Accurate scaling of digital radiographs of the pelvis

A PROSPECTIVE TRIAL OF TWO METHODS

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Magnification of anteroposterior radiographs of the pelvis is variable. To improve the accuracy of templating, reliable and radiographer-friendly methods of scaling are necessary. We assessed two methods of scaling digital radiographs of the pelvis: placing a coin of known diameter in the plane of interest between the patient's thighs, and using a caliper to measure the bony width of the pelvis. A total of 39 patients who had recently undergone hemiarthroplasty of the hip or total hip replacement were enrolled in the study. The accuracy of the methods was assessed by comparing the actual diameter of the head of the prosthesis with the measured on-screen value. The coin method was within a mean of 1.12% (0% to 2.38%) of the actual measurement, the caliper group within 6.99% (0% to 16.67%). The coin method was significantly more accurate ($p < 0.001$). It was also reliable and radiographer friendly. We recommend it as the method of choice for scaling radiographs of the pelvis before hip surgery.

Picture Archiving and Communication Systems (PACS) are designed to replace conventional radiographs with computerised digital images viewed on a screen. Radiographs are acquired either digitally or by traditional methods and then digitised. The images are stored in a large computer archive and transferred via the hospital network to viewing stations when required.[1] PACS (GE Centricity, GE Healthcare, Chalfont St Giles, United Kingdom) was introduced to the Orthopaedic Department at Queen Alexandra Hospital, Portsmouth, in 2002 as an integrated system encompassing plain radiography, CT, MRI, ultrasound and radioisotope scanning. The plain radiological images are taken on a Fuji CR digital system (Fuji Photo Film (UK) Ltd, Bedford, United Kingdom) and transferred to the PACS.

The guidelines of the National Program for Information Technology state that all acute hospitals will have PACS by 2007.[2] This means that all radiological images will be viewed on monitors and there will be no hard copies for acetate templating. Specialist digital templating applications such as OrthoView (Meridian Technique Limited, Southampton, United Kingdom) have been developed to allow onscreen templating of PACS images, which solves the immediate problem of not having hard copies for acetate templating. The introduction of digital templating also presents an opportunity to solve the problems with scaling known to affect traditional templating.

The process of taking anteroposterior (AP) pelvic radiographs results in a quoted magnification factor of 120% (supplied by manufacturer: Stryker Howmedica Osteonics, Newbury, United Kingdom) and acetate templates for hip replacement surgery are manufactured at this magnification. Unfortunately, the magnification factor for each patient varies with body habitus and the thickness of the mattress. This variation also affects PACS. The pelvic radiographs taken in our hospital showed a magnification of between 109% and 128% after hemiarthroplasty.[3] Similar findings were reported by Knight and Atwater,[4] in a prospective study of acetate pre-operative planning for 110 consecutive primary total hip replacements (THRs). They concluded that surgeons needed better methods to estimate magnification and morphology from pre-operative radiographs. They also remarked that as acetate templates were only available in a limited range of magnifications, analogue planning was not reliable for deciding which size of component to use. These discrepancies have serious implications. The knowledge of whether a femoral shaft can accommodate a prosthesis is vital, as fracture of the shaft is reported in 3% to 24% of patients if an oversized prosthesis is used.[5,6]

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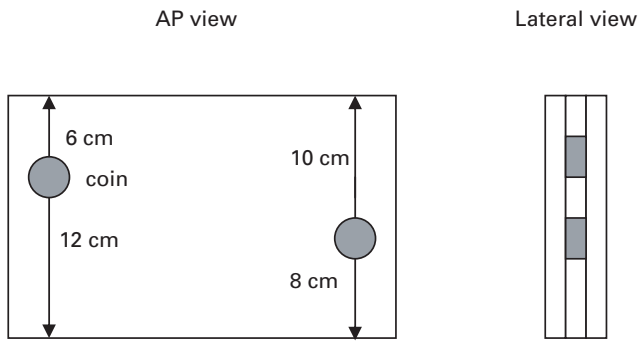

Fig. 1

Anteroposterior (AP) and lateral schematic diagram of the coin scaling device.

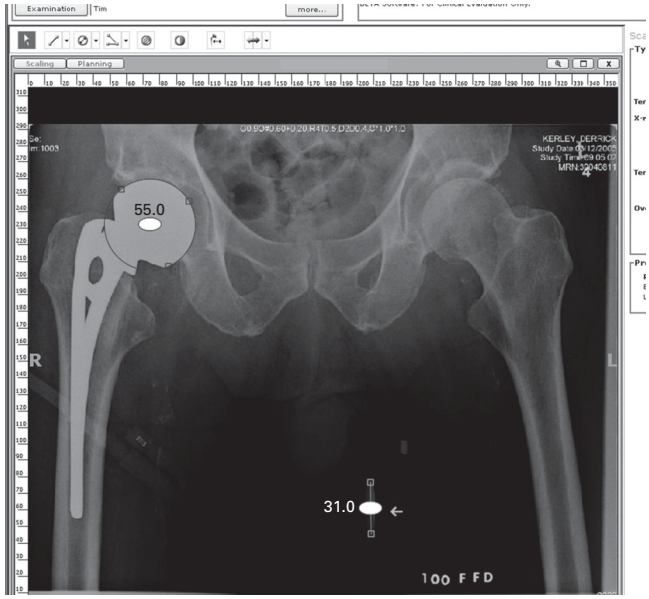

Fig. 2a

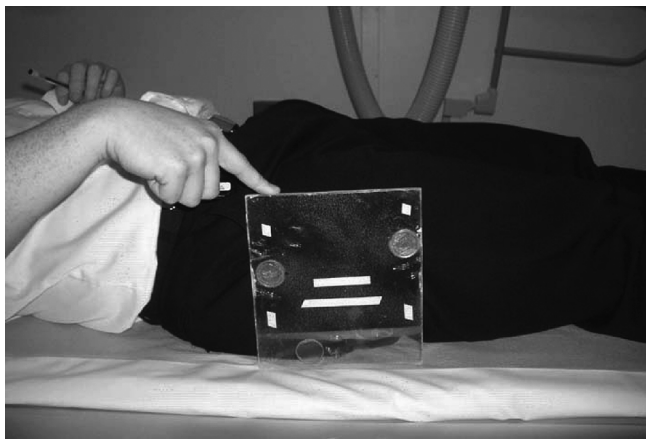

Fig. 2b

Fig. 2c

a) Anteroposterior pelvic radiograph showing on-screen measurement of coin and prosthetic head diameter calculation, b) the coin device placed against the greater trochanter and c) the coin device placed between the patients' thighs.

Digital templates are not of fixed magnification and can be scaled. If the magnification of the radiograph is known, overlaid templates of the same magnification will improve accuracy. Several methods of scaling have been suggested. They include use of radio-opaque markers such as ball bearings,[7] coins of known size or rulers in the plane of interest, or the measurement of bony dimensions such as the width of the pelvis. To support the importance of scaling in the plane of interest, The et al[8] concluded that if the position of the calibration object differs too much from the regions of interest, a structural error in digital correction of magnification will occur. A 10-pence coin may be used to calculate the magnification of acetate radiographs with a significant improvement in the accuracy of templating ($p = 0.05$).[9]

However, none of these methods is practicable in everyday use and most have only been employed experimentally. The method of Conn et al[9] uses a coin placed on the patient's outer thigh. This is difficult in obese patients, when this site may be missed on the AP radiograph of the pelvis.

Materials and Methods

Approval was obtained from the South East Hampshire Research Ethics Committee. Two methods of scaling were evaluated, the placement of a coin of known diameter in the plane of interest between the patients's thighs, and measurement of the bony width of the pelvis using a caliper.

Both methods were used on patients who had undergone hemiarthroplasty or THR. The diameter of the head of the prosthesis was compared to the measured value given by each of the two methods.

The radiology department received formal written instructions and an explanation of how to use the 'coin scaling device'. Their feedback was obtained via an anonymised evaluation form.

Coin method. To ensure that the coin was held in the correct plane, a plastic rectangle was constructed with two

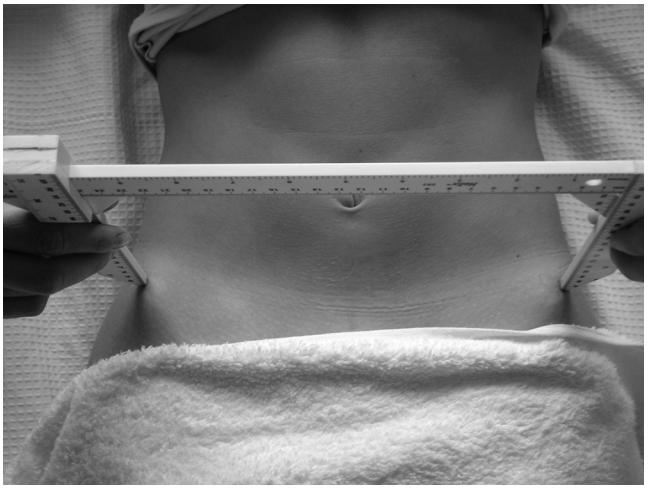

Fig. 3

Photograph of the caliper used to measure anterior superior iliac spine distance.

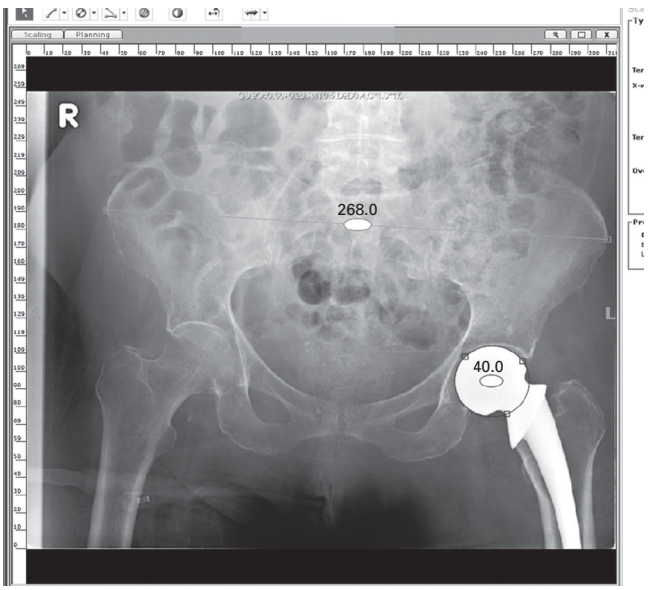

Fig. 4

Anteroposterior pelvic radiograph showing on-screen measurement of anterior superior iliac spine distance and prosthetic head diameter.

Swiss 5 Franc pieces (31 mm diameter) held at specific distances from its edge, namely 12 cm and 6 cm for one coin and 10 cm and 8 cm for the other (Fig. 1). With the patient supine on the X-ray table the device was placed vertically against the palpable greater trochanter. The device could be rotated or flipped through four different positions until one of the coins matched the level of the greater trochanter, which would always be between 6 cm and 12 cm from the surface of the couch. The device was then placed between the patient's thighs as proximally as possible with the selected coin being the more proximal. It appeared in profile on the AP radiograph just below the bony pelvis (Fig. 2). The radiographs were scaled by applying the known 31 mm diameter of the coin. The diameter of the prosthesis was then measured and compared with the known size, thereby enabling the accuracy of the method to be calculated.

Caliper method. The distance between the anterior superior iliac spines was measured with a caliper (Fig. 3). These landmarks are relatively easy to feel, irrespective of body habitus, and lie close to the coronal plane of the hip joints. They are also easy to identify on radiographs and straightforward to measure on the computer screen. The measured distance between the spines was then applied to the same bony landmarks on the AP pelvic radiograph (Fig. 4). This was then scaled and an estimate of the diameter of the hip prosthesis made by measuring it directly on the computer screen. The accuracy of the method was calculated in the same way as with the coin.

Data collection. Two groups of in-patients who had recently undergone hemiarthroplasty or THR were entered into this prospective study, 17 in the coin group and 22 in the caliper group. In the coin group the device was used by the radiographer taking the post-operative pelvic radiograph. The OrthoView templating software (Meridian Technique Limited) was used for the radiological image, which was scaled using the 31 mm coin as the reference. The measurement tools in OrthoView measured the size of the head of the prosthesis which was unknown to the operator (GS). The prosthetic and calculated sizes were compared to determine the reliability and accuracy of the method.

Patients in the caliper group had adequate post-operative AP radiographs in which both iliac spines were seen and where documented evidence of the diameter of the head of the implant was available. The first investigator (SW) measured the distance, in mm, between the anterosuperior iliac spines with a caliper. The blinded second investigator (GS) applied this measurement to the radiograph on the computer screen, scaled this with OrthoView and measured the diameter of the head. The prosthetic and calculated sizes were then compared with determine the reliability and accuracy of the method.

Results

The data are shown in Table I. The mean accuracy of the coin group was within 1.12% (0% to 2.38%) of the true measurement (98.9%) accuracy, (Fig. 5) and that of the caliper group within 6.99% (0% to 16.67%) (93.0% accuracy) (Fig. 6). The maximal margin of error was 2.44% in the coin group and 13.88% in the caliper group. The variability of error in the coin group was significantly smaller than that with the caliper ($p < 0.001$).

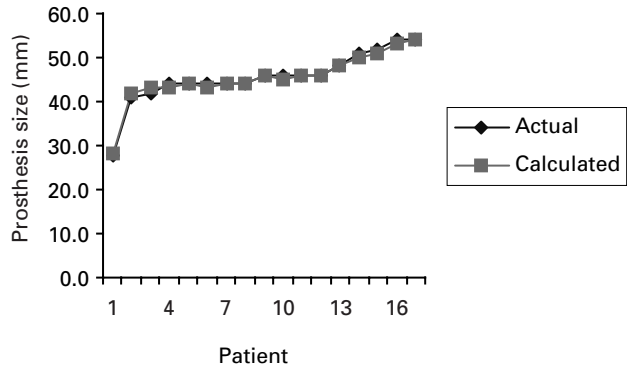

Fig. 5

Graph showing the accuracy of the coin group.

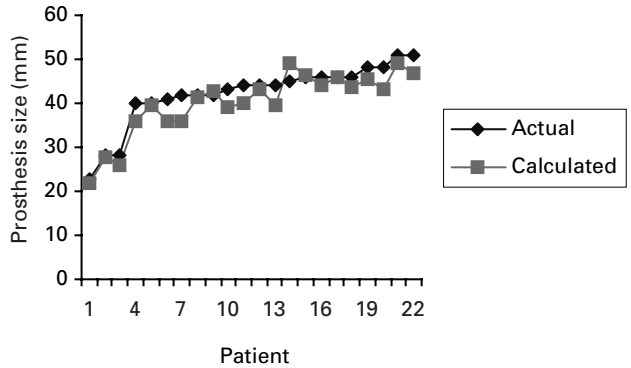

Fig. 6

Graph showing the accuracy of the caliper group.

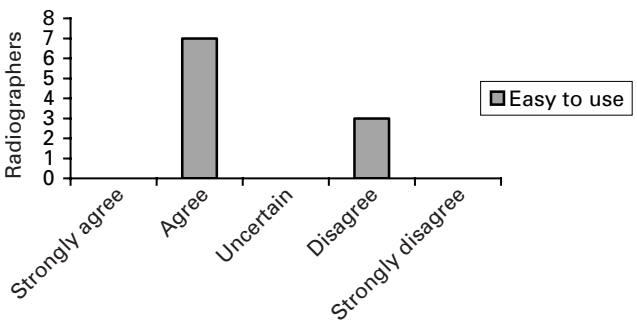

Fig. 7

Graph showing ease of use of coin method.

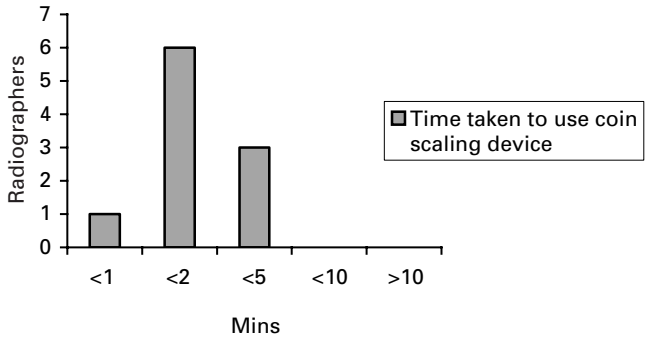

Fig. 8

Graph showing extra workload involved with the coin method.

Table I. Summary of actual and calculated prosthetic head diameters for the coin group and the caliper group

Patient	Coin group actual size (mm)	Coin group calculated size (mm)	Accuracy of coin device (%)	Caliper group actual size (mm)	Caliper group calculated size (mm)	Accuracy of caliper device (%)
1	27.5	28.0	*98.21*	22.5	22.0	*102.27*
2	41.0	42.0	*97.62*	28.0	27.5	*101.82*
3	42.0	43.0	*97.67*	28.0	26.0	*107.69*
4	44.0	43.0	*102.36*	40.0	36.0	*111.11*
5	44.0	44.0	*100*	40.0	39.5	*101.26*
6	44.0	43.0	*102.36*	41.0	36.0	*113.88*
7	44.0	44.0	*100*	42.0	36.0	*116.67*
8	44.0	44.0	*100*	42.0	41.5	*101.2*
9	46.0	46.0	*100*	42.0	42.5	*98.82*
10	46.0	45.0	*102.22*	43.0	39.0	*110.26*
11	46.0	46.0	*100*	44.0	40.0	*110*
12	46.0	46.0	*100*	44.0	43.0	*102.36*
13	48.0	48.0	*100*	44.0	39.5	*111.39*
14	51.0	50.0	*102*	45.0	49.0	*91.84*
15	52.0	51.0	*101.96*	46.0	46.5	*98.92*
16	54.0	53.0	*101.88*	46.0	44.0	*104.55*
17	54.0	54.0	*100*	46.0	46.0	*100*
18				46.0	43.5	*105.75*
19				48.0	45.5	*105.49*
20				48.0	43.0	*111.63*
21				51.0	49.0	*104.08*
22				51.0	47.0	*108.51*

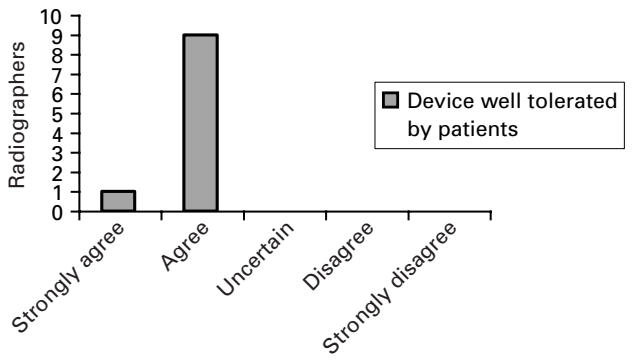

Fig. 9

Graph showing patient tolerance.

Using a paired t-test, estimation of the prosthetic size by caliper significantly under-predicts the true value (95% confidence interval (CI) 1.01 to 3.12, p = 0.001), whereas the coin method does not do so (95% CI -0.15 to 0.56, p = 0.234). The bias of the caliper method was calculated using a two-sample *t*-test and was significantly greater than that obtained by the coin method (95% CI 0.76 to 2.96, p = 0.002). Precision was calculated using Levene's test[10] which demonstrated that the variability of errors in the coin group was significantly smaller than that for the caliper assessments (p < 0.001).

Ten radiographers used the coin device and completed an anonymised feedback form. Four used the device once, three twice and three used it three to five times. Seven found it easy to use (Fig. 7). One found the device took less than one minute to use, six less than two minutes, and three less than five minutes (Fig. 8). All found the device was well tolerated by the patients (Fig. 9).

Discussion

A review of the literature has shown that surgeons run the risk of up to 11% inaccuracy when assuming a standard 120% magnification.[11] We have shown that the scaling of PACS AP pelvic radiographs using a caliper is significantly less accurate than when using a coin placed in the plane of interest. The results of the latter method correspond to the study of The et al,[7] who reported a margin of error of 1.5% when using a stainless steel prosthetic head of the femur.

Both our methods were easy to use. The coin device was used by the radiographers and the caliper by the surgeon but the latter could equally be used by staff in the pre-operative assessment clinic.

Both methods improve the scaling of radiographs. The 98.9% accuracy of the coin method equates to a < 0.5 mm inaccuracy when making on-screen measurements of up to 45 mm, such as reaming of the acetabulum, calculating offset or determining the 'best fit prosthesis'. The caliper method would lead to an inaccuracy of > 3 mm, which is unacceptable if used alone. However, it could be useful preoperatively as an adjunct to 'eyeballing' the anatomy intraoperatively.

Traditional radiographs will be rapidly phased out as digital imaging is introduced and digital templating creates the opportunity to significantly improve accuracy. The coin method evaluated in this study is recommended.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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