Hip Osseous Morphologic Characteristics Using Computer Navigation and Plain Radiographs

INTRODUCTION
With the recognition of femoroacetabular impingement (FAI), there has been a recent interest in hip joint preservation surgery. There is a wide variation in acetabulum morphology from developmental dysplasia to coxa profunda and studies that define the three-dimensional are lacking in the literature. There is a wide variation in hip osseous morphology and an improved understanding of three-dimensional anatomy will allow the orthopedic surgeon to plan the appropriate hip joint preservation surgery. The purpose of the study was to map the osseous morphology of the acetabulum and proximal femur using three-dimensional analysis.

MATERIALS AND METHODS
Thirty-six cadaveric specimens (or 72 hips) were available for analysis. All cadavers had a standard AP radiograph of the pelvis with the patient in a supine position and cross-table lateral views. All radiographs were performed with the coccyx positioned in the midline, about 1 cm above the pubic symphysis (neutral tilt) and the obturator foramina and the greater trochanter were symmetrical (neutral rotation). Once the plain radiographs were reviewed, only hips with Tönnis scale of 0 or 1 were used in the 3-Dimensional morphologic analysis. Hips with Tönnis scale of 2 or 3 were excluded from further analysis.

All radiographs were graded using tools to measure length (mm) and angles (°) provided by the PACS by one orthopaedic surgeon. The joint space was measured at two points, medial and superior. The following parameters were measured: Tönnis angle, Sharp’s angle, the lateral center edge (LCE) angle of Wiberg, femoral head extrusion index, neck-shaft angle, cross-over sign, posterior wall sign, ilioischial line relative to acetabular fossa, center of rotation of femoral head relative to the top of the trochanter.

Those hips that met the study criteria were dissected to the level of the hip joint capsule. The optical sensors were placed in the appropriate bony landmarks including the anterior superior iliac spine and proximal femur according to the manufacturer’s specifications (BrainLab, Inc., Feldkirchen, GERMANY). Using the total hip arthroplasty software, the optical pointer was placed in the deepest point of the acetabular fossa, and 50 points were obtained. Using the optical pointer, 200 points were obtained from the acetabular articular surface by outlining the borders of the articular surface, followed by drawing circumferential lines and radial lines. Using the hip resurfacing software, the optical pointer was used to acquire 250 points on the femoral head by outlining the articular surface, followed by circumferential lines and radial lines. The femoral neck points were acquired by outlining each of the following zones: anterior, inferior, posterior, superior, and notching zone.

The point cloud data acquired with the navigation equipment was translated into a graphical CAD environment (SolidWorks 2007, Dassault Systemes SolidWorks Corp., Concord, MA). Orthogonal datum planes (equivalent to a transverse, sagittal and coronal) were created as a local coordinate system centered at the acetabular/femoral centroids determined by the navigation system. Radial lengths and acetabular depth were thus measured. A clock face template was laid over onto the transverse plane to determine the 9 o’clock to 3 o’clock positions and projections of the arcs onto the transverse plane.

A custom-written program in Visual C++ under Microsoft Foundation Class programming environment produced a mesh from the point cloud data and computed the resulting surface area. This was applied to the acetabular articular surface as well as the fossa. (Fig 2.)

RESULTS
Seventeen patients met study criteria with a mean age of 73.4 ± 11.7 years. Based on plain radiographic measurements, the joint space was 6.2 ± 1.0mm and 4.9 ± 1.1mm for the lateral and medial, respectively. The center edge angle measured 36.2 ± 5.4° and the neck shaft angle measured 130.9 ± 3.7°.

The mean surface area of the acetabular fossa measured 474.1 ± 72.1mm², and the mean surface area of the articular surface measured 2642.5 ± 536.9mm². The mean radius was 23.3 ± 1.7mm and the mean depth was 27.9 ± 2.6mm.

DISCUSSION
The hip anatomy has been difficult to characterize given the complex three-dimensional morphology. The acetabular articular surface was quantified using plain radiographs and computer navigation. The mean articular surface area measured 2642.5 ± 536.9mm². The radial measurements demonstrate the anterior aspect (9 o’clock) of the acetabulum is the smallest and progressively increases to the superior-most aspect (12 o’clock). The postero-superior quadrant is larger than the antero-superior quadrant. Additional studies that provide measurements of the acetabular rim are necessary to determine if there are differences in different hip types.