Age-Related Differences in Radiographic Parameters for Femoroacetabular Impingement in Hip Arthroplasty Patients

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Purpose: To compare the prevalence of femoroacetabular impingement (FAI) radiographic findings between patients aged younger than 50 years and those aged 50 years or older who underwent total hip arthroplasty. **Methods:** Total hip arthroplasty patients aged younger than 50 years and those aged 50 years or older were identified retrospectively from a facility medical record database. Fifty patients from each group were randomly selected, and preoperative radiographs were collected. Dysplastic, inflammatory, post-traumatic, and osteonecrosis patients were excluded. Radiographs were evaluated for FAI-specific findings. Intraobserver and interobserver reliability was evaluated with κ statistics for categorical variables and intraclass correlation coefficients for continuous variables. An independent *t* test was used to compare continuous variables, χ^2 analysis was used for discrete variables, and a z ratio was used to analyze proportions. **Results:** The mean age between the subgroups of patients aged younger than 50 years and those aged 50 years or older (43 years and 68 years, respectively) was significantly different ($P < .05$). Findings in the subgroup aged younger than 50 years included significantly more men ($P < .001$), decreased lateral joint space with maintained medial joint space ($P < .05$), significantly greater alpha angle on both the anteroposterior view and the frog-leg lateral view ($P < .05$), significantly higher Tönnis and Sharp angles ($P < .01$), and significantly lower center-edge angle ($P < .001$). **Conclusions:** This retrospective case series shows an increased prevalence of FAI findings (specifically cam pathology) in a patient population aged younger than 50 years undergoing total hip arthroplasty when compared with a cohort aged 50 years or older. **Level of Evidence:** Level III, retrospective comparative study.

There are multiple etiologies leading to end-stage degenerative joint disease of the hip in young patients. Dysplasia, osteonecrosis, Perthes disease, post-traumatic deformity, and inflammatory arthropathies are among the common causes.[1] However, there are a large number of young patients who appear to have a primary arthritic process. Femoroacetabular impingement (FAI) has been proposed as a significant cause of premature hip degeneration in the young patient.[1-5] The impingement may take the form of cam, pincer, or combined/mixed lesions.[4] Cam abnormalities are observed at the femoral head-neck junction, with excessive bone and cartilage anteriorly and laterally that reduces head-neck offset, creating head asphericity. This equates to an osseous bump on radiographs, a pistol-grip deformity, and flattening of the lateral head. Pincer abnormalities are observed at the acetabulum, with relative overcoverage of the femoral head. This equates to a crossover sign, a posterior wall sign, and excessive acetabular overcoverage. The pathomechanics of an aspherical head in a spherical acetabulum or a mechanical block to motion due to overcoverage may lead to abnormal contact, leading to premature degeneration.[4] Advancements in the diagnosis and understanding of FAI have led to the development of new treatment algorithms and modalities. This is clearly seen in the exponential increase of arthroscopic hip procedures that are performed in contemporary orthopaedic surgery.[6] However, the question still remains as to what is the cause, effect, and relation of FAI to early degeneration of the hip. Furthermore, it is unknown whether surgical correction of radiographic FAI abnormalities halts progression to osteoarthritis.

Clohisy et al.[2] recently reported that 35% of patients aged younger than 50 years who underwent a total hip arthroplasty with a diagnosis of osteoarthritis had radiographic evidence of FAI. They also found a 73% rate

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of arthroplasty or advancement in osteoarthritis grade in the contralateral hip with bilateral findings of FAI. These results suggest a distinct relation between impingement and end-stage hip degeneration. However, in a prospective study of asymptomatic volunteers, Laborie et al.[7] found a 35% rate of cam deformities and a 34% rate of pincer lesions in men (the rates were 10% and 17%, respectively, in women). Moreover, Register et al.[8] found a high prevalence of 3.0-T magnetic resonance imaging–diagnosed FAI findings in asymptomatic volunteers, including a 20% prevalence of osseous bumps. Furthermore, male patients were 8.5 times more likely (95% confidence interval, 1.2 to 56 times) to have an osseous bump than female patients. This calls into question the pathologic relation by showing a high rate of impingement findings in patients without hip disease. Ganz and colleagues[4,5,9] have also proposed that structural abnormalities associated with cam and pincer impingement can lead to advanced arthrosis. Nonetheless, a direct relation between FAI and end-stage hip degeneration has not been established and represents the crux of current hip research in the young patient.

The purpose of this study was to compare the prevalence of FAI radiographic findings between patients aged younger than 50 years and those aged 50 years or older who underwent total hip arthroplasty. We hypothesized that FAI would be significantly more common in a patient population aged younger than 50 years who required hip arthroplasty than an older patient subset.

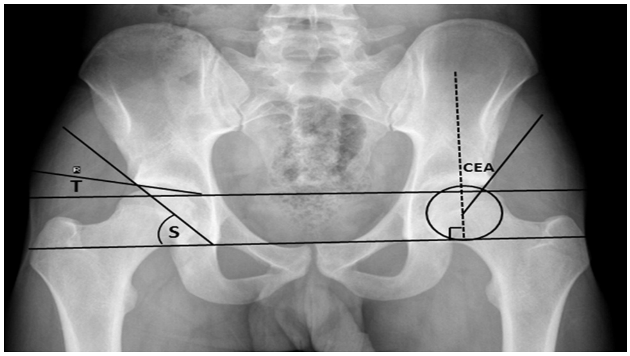

Fig 1. Standing AP pelvis radiograph. The center-edge angle (CEA) is calculated by first drawing a line connecting the inferior tips of the radiographic pelvic teardrops. A vertical line perpendicular to the first line is then drawn through the center of the femoral head (by use of the Mose circle). Next, a line is drawn through the center of the femoral head and the lateral acetabular edge. The CEA is the angle subtended by the vertical line and the latter. The Sharp angle (S) is calculated by first drawing a line connecting the inferior tips of the radiographic pelvic teardrops. Next, a line is drawn connecting the inferior tip of the teardrop to the lateral edge of the acetabulum. The Sharp angle is the angle subtended by these 2 lines. The Tönnis angle (T) is calculated by first drawing a line parallel to the transverse line connecting the radiographic teardrops. Next, a line is drawn connecting the inferior and lateral margins of the sourcil. The Tönnis angle is the angle subtended by these 2 lines.

Methods

Patients who underwent a total hip arthroplasty between January 2007 and June 2009 were retrospectively identified from a facility repository database. Fifty patients each were then randomly selected from 1 of 2 subgroups, and all preoperative radiographs were collected. One subgroup consisted of all patients who were aged younger than 50 years (mean, 43 years; SD, 5.6 years), whereas the other subgroup contained patients who were aged 50 years or older (mean, 68 years; SD, 8.3 years). Both subgroups were chosen with specific inclusion/exclusion criteria. Exclusion criteria included the presence of osteonecrosis, developmental dysplasia of the hip, inflammatory arthritides, and post-traumatic arthritis.

Inclusion criteria included adequate available radiographs with appropriate pelvic tilt and rotation. We assessed rotation by qualitatively assessing the obturator foramen for symmetry, as well as quantitatively by drawing a plumb line from the lumbar spinous processes through the pelvis.[10] A distance between the plumb line and the pubic symphysis of less than 16 mm was considered adequate.[10,11] Pelvic tilt was determined by measuring the distance between the sacrococcygeal joint and the pubic symphysis.[10] An acceptable range for men was between 8 and 50 mm, and for women, it was between 15 and 72 mm.[11]

Two blinded independent observers analyzed the preoperative radiographs. Measurements were made on the anteroposterior (AP) pelvis (Fig 1) and frog-leg lateral (Fig 2) radiographs of the affected hip. The following parameters were determined[12,13]: center of the femoral head, which was identified with the use of Mose circles[14]; alpha angle on the AP and lateral views; neck-shaft angle; Tönnis angle; center-edge angle; Sharp angle[15]; presence of osteophytes; medial/lateral joint space; congruency; presence of herniation pits; lateral head-neck offset ratio; and femoral head extrusion. The center-edge angle was defined as the angle formed by a vertical line and a line through the center of the femoral head and the lateral acetabular edge on an AP pelvis radiograph.[15,16] This equates to the native acetabulum in a radiographically normal hip and an osteophyte in an osteoarthritic hip. The Sharp angle used 2 reference points on an AP pelvis radiograph[15]: one was the lateral edge of the acetabular roof, and the other was the inferior tip of the pelvic teardrop. By use of a line connecting bilateral teardrops and the lateral edge of the acetabular roof, the angle of inclination, or Sharp angle, can be measured (Fig 1). The lateral head-neck offset ratio is defined by the quotient of a series of

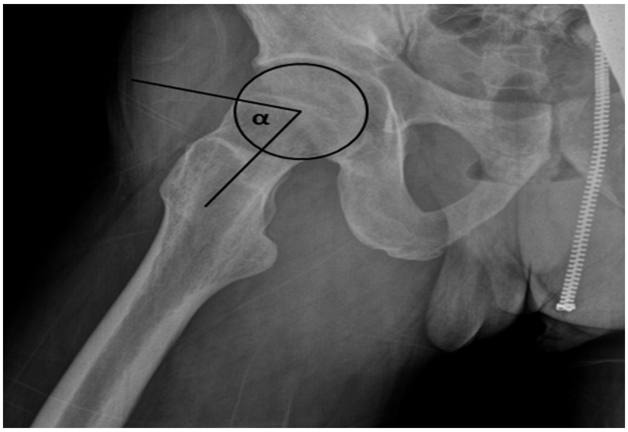

Fig 2. Frog-leg lateral right hip radiograph. The alpha angle is calculated by first drawing a Mose circle best fitting the femoral head. Next, a line is drawn connecting the center of the femoral head and the femoral neck. A line is then drawn from the center of the femoral head to the point at which the femoral head loses its sphericity. The alpha angle is the angle subtended by these 2 lines.

3 lines on the frog-leg lateral radiograph. First, a line is drawn down the center of the femoral neck. Next, a line (line 2) is drawn along the anterior margin of the femoral neck. Then, a line (line 3) is drawn along the anterior margin of the femoral head. The offset ratio is calculated by dividing the distance between lines 2 and 3 by the head diameter. A ratio of less than 0.17 is indicative of cam deformity.[2] Femoral head extrusion may be measured based on the distance from the medial aspect of the femoral head to the ilioischial line.[10] If the latter distance is greater than 10 mm, then the femoral head is considered lateralized or extruded. The radiographs were also assessed for the presence of localized overcoverage, shown radiologically by the crossover and posterior wall signs, or generalized overcoverage of the femoral head, shown in the femoral head extrusion ratio.

Intraobserver and interobserver reliability was evaluated with κ statistics for categorical variables and intraclass correlation coefficients for continuous variables. A power analysis was performed with respect to the alpha angle (on AP and lateral views), showing that a minimum sample size of 37 patients per group was required for 80% power (effect size, 0.67; $P = .05$). Statistical analysis was completed by use of SPSS software (SPSS, Chicago, IL). For categorical variables such as the presence of the crossover and posterior wall signs, the intraobserver and interobserver agreement κ statistic was 0.80 or greater.[7] For continuous variables, the intraobserver and interobserver intraclass correlation coefficients were 0.90 or greater.[7] An independent *t* test was used to compare continuous variables, χ^2 analysis was used for discrete variables, and a z ratio was used to analyze proportions.

Results

Detailed radiographic analysis of the osteoarthritic hips showed structural abnormalities associated with FAI in the patient population aged younger than 50 years as described in Table 1. In the patient group aged younger than 50 years, the mean age was 43 ± 5.66 years, with men comprising 78% and women comprising 22%. This significantly contrasted with the group aged 50 years or older (mean age, 68 ± 8.34 years [$P < .05$]; 36% men and 64% women [$P = .0002$]).

There was no significant difference in lateral joint space, but the group aged younger than 50 years had a significantly larger medial joint space (1.9 ± 2.5 mm *v* 3.28 ± 1.8 mm, $P = .0022$). There was also a significant difference in the Tönnis and Sharp angles, with the group aged younger than 50 years having significantly increased values ($P < .001$ and $P = .0084$, respectively). These findings also correspond with a substantial decrease in the center-edge angle for arthroplasty patients aged younger than 50 years (45.78° ± 12.00° *v* 34.81° ± 7.69°, $P < .001$). The femoral head extrusion index was also increased in these young patients (0.11 ± 0.11 *v* 0.18 ± 0.10, $P < .001$). As predicted, there was a significantly higher alpha angle on both the AP and lateral radiographic views in the patients aged younger than 50 years (46.2° ± 8.90° *v* 62.3° ± 8.95° and 47.8° ± 12.78° *v* 59.8° ± 13.88°, respectively; $P < .001$ for both). Interestingly, there was no difference in the head-neck offset on the AP view, but there was a significant decrease in offset on the frog-leg lateral view in the patients aged younger than 50 years (17.2 ± 4.08 mm *v* 13.1 ± 3.62 mm, $P < .001$).

There were no significant differences in the presence of osteophytes, ischial spine sign on the AP radiograph, position of the ilioischial line, or crossover sign. In the group aged 50 years or older, 18% of patients had a positive crossover sign and 24% of the group aged younger than 50 years had the same findings. There were also no significant differences in femoral head congruency, the varus/valgus position, the neck shaft angle, or the presence of herniation pits.

Discussion

The natural history of FAI and associated pathology is poorly understood. A variety of theories have been proposed but with limited scientific evidence. However, the concept that FAI can lead to premature degeneration of the hip has been supported by many authors.[2-5,17,18] In fact, this is not a new concept. In 1965 Murray[19] described a "tilt deformity" of the femoral head with the formation of excess bone and buttressing of the femoral neck. He linked this phenomenon to premature osteoarthritis in the lateral third of the joint. Early descriptions of the "pistol-grip"

Table 1. Detailed Radiographic Analysis of Osteoarthritic Hips

Measurement	Patients Aged <50 yr (n = 50)	Patients Aged ≥50 yr (n = 50)	Significance (*P* Value)
Age (yr)	43.0 ± 5.66	67.8 ± 8.34	$P < .05$
Gender	78% male and 22% female	36% male and 64% female	$P < .0002$ (z ratio)
Lateral joint space (mm)	1.4 ± 1.53	1.2 ± 1.59	$P = .50$
Medial joint space (mm)	3.28 ± 1.84	1.9 ± 2.49	$P = .0022$
Osteophytes	2.1 ± 0.61	2.3 ± 0.58	$P = .095$ (χ^2)
Presence of crossover sign	24%	18%	$P = .46$ (z ratio)
Presence of ischial spine on AP radiograph	20%	20%	$P > .99$
Relation of ilioischial line to fossa	74% medial, 20% touching, and 6% lateral	54% medial, 28% touching, and 18% lateral	$P = .073$ (χ^2)
Tönnis angle	7.9 ± 3.45	4.95 ± 4.78	$P < .001$
Sharp angle	37.2 ± 4.11	33.81 ± 5.23	$P = .0084$
Center-edge angle	34.81 ± 7.69	45.78 ± 12.00	$P < .001$
Congruency	34% (non)	36% (non)	$P = .834$ (z ratio)
Femoral head extrusion (%)	0.18 ± 0.10	0.11 ± 0.11	$P < .001$
AP head-neck offset (mm)	47.7 ± 5.66	46.9 ± 6.65	$P = .10$
COR-troch (varus, valgus)	52% valgus	36% valgus	$P = .107$ (z ratio)
Alpha angle	62.3 ± 8.95	46.2 ± 8.90	$P < .001$
Neck-shaft angle	134.3 ± 4.22	130.3 ± 5.97	$P = .517$
Presence of herniation pits	10%	20%	$P = .162$ (z ratio)
Frog-leg lateral			
Lateral alpha angle	59.8 ± 13.88	47.8 ± 12.78	$P < .001$
Lateral head-neck offset (mm)	13.1 ± 3.62	17.2 ± 4.08	$P < .001$

NOTE. All measurements are from AP pelvis radiograph, except for lateral alpha angle, and lateral head-neck offset.
COR, center of rotation; non, incongruent; troch, tip of greater trochanter.

deformity in the hip also contributed to our initial understanding of how hip morphology contributes to early degeneration. Ganz et al.[4,5] were then some of the first researchers to revisit this concept and have eloquently summarized the relation of impingement to early hip degeneration in multiple publications. The theory that FAI can lead to early arthritis of the hip has been proposed by multiple authors but not directly established in the contemporary literature. Furthermore, it remains to be seen if this early degeneration leads to end-stage destruction that requires arthroplasty. Our study indirectly supports the relation between FAI and total hip replacement through the evaluation of radiographic abnormalities found in an arthroplasty population aged younger than 50 years compared with patients aged 50 years or older.

Clohisy et al.[2] recently reported on the results of radiographic evaluation of 710 patients who received a hip arthroplasty before the age of 50 years. Overall, 17% of the patients were diagnosed with osteoarthritis of "unknown etiology" and received a comprehensive radiographic evaluation. Of these, 98% were diagnosed with cam, pincer, or combined pathologies. These patients were also more likely to be men. In comparison with an asymptomatic patient population, Clohisy et al. found that there was a significant decrease in the head-neck offset ratio and femoral head sphericity in the affected hips. In relation to the findings of our investigation, a significantly lower lateral head-neck offset ratio was observed in those aged younger than 50 years versus those aged 50 years or older ($P < .001$). This essentially quantifies the size of the osteocartilaginous bump relative to the size of the spherical head, with a smaller ratio indicating a larger relative cam lesion.[10] Furthermore, female patients had an increased acetabular inclination, and patients with pincer lesions had an increased lateral center-edge angle. Interestingly, a subgroup of 70 patients with contralateral imaging showed that all of them also had bilateral structural abnormalities. Thirty-seven percent of these patients underwent contralateral total hip arthroplasty at a mean of 5.4 years, and 36% of them had an increase in Tönnis grade at a mean of 8.4 years. This large study provides insight into the concomitant pathologies of patients who require total hip arthroplasty at an early age.

The relation between radiographic findings and articular damage is also supported by Nepple et al.[20] They studied 355 arthroscopic hip procedures, with 67% of the patients having some degree of acetabular chondromalacia. More specifically, male gender, age, and an alpha angle greater than 50° on the frog-leg lateral view were independent risk factors for more advanced articular damage, with an odds ratio greater than 3.0. Pincer-type impingement was not associated with an increased rate of degeneration. Johnston et al.[21] also described a correlation between radiographic findings and arthroscopic acetabular degeneration. In their study a higher offset alpha angle was associated with acetabular rim chondral defects and full-thickness delamination of the acetabulum.

To further define the degeneration associated with FAI, Beck et al.[17] reviewed the results of 244 hips that were treated with an open dislocation and identified 26 hips that had isolated cam impingement and 16 with only a pincer lesion. They found that the hips with cam impingement had focal damage to the articular cartilage in the anterosuperior region of the acetabulum with separation of the cartilage and the labrum whereas the hips with pincer lesions had a circumferential thin zone of injury to the articular surface. The consistent anterior abutment in pincer lesions may lead to slight posteroinferior femoral head subluxation with subsequent posteroinferior chondral damage, the contra-coup lesion.[17] Anderson et al.[18] also found a close association with cam-type impingement and acetabular delamination. In a retrospective review of 64 surgical dislocations for impingement, they found acetabular cartilage delamination in 44% of patients. Interestingly, male gender and cam lesions were strongly associated with the delamination but acetabular overcoverage was not.

The results of the previous studies must also be regarded in the context of an intriguing study completed by Laborie et al.[7] In a prospective population-based radiographic analysis of asymptomatic hips, they found a 35% rate of radiographic cam impingement in men, with an accompanying 34% rate of pincer lesions. However, women had a 10% rate of cam lesions and a 17% rate of pincer findings. Thus the question remains as to whether symptoms will develop in the 35% of asymptomatic patients with radiographic evidence of impingement in the study by Laborie et al. Beyond this, a separate question exists: Are the impingement signs in 33% of arthroplasty patients in the study by Clohisy et al.[2] merely incidental findings, or do the radiographic findings equate to symptoms?

Our study provides some insight into the complex interactions between FAI and early end-stage osteoarthritic changes. Similar to other studies, there was a much higher percentage of male patients in the arthroplasty group aged younger than 50 years. These young patients also showed decreased lateral joint space with relatively maintained medial joint space. This assessment would support the theory that impingement progresses from a lateral to medial direction because of the forces applied on the acetabular cartilage from the impingement lesion. Furthermore, the patients aged younger than 50 years also had a significantly increased alpha angle on both the AP view and the frog-leg lateral view. However, there was also a significant increase in the Tönnis and Sharp angles, with a significant decrease in the center-edge angle. These findings support the conclusions of Beck et al.[17] and Anderson et al.[18] that cam lesions are more detrimental to the acetabular articular cartilage than pincer deformities. In our study, impingement lesions were analyzed based on a continuous distribution as opposed to the presence or absence of a deformity. We believe that there may be a spectrum of deformities and the reporting of "present" or "absent" may overlook the influence of magnitude on the degeneration of the hip.

Hip joint impingement is commonly believed to lead to end-stage degeneration through a mechanism of mechanical wear and abutment due to morphologic problems with the hip joint.[5] However, these theories have not been robustly defended in the contemporary orthopaedic literature. This study adds to our understanding of this problem with the comparison of arthroplasty patients in treatment-matched cohorts aged younger than 50 years and aged 50 years or older. The young patients did have more significant cam findings, decreased acetabular coverage, and a maintenance of medial joint space. These findings would seem to support a degenerative mechanism that is more reliant on the deformity of the proximal femur and does progress from lateral (or anterosuperior) to medial on AP imaging.

Limitations

There are limitations to our study. One-hundred patients were randomly selected from a larger patient pool for radiographic analysis. There is a possibility of a large degree of variability in many of the measurements taken. However, the interobserver reliability was acceptable, and the statistical testing would have taken into account any variability of results. In addition, more in-depth quantitative evaluation of acetabular version would have been valuable, because version plays a role in joint wear. The crossover and posterior wall signs have been shown to be qualitative dichotomous guides to acetabular retroversion.[3,22] In addition, the ischial spine sign has also been shown to be an indicator of acetabular version.[23] The latter 3 signs are qualitative, dichotomous variables, either present or absent on a radiograph. Our investigation only analyzed the crossover sign. Lastly, this is a retrospective review, and a direct causal relation cannot be established based on radiographic findings.

Conclusions

This retrospective case series shows an increased prevalence of FAI findings (specifically cam pathology) in a patient population aged younger than 50 years undergoing total hip arthroplasty when compared with a cohort aged 50 years or older.

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