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A New Technique for Radiographic Measurement of Acetabular Cup Orientation

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ABSTRACT

Accurate radiographic measurement of acetabular cup orientation is required in order to assess susceptibility to impingement, dislocation, and edge loading wear. In this study, the accuracy and precision of a new radiographic cup orientation measurement system were assessed and compared to those of two commercially available systems. Two types of resurfacing hip prostheses and an uncemented prosthesis were assessed. Radiographic images of each prosthesis were created with the cup set at different, known angles of version and inclination in a measurement jig. The new system was the most accurate and precise and could repeatedly measure version and inclination to within a fraction of a degree. In addition it has a facility to distinguish cup retroversion from anteversion on anteroposterior radiographs.

Radiographic measurement of acetabular cup orientation is important for assessing susceptibility to impingement and dislocation [1,2]. A recent need for accurate measurement of cup orientation has been engendered by clinical problems associated with excessive wear of hip resurfacing or, more generally, metal-on-metal (MOM) prostheses. Local excessive wear near the rim of the cup can be caused by impingement, edge loading and a deficiency in lubrication [3–5].

Adverse tissue reactions and high metal ion concentrations in the blood appear to be associated with inappropriate orientation of MOM acetabular components [6–11]. Some have suggested that there might be a "safe zone" (similar to that of Lewinnek[1]) or a range of cup inclination and anteversion angles within which edge loading and excessive metal release is less likely to occur [7,9,11]. If this is true, cup orientation measurement could form part of the mandatory follow-up assessment including blood metal ion levels. Patients with inappropriate cup orientation could be selectively screened with cross sectional imaging – which is expensive and labour intensive if used routinely. The need for a simple screening technique is demanded by the sheer weight of numbers requiring follow-up. For instance, for just one brand of MOM prosthesis (the recently recalled ASR (DePuy)), over 93,000 have been implanted worldwide [12].

Using standard A-P radiographs of the pelvis, cup version and inclination is normally determined from measurements of the axis lengths and orientation of the of the elliptical cup opening image. However, with MOM prostheses, the large femoral head obscures most of the cup opening image and only the extremities of the ellipse are visible. It is then very difficult to determine cup version using the standard technique [7]. Furthermore, if the cup has a high angle of anteversion, even cup inclination can be difficult to measure manually due to the problem of accurately identifying the extremities of the ellipse.

Some have suggested that only CT scans enable accurate determination of cup orientation,[13,14] especially for MOM cups [7]. However, the high radiation dose, the availability of scanner time, and the expense of CT scans make them prohibitive for routine screening. In addition, it is questionable whether the angle of the anterior pelvic plane (used as a reference plane) can be measured to a sufficient degree of accuracy. Others have suggested that a standard measurement software technique such as EBRA can be used [15].

We have developed a new software system – Wrightington Cup Orientation software (WCO) – for measuring acetabular cup orientation from an anteroposterior (A-P) radiograph of the pelvis. The software corrects the cup version and inclination measurements for rotational artefact caused by X-ray beam offset from the hip. It can also distinguish cup retroversion from anteversion in anteroposterior radiographs. We used a laboratory jig to validate the new system and to compare it to two commercially available software programs. We tested the null hypothesis that the there was no difference between the three measurement systems.

Method

Three different prostheses were assessed: a 50 mm head, Birmingham Hip Resurfacing (BHR) prosthesis (Smith & Nephew); a

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49 mm head, ASR resurfacing prosthesis (DePuy); and a Trilogy uncemented cup (64 mm) with a plastic liner and a 28 mm metal femoral head (Zimmer Orthopaedic). Each prosthesis was fixed to a special radiotranslucent jig (Fig. 1). The main components of the jig were made from Perspex, and all pegs and fasteners were made from Nylon. The overall thickness of the Perspex components was chosen in an attempt to simulate the X-ray scatter and absorption effect observed on typical pelvic radiographs (Fig. 2A, B). The jig could tilt the cup to known version angles in 10° increments from −20° retroversion to 20° anteversion. It could also set the cup inclination at 35°, 45° and 55° in the radiographic plane. The cup center remained at the center of version and inclination rotations at all settings and its height above the X-ray table (120 mm) was similar to a typical height of a patient's hip during X-ray examinations [16]. A tantalum marker bead was fixed in the surface of the Perspex base plate of the jig so that its location in the radiographic plane simulated a typical position of the pubic symphysis relative to the cup center.

A Siemens Axiom Luminos dRF digital X-ray machine was used for radiography. With the focus-to-film distance set at 1150 mm and the central X-ray beam focused on the marker bead, a series of X-rays was taken of each cup set at all combinations of version and inclination settings. The digital radiographic image files were named according to the individual settings. A duplicate set of the image files was then re-named so as to blind the observers to the true measurements (see below).

The radiographic image was loaded into the WCO software and the X-ray focus-to-film distance and image resolution were inputted (these were required for the angular correction for X-ray beam offset). A horizontal reference line was placed on the image (in a clinical radiograph, this would be a line placed tangentially to the inferior borders of the ischial tuberosities). A point was then taken at the image of the tantalum marker (simulating the focus point at the pubis). After creating a zoom window around the acetabular cup, an elliptical line drawing was placed over the image of the cup opening. "Handles" on the ellipse enabled its position, shape and orientation to be adjusted manually so that the ellipse fitted the contour of the cup opening image. A further, automatic ellipse fitting step was available, in which the contour of the cup opening image was edge-detected prior to ellipse fitting. However, for metal cup/shell images, we found that the manual ellipse fitting (by eye) was more accurate than the automatic fitting and so only manual measurements were recorded. Inclination and version were determined from the inclination and shape of the ellipse.

Two other measurement systems were compared to the WCO system: EBRA[15,17], and TraumaCad (www.voyanthealth.com). TraumaCad has a similar manual ellipse fitting technique to the WCO system whereas EBRA requires several points to be taken around the periphery of the cup opening before an ellipse is automatically fitted.

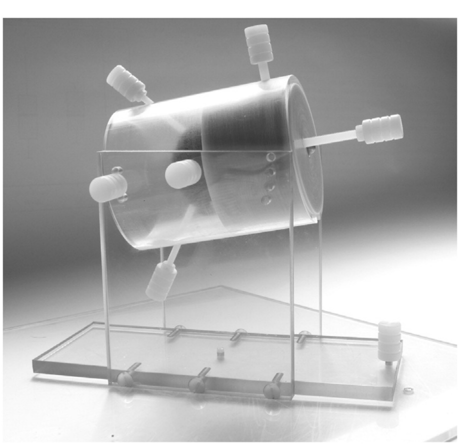

Fig. 1. The measurement jig is made entirely of plastic. The cup is contained within the Perspex cylinder which can be pegged at 10° intervals to ± 20° version. The jig can rotate about the base to provide 35°–55° inclination settings.

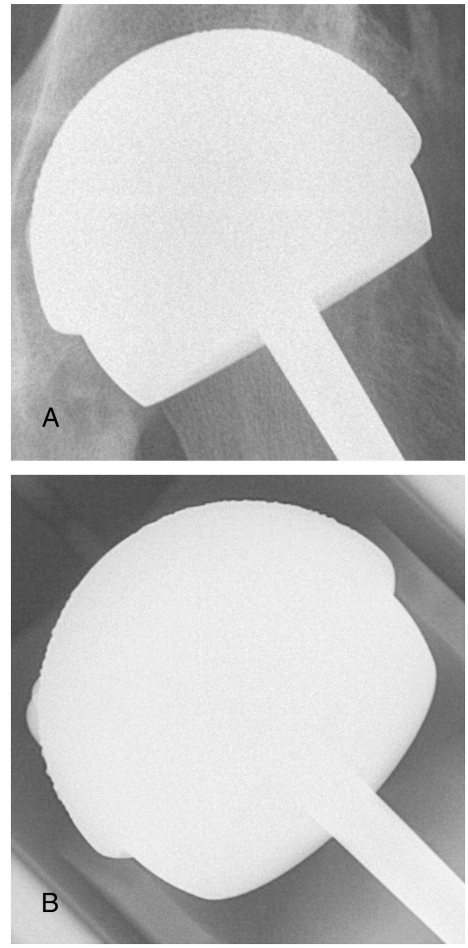

Fig. 2. (A) A typical clinical radiographic image of a resurfacing hip prosthesis. (B) A radiographic image of a resurfacing hip prosthesis in the measurement jig.

TraumaCad and WCO measurements of the BHR, ASR and Trilogy cup images were carried out at one institution by two observers who were experienced users of both systems. EBRA measurements of the Trilogy cup images were carried out at another institution by two different experienced observers, one of whom also measured the BHR images. Each set of images was measured twice by each observer. The WCO system had been adapted so that the results panel and the results table could not be viewed during the measurements. However, measurements using TraumaCad could not be blinded in this way. The two EBRA observers were blinded to the image identities (which included the true measurement values) and were unaware of the range and increments of the settings.

The WCO measurement software had a facility for detecting the type of version (ante or retro) from anteroposterior radiographs. This detection was automatic if the orientation of a hip centered radiographic image was measured first, followed by that of a "pubic symphysis" centered image. The version type is determined from the small difference in version angle between the two radiographs [18]. As a separate aspect of this study, we tested this facility by creating and measuring additional hip centered radiographs for the WCO software only. It is emphasised that, in order to ensure a fair comparison of the three systems, only the "pubis"-centered radiographic measurements were compared and all version measurements were deemed to be positive (i.e. anteversion).

The software was evaluated in a clinical situation by measuring 21 images of Birmingham Hip Resurfacing cups from 16 patients. Each