Radiology

Cam and Pincer Femoroacetabular Impingement: Characteristic MR Arthrographic Findings in 50 Patients[1]

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Purpose: To retrospectively characterize magnetic resonance (MR) arthrographic findings in patients with cam femoroacetabular impingement (FAI) and in those with pincer FAI.

Materials and Methods: Institutional review board approval and informed consent were not required. MR arthrographic studies obtained in 50 consecutive patients (30 men, 20 women; mean age, 28.8 years) with FAI were analyzed for labral abnormalities, cartilage lesions, and osseous abnormalities of the acetabular rim. The nonspherical shape of the femoral head at the head-neck junction was measured in eight positions around the femoral head and neck and used to calculate the α angle. Acetabular depth was measured. Surgical diagnosis served as the reference standard. The Wilcoxon rank sum test was used for statistical analysis.

Results: At surgery, hips in 33 patients were classified as having cam FAI and hips in 17 patients were classified as having pincer FAI. In both groups, the mean age of patients was 28.8 years. There were significantly more men (n = 27) with cam FAI and more women (n = 14) with pincer FAI. The α angle was significantly larger in patients with cam FAI at the anterior and anterosuperior positions. The acetabulum was significantly deeper in patients with pincer FAI than in patients with cam FAI. Cartilage lesions at the anterosuperior and superior positions were significantly larger in patients with cam FAI than in patients with pincer FAI. Cartilage lesions at the posteroinferior position were significantly larger and labral lesions at the posterior and posteroinferior positions were more pronounced in patients with pincer FAI than in patients with cam FAI. Osseous abnormalities were not significantly different between the groups. Osseous bump formation at the femoral neck was significantly more common in patients with cam FAI than in patients with pincer FAI.

Conclusion: Characteristic MR arthrographic findings of cam FAI include large α angles and cartilage lesions at the anterosuperior position and osseous bump formation at the femoral neck; characteristic findings of pincer FAI include a deep acetabulum and posteroinferior cartilage lesions.

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Femoroacetabular impingement (FAI) occurs when there is a conflict between the proximal femur and the acetabular rim (1). FAI is a cause of premature osteoarthritis in the hip (2). Cam FAI and pincer FAI can be differentiated on the basis of a predominance of either a femoral or an acetabular abnormality (1,3,4). In cases of cam FAI, the nonspherical shape of the femoral head at the femoral head-neck junction and reduced depth of the femoral waist leads to abutment of the femoral head-neck junction against the acetabular rim (5). In cases of pincer FAI, acetabular overcoverage limits the range of motion and leads to a conflict between the acetabulum and the femur (1). It is important to identify the type of FAI because surgical treatment differs for each type. In cases of cam FAI, the surgical approach is to reshape the femoral waist and restore the spherical shape of the femoral head. In cases of pincer FAI, the surgical approach is to reduce acetabular overcoverage by trimming the acetabular rim. Magnetic resonance (MR) imaging is used to assess the degree of damage within the joint (6). It is important to differentiate cam FAI from pincer FAI and to know the distinct pattern of joint damage before intracapsular hip surgery. Thus, the purpose of our study was to retrospectively characterize MR arthrographic findings in patients with cam FAI and in those with pincer FAI.

Advances in Knowledge

- Characteristic acetabular cartilage lesions are located at the anterosuperior postion in patients with cam impingement, whereas characteristic cartilage lesions are located at the posteroinferior position in patients with pincer impingement.
- The α angles are significantly different at the anterior and anterosuperior positions between patient groups, whereas differences are not significant at any other position around the femoral neck.
- The acetabulum is significantly deeper in patients with pincer impingement than in patients with cam impingement.

Materials and Methods

Patients

Fifty consecutive patients (30 men, 20 women; mean age, 28.8 years; age range, 19–48 years) who met our inclusion criteria were included after a review of the radiology information system and the electronic patient record. Patients were included if *(a)* MR arthrography was performed in accordance with the standard protocol at our institution, *(b)* they had not undergone previous surgery, *(c)* surgical hip dislocation for treatment of FAI was performed within 3 months after MR imaging, and *(d)* classification of the type of FAI (cam or pincer) was included in the surgical report. Surgical diagnosis served as the reference standard.

Our institutional review board does not require its approval or informed consent for the retrospective review of patients' records or images. Patients' rights are protected by a law that requires that they be informed that their charts and images might be reviewed for scientific purposes and grants them the opportunity to forbid such use of their data. All patients included in our study agreed to the use of their data.

MR Arthrography

A musculoskeletal radiologist (C.W.A.P., B.M., M.Z., J.H., with 7, 3, 12, and 21 years of experience in musculoskeletal radiology, respectively) injected intraarticular contrast material in a standardized fashion. One milliliter of a local anesthetic (mepivacaine hydrochloride 2%, Scandicain; AstraZeneca, London, England), 1 mL of an iodinated contrast agent (iopamidol 200 mg/mL, Iopamiro 200; Bracco, Milan, Italy), and 6–14 mL (mean, 8 mL) of a diluted MR contrast agent (gadopentetate dimeglumine, Magnevist; Schering, Berlin, Germany) at a concentration of 4 mmol/L were injected with fluoroscopic guidance.

MR imaging was performed with a 1.5-T system (Symphony; Siemens Medical Solutions, Erlangen, Germany). A flexible wraparound receive-only surface coil was used. A coronal T1-weighted spin-echo sequence (section thickness, 3 mm; intersection gap, 0.6 mm; repetition time msec/echo time msec, 524/14; field of view, 16 cm; matrix, 512 × 512; one signal acquired), a coronal intermediate-weighted fast spin-echo sequence with fat saturation (section thickness, 3 mm; intersection gap, 0.6 mm; 2500/42; flip angle, 180°; field of view, 16 cm; matrix, 512 × 512; turbo factor, seven; one signal acquired), a sagittal water excitation three-dimensional double-echo steady-state sequence (section thickness, 1.7 mm; no intersection gap; 24.0/6.5; flip angle, 25°; field of view, 15 cm; matrix, 512 × 512; one signal acquired), a sagittal T1-weighted spin-echo sequence (section thickness, 4 mm; intersection gap, 0.8 mm; 350/14; field of view, 16 cm; matrix, 512 × 512; two signals acquired), and a transverse oblique (parallel to the long axis of the femoral neck) water excitation three-dimensional double-echo steady-state sequence (section thickness, 1.25 mm; no intersection gap; 24.0/11.8; flip angle, 25°; field of view, 17 cm; matrix, 512 × 512; two signals acquired) were performed. The transverse oblique three-dimensional data set was used to reconstruct radial reformations by using the long axis of the femoral neck as a rotation axis.

Image Analysis

Two musculoskeletal radiologists (B.M., C.W.A.P., 3 and 7 years of experience, respectively) analyzed all MR images in

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Abbreviation:
FAI = femoroacetabular impingement

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Guarantors of integrity of entire study, C.W.A.P., J.H.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; manuscript final version approval, all authors; literature research, C.W.A.P., F.K.; clinical studies, C.W.A.P., B.M., C.D., F.K.; statistical analysis, C.W.A.P., M.Z., J.H.; and manuscript editing, all authors

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consensus. The MR images were mixed so that they did not appear in an ordered fashion for analysis. Readers were blinded to the surgical diagnosis.

The nonspherical shape of the femoral head-neck junction was measured in eight positions around the femoral head and neck by using the radially reformatted images to calculate the α angle in accordance with the method described by Notzli et al (7). The first line defining the α angle was located between the center of the femoral head and the point where the distance from the center of the femoral head to the peripheral contour of the femoral head exceeded the radius of the femoral head. The second line defining the α angle was the axis of the femoral neck, which was defined as a line that passed through the center of the femoral head and the center of the femoral neck at its narrowest point. Thus, a larger α angle corresponded to a more pronounced nonspherical shape of the femoral head.

The acetabular depth was measured on the transverse oblique image obtained through the center of the femoral neck. The depth of the acetabulum was defined as the distance between the center of the femoral neck and the line connecting the anterior acetabular rim to the posterior acetabular rim. The value was positive if the center of the femoral neck was lateral to the line connecting the acetabular rim.

Acetabular cartilage abnormalities, acetabular labral abnormalities, and acetabular bony contours were assessed qualitatively at six positions (position 1, anterior; position 2, anterosuperior; position 3, superior; position 4, posterosuperior; position 5, posterior; position 6, inferoposterior). The topographic extent of the acetabular cartilage damage was rated as absent, extending no more than 5 mm medially to the acetabular rim, or extending more than 5 mm medially to the acetabular rim. The acetabular labrum was rated as normal, degenerated (abnormal signal intensity), or torn (abnormal linear signal intensity extended to the labral surface). Bony abnormalities of the acetabular rim were rated as absent, as ossification of the acetabular

Figure 1

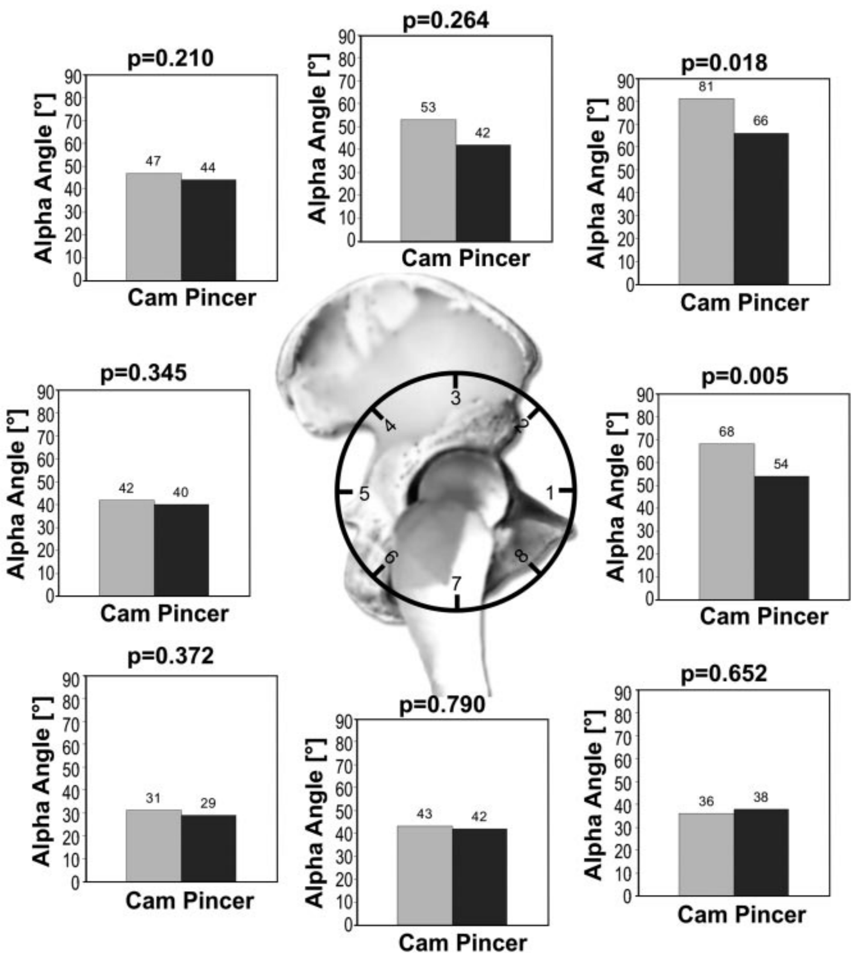


Figure 1: Graphs show mean α angles in eight positions around the femoral neck. *P* values were calculated with the Wilcoxon rank sum test.

Table 1

α Angle in Eight Positions around the Femoral Head in Patients with Cam and Pincer FAI

Position	α Angle in Patients with Cam FAI (degree)	α Angle in Patients with Pincer FAI (degree)	*P* Value*
Anterior	68 ± 19	54 ± 11	.005
Anterosuperior	81 ± 15	66 ± 19	.018
Superior	53 ± 20	42 ± 5	.264
Posterosuperior	47 ± 8	44 ± 10	.210
Posterior	42 ± 10	40 ± 10	.345
Posteroinferior	31 ± 7	29 ± 7	.372
Inferior	43 ± 7	42 ± 7	.790
Anteroinferior	36 ± 10	38 ± 10	.652

Note.—Data are mean ± standard deviation. Mean acetabular depth was 4.8 mm ± 2.6 in patients with cam FAI and 0.4 mm ± 3.2 in patients with pincer FAI ($P < .001$). Smaller values correspond to a deeper acetabulum.

* *P* values were calculated with the Wilcoxon rank sum test.

labrum (bone marrow signal intensity extended into the substance of the acetabular labrum), or as a separated ossicle at the acetabular rim (os acetabuli).

Formation of an osseous bump at the femoral neck was qualitatively rated as present or absent by using the transverse oblique sequence and radially reformatted images. The presence of a herniation pit was noted. A herniation pit was diagnosed if a round or oval cystic area was present at the anterior aspect of the femoral neck.

Table 2

Acetabular Cartilage Lesions in Patients with FAI

Position	Size of Lesion in Patients with Cam FAI (n = 33)*			Size of Lesion in Patients with Pincer FAI (n = 17)*			*P* Value†
	Normal	≤5 mm	>5 mm	Normal	≤5 mm	>5 mm	
Anterior	24	7	2	15	2	0	.196
Anterosuperior	3	12	18	5	11	1	.001
Superior	4	14	15	5	10	2	.018
Posterosuperior	19	7	7	11	5	1	.455
Posterior	31	2	0	13	1	3	.059
Posteroinferior	31	2	0	12	0	5	.017

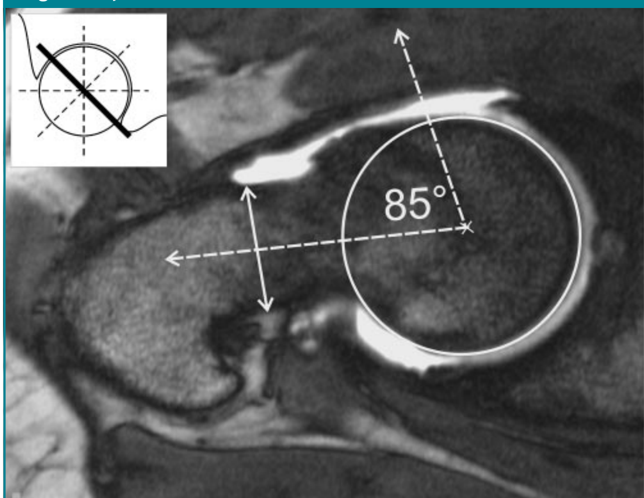
* Data are the number of patients.

† *P* values were calculated with the Wilcoxon rank sum test.

Statistical Analysis

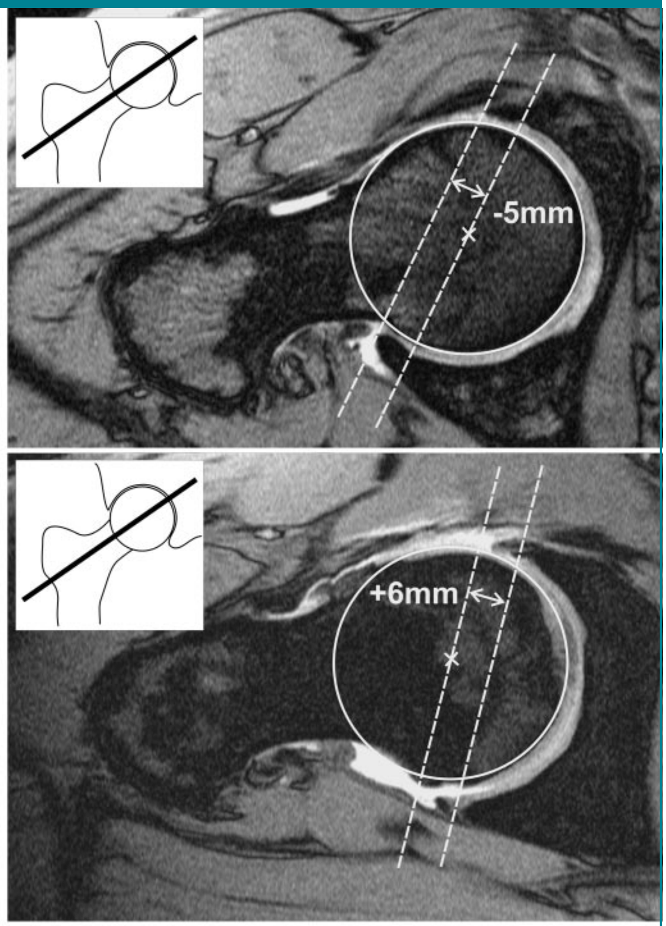
Continuous and ordinal variables were tested for significant differences with the Wilcoxon rank sum test. Mean values and standard deviations were calculated for continuous data. Differences for dichotomous variables were tested with the Fisher exact test. A software package (SPSS, version 10.0.7; SPSS, Chicago, Ill) was used for all statistical calculations. A *P* value of less than .05 was considered to indicate a significant difference.

Figures 2, 3



2.

Figure 2: Measurement of the α angle on a radial reformation MR image (water excitation three-dimensional double-echo steady-state sequence, 24.0/11.8, 25° flip angle) in a patient with cam FAI. The α angle was defined by a line between the center of the femoral head and the point where the distance from the center of the femoral head to the peripheral contour of the femoral head exceeded the radius of the femoral head and a second line in the axis of the femoral neck that passed through the center of the femoral head and the center of the femoral neck at its narrowest point.



3.

Figure 3: Measurement of acetabular depth on transverse oblique MR images (water excitation three-dimensional double-echo steady-state sequence, 24.0/11.8, 25° flip angle) obtained through the center of the femoral neck in a patient with pincer FAI due to protrusio acetabuli (top) and a patient with cam FAI (bottom). Depth of the acetabulum was defined by the distance between the center of the femoral neck and the line that connected the anterior and posterior acetabular rim. The acetabulum is considerably deeper in the patient with pincer FAI (−5 mm) than in the patient with cam FAI (6 mm).

Figure 4

Figure 4: Consecutive sagittal water excitation three-dimensional double-echo steady-state MR images (24.0/6.5, 25° flip angle) moving from medial (left) to lateral (right) in a patient with cam FAI. Note advanced acetabular cartilage damage at the anterior aspect of the acetabulum (white arrowheads). The cartilage is normal at the posterior aspect of the acetabulum (black arrowheads). An os acetabuli (curved arrow) is present at the anterosuperior aspect of the acetabular rim. Note the herniation pit (straight arrow) at the anterior femoral head-neck junction.

Results

Demographic Data

At surgery, hips in 33 patients were classified as having cam FAI and hips in 17 patients were classified as having pincer FAI. Patient age was not significantly different between groups (cam FAI: mean age, 28.8 years ± 6.5 [standard deviation]; pincer FAI: mean age, 28.8 years ± 9.4). There were significantly ($P < .001$) more men ($n = 27$) in the cam FAI group and more women ($n = 14$) in the pincer FAI group.

Imaging Data

The α angles were significantly larger in the cam FAI group than in the pincer FAI group at the anterior position (68° and 54°, respectively; $P = .005$) and at the anterosuperior position (81° and 66°, respectively; $P = .018$) (Figs 1, 2; Table 1). In all other positions, no significant difference was seen. The acetabulum was significantly ($P < .001$) deeper in the pincer FAI group (mean depth, 4.8 mm) than in the cam FAI group (mean depth, 0.7 mm) (Fig 3).

Cartilage lesions (Table 2) in patients with cam FAI were significantly larger at the anterosuperior ($P = .001$) and superior ($P = .018$) positions than were cartilage lesions in patients with pincer FAI (Fig 4). Cartilage lesions in patients with pincer FAI were significantly ($P = .017$) larger at the posteroinferior position than were cartilage lesions in patients with cam FAI (Fig 5).

Distribution of labral lesions (Fig 6) between the two FAI groups in six positions around the acetabulum (Table 3) showed significantly ($P = .047$) more pronounced labral lesions at the posterior and posteroinferior positions in patients with pincer FAI.

Distribution of acetabular osseous abnormalities between the two FAI groups in six positions around the ace-

Figure 5

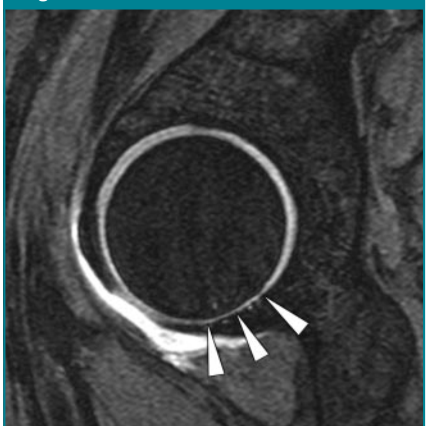


Figure 5: Sagittal water excitation three-dimensional double-echo steady-state MR image (24.0/6.5, 25° flip angle) in a patient with pincer FAI. Note cartilage damage (arrowheads) at the posteroinferior aspect of the acetabulum.

Figure 6

Figure 6: Labral tear (arrow) in a patient with cam FAI (transverse oblique section, water excitation three-dimensional double-echo steady-state MR sequence, 24.0/11.8, 25° flip angle) obtained through the center of the femoral neck. Note the osseous bump (arrowheads) at the anterior aspect of the femoral head.

tabulum (Table 4) showed that osseous abnormalities at the acetabular rim were most pronounced at the anterosuperior and superior positions (Fig 7). However, no significant differences between the two groups were observed.

Osseous bump formation at the femoral neck was significantly (P = .001) more common in patients with cam FAI (15 of 33 patients) than in patients with pincer FAI (six of 17 patients). The presence of herniation pits (Fig 4) was not significantly different (cam FAI, seven of 33 patients; pincer FAI, three of 17 patients; P = .728).

Discussion

FAI leads to premature osteoarthritis in the hip joint (1,2). FAI often becomes symptomatic in the 2nd or 3rd decade of life in patients with increased sports activity. The identification of FAI as a cause of cartilage damage and labral tears may allow surgeons to correct it early in its natural history and delay or prevent end-stage osteoarthritis (8). It is important to know that surgical treatment of FAI is only suitable in patients without advanced degenerative changes and without extensive articular cartilage damage (6). Patients at greatest risk for a bad outcome after surgery have advanced osteoarthritis before surgery (9). The most important role of preoperative MR imaging in patients with FAI is to assess the exact extent of the damage already present within the joint. MR arthrography is superior to MR imaging in the detection and staging of acetabular labrum lesions (10–13).

Anatomic variations in the proximal femur should be considered a possible cause of cam FAI. A nonspherical femoral head leads to outside-in abrasion of the articular cartilage and damage to the adjacent labrum. Ito et al (5) measured the depth of the femoral waist in circumferential positions around the femoral neck by using MR data from patients with FAI and healthy volunteers. When paired according to sex and age, patients with cam FAI showed a significant reduction in mean depth of the femoral waist at the anterior aspect of the femoral neck when compared with that in patients with pincer FAI. This was consistent with the site of symptomatic FAI in flexion and internal rotation and with lesions in the adjacent rim (5).

Notzli et al (7) compared MR images obtained in 39 patients with FAI with MR images obtained in 35 asymptomatic control subjects. They measured the nonspherical shape of the femoral head-neck junction by measuring the α angle at the anterior position. The average α angle was 74° in patients with FAI and 42° in control subjects (P < .001). A cut-off angle of 55° was proposed to diagnose FAI. The findings of Notzli et al (7) are consistent with our findings. At the anterior position, the α angle was 68° in patients with cam FAI and 54° in patients with pincer FAI. However, the largest α angles were seen at the anterosuperior position (mean α angle of 81° in patients with cam FAI and 66° in patients with pincer FAI). This emphasizes the need for radial images rotated around the center line of the femoral neck for optimal visualization of the anterosuperior area of the femoral neck. Surgical treatment of FAI focuses on improving hip motion and alleviating femoral abutment against the acetabular rim (4). Cam impingement is relieved by reshaping the nonspherical peripheral portion of the femoral head and the adjacent femoral neck.

In pincer FAI, the reason for the conflict between the acetabulum and the femur is an overcoverage of the acetabulum. The acetabular overcoverage can be general, as in a patient with protrusio acetabuli, or localized, as in a patient with acetabular retroversion (14). Protrusio acetabuli is diagnosed on the basis of an anteroposterior radiograph of

Table 3

Labral Lesions in Patients with FAI

Position	Labrum Condition in Patients with Cam FAI (n = 33)*			Labrum Condition in Patients with Pincer FAI (n = 17)*			
	Normal	Degeneration	Tear	Normal	Degeneration	Tear	P Value†
Anterior	18	11	4	9	6	2	.936
Anterosuperior	2	18	13	1	6	10	.336
Superior	4	14	15	2	9	6	.581
Posterosuperior	19	10	4	11	4	2	.673
Posterior	33	0	0	15	2	0	.047
Posteroinferior	33	0	0	15	2	0	.047

* Data are the number of patients.

† P values were calculated with the Wilcoxon rank sum test.

Table 4

Ossification of the Acetabular Rim in Patients with FAI

Position	Cam FAI (n = 33)*			Pincer FAI (n = 17)*		
	Normal	Ossification	Ossicle	Normal	Ossification	P Value†
Anterior	32	1	0	15	2	.223
Anterosuperior	17	11	5	10	7	.383
Superior	21	12	0	10	7	.742
Posterosuperior	28	5	0	11	6	.107
Posterior	33	0	0	16	1	.164
Posteroinferior	33	0	0	16	1	.164

* Data are the number of patients.

† P values were calculated with the Wilcoxon rank sum test.

the pelvis that shows a medialization of the medial wall of the acetabulum past the ilioischial line (15). Acetabular retroversion is associated with osteoarthritis of the hip. Giori and Trousdale (14) compared pelvic radiographs obtained in patients with (n = 131) and those without (n = 99) primary osteoarthritis of the hip; acetabular retroversion was significantly more prevalent in patients with primary osteoarthritis (20%) than in the control group (5%). Surgical treatment of pincer FAI includes trimming the acetabular rim to reduce overcoverage of the acetabulum (9). Periacetabular osteotomy is an effective way to reorient the acetabulum in young adults with symptomatic anterior FAI due to acetabular retroversion (16).

Schmid et al (17) analyzed cartilage lesions in patients with FAI. Cartilage lesions were most commonly found at the anterosuperior part of the acetabulum. Our data are in line with this finding. Wagner et al (2) histologically analyzed the cartilage in patients with FAI. The cartilage showed clear degenerative signs that were similar to the findings in patients with osteoarthritic cartilage. The tissue alterations were distinctly different when compared with tissue obtained in control subjects, which substantiates the possibility that an impingement conflict is an early mechanism for degeneration at the hip joint periphery (2).

MR arthrography enables accurate detection and staging of acetabular cartilage lesions (18). However, acetabular cartilage delamination may be present in patients with FAI (19). Diagnosis of acetabular cartilage delamination may be difficult, even with MR arthrography. We found that patients with pincer FAI showed more severe cartilage damage at the posterior and posteroinferior aspect of the acetabulum than did patients with cam FAI. The typical location of cartilage damage in cases of pincer FAI has been attributed to countercoup cartilage damage (1).

Labral and bony changes of the acetabular rim coincide frequently in cases of FAI. Wenger et al (20) found that the majority of patients with labral tears have a hip abnormality that can be detected with conventional radiography. In our study, both labral and bony changes were most frequently present at the quadrant between the anterior and superior positions. Ossification of the acetabular rim leads to further overcoverage of the femoral head, which aggravates the FAI. The os acetabuli, which is the epiphysis of the pubis, starts to develop at about 8 years of age and unites with the os pubis at about 18 years of age (21) In patients with FAI, a separated bone fragment at the acetabular rim or os acetabuli is frequently observed (22). In cases of FAI, the acetabular rim is subject to abnormal stress, which may cause fractured bone tissue to separate from the adjacent bone margin (23).

Figure 7

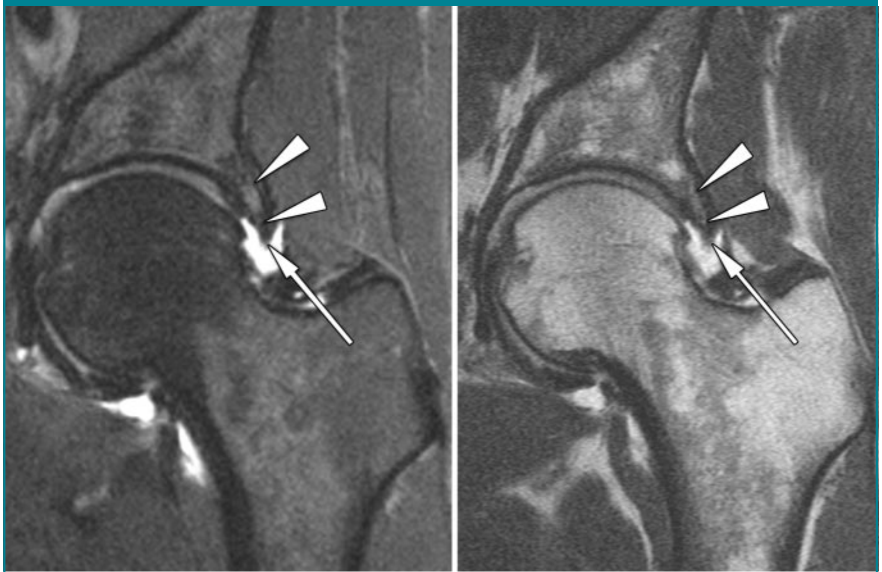


Figure 7: Coronal MR images obtained with an intermediate-weighted fast spin-echo sequence with fat saturation (2500/42) (left) and a T1-weighted spin-echo sequence (524/14) (right) show ossification of the acetabular labrum in a patient with pincer FAI. Bone marrow signal (arrowheads) extends into the substance of the acetabular labrum (arrow).

FAI is often associated with an osseous bump deformity on the femoral head-neck junction; we found a bump formation in almost half of the patients with cam FAI and in one-third of the patients with pincer FAI. It is unclear if this bump is a primary deformity or if it has developed because of chronic mechanical irritation. Jager et al (24) prospectively investigated 17 patients who had an osseous bump at the anterolateral head-neck junction. To elucidate the local osteogenic potential, tissue specimens of the perilesional capsule were investigated immunohistochemically. Various antigens and protein synthesis products served to identify osteoblastic cells and progenitor cells. Immunohistochemical studies showed perilesional recruitment of osteoprogenitor cells (24).

There are study limitations to be considered. We did not include a control group of healthy subjects. Also, because of the inclusion criteria, only patients who underwent surgery were studied; therefore, our study probably included only patients with advanced disease.

In conclusion, characteristic MR arthrographic findings of cam FAI include large α angles and acetabular cartilage lesions at the anterosuperior position and osseous bump formation at the femoral neck; characteristic findings of pincer FAI include a deep acetabulum and posteroinferior acetabular cartilage lesions.

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