ACCURATE MEASUREMENT OF FEMORAL OFFSET: CLINICAL COMPARISON OF CT SCANS, AP-PELVIS AND AP-HIP RADIOGRAPHS

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INTRODUCTION

Accurate restoration of femoral offset (FO) in total hip arthroplasty (THA) provides patients with a better functional outcome in terms of improved abductor muscle strength [1,2] and greater range of motion (ROM) [1,3-5] and helps to minimise the risk of post-operative complications such as limp, dislocation or wear-related implant failure in the long-term [3,6-8]. Computed tomography (CT) is considered the gold standard for accurate FO assessment [9,10]; however, routine performance of a CT scan is questionable because of higher radiation doses, higher costs and limited availability. The aim of the present study was to investigate whether accurate measurement of FO could be achieved with standard AP radiographs through centering the beam on the femoral head rather than the pubic symphysis.

METHODS

In a retrospective cohort study, pre-operative AP pelvis radiographs, AP hip radiographs and hip CT scans of a consecutive series of 100 patients (43 males, 57 females, mean age 61 (range: 45-74) years, mean body-mass-index (BMI) 27 (range: 20-45) kg/m^2) with primary hip osteoarthritis (OA) were assessed.

Radiographs were taken with the patients in supine position both legs internally rotated by 15 degrees using a foot retainer. When internal rotation of the leg on the AP pelvis view was not sufficient to bring the femoral neck into the coronal plane, the affected hip was elevated by 15 degrees using a wedge-shaped underpad on the AP hip view. All images were calibrated with a metal sphere of 25 mm. All hip CT scans were performed with the patients position in a supine position with legs in neutral rotation.

Using validated custom MATLAB programmes [version 7.10, The MathWorks Inc. MA, USA], FO was measured on corresponding plain radiographs and FO and femoral anteversion (FA) were assessed on CT scans. For CT measurement of femoral offset, three axial CT slices were selected; the slice with largest femoral head diameter (S1), the centroid (S2) and the centre of the isthmus (S3) (Figure 1). In total three measurements of femoral offset were recorded for each patient; femoral offset measured from AP pelvis radiographs (FO_p), femoral offset measured from AP hip radiographs (FO_h) and femoral offset measured from CT scans (FO_c).

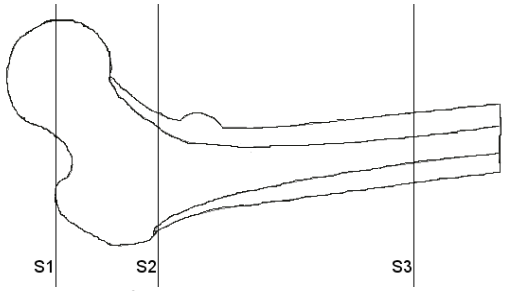

Figure 1: Position of the three CT slices used to measure FO.

Inter- and intra-observer reliability was evaluated using intra-class correlation coefficients (ICC). The distributions of variables were tested for normality using the Kolmogorov-Smirnov test and all (FO_p, FO_h, FO_c, and FA) were normally distributed (range: p=0.06-0.20). For descriptive analysis, absolute mean values for FO were expressed in millimeters with 95% confidence intervals, FA was expressed in degrees with 95% CI. Different measurement methods of FO values were compared using paired-sample t-tests for pair observations and independent sample t-tests for unpaired observations. Results with p values < 0.05 were considered significant, p values of < 0.001 were considered highly significant. Scatter plots and Pearson's correlation coefficient (r) were used to evaluate associations between continuous variables. Statistical analysis was performed using PASW Statistics 18 [SPSS Inc. an IBM company, IL, USA].

RESULTS AND DISCUSSION

In the entire cohort, mean FO was 39.0 (95%CI: 37.4 to 40.6 mm) on AP pelvis radiographs, 44.0 mm (95%CI: 42.4 to 45.6 mm) on AP hip radiographs and 44.7 mm (95%CI: 43.5 to 45.9 mm) on CT scans. Mean FA was 14.9 degrees. AP pelvis based FO measurements (FO_p) were significantly ($p < 0.001$; 13%) underestimated compared to AP hip measurements (FO_h). The difference in mean FO between AP hip radiographs and CT (FO_c) was not significant ($p = 0.191$) and absolute measurements demonstrated a good correlation ($r = 0.767$, $p < 0.001$, figure 2).

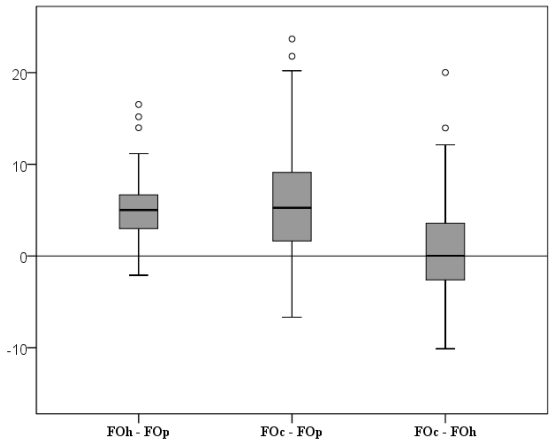

Figure 2: Differences (mm) in femoral offset (FO) between AP hip and AP pelvis radiographs (FO_h-FO_p), AP pelvis radiographs and CT (FO_c-FO_p) and AP hip radiographs and CT (FO_c-FO_h), as boxplots.

Considering the transverse plane, the difference in FO measurements observed between AP pelvis and AP hip radiographs can be represented by the trigonometric relation between the focal length (*f*), angle between the femoral neck and the focal plane (θ), distance between the centre of the femoral head and the x-ray source (*x)*, true offset (*l*), and the distance between the femoral head and the focal plane (*h*) (Figure 3, Equation 1).

$$FOp = \frac{fx + fl\cos\theta}{f - h + l\sin\theta} - \frac{fx}{f - h} \qquad \text{Equation 1}$$

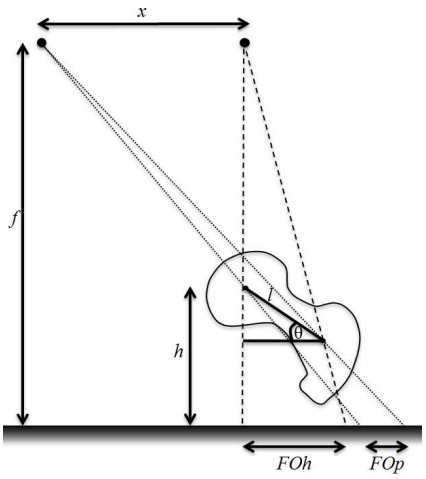

Figure 3: Illustration of the reduction in measured offset when the beam is focused on the femoral head (FO_h) compared with when it is focused a distance (*x*) away from the femoral head (FO_p).

Through examination of the partial derivative of Equation 1 with respect to *x* (Equation 2) it was determined that the measured femoral offset value decreases linearly with increasing *x* and that the degree of anteversion (related to θ) greatly influences this effect.

$$\frac{\partial FOp}{\partial x} = \frac{-fl\sin\theta}{(f-h)^2 + (f-h)l\sin\theta} \qquad \text{Equation 2}$$

In this study, an attempt was made to correct positioning of patients with external rotation contracture during radiography using a wedge shaped underpad. According to Equation 2, this should reduce θ and therefore minimise the effect of *x*. Nevertheless a significant difference was observed between measured FO from AP hip and AP pelvis radiographs. This demonstrates the difficulty in correcting for external rotation contracture and the benefit of AP hip radiographs in accurate measurement of FO.

CONCLUSIONS

The present study suggests that femoral offset is underestimated on AP pelvis views but can be accurately and reliably assessed on AP hip radiographs with correction for femoral anteversion and external rotation contracture in patients with primary end-stage hip osteoarthritis.

A mathematical model was proposed to explain the underestimation of femoral offset in AP pelvis views and this model predicted that a high degree of anteversion would increase the error observed in measurement.

We therefore recommend to routinely obtain AP hip radiographs for pre-operative assessment of femoral offset in THA planning.

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