Magnification error of digital x rays on the computer screen

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ABSTRACT

Templating x-rays of total hip and knee replacements pre-operatively are important to plan surgery. This is usually done using acetate templates of the prosthesis on hard copies of the x-ray. With the change in practice, to use digital x-rays on computer screens instead of hard copies, it is important to assess if acetate templates can be used for digital x-rays on the computer screen. This is a retrospective x-ray study of 19 hip replacements and 30 knee replacements to assess their magnification using the Patient Archiving Computerised System (PACS) software. This study was done to assess the accuracy of magnification, using acetate templates over a computer screen. In total hip replacement, the outer cup diameter was also measured using the digital measurement scale. The mean magnification was 0.59 for the acetabular cup and the femoral stem in total hip replacement and 0.48 for the femoral and tibial implant in total knee replacement. The mean difference in cup diameter comparing to the real size was an excess of 10.21 mm. The study showed over-magnified hip and knee x-rays thus suggesting that acetate templates and measurement scales on PACS was not reliable.

Keywords: Total hip replacement, Total knee replacement

INTRODUCTION

Pre-operative planning for total hip replacement and total knee replacement is important.[1, 2] Measurements and templating for the prosthesis size help to organise the operation.[2, 3] Surgeons have been facing difficulties with templating and pre-operative planning as hospitals have stopped printing hard copies of the radiograph. Instead, the use of digital images on the PACS system, read on computer screens has become more common.[4]

Since the introduction of digital x-rays in our hospital, in the year 2005, hard copies have not been available. They were previously used to template the size of the prosthesis and for pre-operative planning. Owing to the lack of the requisite software for digital templating, we resorted to the use of acetate templates, provided by the manufacturer of the prosthesis. These acetate templates were put on the computer monitor after adjusting the digital radiological image to one magnification. Difficulty with this technique was encountered as the size of the joint and the bones noted on the computer screen at one magnification looked abnormally large or small. This formed the basis of this study.

Therefore, the aim of this study was to analyse if the digital computer measurements for total hip and knee replacement x-rays were accurate indicators of magnification, and if it was possible to measure the size of hip and knee implants appropriately on the computer screen using recommended acetate templates.

MATERIALS AND METHODS:

The x-rays of patients who had total hip and total knee replacement under a single consultant from October 2005 to October 2006 were studied retrospectively. The actual size of the hip or knee prosthesis implanted into the patient was noted from the operation theatre register.

MEASUREMENTS DONE FOR TOTAL HIP REPLACEMENT X-RAYS:

The outer diameter of the acetabular cup was measured between the two furthest points on the upper and lower extremes of the cup rim seen on the x-ray. The computers' measurement scale was used to measure this distance. This represented the diameter of the acetabular cup seen on the computer screen. This measurement was compared to the actual outer diameter noted from the operation theatre register. The difference was then calculated and analysed.

Acetabular cups and the femoral stems were also measured for their magnification, comparing it to the recommended acetate templates. For the acetabulum, an Anatomical Medullary Locking (AML) total hip replacement template with a magnification of 15% was used. Similarly for the femoral stem, an AML template with a magnification of 15% and Corail, Versys and Collarless Polished Taper (CPT) total hip replacement templates with a magnification of 20% was used. The template was placed by hand on the screen of the computer, laying it over the digital picture of the implant.

Using the Patient Archiving computerised system (PACS) software the image was gradually adjusted to match the size of the appropriate acetate template. This magnification was also noted.

MEASUREMENTS DONE FOR TOTAL KNEE REPLACEMENT X-RAYS:

The images of the prosthesis on the computer screen were adjusted to match the appropriate acetate template of the implant, in the same manner as done for the hips. The Scorpio Knee template used had a 10% magnification.

All measurements were done using one particular computer, performed by a single person, and rechecked by his senior. The data was then loaded on the computer using SPSS 21 software for analysis. A one-sample t test was done to show the significance of the measurements and the magnification error.

RESULTS:

A total number of 19 total hip replacement x-rays were studied. Out of the total with relation to acetabular cups, 14 were Duraloc cups, two Trilogy cups and three Zimmer Cemented Acetabular (ZCA) polyethylene cups. Similarly with relation to femoral stems, there were nine corail stems, five AML stems, two Versys stems and three CPT stems. The three ZCA cups were not measured for magnification because they did not have a clear margin on the x-ray, hence it was difficult to template them accurately. Therefore, a total of 16 cups and 19 stems were measured for magnification, however the diameters of 19 acetabular cups were measured using the scale on the computer. Out of the total measurements done for total hip replacement x-rays, 11 were on the left side and eight on the right.

Similarly, 30 Scorpio total knee replacements were considered for the magnification error measurement (right: 17; left: 13). The commonest size used for the femoral implant was 9, but the commonest size for the tibial tray was 7.

Analysis of the acetabular cup diameter showed that the mean real diameter of the cups as noted in the operation theatre register was 54.68 mm (SD: 3.82). Alternatively, the mean diameter of the cups as measured on the computer screen was 64.89mm (SD: 5.92). Therefore, the difference in mean diameter comparing the real with the measured was 10.21mm (SD: 2.78). There were similar differences in the mean diameter, taking into account the acetabular cups on the right side (11.44mm, SD: 2.51,) as well as the one on the left (9.10mm, SD: 2.64) separately ($p<0.001$) (Table 1).

The acetabular magnification measurement showed a mean magnification of 0.58 (SD: 0.054) when compared to the standard template size, which itself had a magnification of 15% (Table 1). Similarly, the mean magnification for the femoral stem was also 0.58 (SD: 0.045) ($p<0.001$) (Table 1).

In total knee replacement, the femoral implant's mean magnification was 0.47 (SD: 0.045) and tibial tray's mean magnification was 0.48 (SD: 0.043). (Table 2) ($p<0.001$).

Table 1: Measurements in total hip replacement

Total Thr Studied	19
Total Acetabulum Studied	16
Mean Real Acetabulum Size	54.68mm, SD: 3.82, 95%CI: 52.84 to 56.52
Mean Acetabulum Size On X-Ray	64.89mm, SD: 5.92, 95%CI: 62.04 to 67.75
Mean Acetabulum Size Difference	10.21mm, SD: 2.78, 95%CI: 8.87 to 11.55
Mean Acetabulum Size Difference (Right)	11.44mm, SD: 2.51, 95%CI of 9.52 to 13.37
Mean Acetabulum Size Difference (Left)	9.10mm, SD: 2.64, 95%CI of 7.21 to 10.99
Mean Acetabulum Magnification	0.58, SD: 0.054, 95%CI: 0.55 to 0.61
Mean Femur Magnification	0.58, SD: 0.045, 95%CI: 0.55 to 0.60
One Sample T Test For Acetabulum Magnification	<0.001 (Test value: 1.15)
One Sample T Test For Femur Magnification	<0.001 (Test value: 1.15)
One Sample T Test For Acetabulum Size Difference	<0.001 (Test value: 0)

Table 2: Measurements in total knee replacement:

Total Tkr Studied	30
Mean Femur Magnification	0.47, Sd: 0.045, 95%Ci: 0.46 To 0.49
Mean Tibia Magnification	0.48, Sd: 0.043, 95%Ci: 0.46 To 0.49
One Sample T Test For Femur Magnification	<0.001 (Test Value: 1.10)
One Sample T Test For Tibia Magnification	<0.001 (Test Value: 1.10)

DISCUSSION:

Pre-operative templating for total hip replacement and total knee replacement has been routinely recommended, though its interpretation in total knee replacement needs to be concluded with caution.[1,2, 5, 6] Templating for pre-operative planning in total hip replacement has however been seen to be more dependable, thus affecting the outcome of the surgery. [2,3]

Types of x-ray images available to surgeon have changed from analogue x-ray plates to digital images on computer screen. There are studies that have shown the inaccuracy of digital magnification compared to an analogue system.[7, 8] Alternatively, others have also shown ways of correcting the magnification error using a marker for total hip replacement and hip hemiarthroplasty.[9, 10]

This study has tried to assess the reliability of digital x-ray pictures on the computer screen, for templating and measurements in total joint arthroplasty. The necessity to reduce the magnification of the x-ray while viewing the acetabulum on the computer screen, to a mean of 0.58 suggests that digital pictures for the acetabulum had a higher magnification than the actual size. It was therefore observed that the x-ray image magnification of the acetabulum on the computer screen had to be decreased to 58% to match the template magnification of 115%. Similarly, the x-ray image magnification of the femoral stem also needed to be reduced to 59% magnification on the computer screen with relation to femoral stem template magnification of 115 to 120%.

For total knee replacement, the magnification on the computer screen was 47% to match the template size of 110%, suggesting the same error in the knee replacement x-rays. The reason of variation in magnification is not clear though several factors could be associated with it. The distance between the camera and the implant and the distance between the x-ray plate and the implant could influence the magnification.

Magnification mathematically is the distance between the camera and the x-ray plate (d1) divided by distance between the camera and the object (d2).[11] The distance between the camera and the x-ray plate usually remains constant, thus the factor that could affect the magnification is the position of the object (d2). That could explain why the total knee replacement x-rays measured had a higher magnification considering that the knee would be slightly flexed in the early post- operative phase. This would increase the distance between the implant and the x-ray plate thus increasing the ratio between d1 and d2.

Magnification error can also occur while trying to match the image on the computer with the picture on the template. The magnification occurs based on the same principle previously discussed.[11] Considering the eye as a camera, distance d1 is the distance between the eye and the x-ray image on the computer screen, whereas, d2 is the distance between the eye and the picture of the implant on the template. Therefore, greater the distance between the template and the image, lesser is the distance d2, hence an increase in magnification. Alternatively, greater the distance of the eye from the image on the computer screen (d1), lesser is the magnification owing to decrease in ratio between d1 and d2. So, it is important to be aware that just moving your head close or away from the computer while templating effects magnification. All measurements taken were therefore from a constant arms' length.

It is also necessary to be aware that the distance between the image and the template can never be zero. Therefore, there will always be a magnification of a small degree while templating on the computer.

Finally, the accuracy of the PACS software could also be questioned considering that the magnification measured on the computer was expressed in a single decimal. It was quite clearly obvious that while magnifying the image from one decimal of magnification to the next a substantial change in size of the image was observed.

The measurement scale used by the PACS software in the computer was seen to be unreliable too taking into consideration the mean diameter difference of 10mm, comparing the real known diameter of the acetabular cup to the mean diameter measured on the computer screen. Hence, it is advisable not to use the computer scale for measurement purposes. The measurement error seen while measuring the diameter of the acetabulum could be associated with the magnification error, which the software does not account.

This study has therefore showed that hip and knee x-rays viewed on the computer screen using the PACS software is magnified. It confirms that templating on digital x-ray pictures, on-screen using standard acetate templates for total hip replacement and total knee replacement is not recommended. It is also advisable not to depend on the measurement scale of the PACS software on the computer for pre-operative measurements.

The suggestion is therefore to template using standard acetate templates on hard copies of the x-ray plate. An alternative is to use a standard marker of known length to correct magnification, whether it is for digital hard copies or for digital pictures on the computer screen.[9, 10] A finer refinement of the above could be the use of templating software available in the market.[12]

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