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A novel computer-based method for measuring the acetabular angle on hip radiographs

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ABSTRACT

Objective: The aim of this study was to propose a new computer based method for measuring acetabular angles on hip radiographs and to assess its practicality, sensitivity and reliability for acetabular angle measurement.
Methods: A total of 314 acetabulum were assessed on 157 pelvic X-ray images. Acetabular angles were measured with both the conventional method (Method 1) and our proposed method (Method 2). All the Acetabular Index (AI) angle, Acetabular Angle (AA) and Acetabular Center (ACM) angle were measured with both methods.
Results: The mean AI angle for Method 1 is 11.02° ± 2.7° and the mean AI angle for Method 2 is 10.08° ± 1.88°, the mean AA angle for Method 1 is 39.5° ± 5.3° and the mean AA angle for Method 2 is 39.36° ± 4.68°, the mean ACM angle for Method 1 is 50.5° ± 6.01° and the mean ACM angle for Method 2 is 55.42° ± 12.43°.
Conclusion: Our novel automated method appear to be reliable and practical for acetabular angle measurement on hip radiographs.
Level of Evidence: Level III, Diagnostic study

Anteroposterior (AP) pelvic X-ray imaging is one of the most commonly used radiographic projections of the pelvis. Assessment of the acetabular morphology and the femoral head-acetabulum congruency with angular measurements is one of the basic steps of AP pelvis radiographical analysis.[1,2] For this reason, an easy, reliable and accurate measurement of the acetabular angle is very important.[3] In the literature, various techniques have been proposed for acetabular angle measurements, including the acetabular index (AI), defined by Hilgenreiner and Tönnis[4]; acetabular angle (AA), defined by Sharp[5]; and acetabular center–margin (ACM) angle, defined by Idelberger and Frank.[6] The AI and AA angles provide information about the slope of the acetabulum while the ACM angle measures its depth. These angles are the most preferable 'conventional manual angle measurement methods'. Nevertheless, there is still an ongoing debate in the literature about the gold standard measurement method, since the manual measurement of the acetabular angle is very dependent on the experience of the observer and the quality of the AP radiograph.[7] To overcome these controversies, methods about the computer-assisted extraction of new anatomical landmarks and calculation of angles automatically on hip radiographs have been recently developed.[8–14]

In this paper, we aimed to describe new anatomical landmarks and reference lines in regards to establishing a fully automated acetabular angle measurement method which is based on the obturator foramen.

Patients and methods

Between January 2014 and December 2014 and between June 2011 and May 2012, all patients who were admitted to Orthopedics Department in outpatient clinics in two different hospitals (one university hospital, one military hospital), and who were scheduled

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to undergo pelvic X-ray evaluation, were considered for this study. This study was approved by the Institutional Review Board of Başkent University (November 28, 2013) and ethical approval was received from Gülhane Military Medical Academy Hospital Ethics Committee (May 25, 2011). In order to prevent any bias and to acquire a homogenous study population, all X-rays were taken under a standard procedure.

As an inclusion criterion, only 'mature pelvic X-rays' without obvious osteophyte formation, bone defects or other pathological changes on the acetabular rim were accepted. Patients who had a previous pelvic or lumbosacral surgery, previous fracture history regarding the acetabulum, or patients with coxarthrosis, severe bone deformities and metabolic bone disorders, radiographs of suboptimal quality, and an excessive pelvic rotation as assessed by an obturator foramen index beyond the range of 0.6–1.8[4] were excluded from the analyses. Eventually, a total of 157 pelvic X-rays (314 hips) were found eligible. The study group consisted of 123 male and 43 female patients with a mean age of 56.7 ± 13.3 years.

All X-rays were digitally recorded in the Orthopedics Department and the PACS v.2.0 (picture archiving and communications systems) software was used to store the DICOM (Digital Imaging and Communications in Medicine) images.

All conventional manual measurements (Method 1) were done with two experienced observers after printing the high-quality pelvic X-ray images. In order to perform the standardized measurements as precisely as possible, a detailed common understanding of important pelvic landmarks of all the measurements was ensured prior to the analyses.

Three previously mentioned acetabular measurement methods were used for the conventional radiographic evaluation:

1. Acetabular index (AI) defined by Hilgenreiner and Tönnis.[4] AI is the angle between the horizontal teardrop line and a line drawn through the medial point of the sourcil and the lateral acetabular rim.
2. Acetabular angle (AA) defined by Sharp.[5] AA is the angle between the horizontal teardrop line and a line through the inferior teardrop point and the lateral rim of the acetabulum.
3. Acetabular center–margin (ACM) angle defined by Idelberger and Frank.[6] The ACM is defined as the angle between the MC and CA lines constructed on the acetabulum. (**A**: the upper point of acetabulum, **B:** the lower point of the acetabulum, **C**: the intersection point of the acetabulum with the orthogonal line drawn from the center of the **AB** line, **MC:** the line which was passed through the center of the **AB** line, **CA**: the line that connects the A and C points.)

Our proposed method (Method 2) is a novel, geometric method which uses the AutoCAD 2013 (Autodesk Inc., San Rafael, CA, USA) and MATLAB 7.13.0 (The MathWorks Inc., Natick, MA, USA) softwares. First, a reference image was determined by clinicians as a gold standard image and it was used to present the proposed novel geometric angle measurement method drawings. The image was transferred to AutoCAD and was opened on the user interface. Then, a hand drawn template was designed on this interface based on the reference image. After that, the fully automated angle measurement algorithm framework was developed on MATLAB. 157 images were executed for each run of this algorithm and angle measurement results were produced as an output. The template was operated on a sample image (x1) row by row (Fig. 1) to find the best fitting sub-image as the obturator foramen, by using some image processing techniques whose descriptions are beyond the scope of this paper. After the obturator foramen was detected, its center of mass was determined as the major reference point for all subsequent measurements. The measurements of acetabular angles

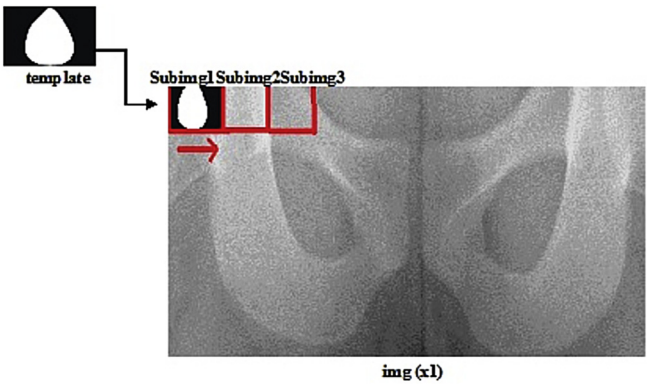

Fig. 1. Identifying the starting reference point (center of mass of the obturator foramen). Note that, first, a hand-drawn template is designed on AutoCAD. Then, it is operated on the hip radiograph (x1) to detect similarities between the sub-images and this is used to decide the most similar sub-image to the template image as the obturator foramen. Then, the center of mass of the obturator foramen is identified.

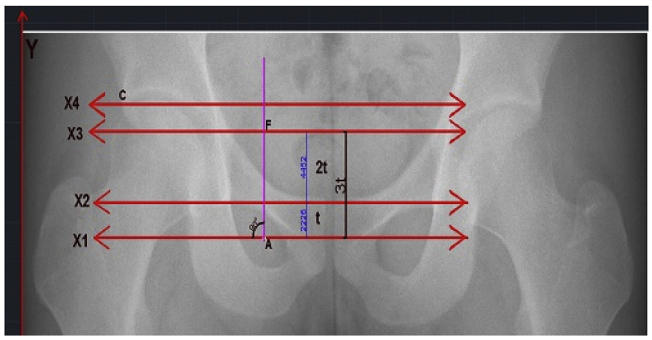

Fig. 2. Reference lines are drawn automatically after detection of the center of mass of the obturator foramen. **X1 line:** The line parallel to the X-axis and passes through the center of mass of the obturator foramen (**Point A**) and intersects with the Y-axis. **X2 line:** The reference line parallel to the X1-axis and passes through the superior margin of the obturator foramen and intersects with the Y-axis. The distance between these two lines are referred as "**t**" distance. **X3 line**: The line parallel to the X2-axis and passes through **3t** above the center of mass of the obturator foramen and intersects with the Y-axis. **X4 line**: The reference line which is parallel to the X3-axis and passes through the lateral margin of the acetabular roof (**Point C**) and intersects with the Y-axis. After establishing these reference lines, the angular measurements are performed by the computerized method.

were based on the four reference lines which were drawn automatically, as the second step of the proposed method (Fig. 2).

The angle formed between the X3 line and the line drawn from point F to point C was accepted as AI (Fig. 3).

The angle formed between the X1 line and the line drawn from point A to point C was accepted as AA (Fig. 4).

The angle formed between the LR line and the CL line was accepted as ACM angle. The method of measurement is summarized in Fig. 5.

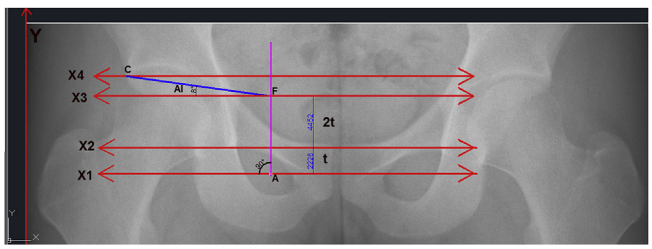

Fig. 3. Geometrical-based measurement method for the acetabular index (AI). The AI is the angle formed between the **CF** and **X3** lines.

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