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Hip Resurfacing Implant Orientation Analysis: A Comparison of a Computer-Added Design Technique and Computed Tomography

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ABSTRACT

Background: Accurate acetabular component orientation in hip resurfacing is mandatory. The aim of this study is to analyze if interpretation of pelvic radiographs with computer-added design (CAD) software is comparable to computed tomography (CT) in measurement of acetabular anteversion and inclination of a Birmingham Hip Resurfacing (BHR) hip.
Methods: A consecutive series of 49 patients (50 hips) who underwent hip resurfacing arthroplasty between 2005 and 2007 with the BHR system were retrospectively included. The surgical procedure was performed by 1 orthopedic surgeon in the beginning of his learning curve. Computer-added design software was used to measure acetabular component orientation on an anteroposterior pelvic radiograph. These measurements were compared with CT measurements. We calculated the correlation between the CAD software and CT analysis. The degree of underestimation or overestimation was determined, and a Bland-Altman plot was created to visualize the agreement between CAD software and CT results.
Results: We analyzed 50 BHR hips with mean inclination of 54.6° and 55.6° and mean anteversion of 24.8° and 13.3° measured by CT and CAD, respectively. Pearson correlation coefficient for inclination was 0.69 ($P < .001$) and for anteversion 0.81 ($P < .001$). Computer-added design showed a mean underestimated anteversion of 11.6° ($P < .001$). There was no significant underestimation or overestimation of inclination with CAD analysis compared to CT measurements.
Conclusion: The CAD software is useful to assess acetabular inclination in hip resurfacing but underestimates anteversion.

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When evaluating patients with resurfacing hip arthroplasty, it is important to accurately assess acetabular orientation, especially in a painful hip.

Accurately measuring inclination of the acetabular component in hip resurfacing is important because a high inclination angle of the acetabular component in hip resurfacing is related to wear. Wear is due to edge loading and results in high serum metal ion levels and pseudotumor formation [1-5].

Recent studies suggested that excessive anteversion may be an equally important factor, but these findings are not consistently reproduced in studies [1,2,5-8].

Incorrect anteversion can also cause iliopsoas irritation [8], impingement, reducing range of motion, increased risk of fracture, dislocation, and loosening [9-11].

Radiologic anteversion was described by Murray [12] as the angle between the axis of the acetabulum and the coronal plane. Various techniques exist for measuring cup anteversion and inclination.

Computed tomography (CT) has been widely used to measure cup orientation and showed to be more accurate than manually interpreted plain radiographs in hip resurfacings but involves significant radiation exposure [3,13-17].

Cross-table lateral radiographs are often used but have been shown to be of limited use [13]. Evaluation of anteroposterior (AP) radiographs with EBRA (Einzel-Bild-Roentgen-Analysis, University of Innsbruck, Austria) has been validated as an accurate method in hip resurfacing, but it is not available in many orthopedic departments [18]. TraumaCad also offers a measurement tool for cup anteversion and inclination. Westacott et al [1] described its validation. They concluded that TraumaCad correlates well with CT and has good intraobserver and interobserver reliability but underestimates anteversion by 12° on average [1].

The Implant Development Centre of Smith and Nephew (S&N) (Warwick, United Kingdom) developed also a computer-added design (CAD) technique that can be used as a tool to measure acetabular cup

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anteversion and inclination and stem anteversion and inclination of the femoral head. As far as we know, this technique has not been clinically validated.

We, therefore, want to determine if analysis of pelvic radiographs with the S&N CAD software is a reliable method of assessing acetabular component orientation in hip resurfacing.

Methods

A consecutive series of 49 patients (50 hips) who underwent hip arthroplasty between 2005 and 2007 with the Birmingham Hip Resurfacing (BHR) system (S&N) were retrospectively included. The surgical procedure was performed by 1 orthopedic surgeon in the beginning of his learning curve. Five years after the index operation, patients underwent an AP pelvic radiograph, ultrasonography, and CT of the hip. Institutional review board approval was received, and the study was carried out in the context of national guidelines on the follow-up of metal-on-metal hip arthroplasty patients as part of routine clinical care. The study was performed according to the ethical standards of Gelre Hospital and the Helsinki Declaration.

Image Acquisition and Measurements

Anteroposterior pelvic radiographs were taken with the patient supine and the legs slightly abducted and internally rotated so the feet made a right angle with the toes touching. The beam source to detector distance was 100 cm and at 90° to the table; the beam centered at the pubic symphysis. All images were digitally acquired and sent to Picture Archiving and Communication System (PACS) (Sectra, Linköping, Sweden). Anonymous digital copies of the radiographs were sent to S&N. Anteversion and inclination of the acetabular component were measured by a single user of S&N who is experienced using the S&N CAD software for hip resurfacing implant orientation analysis. The user was blinded to patient history and symptoms, and S&N was fully independent involved in this study without financial or other conflicting interests.

The S&N CAD technique exists of a ProEngineer Wildfire 4 with ISDX II extension software, which generates CAD models of BHR devices [19]. By superimposing the models onto the AP x-ray image and using the anatomical and specific features of the BHR device, the in vivo implant inclination and anteversion of an acetabular cup can be obtained (Fig. 1).

Computed Tomographic Measurements

Computed tomographic scans were acquired on a Siemens AS 64 CT scanner (Siemens, Erlangen, Germany). The protocol used a collimation of 64 × 0.675 mm, 120 kV, 250 mAs, and metal artifact reduction bone algorithm. Axial and coronal images (parallel to the table surface), with a slice thickness of 4 mm and a reconstruction interval of 3 mm, were calculated from the raw data set. The images were sent to PACS where the acetabular cup inclination and anteversion angles were measured on the optimal slice determined by scrolling through the stack of images, using optimal window width and level as determined by the radiologist. Pelvic CT scans were interpreted by an experienced musculoskeletal radiologist. The radiologist was blinded to patient history and symptoms.

Computed Tomographic Anteversion

Acetabular anteversion with CT was calculated by measuring a line connecting the most anterior and the most posterior rim of the cup (line A, Fig. 2) and a line drawn parallel to the horizontal plane of the image (line B). Because the patients' pelvis was not exactly parallel to the tabletop, we corrected for this slight deviation. This was done by drawing the line connecting the posterior acetabular columns (line C) and measuring the angle between lines B and C. The corrected angle was calculated by adding or subtracting angle BC from angle AB. Thus, the anteversion angle amounted to 90°—the corrected angle. The anteversion measured by CT was considered as the reference standard for acetabular anteversion [16,20].

Computed Tomographic Inclination

Acetabular inclination was assessed by measuring the angle between a line connecting the most superior and the most inferior rim of the cup (line D, Fig. 3), and a second line was drawn parallel to the horizontal plane of the image (line E). Similar to the anteversion measurement, we corrected for the coronal plane of the patient not being exactly parallel to the image plane. This was done by drawing the intertuberous or interpubic line (line F) and measuring the angle between line E and F. The true inclination angle was calculated by adding or subtracting angle EF from angle DE (Fig. 3).

Fig. 1. Picture of S&N CAD software with measurement results.