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Validating a Modified Circle Theorem Method for the Measurement of Acetabular Cup Anteversion on Plain Radiography with Intra-Operative Data from Robotic Assisted Total Hip Arthroplasty

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ABSTRACT

This study aims to validate a modified circle theorem method for the calculation of true version of the acetabular component on anteroposterior x-rays with intra-operative version data derived from robotic assisted total hip arthroplasty (THA). Planar anteversion measurements recorded intraoperatively in 80 THAs were correlated to measurements on anteroposterior radiographs. The mean anteversion of the cohort measured by the robotic system and on plain radiography was 21.2° ± 2.0° and 19.9° ± 3.4° respectively and 97.5% of cases were in a 30% relative error. The correlation between the true and planar measurements of anteversion on plain radiographs was strong (Pearson correlation coefficient of 0.9422). We conclude that the circle theorem method can be validated with data from robotic guided THA.

Acetabular cup position affects stability, range of motion and impingement in total hip arthroplasty (THA) [1]. Inclination and anteversion are the two most commonly analyzed parameters of cup positioning [2]. Lewinnek et al proposed a safe zone for acetabular inclination of 15° ± 10° to minimize dislocation rates [3]. More recently, Dorr et al defined a safe zone for combined anteversion of the acetabulum and femur of 25° to 50° [4]. Following on from this, Nakashima et al demonstrated that THAs with a combined anteversion (Fig. 1) outside of the range of 40° to 60° were 5.8 times more likely to dislocate than those within this range [5].

Several methods have been developed to help surgeons correctly position the acetabular component intra-operatively. These methods can be divided into implantation with the assistance of anatomical landmarks [6], mechanical alignment guides [7], computer navigation [8] and robotic assistance [9]. Several studies have shown that navigation increases the percentage of components within the safe zone compared to non-navigated methods [8,10,11]. More recently, robotic technology has been developed to help surgeons not only with component positioning but also haptic conical reaming. Domb et al reported on a series in which 97.1% of cups were placed in the Lewinnek safe zones with robotic assistance compared to 80% of cups with mechanical alignment guides [9].

Several methods have been proposed to calculate acetabular cup version on antero-posterior cup radiographs [12–14]. The circle theorem method proposed by Kosiyatrakul et al is based on simple descriptive geometry and does not rely on conversion tables or complex computer calculations [15]. The method has yet to be validated on x-rays in patients with THA. The purpose of this study is to validate a modified circle theorem method for the calculation of true version of the acetabular component on anteroposterior x-rays of the pelvis with intra-operative version data derived from robotic assisted THA. To our knowledge, this type of validation has not been previously performed. The modification and methodology proposed are also more precise in defining the rim of an uncemented acetabular component.

Patients and Methods

Patient Selection

103 randomly selected patients who had undergone robotically assisted THA between the period of July 2012 and August 2014 were included in the study (Table 1). All patients had the same acetabular prosthesis implanted. The acetabular component was an uncemented titanium porous coated hemispherical cup (Trinity Corin, Circencester, United Kindgom).

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Plain Radiography

All patients had post-operative anteroposterior plain radiographs of the pelvis. Patients were excluded if they did not have well centered radiographs as obliquity can cause erroneous measurements [14]. Anteroposterior radiographs of the pelvis were taken with the X-ray beam centered on the pubic symphysis. Radiographs were considered well centered if the tip of the coccyx was centered within 2 cm of the pubic symphysis and the obturator foramen was symmetrical [15]. As a consequence of this exclusion criterion, 23 patients were excluded from the cohort leaving 80 patients eligible for inclusion in the study.

Surgical Technique

THA was performed with the MAKOplasty Total Hip Application (MAKO Surgical Corp., Fort Lauderdale, FL, USA), a robotic-guided computer navigation designed to place THA components with increased precision. It is based on a three-dimensional model of the patient's hip, reconstructed from CT.

Preoperative CT Scan

The preoperative CT scan has about ten times the radiation of a normal hip radiographic series [16]. Specialized software is used to create a patient specific virtual 3-D model of the pelvis and femur. Intra-operatively specific points are defined on the patient's anatomy to help the software determine the patient's pelvic position. The software accounts for the pelvic tilt by using the patient's anterior/posterior tilt when lying supine on the CT table. All inclination and version measurements use this tilt.

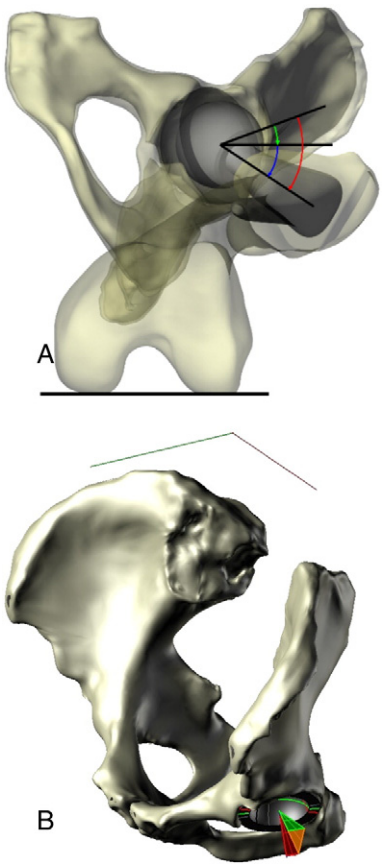

Fig. 1. (A) Projection in the Transverse plane of the THA. The combined anteversion (red) is the sum of the Acetabular Cup True Anteversion (Green) and of the Femoral Anteversion (Blue). (B) Difference between the True (Green) and planar (Red) Anteversions.

Table 1
Demographic Data.

Demographic characteristics	Number
Total Number of Cases	103
Age (Mean and range)	67.6 (43.8–79.1)
Male:Female	46:57
BMI(Mean ± Std Dev)	29.6 ± 5.3
Cup Size (Median and Range)	54 (42–60), 100% Corrin Trinity Cup
Stem	100% Corrin Metafix Uncemented femoral stem
Number with post-operative x-rays	103 (100%)
Number with inadequate centered x-rays	23 (22.3%)

Preoperative Planning

The depth, inclination and version of the cup in the acetabulum are positioned preoperatively in the computer-generated model to guide the robotic assisted reaming. The stem is positioned in the femoral canal to determine the correct site of femoral neck osteotomy so as to reconstruct the leg length and offset.

Surgical Approach

Patients underwent either an anterior or posterior approach for implantation of components. A posterior approach was chosen in those patients in whom the overhanging abdominal adiposity was considered to potentially increase wound complications. The anterior approach was performed on a traction table as described by Matta et al [17]. The posterior approach was performed as described previously [9].

Pelvic Array Placement

The first step in robotic THA was to place the three pelvic threaded pins into the thickest portion of the iliac crest (ipsilateral iliac crest in the cases that underwent a posterior technique, and contralateral iliac crest in those cases that underwent an anterior technique). The pins hold the pelvic array, which allows the robotic camera to visualize the exact 3D orientation of the pelvis.

Femoral Registration and Osteotomy

Femoral registration requires insertion of two screws; one large screw for holding the femoral array and a smaller screw to be used to

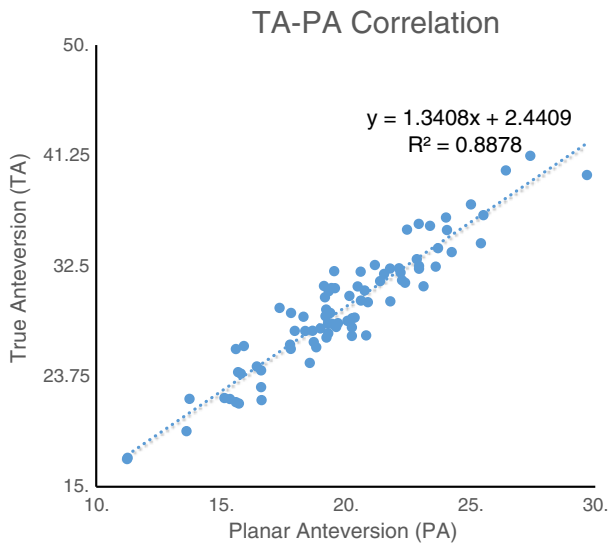

Fig. 2. Correlation found between the True Anteversion and the Planar Anteversion measured on X-rays.