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Measurement of the femoral head diameter at hemiarthroplasty of the hip

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Abstract

This paper is focusing on the measurement methods of the femoral head at the hip hemiarthroplasty surgery. The measurement result of 10 femoral head specimens using four different methods of Vernier calliper, ring gauge, CT scan and X-ray were compared. It is generally believed that under sizing of the implant may cover the errors of the measurement methods, but the result of this study shows that the callipers and ring gauge measurements are more reliable than the CT and X-ray methods. Conclusively, the full-circle ring gauge or femoral head template is the recommendation for measurement of the femoral head diameter in the hip hemiarthroplasty surgery.

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Keywords: Hip arthroplasty; femoral head; Vernier calliper; ring gauge; X-ray; CT scan

1. Introduction

Selection of a hip implant for a patient who is taking hemi or total hip replacement is not a proven procedure [1]. The surgeons normally take a radiographic image of the patient's hip and then estimate the stem size of the prosthetic as part of the pre-operation planning stage. The surgeon then keeps a selection of heads at the operating

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theatre, where during the procedure; they measure the diameter of the femur head once it is removed. After using either a Vernier calliper or a ring gauge to measure the diameter of the femur head, the implant is selected in the operating theatre and used in the surgery [2, 3]. Preference of method comes with time and experience, thereby leaving younger surgeons without experience at an unfair advantage.

A series of experimental measurements have been performed in this study to investigate which method or mode of measurement is more reliable with measuring the diameter of the femur head. This will, in theory, help surgeons to select the best fit implant option before a hip arthroplasty. Therefore, the main objective of this study is to find out which method is the most precise at measuring the diameter of a femoral head for those who are undergoing either hemiarthroplasty or total hip total hip arthroplasty.

2. Methods

After receiving the samples group of femoral heads from different surgeons, each sample was cleaned from possible adhesive soft tissues and prepared for the experimental examination. The samples were kept frozen in a same condition prior to the examination. From 25 samples 15 samples were already used and the result reported in our previous study [1]. The remaining 10 samples were analysed in this study. 7 of the samples belonged to female patients and 3 of the samples were from male patients. Fig. 1a showing the samples received from the surgeons following either total arthroplasty or hemiarthroplasty of the hip. Further experimental analysis was performed on the selected samples. The 10 selected samples are shown in Fig. 1b.



Fig. 1. The samples received from the surgeons following the hip arthroplasty surgery (a); 10 samples were prepared for the experimental examination of this study (b)

2.1. Mechanical measurements

2.1.1. Ring gauge

A ring gauge was used to check the external diameter of the femoral head samples by an experienced surgeon. The samples were examined in a fitting circle on the ring gauge to obtain the best fit diameter. The measurement reading of all 10 samples which were done by the same surgeon were recorded as shown in Table 1.

Table 1. Diameter measurement of 10 femur head samples using a ring gauge by an experienced surgeon

Sample No.	01	02	03	04	05	06	07	08	09	10
Diameter, mm	53	44	42	56	43	46	49	44	49	52

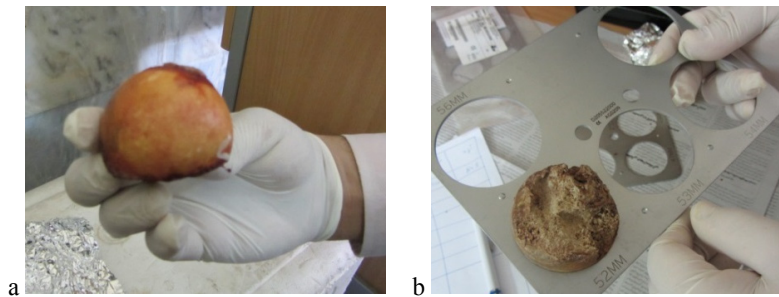


Fig. 2. The measurement of all 10 samples were done by the same surgeon using a full circle ring gauge

2. 1.2. Vernier Calliper

A digital Vernier calliper was used to measure the diameter of the femur head samples. All the samples were measured by an experienced surgeon. The diameter of each sample was measured from at least three different positions and the best fit diameter (average diameter) was recorded. The results of the average readings of the 10 samples are summarized in Table 2.

Table 2. Vernier calliper measurement of the 10 femur head samples

Sample No.	01	02	03	04	05	06	07	08	09	10
Diameter, mm	52.3	44.2	42.6	56.4	42.7	45.6	49.2	44.8	47.9	51.2

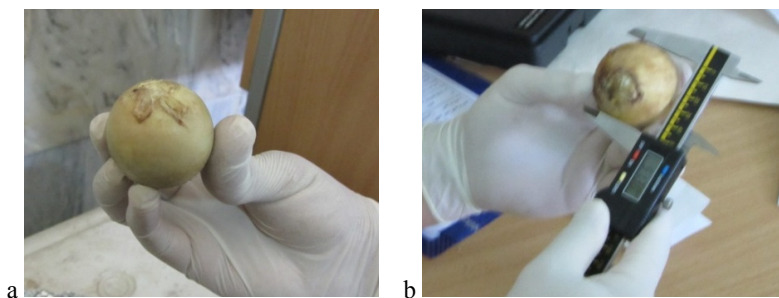


Fig. 3. The surgeon measured the diameter of samples from different positions and the best fit diameter (average diameter) was recorded

2.2. Radiographic measurements

Taking radiographic images of the patient's hip and measuring the size of femur head is a stage before the hip arthroplasty surgery. In order to validate this, the measurements are taken from greyscale images of the patient's hip with those obtained from the above mentioned mechanical measurements; X-ray and computed tomography (CT) scan were performed on the 10 femur head samples. Both X-ray and CT scanning were performed in a clinical environment in the Akhtar Hospital, Tehran, Iran.

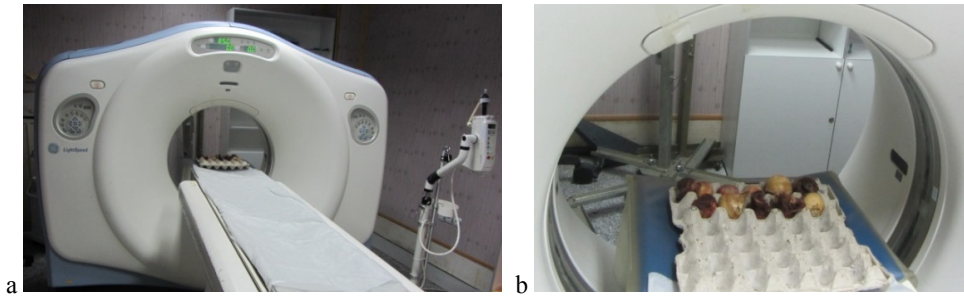


Fig. 4. Grayscale image scanning of the 10 samples carried out in the Akhtar Hospital

2.2.1. X-ray

The 10 samples were placed in an egg tray, as shown in Fig. 4, and then the X-ray image of the samples was taken as shown in Fig. 5. The X-ray image then was used to analyse the size of the femur head using Image J software (National Institutes of Health, US). Using the measure function of the Image J software, virtual pointers are placed on the image in order to measure the pixel elements, which are translated using pre-set scaling that is applied to the images beforehand. The analysed patient samples and their recorded diameters are presented in the Table 3.

Table 3. Largest diameter recorded from X-ray images of the patient samples

Sample No.	01	02	03	04	05	06	07	08	09	10
Diameter, mm	54.7	44.6	44.2	57.1	43.6	46.8	49.5	46.9	49.7	52.0

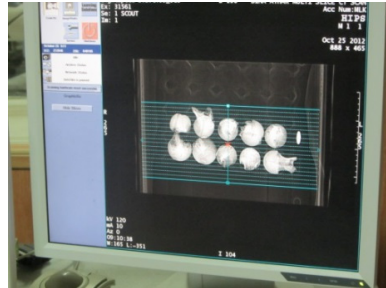


Fig. 5. The 10 samples were placed in an egg tray and then the X-ray image of the samples was taken

2.2.2. CT

The 10 samples were scanned using the CT scan machine with the same conditions as the X-ray examination, Fig. 6a. The CT data was then used to create a 3D model of each sample. The 3D model were generated in Mimics software (Materialise, NV) and then imported as a CAD model onto the design program NX 7.5 (Siemens Plm, NX) for further analysis. In the NX program, a circle was fitted onto the 3D model of each sample to find the best-fit circle for each sample head. Fig. 6b shows how a circle is fitted onto the 3D model created from the CT data of each sample. The results of the best fitted diameter of the samples are reported in Table 4.

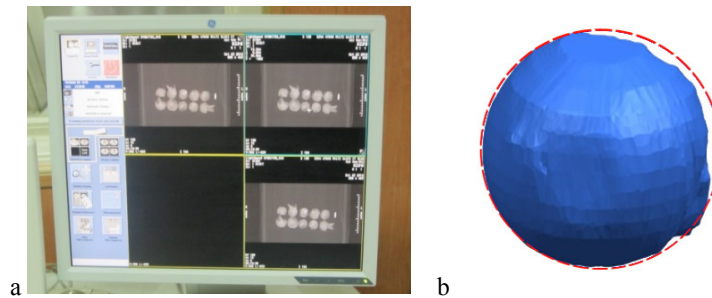


Fig. 6. The 10 samples were CT scanned (a); typical best fit circle (dash circle) to a 3D model of a femur head specimen (b)

Table 4. The best-fit diameter for each femur head sample obtained from CAD models

Sample No.	01	02	03	04	05	06	07	08	09	10
Diameter, mm	54.5	44.6	42.5	55.9	43.6	45.0	48.9	44.4	48.8	52.0

3. Result and discussion

Considering the measurement reading of the four methods; Vernier calliper, ring gauges, X-ray and CT scan, there was no major difference between the results. This was in agreement with our previous report [1]. It was observed that the results of the Vernier calliper and ring gauges show less variation in readings in comparison with X-ray and CT scan methods. Although the sizes of the femoral head and stem components of prosthetics may produce in intervals of 2 mm, the range of direct error within the methods themselves being less than 2 mm for most samples and this would make each method as viable a solution as the others.

With the results obtained from grey scale images of the samples, it has to be kept in mind that some sample heads were damaged over the time and therefore some of the recordings made show low precision. Also the best-fit circle method used for both the X-ray and CT-scan method do not account for a certain amount of human error in the recording of the data. The X-rays suffer from errors such as the scaling applied to the original X-ray image, which would skew measurements, thereby following-on to the image analysis performed later on the samples. The CT scan models exported to file have fine texturing and meshing applied, yet certain sample heads due to their condition, do not produce smooth faces across the surface [1].

The size of implant should be the closest size to the patient's femoral head and should be slightly undersized to allow a smooth fit and a good range of movement without the risk of dislocation. However, larger femoral heads are known to suffer greater stresses when being greatly undersized [5, 6, 7]. The under-sizing of 1 mm can be considered acceptable in accordance with Harris [4]. However, the result of this study shows the boundary of the errors with the four introduced methods may be more than 1 mm, so caution should be taken when deciding the preferred measurement method.

Further repetition with a larger patient sample may be required to give a complete statistical analysis in order wholly compare the four methods. The inclusion of the post-operative analysis for each patient to warrant a threshold of sizing that affects the comfort of the patient would also greatly aid the results.

The ring gauge mode of measure provides reliability and convenience which is suited to hemiarthroplasty surgery. It is the most practical method when the instance calls for the surgery to be done as soon as possible. The ring gauge in conjunction with the use of the vacuum test [5] is recommended as it negates any doubt concerning the fit of the implant and ensuring a good range of motion, and can be performed by a surgeon regardless of the expanse of their experience.

Finally, the findings of the current study may help clinicians about the use of the described measurement methods. However, an improvement could be made to the study by including the post-operative analysis for each patient. This would present an idea of the fit of an implant and the threshold of sizing that affects the comfort of the patient. Furthermore, the study did not include statistical analysis on the obtained raw data as the research is still ongoing. We are hoping to complete the research in our next report.

3. Conclusion

X-ray and CT scan measurement methods were used against the ring gauge and Vernier calliper methods to examine the sensitivity of the measurement of the femur heads. Although, the sizes of the femoral head and femur components of prosthetics are produced in intervals of 2 mm, the range of direct error within the methods themselves being less than 2 mm would make each method as viable a solution as the others. However, it was proved that the measurement with the Vernier calliper and ring gauge instruments are the most appropriate method to quantify the diameter of the femur head at the occasion of a hip arthroplasty.

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