A Systematic Approach to the Plain Radiographic Evaluation of the Young Adult Hip

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Introduction

Orthopaedic evaluation of hip pain in the young adult population has undergone a rapid evolution over the past decade[1,2]. This is in large part due to enhanced awareness of structural hip disorders, including developmental dysplasia of the hip and femoroacetabular impingement[1-5]. Surgical treatment for these disorders continues to be refined[6-9], and our ability to identify patients along the spectrum of disease continues to improve[10-15]. Yet, despite our advances, obtaining an accurate diagnosis can remain challenging, especially in the setting of mild structural abnormalities. Therefore, radiographic examination is a critical component of the diagnostic evaluation and treatment decision-making process. It is essential that physicians have common and reliable radiographic views as well as parameters for plain radiographic assessment that can serve as a foundation for accurate diagnosis, disease classification, and surgical decision-making.

Many different radiographic measurements have been described as indicators of structural disease. In particular, measurements such as the lateral center-edge angle of Wiberg[16], the anterior center-edge angle of Lequesne[17], the acetabular index of depth to width described by Heyman and Herndon[18], the femoral head extrusion index[19], and the Tönnis angle[20] have been used as markers for acetabular dysplasia. Similarly, measurements of acetabular version[21], the head-neck offset (initially described by Eijer)[3,22], and the alpha angle[19] have been used in the diagnosis of femoroacetabular impingement. Nevertheless, there is limited literature that provides comprehensive information regarding the details of radiographic evaluation in the young patient with hip symptoms. This paper summarizes the recommendations of the ANCHOR (Academic Network for Conservational Hip Outcomes Research) study group regarding the most important aspects of radiographic technique and image interpretation to evaluate the symptomatic, skeletally mature hip.

Radiographic Techniques

In order to fully evaluate patients who present with a complaint of hip pain, the following radiographic views can be considered: an anteroposterior view of the pelvis (anteroposterior pelvic view)[21,23], a cross-table lateral view[22], a 45° or 90° Dunn view[24,25], a frog-leg lateral view[26], and a false-profile view[17] (Figs. 1-A through 1-F). Each radiographic view provides discrete information regarding the structural anatomy of the hip, and individual physicians will have distinct preferences for the views obtained. Image quality is highly technique-dependent, and variability in patient positioning can substantially impact the ability to properly diagnose structural abnormalities. To improve diagnostic accuracy and disease classification, radiographs must be obtained with use of the same standardized imaging protocol. The following section will address the proper technique for obtaining each of the noted views.

Anteroposterior Pelvic View

The anteroposterior pelvic radiograph should be made with the patient supine on the x-ray table with both lower extremities oriented in 15° of internal rotation in order to maximize the length of the femoral neck (Figs. 2-A and 2-B). The x-ray tube-to-film distance should be 120 cm, with the tube oriented perpendicular to the table. The crosshairs of the beam

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Fig. 1-A

Figs. 1-A through 1-F Radiographic views: anteroposterior pelvic (Fig. 1-A), cross-table lateral (Fig. 1-B), 45° Dunn (Fig. 1-C), 90° Dunn (Fig. 1-D), frog-leg lateral (Fig. 1-E), and false profile (Fig. 1-F).

should be centered on the point midway between the superior border of the pubic symphysis and a line drawn connecting the anterior superior iliac spines.

Cross-Table Lateral View

The cross-table lateral radiograph[27] should be made with the patient supine on the x-ray table with the contralateral hip and knee flexed beyond 80° and the symptomatic limb internally rotated 15° to expose the anterolateral surface of the femoral head-neck junction. The x-ray beam should be parallel to the table and oriented at a 45° angle to the symptomatic limb, with the crosshairs directed at the center of the femoral head. Depending on the size of the patient, filters may be required to limit the effect of excess soft tissue on the final image quality (Fig. 3).

45° or 90° Dunn View

The 90° Dunn radiograph is made with the patient supine on the x-ray table. The symptomatic hip is flexed 90° and abducted 20° while being maintained in a position of neutral rotation. The crosshairs of the beam are then directed at a point midway between the anterior superior iliac spine and the pubic symphysis. The x-ray tube-to-film distance should be approximately 40 in (102 cm) in a line directed perpendicular to the table (Figs. 4-A and 4-B). The 45° Dunn view is performed in a similar fashion, with the only exception being hip flexion to 45° (Figs. 5-A and 5-B).

Frog-Leg Lateral View

To make a frog-leg lateral radiograph of the hip, the patient should be positioned supine on the x-ray table with the affected limb flexed at the knee approximately 30° to 40° and the hip abducted 45°. The heel of the affected limb should rest

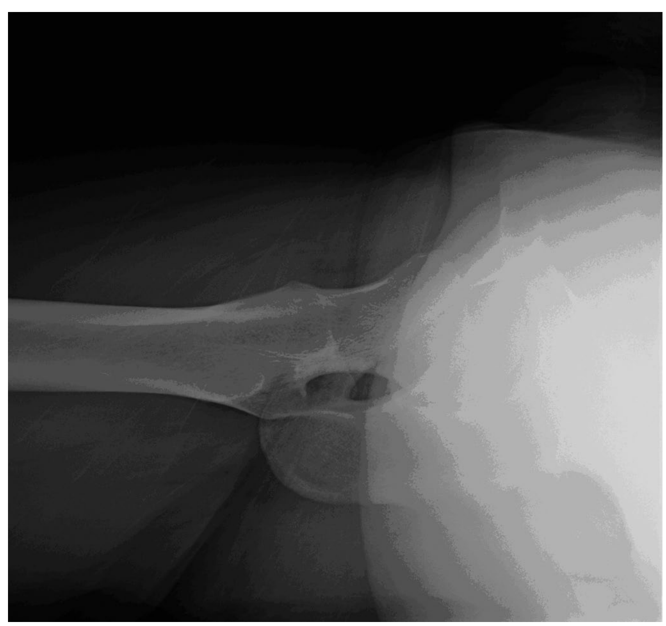

Fig. 1-B

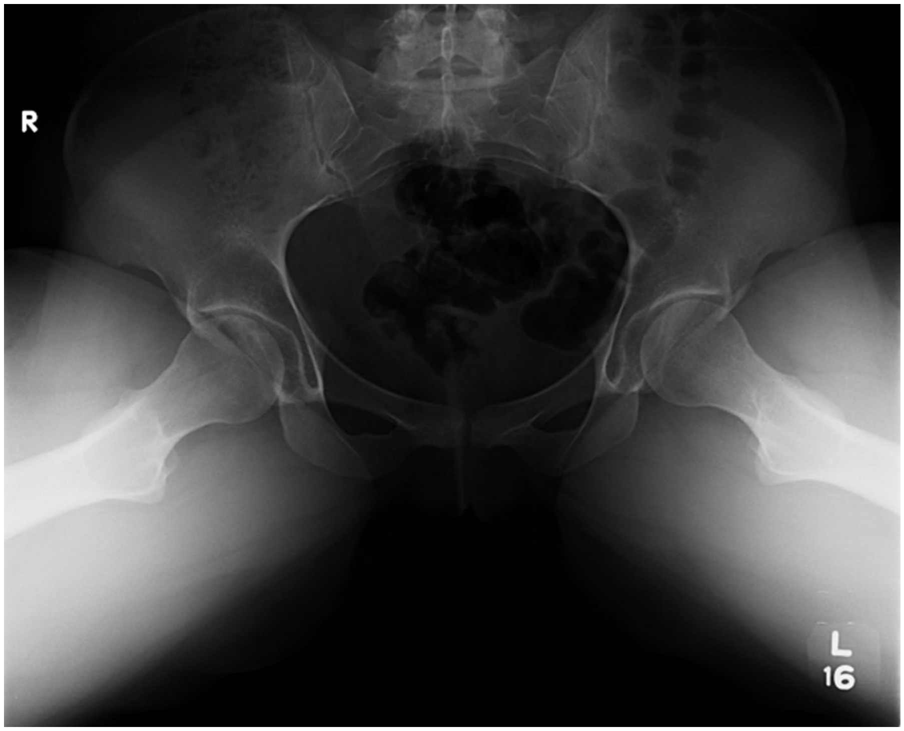

Fig. 1-C

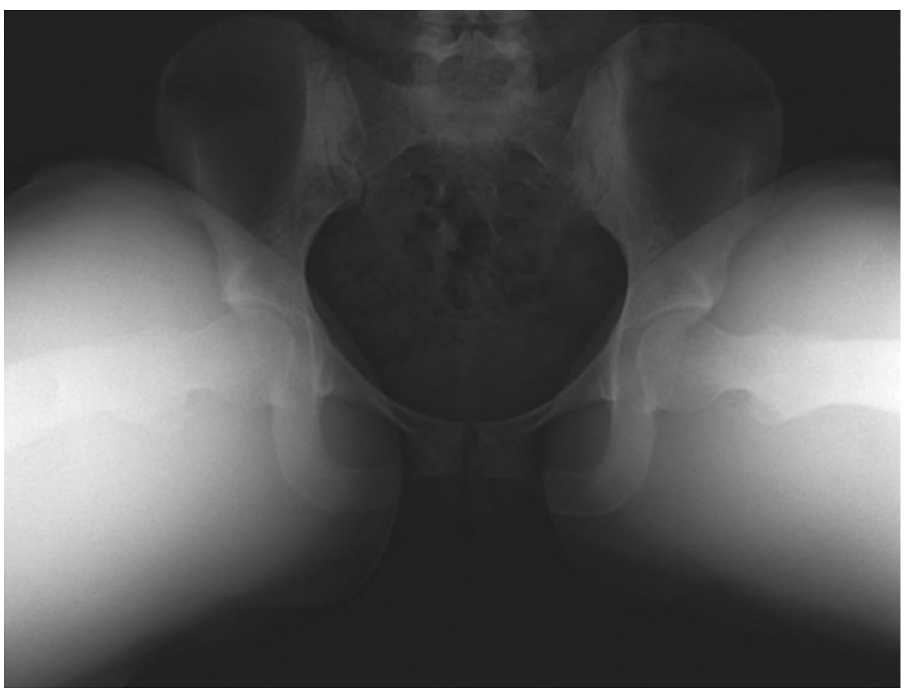

Fig. 1-D

against the medial aspect of the contralateral knee (Fig. 6). The cassette is placed so that the top of the film rests at the anterior superior iliac spine. The crosshairs of the beam are then directed at a point midway between the anterior superior iliac spine and the pubic symphysis. Again, the x-ray tube-to-film distance should be approximately 40 in (102 cm).

False-Profile View

The false-profile radiograph is made with the patient in a standing position with the affected hip against the cassette and the pelvis rotated 65° in relation to the bucky wall stand (Fig. 7). The foot on the same side as the affected hip should be positioned so that it is parallel to the cassette. The central beam

Fig. 1-E

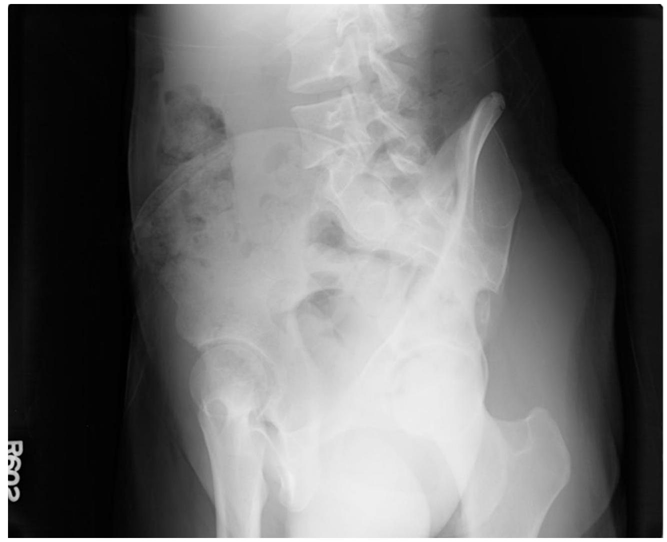

Fig. 1-F

is then centered on the femoral head, with a tube-to-film distance of approximately 40 in (102 cm).

If the above techniques are followed, the majority of images will be of sufficient quality to contribute information regarding the structural anatomy of the hip. However, every radiograph should be carefully scrutinized to ensure that patient positioning was appropriate. In particular, tilt and rotation should be routinely assessed during evaluation of an

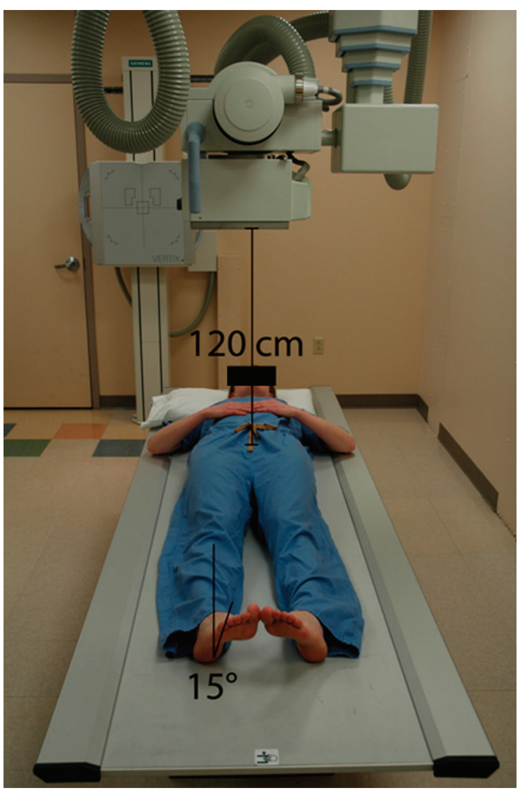

Fig. 2-A

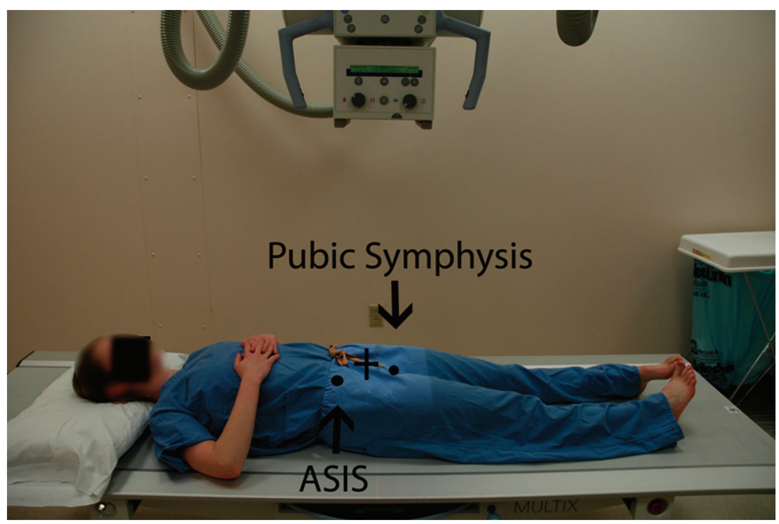

Fig. 2-B

Figs. 2-A and 2-B The positioning for an anteroposterior pelvic radiograph (ASIS = anterior superior iliac spine).

Fig. 3

The positioning for a cross-table lateral radiograph with the limb in 15° of internal rotation. The black arrow points to the center of the femoral head (black dot), the target for the crosshairs of the x-ray beam.

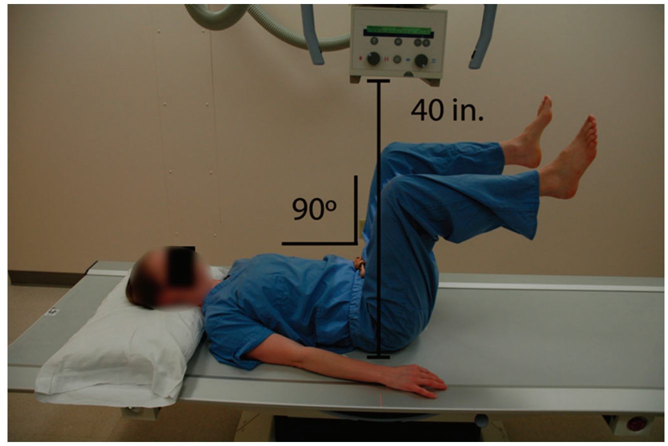

Fig. 4-A

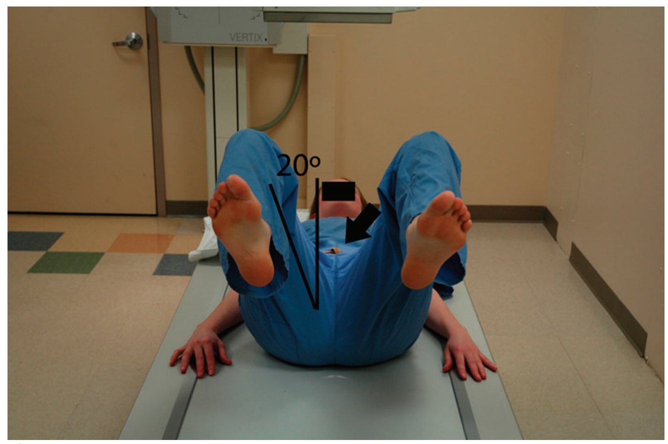

Fig. 4-B

Figs. 4-A and 4-B The positioning for a 90° Dunn view with the hips flexed 90° and abducted 20°. **Fig. 4-B** The black arrow points to the crosshairs, centered at a point midway between the pubic symphysis and the anterior superior iliac spine.

anteroposterior pelvic radiograph. As seen in Figure 8, the coccyx should be directly in line with the pubic symphysis, and the iliac wings, obturator foramina, and radiographic teardrops should be symmetrical in appearance. Additionally, if pelvic inclination is appropriate, the distance between the superior border of the pubic symphysis and the tip of the coccyx should be approximately 1 to 3 cm. Siebenrock et al.[28], who published sex-specific values for pelvic tilt (referencing the distance between the superior aspect of the symphysis and the sacrococcygeal junction), noted that an average distance of 32.3 mm was typical in men, as compared with 47.3 mm in women. However, visualization of the sacrococcygeal junction can often be difficult, making the tip of the coccyx a more reliable landmark.

The various lateral views have specific advantages and disadvantages. For example, the frog-leg lateral view usually profiles the head-neck junction adequately, yet the greater trochanter can obscure the head-neck anatomy. The cross-table lateral radiograph can be variable in terms of achieving sufficient internal rotation of the limb. Additionally, the greater trochanter should not be seen to overhang posteriorly, while visualization of the lesser trochanter indicates sufficient internal rotation. This projection can also be difficult in large patients due to obscuration of the osseous landmarks by soft-tissue radiodensities. These points emphasize the need to attend to the detail of radiographic technique.

Interpretation of Images

Each of the five radiographic views provides important and unique information relevant to establishing a final diagnosis. In general, the anteroposterior pelvic and false-profile views provide the most information about acetabular morphology, whereas the lateral and Dunn views highlight pathoanatomy of the proximal part of the femur. In this section, we review image interpretation for the anteroposterior pelvic, cross-table lateral, 45° or 90° Dunn, frog-leg lateral, and false-

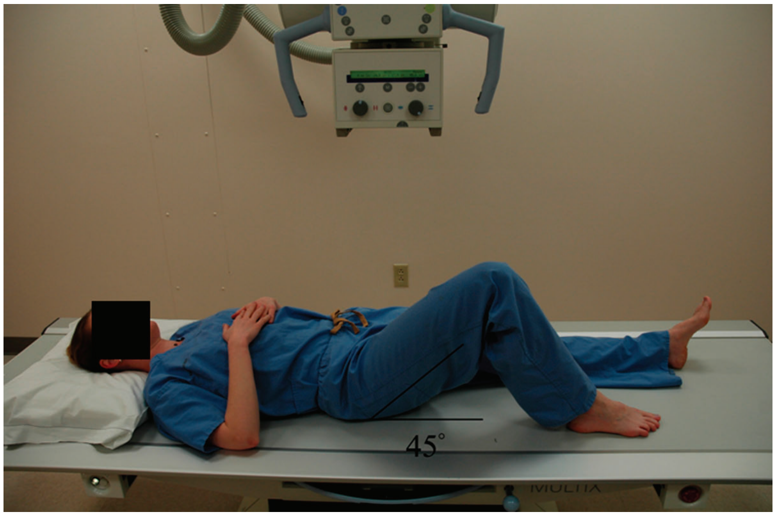

Fig. 5-A

Figs. 5-A and 5-B The positioning for a 45° Dunn view with the hips flexed 45° and abducted 20°. The x-ray beam is centered at a point midway between the pubic symphysis and the anterior superior iliac spine. **Fig. 6** The positioning for a frog-leg lateral view with the hip abducted 45° and the crosshairs centered at a point midway between the anterior superior iliac spine (black dot) and the pubic symphysis (black line). **Fig. 7** The false-profile view of the right hip is obtained with the pelvis rotated 65° in relationship to the bucky wall stand, with the foot on the affected side parallel to the radiographic cassette (shown with two black lines).

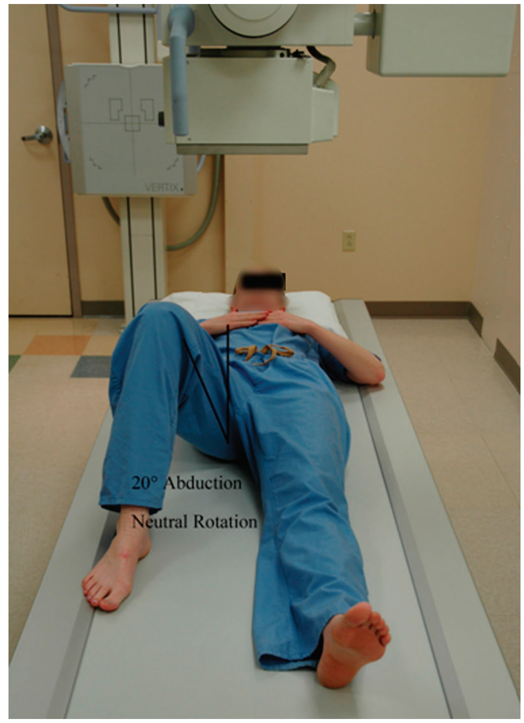

Fig. 5-B

Fig. 6

Fig. 7

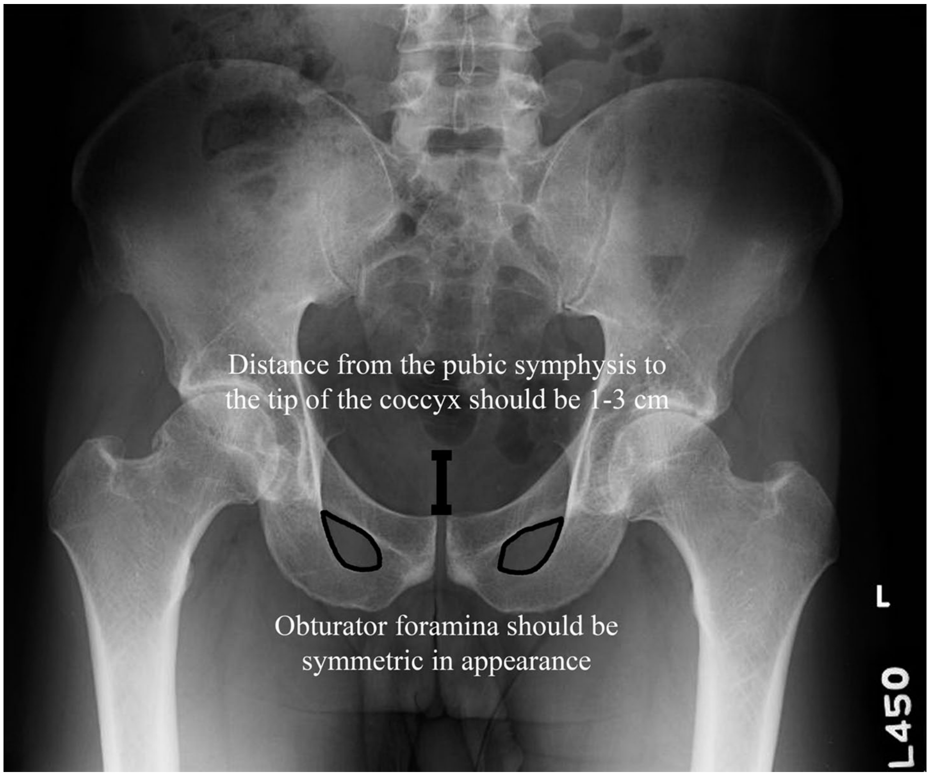

Fig. 8

The technique for assessing the tilt and rotation of an anteroposterior pelvic radiograph is described.

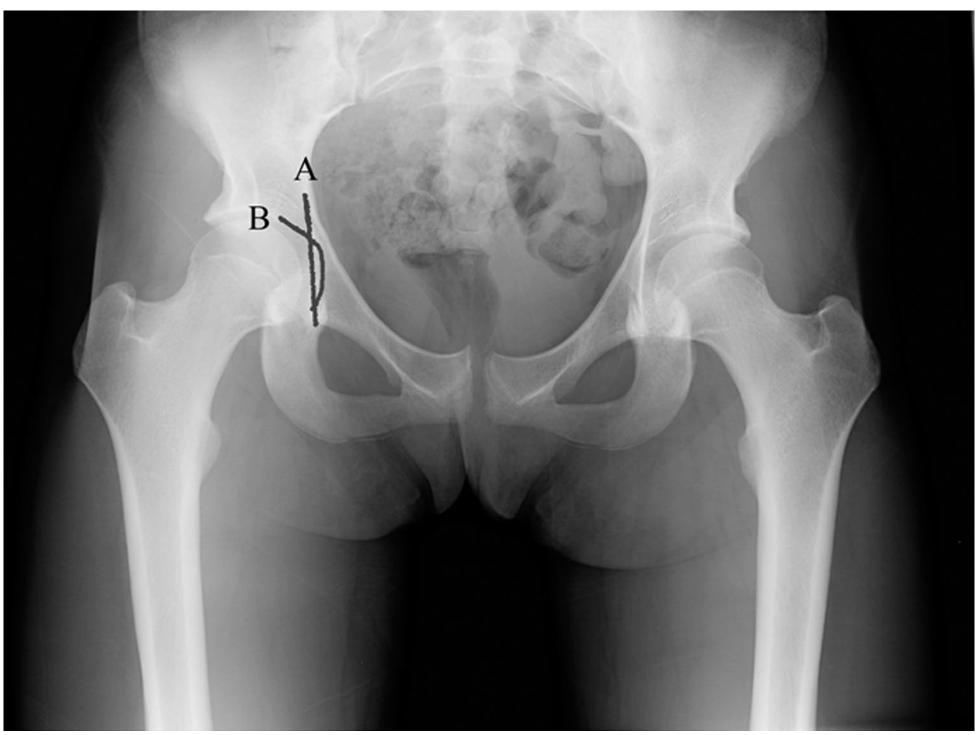

Fig. 9

The radiographic appearance of coxa profunda on an anteroposterior pelvic view. Line A represents the ilioischial line, and line B represents the floor of the acetabular fossa, which is medial to line A. A similar pathologic condition can also be seen on the radiograph of the patient's left hip.

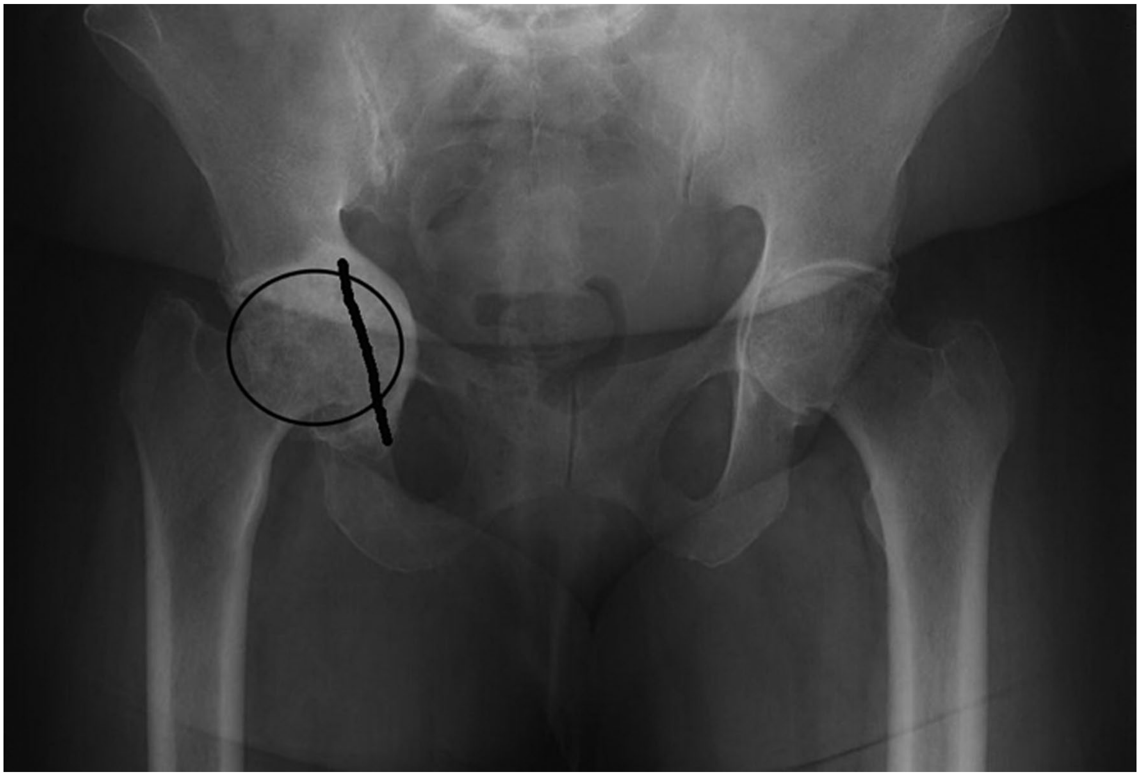

Fig. 10
The radiographic appearance of protrusio acetabuli, with the medial aspect of the femoral head medial to the ilioischial line.

profile radiographs. Specific attention is directed at assessing various radiographic parameters for each view. Depending on the radiographic projection, these may include the following features:

Acetabular Depth

On an anteroposterior pelvic radiograph, the relationship of the floor of the fossa acetabuli and the femoral head should be evaluated relative to the ilioischial line. Hips are classified as *coxa profunda* if the floor of the fossa acetabuli touches or is medial to the ilioischial line (Fig. 9), and as *protrusio acetabuli* if the medial aspect of the femoral head is medial to the ilioischial line (Fig. 10)[6]. All hips that do not meet these criteria can be assigned to a catchall group and classified as "not deep."

Acetabular Inclination

Again, on an anteroposterior pelvic view, acetabular inclination can be classified into three broad groups—normal, increased, or decreased—on the basis of the degree of the Tönnis angle. The measurement of the Tönnis angle can be determined by drawing three lines on the anteroposterior pelvic radiograph: (1) a horizontal line connecting the base of the acetabular teardrops; (2) a horizontal line parallel to line 1, running through the most inferior point of the sclerotic acetabular sourcil (point I); and (3) a line extending from point I to a point L at the lateral margin of the acetabular sourcil (the sclerotic weight-bearing portion of the acetabulum). The Tönnis angle is formed by the intersection of lines 2 and 3 (Fig. 11-A). It should be noted that the original description of this measurement[20] did not include creation of line 1; however, our experience has shown that a representation of the transverse pelvic axis can be created more accurately with use of a line connecting the acetabular teardrops than with a line drawn perpendicular to the vertical axis of the sacrum. Nevertheless, acetabula having a Tönnis angle of 0° to 10° are considered normal, whereas those having an angle of >10° or <0° are considered to have increased and decreased inclination, respectively. Acetabula with increased Tönnis angles are subject to structural instability, whereas those with decreased Tönnis angles are at risk for pincer-type femoroacetabular impingement.

Other quantitative indicators of structural instability include the anterior and lateral center-edge angles, both useful measures of acetabular coverage of the femoral head. The lateral center-edge angle, or center-edge angle of Wiberg, is obtained from an anteroposterior pelvic radiograph and can be used to assess the superolateral coverage of the femoral head by the acetabulum[6]. It is calculated by measuring the angle between two lines: (1) a line through the center of the femoral head, perpendicular to the transverse axis of the pelvis, and (2) a line through the center of the femoral head, passing through the most superolateral point of the sclerotic weight-bearing zone of the acetabulum

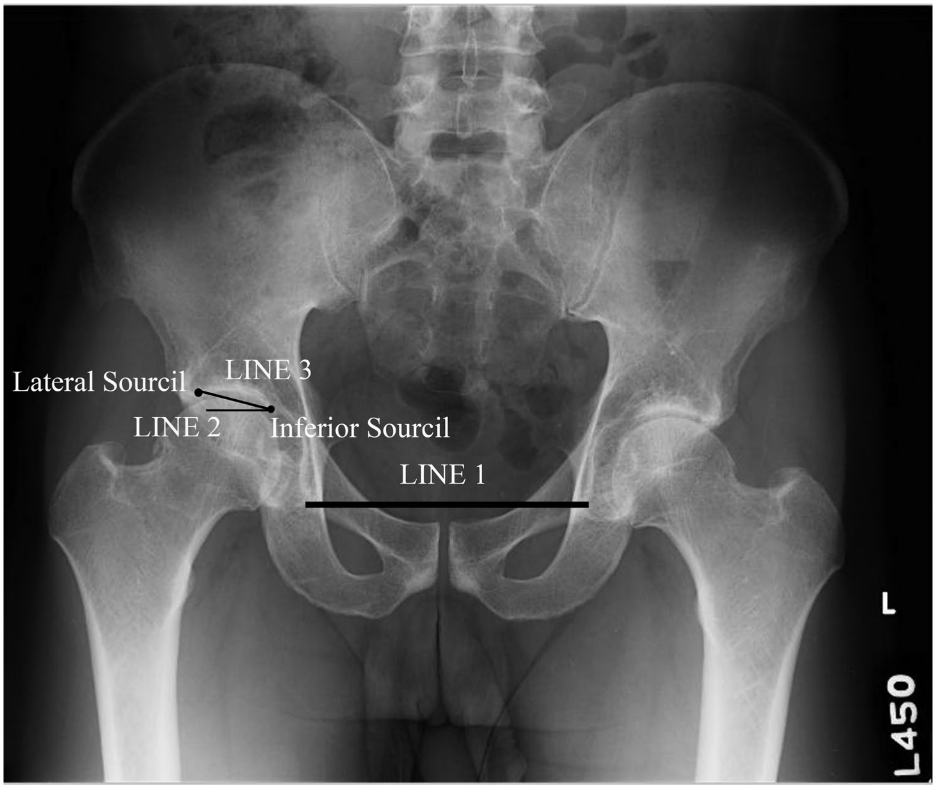

Fig. 11-A

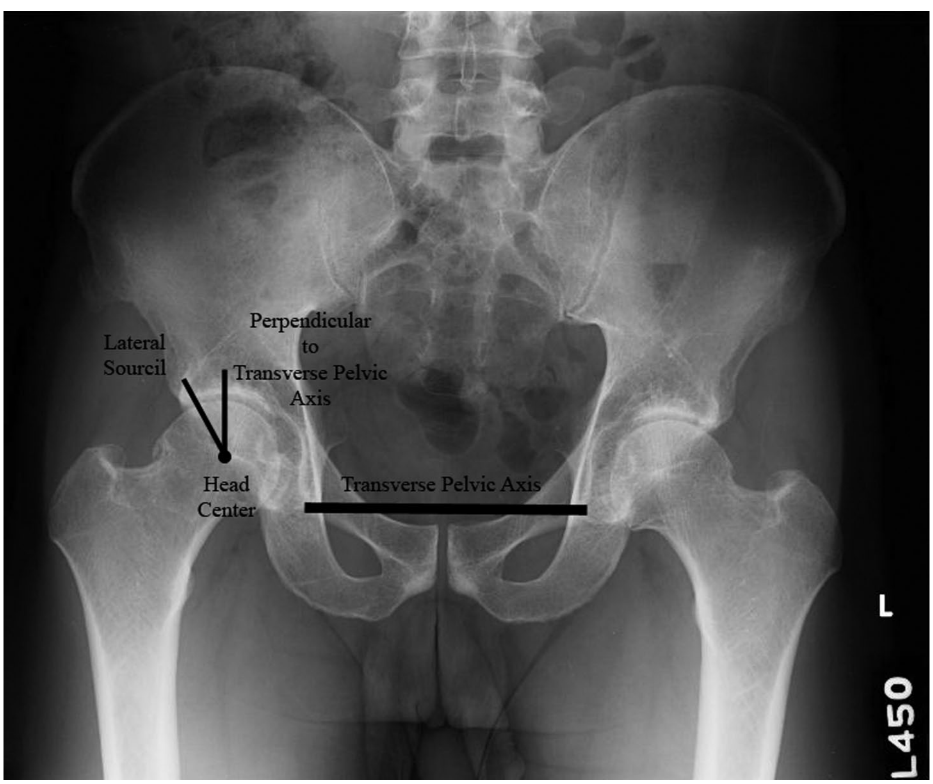

Fig. 11-B

Figs. 11-A and 11-B Technique for calculation of acetabular inclination and the lateral center-edge angle. A line is drawn connecting the inferior aspect of the left and right-sided acetabular teardrops (line 1). A second line, parallel to the first (line 2), is drawn through the inferior aspect of the acetabular sourcil. Lastly, a line connecting the inferior and lateral aspects of the acetabular sourcil is drawn (line 3). The angle created by the intersection of lines 2 and 3 (the Tönnis angle) should be between 0° and 10° (Fig. 11-A). To determine the lateral center-edge angle, a line is drawn through the center of the femoral head, perpendicular to the transverse axis of the pelvis. A second line is drawn through the center of the femoral head, passing through the most superolateral point of the sclerotic weight-bearing zone of the acetabulum. The angle created by the intersection of these two lines is the lateral center-edge angle (Fig. 11-B). Values of <25° may indicate inadequate coverage of the femoral head.

Fig. 12
Technique for calculating the anterior center-edge angle on a false-profile radiograph. A vertical line is drawn through the center of the femoral head. A second line is drawn through the center of the femoral head, passing through the most anterior point of the acetabular sourcil[7]. The angle created by the intersection of these two lines is the anterior center-edge angle. Values of <20° can be indicative of structural instability.

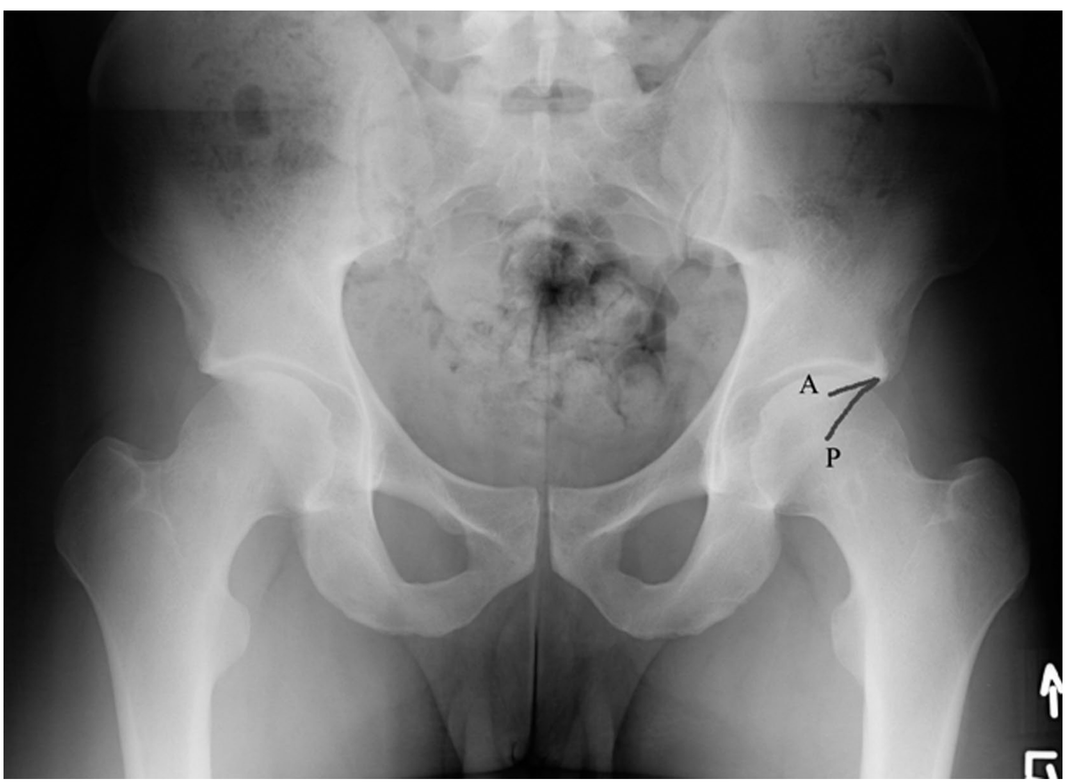

Fig. 13-A

Figs. 13-A and 13-B The radiographic appearance of an anteverted (Fig. 13-A) and retroverted (Fig. 13-B) acetabulum with the presence of a crossover sign in the latter. The contralateral, unmarked hips demonstrate similar anatomy in both images.

Fig. 13-B

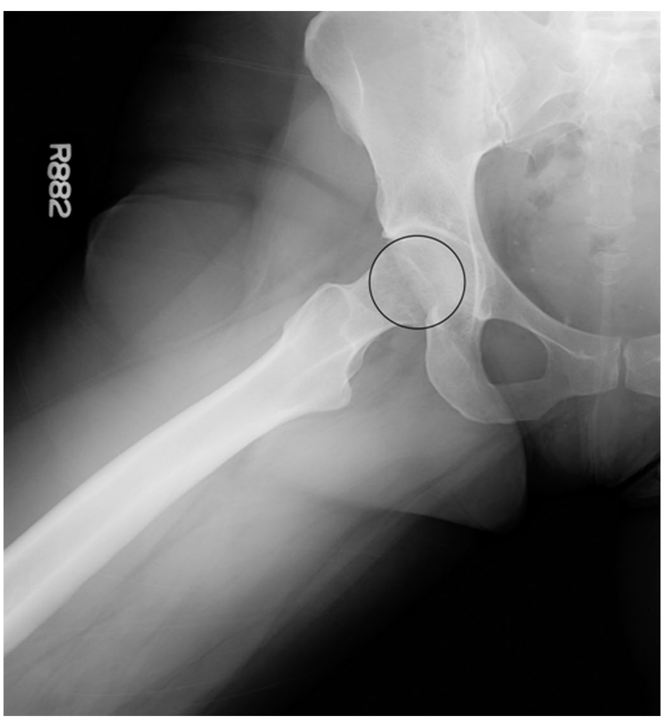

Fig. 14-A

Fig. 14-B

Figs. 14-A and 14-B Radiographs demonstrating a spherical femoral head (Fig. 14-A) and a femoral head with a Perthes-like deformity (Fig. 14-B). A Mose template is useful in making this determination in hips with a subtle deformity.

Fig. 15-A

Fig. 15-B

Figs. 15-A and 15-B An example of a patient with a spherical femoral head noted on an anteroposterior pelvic radiograph (Fig. 15-A) despite a clear head-neck offset deformity on the frog-leg lateral radiograph (Fig. 15-B).

Fig. 16-A

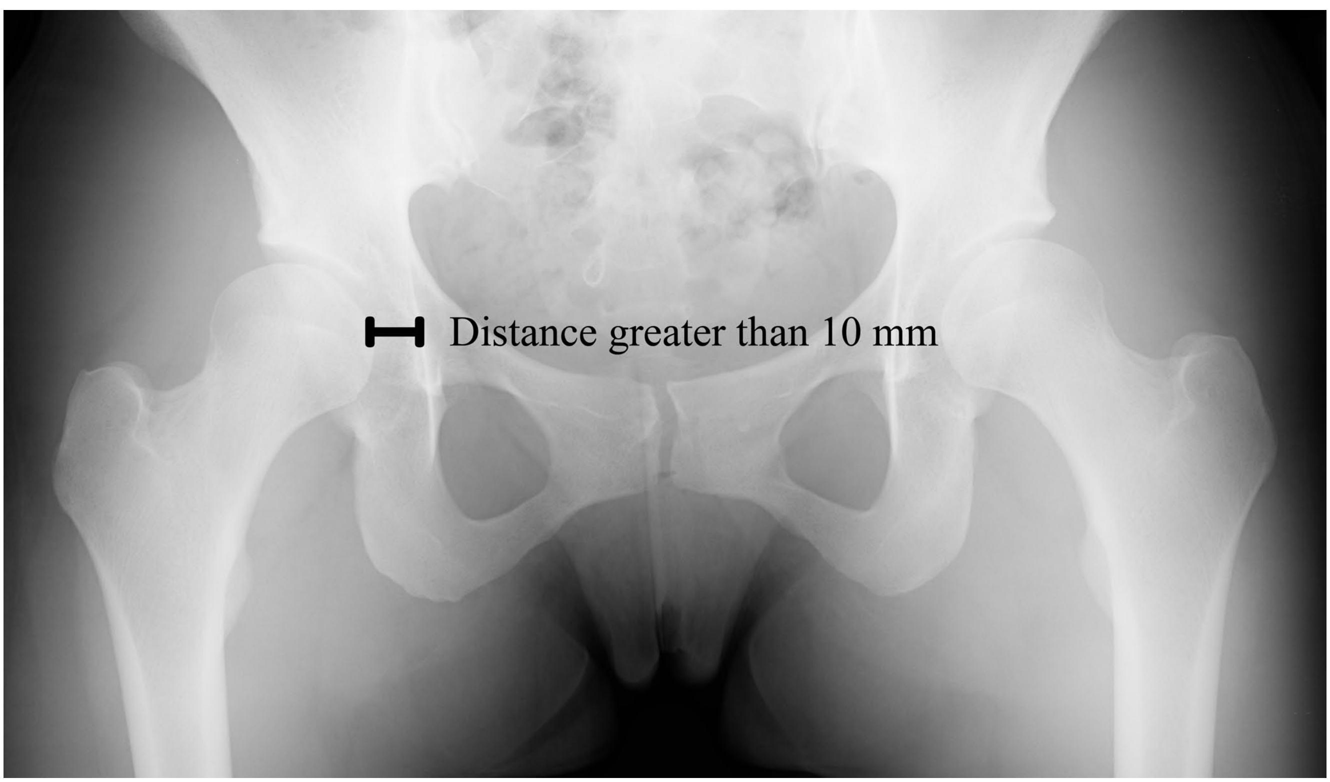

Fig. 16-B

Figs. 16-A and 16-B These radiographs demonstrate the normal position of the femoral head (Fig. 16-A) as compared with a lateralized femoral head in a patient with a dysplastic hip (Fig. 16-B).

Fig. 17-A

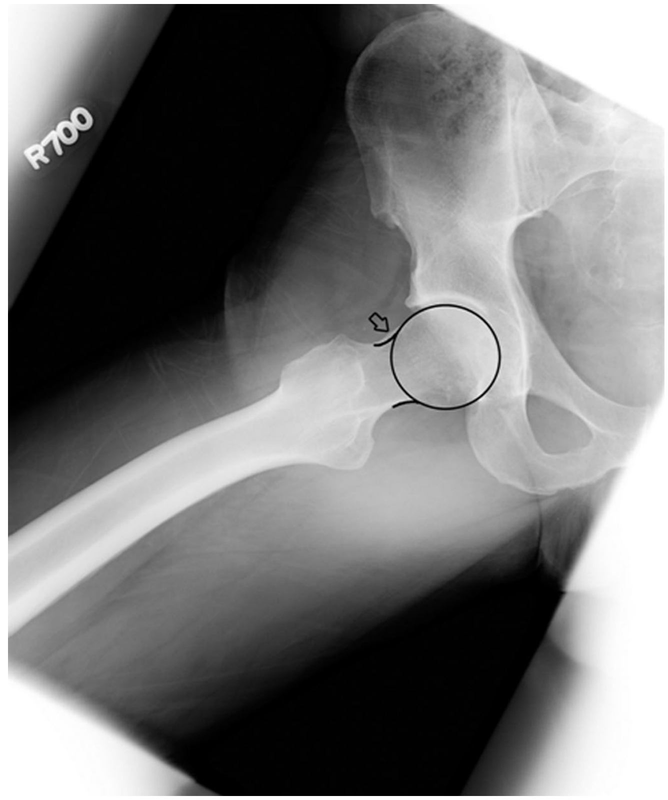

Fig. 17-B

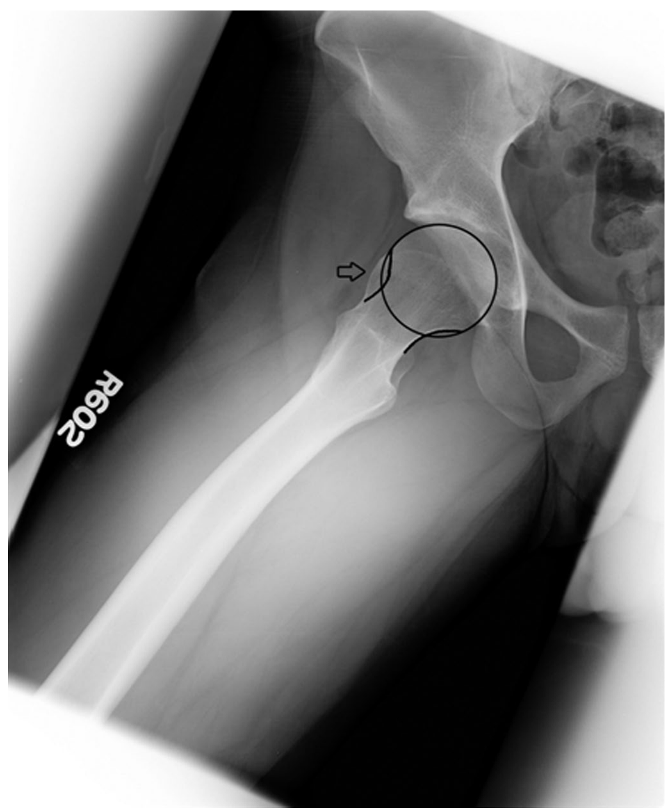

Fig. 17-C

Fig. 17-A, 17-B, and 17-C These radiographs demonstrate a spectrum of abnormalities with regard to femoral head-neck offset including: normal and/or symmetric concavities (Fig. 17-A), moderate reduction in head-neck offset and/or mild cam impingement (Fig. 17-B), and anterolateral head-neck prominence (Fig. 17-C). The arrows highlight regions of reduced head-neck offset.

(Fig. 11-B). Values of <25° may indicate inadequate coverage of the femoral head.

The anterior center-edge angle, or angle of Lequesne, is created on the false-profile view (Fig. 12). Designed to assess anterior coverage of the femoral head, it can be calculated by measuring the angle between a vertical line through the center of the femoral head and a line connecting the center of the femoral head and the most anterior point of the acetabular sourcil[7]. Values of <20° can be indicative of structural instability.

Acetabular Version

With use of an anteroposterior view of the pelvis, all acetabula can be labeled as retroverted or anteverted on the basis of the presence or absence of a *crossover* or *figure-of-eight* sign. An acetabulum is considered to be anteverted if the line of the anterior aspect of the rim does not cross the line of the posterior aspect of the rim before reaching the lateral aspect of the sourcil, and retroverted if the line of the anterior aspect of the rim does cross the line of the posterior aspect of

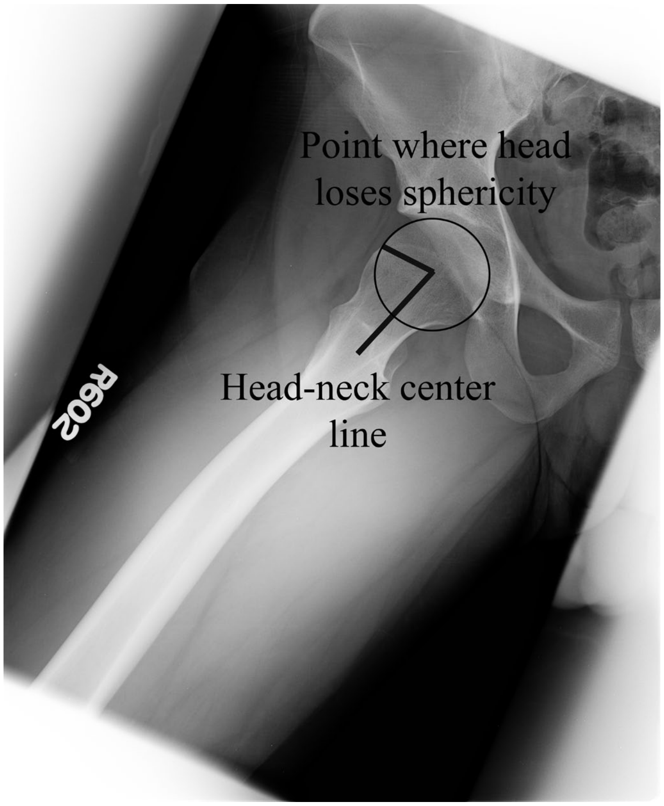

Fig. 18
The technique for calculating the alpha angle on a frog-leg lateral radiograph. A line is drawn connecting the center of the femoral head and the center of the femoral neck. A second line is drawn from the center of the femoral head to the point on the anterolateral head-neck junction where the radius of the femoral head begins to increase beyond the radius found more centrally in the acetabulum where the head is more spherical (i.e., where a prominence starts). The intersection of these two lines forms the alpha angle, and values of >42° are suggestive of a head-neck offset deformity.

the rim before reaching the lateral edge of the sourcil (Figs. 13-A and 13-B). This can be a difficult determination to make, and it requires careful assessment of the film quality, as a large element of error may be introduced by (1) excessive pelvic tilt or rotation[29] or (2) a lack of clarity of the anterior and posterior acetabular margins. Detection of the posterior aspect of the rim inferiorly at the transition to the ischium can facilitate distinction between the anterior and posterior margins. Prominent extension of the ischial spine into the pelvis is an additional finding that is associated with acetabular retroversion[30]. It should be noted that true acetabular retroversion is associated with a deficient posterior wall (the center of the femoral head is lateral to the posterior aspect of the hip), while *anterior overcoverage* refers to the hip with a crossover sign but no posterior wall deficiency.

Head Sphericity

With use of an anteroposterior pelvic, a 45° or 90° Dunn, a frog-leg lateral, and/or a cross-table lateral view, the femoral head can be classified as either spherical or aspherical (Figs. 14-A and 14-B). Although gross visual inspection may be sufficient to make this determination, a Mose template[31,32] (concentric circles) can also be used as a reference. As a rudimentary guideline, if the femoral epiphysis extends beyond the margin of a reference circle by more than 2 mm, the femoral head is considered aspherical. If the epiphysis of the femoral head does not extend beyond the Mose template by more than 2 mm, it can be considered spherical (Fig. 14-A). It is imperative to assess femoral head sphericity on both the anteroposterior and lateral radiographs because patients can have a spherical femoral head on the anteroposterior pelvic view but not on the lateral view (Figs. 15-A and 15-B). It is also important to note that femoral head sphericity is distinct from head-neck offset, which refers to the contour of the head-neck junction rather than the shape of the femoral head.

Position of the Hip Center

With use of an anteroposterior pelvic view, the position of the hip center can be evaluated. It can be classified as *lateralized* or *not lateralized* on the basis of the position of the medial aspect of the femoral head relative to the ilioischial line. The hip center is considered to be lateralized if the medial aspect

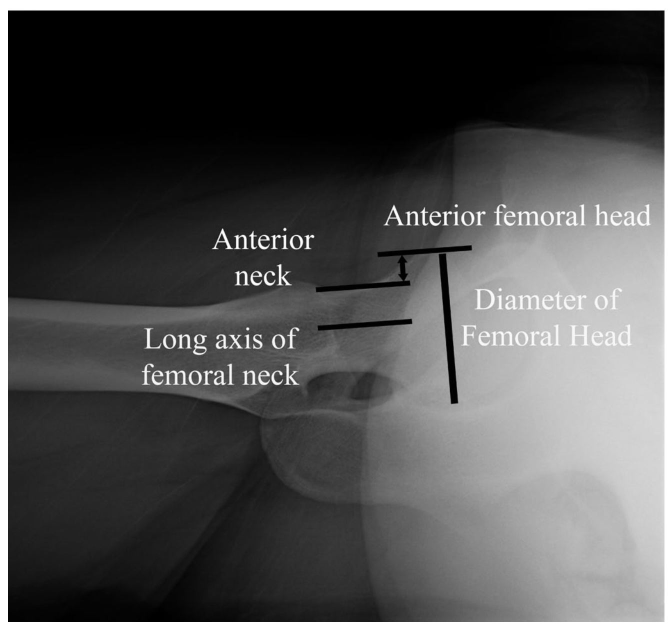

Fig. 19
The technique for calculating the head-neck offset ratio. Three parallel lines are drawn, with line 1 drawn through the center of the long axis of the femoral neck, line 2 drawn through the anteriormost aspect of the femoral neck, and line 3 drawn through the anteriormost aspect of the femoral head. The head-neck offset ratio is calculated by measuring the distance between lines 2 and 3 and dividing by the diameter of the femoral head[3]. If the ratio is <0.17, a cam deformity is likely present.

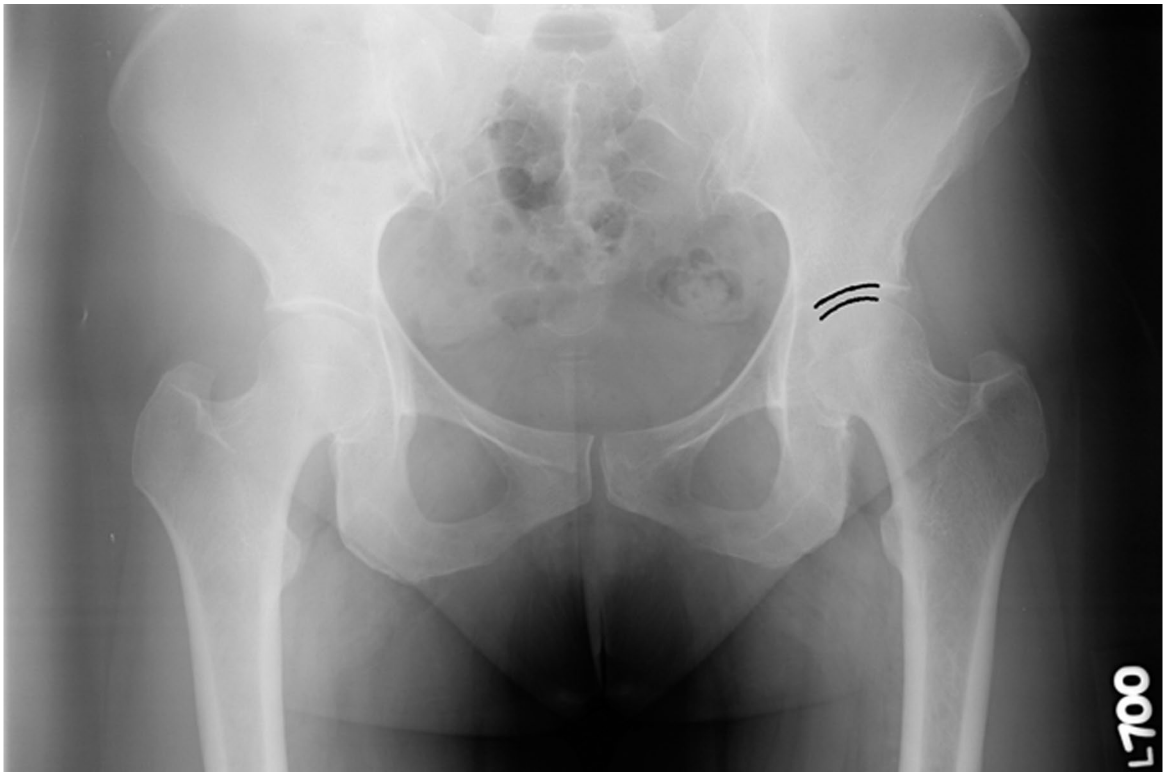

Fig. 20-A

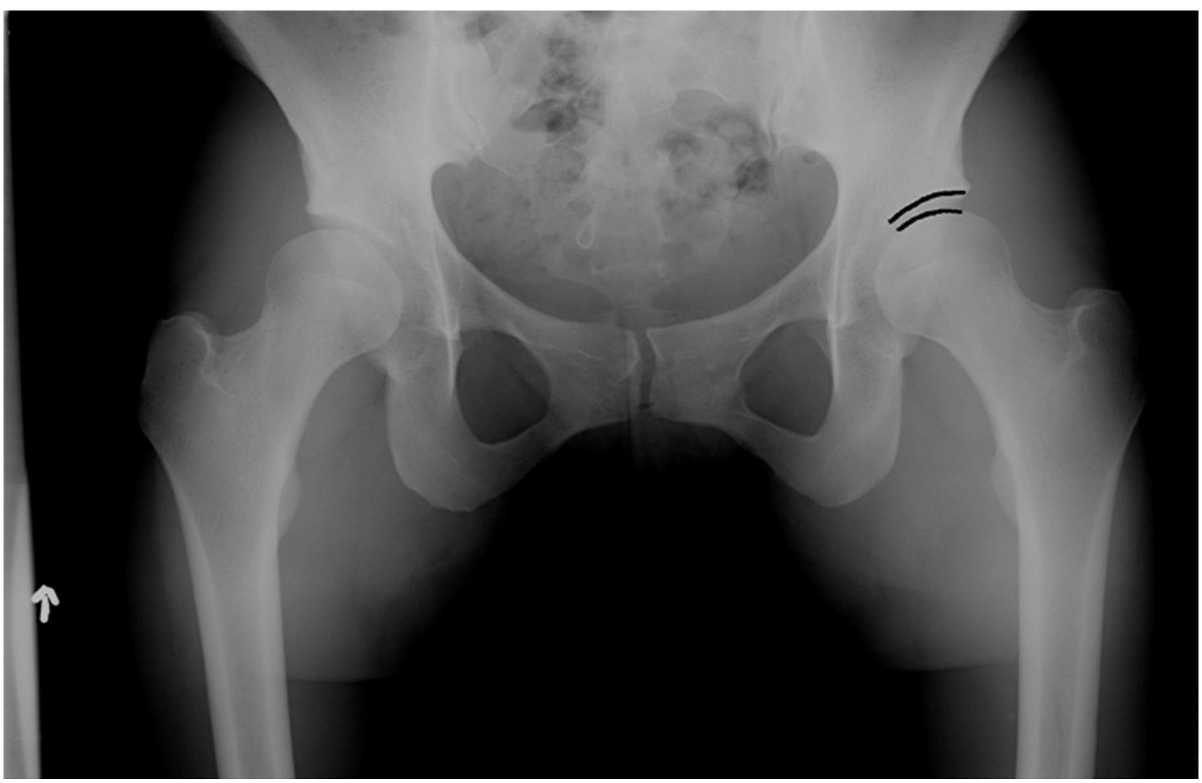

Fig. 20-B

Figs. 20-A and 20-B Radiographs demonstrating a congruent (Fig. 20-A), a mildly incongruent (Fig. 20-B), and an incongruent (Fig. 20-C) joint.

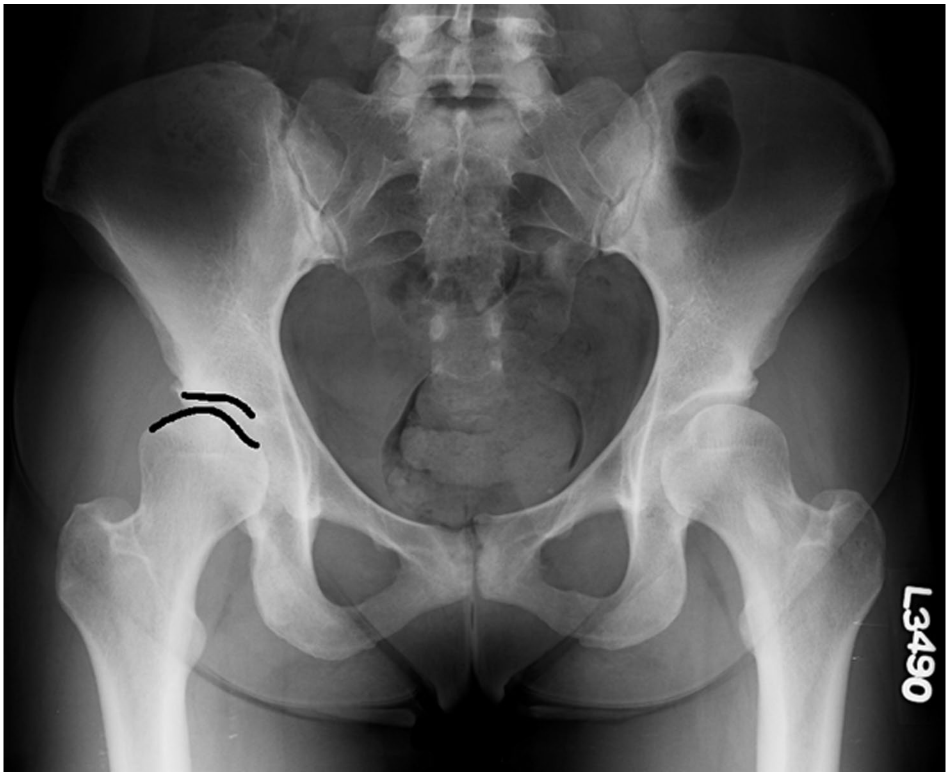

Fig. 20-C

of the femoral head is >10 mm from the ilioischial line, and not lateralized if the medial aspect of the femoral head is 10 mm or less from the ilioischial line (Figs. 16-A and 16-B). The distance of 10 mm should be considered a general reference number as opposed to a strict parameter, as magnification errors and variability in patient size can influence this measurement.

Head-Neck Offset and Head-Neck Junction

With use of an anteroposterior pelvic, a 45° or 90° Dunn, a frog-leg lateral, and/or a cross-table lateral view, the anterior aspect of the femoral head-neck junction can be classified in relation to the posterior aspect of the femoral head-neck junction on the basis of the gross appearance of the radius of curvature at each location. If the anterior and posterior concavities are grossly symmetric, the head-neck junction can be defined as having a symmetric concavity (Fig. 17-A). Conversely, if the concavity at the anterior aspect of the head-neck junction has a radius of curvature that is greater than that at the posterior aspect of the head-neck junction, the hip can be considered to have a moderate decrease in head-neck offset (Fig. 17-B). Lastly, if the anterior aspect of the head-neck junction has a convexity, as opposed to a concavity, the head-neck junction is considered to have a prominence (Fig. 17-C).

Other useful quantitative measures of head-neck junction deformities include the alpha angle and the head-neck offset ratio. Although classically described for use with axial magnetic resonance imaging scans[9], the alpha angle (Fig. 18) can be extrapolated for use with lateral radiographs. It is calculated by measuring the angle between two lines: (1) a line from the center of the femoral head to the point on the anterolateral aspect of the head-neck junction where the radius of the femoral head first becomes greater than the radius of the femoral head found more centrally in the acetabulum (i.e., where a prominence starts), and (2) a line drawn through the center of the femoral neck, connecting to the center of the femoral head. Values of >42° are suggestive of a head-neck offset deformity.

The head-neck offset ratio (Fig. 19) can also be obtained from lateral radiographs. It is determined by three lines: (1) a line through the center of the long axis of the femoral neck, (2) a line parallel to line 1 through the anteriormost aspect of the femoral neck, and (3) a line parallel to line 2 through the anteriormost aspect of the femoral head. The head-neck offset ratio is calculated by measuring the distance between lines 2 and 3, and dividing by the diameter of the femoral head[3]. If the ratio is <0.17, a cam deformity is likely present.

Congruency

By making use of all of the radiographic views (but focusing on the anteroposterior pelvic view), each hip can be classified as congruous or incongruous on the basis of a subjective assessment of the degree of conformity between the femoral head and the acetabulum. Yasunaga et al.[33] introduced a classification system in which congruency was graded into one of

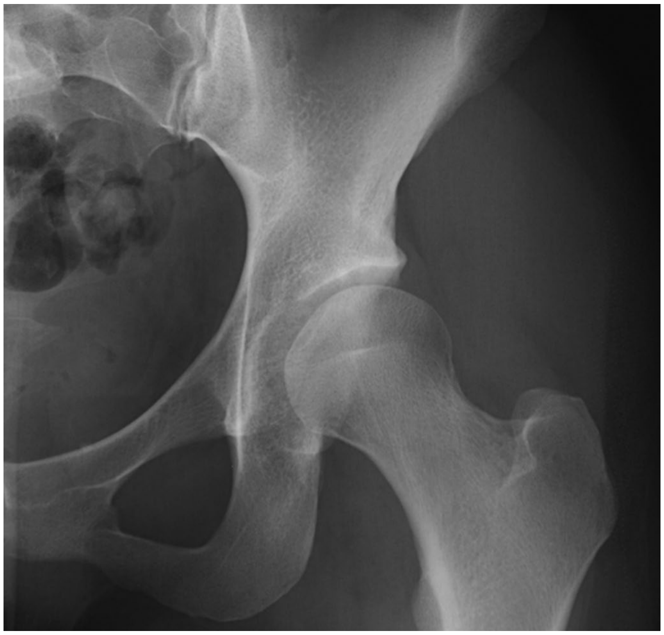

Fig. 21-A

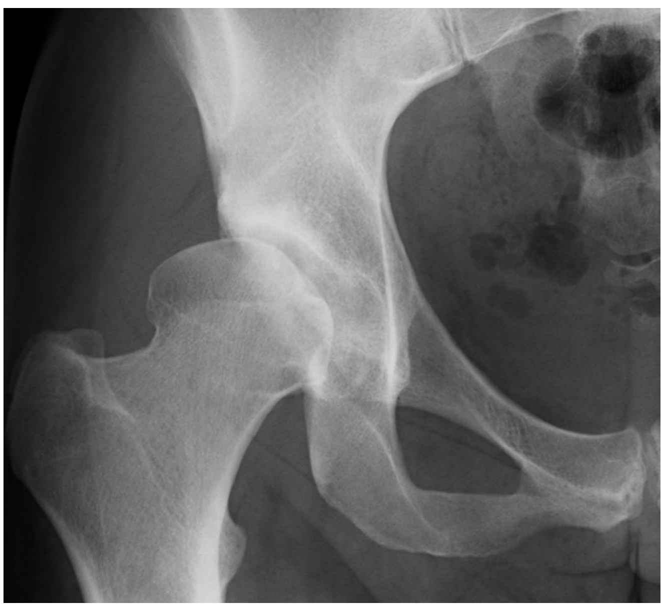

Fig. 21-B

Figs. 21-A through 21-D These radiographs demonstrate the four grades of osteoarthritis, as described in the Tönnis classification system. **Fig. 21-A** Grade 0: no signs of osteoarthritis. **Fig. 21-B** Grade 1: slight joint-space narrowing and mild sclerosis of the acetabulum.

four categories (excellent, good, fair, or poor). While there is certainly a spectrum of deformity in this regard, for general purposes, hips can be considered congruous if the roundness of the head matches the roundness of the acetabulum, and incongruous if the two surfaces do not run in parallel (Figs. 20-A, 20-B, and 20-C). Unlike the other views, the false-profile view can be useful in determining the degree of posterior joint congruity.

Tönnis Grade

By making use of all radiographs available, the degree of osteoarthritis present in each hip can be determined with use of the Tönnis classification system[20] (Figs. 21-A through 21-D). As defined by Tönnis, grades of osteoarthritis range from 0 to 3, with Grade 0 indicating no signs of osteoarthritis; Grade 1, increased sclerosis of the head and acetabulum, slight joint-space narrowing, and slight lipping at the joint margins; Grade 2, small cysts in the head or acetabulum, moderate joint-space narrowing, and moderate loss of sphericity of the head; and Grade 3, large cysts in the head or acetabulum, joint-space obliteration or severe joint-space narrowing, severe deformity of the femoral head, or evidence of necrosis.

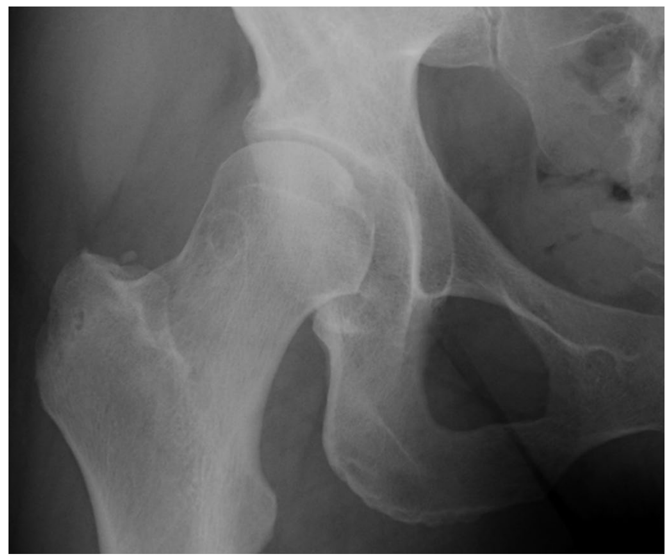

Fig. 21-C

Fig. 21-D

Fig. 21-C Grade 2: moderate joint-space narrowing, small cysts in the acetabulum, and mild loss of head sphericity. **Fig. 21-D** Grade 3: severe joint-space narrowing with large acetabular or femoral head cysts or more advanced asphericity of the femoral head.

While commonly most views will correlate, the final grade is determined on the basis of the single view with the highest overall degree of osteoarthritic change.

Discussion

We have outlined a systematic approach to radiographic evaluation for the adult patient who has clinical signs and symptoms of hip dysfunction. It is our opinion that such a structured review of plain radiographs should help to facilitate a more reliable diagnostic and surgical decision-making process. However, it should be emphasized that an accurate diagnosis can only be obtained by interpreting radiographic findings in conjunction with a detailed history and physical examination. Advanced imaging studies, such as a magnetic resonance arthrogram and/or a computed tomography scan, can also be helpful to confirm a suspected diagnosis, identify mild impingement abnormalities, or act as a supplement in the treatment planning process. Nevertheless, many patients with prearthritic or early arthritic hip dysfunction have developmental dysplasia of the hip and/or femoroacetabular impingement that is readily apparent on properly made radiographs, making it important to be able to adequately and reliably recognize the structural features of these disorders. ■

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