantly more accurate than using ERM in digital templating of THA [15].

Another study on pre-operative digital templating in cemented hip hemiarthroplasty for neck of femur fractures evaluated the accuracy of digital templating using the distance method in 40 patients who had cemented hip HA by comparing templated implant sizes to actual implant sizes. They were able to template the implant head size and stem size correctly within two head sizes in 81% and 89%, respectively [10].

Additionally, a study on digital templating in hip replacement with and without radiological markers attempted to evaluate the precision of digital templating in hip replacement (both HA and THA). Using radiographic marker and distance technique, they templated the implant head size of 22 post-operative radiographs and compared the result to the known size listed in the medical records. The accuracy was found to

be comparable, with mean absolute measurement errors for the radiological marker and the distance technique being 2.8% and 2.6%, respectively (p = 0.75) [18].

Another study conducted on digital templating without a calibration marker in predicting implant size for hip hemiarthroplasty has shown that femoral head size and offset can be properly predicted using digital templating with a set magnification factor of 120%. Fifty preoperative radiographs of patients underwent hip HA were templated using digital software by two blinded observers, who then compared the outcome to the actual implant size. The accuracy was found to be 90% (n=45) for predicting the offset and head size within 2 mm with substantial to excellent inter-observers agreement [16].

In our study, both observers predicted the femoral head size in 80% (n=28) and 77% (n=27) of cases using a fixed magnification factor of 118%, which is lower than a study reported by Mina Derias et al [16]. This may be due to the software which we use for templating the radiographs. We used Radiant Dicom viewer in all cases, not a specific digital software designed for that particular implant. Additionally, we were not sure that whether the radiographers filmed the pelvic X-ray from a fixed distance which might also affect the magnification factor.

Our study also showed that the accuracy of predicting implant head size in hip HA using both methods, i.e., external radiographic marker and fixed magnification factor is similar with a mean relative error of method 1 (2.8 & 3.1% for observers A & B, respectively) and method 2 (3.3 & 3.4% for observers A & B, respectively), the p-value for both observers A & B was 0.46 & 0.59 with 95% CI). Interobservers agreement for both methods 1 & 2 is excellent when a precision scale of 1 size is used with kappa values of 0.84 and 0.93, respectively.

Conclusion

Digital templating of hip HA using a fixed magnification factor is as accurate as the radiographic marker method in predicting implant head size with excellent interobservers reliability. The study also conclude that 15-20% of the femur heads cannot be predicted within 2mm by any of the methods.

So, digital templating of the femur head using a set magnification factor can be used as an alternative effective and reliable method for ERM method. It is better to have all sizes of HA implant in the operation theatre stoke. Radiologists should also take adequate pelvic AP X-ray from a fixed distance. Researchers need to conduct further studies with a larger sample size, and a prospective study is also recommended for better accuracy assessment.

Limitations of the study

The primary limitations of this research are the limited sample size and the retrospective nature of the study methodology. The accuracy of each method could have been better assessed had we compared the templated result with the native femur head size rather than the size of implant used.

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Ethical consideration

Data collection was done after obtaining ethical approval by the institution review board of Addis Ababa University. Patients' medical data were kept confidential throughout the project.

Consent to publish

Participants consent for publication is not applicable.

Authors contribution

Study conception and design: Natnael Shewatatek (NS), Misgana Temesgen (MT), Biruk Lambisso (BL); data collection: NS; formal analysis and interpretation of results: NS, Tadiwos Niguss (TN); draft manuscript preparations; NS, TN. All authors reviewed the results and approved the final version of manuscript.

Conflict of interest

The authors report no conflicts of interest in this work.

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