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ORIGINAL STUDY

Reliability of measurements with digital radiographs – a myth

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The purpose of this study was to assess the accuracy of digital radiographs and hence their effectiveness in templating. The methodology involved a retrospective study of post operative radiographs of patients with hemiarthroplasty of the hip. Three observers made observations blinded to each other's measurements. A statistical analysis of the data highlights magnification varying from 6 to 31 percent. There is a statistically significant relationship between the size of the error (size measured on radiograph minus implant size, i.e. magnification) and the implant size (p = 0.005) but the percentage error (error/implant size × 100) is independent of implant size (p = 0.505). It is our impression that digital radiographs and templating on the digital radiographs should not be considered a precise process.

Keywords : digital radiographs ; accuracy ; measurements ; templating.

INTRODUCTION

The introduction of digital imaging systems in the NHS has brought in a silent revolution to image archival and retrieval. Though CT based techniques have been used and shown to be accurate (*10*), the plain radiograph forms the bedrock of templating. Personal experience with the use of digital radiographs without specialised templating software has had doubtful results when applied to templating. Published literature shows better results with analog templating (*3,5,12*) compared to digital templating in some instances. Templating of digital radiographs has been shown to get better with calibration techniques (*1,3,8,13*). The aim of this study was to assess the reliability of the digital radiographs in making accurate linear measurements.

MATERIALS AND METHODS

Statistical advice was sought for assessing the numbers before the study. A series of postoperative AP radiographs performed after hemiarthroplasty of hips were evaluated retrospectively. Measurements of digital radiographs were made by three different observers, based on a standard measurement protocol. The observers were at three different levels of seniority/grade : Consultant, registrar and

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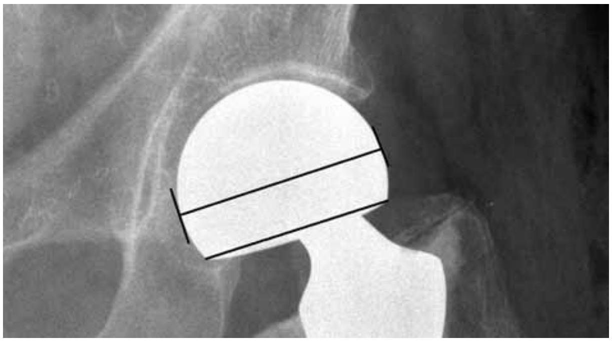

Fig. 1. — Method of measurement – First line drawn along base of implant. Measurement of diameter made from a parallel line joining the tangents at the maximum width of the implant.

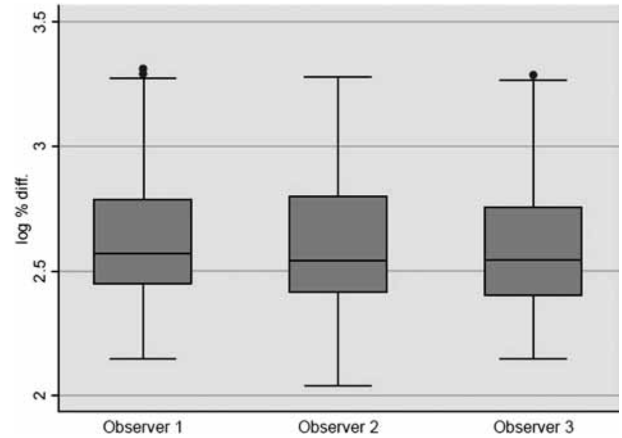

Fig. 2. – Log transformation of the magnification errors of the observers.

foundation doctor. The measurements were made on radiographs, at full magnification on the AGFA Web1000 PACS system. The measurements were made along the longest parallel to the base of the globular component. To do this a line was drawn along the base of the globular component. A further line was drawn connecting two tangents to the further most points on the globular component parallel to the first line. The cursor on the software automatically provides the tangents by being perpendicular to a drawn line.

Statistical analysis

The results were analysed by author A.S., using Stata9.2. (StataCorp. Texas, USA). The model used for analysis was a linear mixed (variance components) model, with the natural log of the percentage difference between actual implant size and that measured as the dependent variable ; subject and observer were incorporated in the model as random factors.

RESULTS

There is a statistically significant relationship between the size of the error (size measured on radiograph minus implant size, i.e. magnification) and the implant size ($p = 0.005$) but the percentage error (error/implant size × 100%) is independent of implant size ($p = 0.505$). The magnification errors were positively skewed, but a logarithmic transform of the data rendered the data closer to a normal distribution (Fig. 2). The natural log of the percentage error was therefore modeled and the (geometric) mean percentage error and prediction intervals were obtained by applying the inverse (exponential) transform (Fig. 3).

Two subjects were excluded from the analysis. One subject had an error in the recording of the true implant size. The other subject was excluded due to an extremely large magnification factor (> 40%), probably due to a significant departure from standard technique in production of the radiograph. This subject is however, included in Figure 3.

The mean percentage error (magnification) was 13.725%. The 99% Prediction Interval was 5.983% to 31.469% [95% Prediction Interval (PI) : 7.893% to 23.855%]. The above analysis applies to all three observers.

On analysing the inter-observer varability, approximately 6.3% of the total variance was explained by observer variation in the implant measurements, the remainder being due to variability between subjects in the sample. For a given implant, the standard deviation of the magnification factor, as measured by the three different observers, was in most cases less than 1%, but there were a few cases where this could be up to 4%.

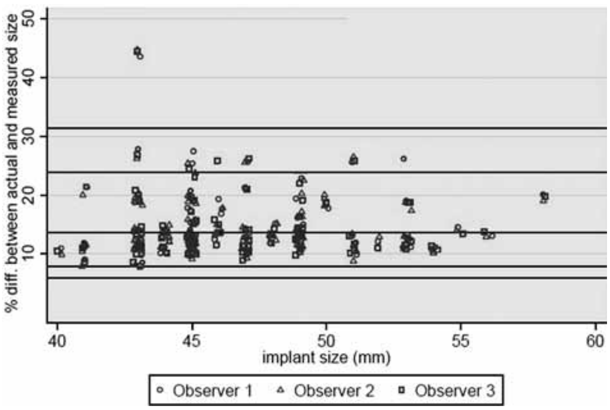

Fig. 3. – Mean, upper and lower 95% and 99% prediction intervals.

The possible explanation for such wide variation in the magnification factor (i.e. Error) is

- Patient size
- Non-standardisation of technique followed by the radiographers, which could be in the form of variation in source to film and/or object to film distance and distortion due to the implant not being parallel to the film.

DISCUSSION

The radiographs were performed with a distance of 1 metre between the source and the film. The plate was placed directly underneath the patient. The hips were internally rotated till the patellae pointed forwards. Linear measurements were chosen for assessment of the digital radiographs, as these are the more common measurements made in day to day orthopaedic practice. The hemiarthroplasty prosthesis was selected for measurement as this is spherical and well centred in radiographs of the hip. The measurements would be the same even if measured from slightly different points by different observers. A uniform protocol was used for measurement to ensure that we were comparing similar sets of measurements between the observers.

Much of published literature compares templating to the actual implants, predominantly hip replacements (*1,3,5,7-9,12,13*). This is prone to inaccuracies due to the error based on surgical error/judgement (*2*). Due to the variable results, none of these have become tested methods. The use of prints of digital radiographs for templating has been documented to undersize the implant (*8,12*). This may be because the images are rescaled to fit the radiographic film, or a direct consequence of the software modifying the print sequence (*11*).

In a prospective study, of a simple guide to assess magnification in radiographs using a taped coin, the accuracy of prediction of the prosthesis size improved from 59 to 69% (*2*). An investigation of different scaling devices, showed greater accuracy for markers at the level of the trochanter but not in contact with the skin (*1*). It also demonstrated the difficulty in achieving this position with a marker. In another study use of a taped coin was found to be the best way of scaling THA (to within 0.9%) compared to digital lines and measurements on hard copy of digital radiographs (*8*). A prospective study of comparison between a scaling coin between the thighs and a clinical measurement of the bony width of the pelvis found the coin group to be more accurate (*13*). A comparison of analog films of THA with digital radiographs with a magnification marker (spheres set in plastic) showed more predictable results with analog planning than with digital (*5*). The authors did however exclude cases where the magnification was outside the range of 110-130%, inferring inaccurate placement from this. In a study using reverse calibration in 20 THA's based on CT studies, it was concluded that this is a better process than that of a magnification marker in the calibration of films in 80% of the cases (*7*). They did however supplement the reverse calibration with the subjective assessment of the size patient by the radiographer into 3 categories to assess the other 20%. This is a small series. It also hurries to confer legitimacy on the reverse calibration process, which has calculated the size of the head based on a hip to bed distance of 117 mm (range 79 to 142). In a study of 40 tibial nailings, better accuracy was seen with calibrated image under lab conditions compared to clinical images (*4*). These cases document the difficulty in accurate calibration of images in the clinical setting. In a study of magnification of digital images of implants in trauma, it was shown that the variability was more with objects of bigger size (*6*).

Our study was limited by being retrospective in nature. We analysed images already available. However, all the images were taken according to a standard protocol. This would reflect the normal clinical setting. Our results show variability in the magnification between 5.983% to 31.469% (99% Prediction Interval) and 7.893% to 23.855% [95% Prediction Interval (PI)].

Pre-operative templating is important as much for the exercise, as for the inference we draw from it ; the surgeon is encouraged to think about the probable procedure and potential pitfalls. There is however much being read into an imperfect science.

CONCLUSION

The investigation has documented accuracy in the measurements between observers. The variation in the magnification of the images could be accounted for by the patient habitus. Templating would help the surgeon, who makes decisions based on the combined clinical and radiological picture. However, until digital radiographs and templating become reliable as a science they should not be regarded as being infallible.

REFERENCES

1. **Bayne CO, Krosin M, Barber TC.** Evaluation of the accuracy and use of X-ray markers in digital templating for total hip arthroplasty. *J Arthroplasty* 2009 ; 24 : 407-413.
2. **Conn KS, Clarke MT, Hallett JP.** A simple guide to determine the magnification of radiographs and to improve the accuracy of preoperative templating. *J Bone Joint Surg* 2002 ; 84-B : 269-272.
3. **Crooijmans HJ, Laumen AM, van Pul C, van Mourik JB.** A new digital preoperative planning method for total hip arthroplasties. *Clin Orthop Relat Res* 2009 ; 467 : 909-916.
4. **France MA, Koval KJ, Hiebert R *et al.*** Preoperative assessment of tibial nail length : accuracy using digital radiography. *Orthopedics* 2006 ; 29 : 623-627.
5. **Gonzalez Della Valle A, Comba F, Taveras N, Salvati EA.** The utility and precision of analogue and digital preoperative planning for total hip arthroplasty. *Int Orthop* 2008 ; 32 : 289-294.
6. **King, RJ, Craig PR, Boreham BG, Majeed MA, Moran CG.** The magnification of digital radiographs in the trauma patient : implications for templating. *Injury* 2009 ; 40 : 173-176.
7. **Kulkarni A, Partington P, Kelly D, Muller S.** Disc calibration for digital templating in hip replacement. *J Bone Joint Surg* 2008 ; 90-B : 1623-1626.
8. **Oddy MJ, Jones MJ, Pendegrass CJ, Pilling JR, Wimhurst JA.** Assessment of reproducibility and accuracy in templating hybrid total hip arthroplasty using digital radiographs. *J Bone Joint Surg* 2006 ; 88-B : 581-585.
9. **The B, Diercks RL, van Ooijen PM, van Horn JR.** Comparison of analog and digital preoperative planning in total hip and knee arthroplasties. A prospective study of 173 hips and 65 total knees. *Acta Orthop* 2005 ; 76 : 78-84.
10. **Viceconti M, Lattanzi R, Antonietti B *et al.*** CT-based surgical planning software improves the accuracy of total hip replacement preoperative planning. *Med Eng Phys* 2003 ; 25 : 371-377.
11. **Whiddon DR, Bono JV.** Digital templating in total hip arthroplasty. *Instr Course Lect* 2008 ; 57 : 273-279.
12. **White SP, Shardlow DL.** Effect of introduction of digital radiographic techniques on pre-operative templating in orthopaedic practice. *Ann R Coll Surg Engl* 2005 ; 87 : 53-54.
13. **Wimsey S, Pickard R, Shaw G.** Accurate scaling of digital radiographs of the pelvis. A prospective trial of two methods. *J Bone Joint Surg* 2006 ; 88-B : 1508-1512.