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TABLE E-1 Important Radiographic Findings and Considerations in the Evaluation of Femoroacetabular Impingement

Radiographic Finding	Considerations
Alpha angle	The alpha angle can be determined on an anteroposterior and a lateral radiograph of the hip. It is defined as the angle subtended between the midline of the femoral neck and a line connecting the center of the femoral head to the point along the head-neck junction that first deviates from the sphericity of the femoral head. An elevated value (>50°) may be consistent with a cam-type impingement morphology. Elevated values on the anteroposterior and lateral views indicate a superolateral and an anterior cam-type deformity, respectively.
Beta angle	The beta angle, as defined by Brunner et al.[134], is a reliable assessment of improvement in functional range of motion independent of the specific femoral or acetabular impingement lesions. The point of deviation from sphericity of the femoral head at the head-neck junction and the superior and lateral osseous margin of the acetabulum are defined. Lines from each of these points are drawn to the femoral head center, and the intersecting angle is measured between these two lines.
Center-edge angle	The center-edge angle of Wiberg is determined by the angle subtended between a vertical line (orthogonal to the line defined by the inferior aspect of the ischial tuberosities) and a line connecting the center of the femoral head and the lateral aspect of the acetabulum. A measurement of <25° may be consistent with dysplasia.
Crossover sign	The crossover sign has been associated with cephalad acetabular retroversion on an anteroposterior radiograph of the pelvis and is characterized by the anterior rim of the acetabulum projecting more laterally than the posterior rim. This relationship corrects more distally, resulting in the appearance of a "crossover" between the anterior and posterior wall on a well-positioned anteroposterior radiograph of the pelvis[86].
Femoral head-neck offset	Femoral head-neck offset is determined on a lateral view of the hip. A line is drawn through the center of the long axis of the femoral neck. A parallel line is drawn tangent to the anteriormost aspect of the femoral neck and another parallel line was drawn tangent to the anteriormost aspect of the femoral head. The distance between these lines defines the offset and is normally >10 mm. Loss of offset may be consistent with a femoral impingement morphology.
Tönnis angle	The Tönnis angle is determined by identifying the sourcil. The sourcil is the sclerotic, weight-bearing portion of the superior aspect of the acetabulum. The medial and lateral extents of the sourcil are connected with a line, and the angle subtended between this line and a horizontal line parallel to one connecting the inferior aspect of the ischial tuberosities is determined. An angle >10° may be consistent with dysplasia.

Computed tomography (CT) imaging	Location and morphology of a cam-type lesion, the alpha angle, the neck-shaft angle, the femoral version, and the acetabular version at twelve o'clock through three o'clock can be defined on high-resolution CT imaging. Femoral version is defined by the angle of the femoral neck relative to the posterior condylar axis defined by axial CT images of the distal part of the femur. The center of the femoral neck can be defined by multiaxial radial sequences to define the central axis in the superior-inferior, medial-lateral, and anterior-posterior planes. Acetabular version can be measured with a three-dimensional CT technique, as recently validated and described by Dandachli et al.[135].
Magnetic resonance (MR) imaging	MR imaging is also valuable and can characterize the location of the labral tear and definition of chondral status of the femoral head and acetabular articular surfaces. MR imaging is also useful to define injury to the periarticular soft tissues as well as the presence of femoral and pelvic osseous stress reaction or fracture.

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TABLE E-2 Participant Demographics for Studies Evaluating Operative Treatment of Femoroacetabular Impingement*

Study	Level of Evidence	Hips	Follow-up *(yr)*	Percent Follow-up	Mean Age *(yr)*	Unique Features
Siebenrock et al.[90]	Retrospective case series, Level IV	29	2.5	100%	23	Impingement due to acetabular retroversion
Beck et al.[50]	Retrospective case series (prospectively collected), Level IV	19	4.7	95%	36	NA
Murphy et al.[128]	Retrospective case series, Level IV	23	5.2	100%	35.4	NA
Espinosa et al.[93]	Retrospective comparative study, Level III	60	2	100%	30	Labral debridement vs. labral refixation
Peters and Erickson[8]	Retrospective case series (prospectively collected), Level IV	30	2.7	100%	31	NA
Beaulé et al.[54]	Retrospective case series, Level IV	37	3.1	100%	40.5	NA
Ilizaliturri et al.[125]	Retrospective case series (prospectively collected), Level IV	14	2.5	100%	30.6	Impingement secondary to pediatric hip disorders
Ilizaliturri et al.[126]	Retrospective case series (prospectively collected), Level IV	19	2.4	95%	34	Cam-type impingement
Laude et al.[69]	Retrospective comparative study, Level III	100	4.9	94%	33.4	NA
Philippon et al.[74]	Retrospective case series, Level IV	112	2.3	80%	40.6	NA
Brunner et al.[56]	Retrospective case series, Level IV	53	2.4	100%	42	NA
Fabricant et al.[124]	Retrospective case series, Level IV	27	1.5	100%	<19	Adolescent athletes
Schilders et al.[130]	Retrospective comparative study, Level III	101	2.44	100%	37	Labral debridement vs. refixation
Larson and Giveans[68]	Retrospective comparative study, Level III	75	1.6	100%	29	Labral debridement vs. refixation
Peters et al.[73]	Retrospective case series, Level IV	96	2.2	100%	28	NA
Graves and Mast[63]	Retrospective case series, Level IV	48	3.2	100%	33	Surgical dislocation
Yun et al.[79]	Retrospective case series, Level IV	15	2.2	100%	35.8	Surgical dislocation
Bizzini et al.[55]	Retrospective case series, Level IV	5	2.5	100%	21.4	Athletes return to team practice after open surgical dislocation
Gedouin et al.[62]	Retrospective case series, Level IV	111	0.8	100%	31	NA

Horisberger et al.[65]	Retrospective case series, Level IV	20	3	100%	47.3	Arthroscopy not indicated with advanced osteoarthrosis
Philippon et al.[129]	Retrospective case series, Level IV	28	2	100%	27	NA
Singh and O'Donnell[101]	Retrospective case series, Level IV	27	1.8	100%	27	NA
Byrd and Jones[59]	Retrospective case series, Level IV	207	1.4	100%	33	NA
Nepple et al.[22]	Retrospective comparative study, Level III	48	1.8	100%	35	Arthroscopic vs. combined
Nho et al.[121]	Retrospective case series, Level IV	47	2.2	70%	22.8	High-level athletes
Byrd and Jones[60]	Retrospective case series, Level IV	200	1.6	100%	28.6	Athletes
Larson et al.[127]	Retrospective comparative study, Level III	227	2.2	100%	31.8	Poor outcomes with advanced joint-space narrowing
Naal et al.[118]	Retrospective case series, Level IV	22	3.8	100%	19.7	Surgical dislocation for high-level athletes

*NA = not applicable.

TABLE E-3 Clinical Outcomes Reported from Studies Evaluating Femoroacetabular Impingement*

Study	Surgical Approach	Clinical Outcome Scores	Clinically Good or Excellent Outcome	Mean Change in Hip Score	Definition of Failure	Treatment Failure
Siebenrock et al.[90]	Open	Merle d'Aubigné score	28 hips (96%)	2.9 pts	Fair results/residual pain	1 (3%)
Beck et al.[50]	Open	Merle d'Aubigné score	13 hips (68%)	2.4 pts	Conversion to total hip arthroplasty	5 (26%)
Murphy et al.[128]	Open	Merle d'Aubigné score	NA	3.7 pts	Conversion to total hip arthroplasty	7 (23%)
Espinosa et al.[93]	Open	Merle d'Aubigné score	52 hips (87%); LRS group: 19 hips (76%); LRF group: 33 hips (94%)	LRS group: 3 pts; LRF group: 5 pts	Group I, poor results; group II, moderate results	1 (4%); 2 (6%)
Peters and Erickson[8]	Open	HHS	NA	17 pts	Pain and/or progressive arthrosis	4 (13%)
Beaulé et al.[54]	Open	WOMAC, UCLA, SF-12	N/A	WOMAC, 20.2 pts; UCLA, 2.7 pts; SF-12 physical, 8.3 pts; SF-12 mental, 4.8 pts	Unsatisfactory outcome, no clinical improvement and/or worsening WOMAC score	6 (16%)
Ilizaliturri et al.[125]	Arthroscopic	WOMAC	NA	9.6 pts	NA	0 (0%)

Ilizaliturri et al.[126]	Arthroscopic	WOMAC	NA	7 pts	Advanced osteoarthrosis, recommended total hip arthroplasty	1 (5%)
Laude et al.[69]	Combined (limited open/ arthroscopic)	NAHS	NA	29.1 pts	Conversion to total hip arthroplasty	11 (11%)
Philippon et al.[74]	Arthroscopic	MHHS, HOS activities of daily living, HOS Sport, NAHS	NA	MHHS, 24 pts; HOS activities of daily living, 17 pts; HOS Sport, 24 pts; NAHS, 14 pts	Conversion to total hip arthroplasty	10 (9%)
Brunner et al.[56]	Arthroscopic	SFS, NAHS, VAS	NA	SFS, 1.06 pts, NAHS, 31.3 pts, VAS, 4.1 pts	NA	NA
Fabricant et al.[124]	Arthroscopic	HHS, HOS	NA	HHS, 21 pts; HOS, 16 pts	NA	NA
Schilders et al.[130]	Arthroscopic	HHS, MHHS	NA	Group 1, 33 pts (HHS); Group 2, 26 pts (HHS); 7 pts greater (MHHS) in Group 1 compared with Group 2	NA	NA
Larson and Giveans[68]	Arthroscopic	HHS, SF-12, VAS	Group 1, 66.7%; Group 2, 89.7%	Group 1: 25 pts (HHS), 19 pts (SF-12), 5 pts (VAS); Group 2: 32 pts (HHS), 24 pts (SF-12), 5 pts (VAS)	HHS <70, recommended conversion to total hip arthroplasty or repeat debridement	Group 1, 11.1%; Group 2, 7.7%
Peters et al.[73]	Open	HHS	NR	24 pts	Conversion to total hip arthroplasty, or lower HHS	6.3%

Graves and Mast[63]	Open	Merle d' Aubigné score	NA	4 pts	NA	NA
Yun et al.[79]	Open	HHS	NR	17 pts	NR	0
Bizzini et al.[55]	Open	Time to return to hip range of motion, core muscle strength, return to competitive hockey	NA	NA	NA	NA
Gedouin et al.[62]	Arthroscopic	WOMAC	NA	23 pts	NA	NA
Horisberger et al.[65]	Arthroscopic	NAHS, Tönnis grade, VAS	NR	NAHS, 28 pts; VAS, 4 pts	NR	8.6% (9 total hip arthroplasty)
Philippon et al.[129]	Arthroscopic	MHHS	NR	25 pts	NR	NR
Singh and O'Donnell[101]	Arthroscopic	MHHS, NAHS	NR	MHHS, 10 pts; NAHS, 15 pts	Continued hip pain or pain that required additional surgical intervention	0%
Byrd and Jones[59]	Arthroscopic	MHHS	NR	20 pts	NR	NR

Nepple et al.[22]	Mini-open anterior with arthroscopic assistance	MHHS	Group 1, 74%; Group 2, 92%	Group 1, 8 pts; Group 2, 22 pts	MHHS <70	Group 1, 26%; Group 2, 4%
Nho et al.[121]	Arthroscopic	HOS, MHHS	93%	HOS, 13 pts; MHHS, 20 pts	Inability to return to team practice	7%
Byrd and Jones[60]	Arthroscopic	MHHS	95%	21 pts	Conversion to total hip arthroplasty, inability to return to play (RTP)	0.5% to total hip arthroplasty; 5% professional RTP; 15% intercollegiate RTP
Larson et al.[127]	Arthroscopic	HHS, VAS, SF-12	NA	HHS, 22.8 pts; SF-12, 20.9 pts; VAS, 4.5 pts. With osteoarthrosis: HHS, 3.7 pts; SF-12, 4.3 pts; VAS, 2.6 pts	No sustained improvement in HHS	12% failure rate, 33% failure rate with mild joint-space narrowing, and 82% failure rate with osteoarthrosis
Naal et al.[118]	Open	HOS, SF-12, UCLA, VAS	18 hips (82%)	NA	Unable to return to team practice	14%

*Pts = patients, NA = not applicable, LRS = labral resection, LRF = refixation, HHS = Harris hip score, UCLA = University of California, Los Angeles, hip score, SF-12 = Short Form-12, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index, NAHS = nonarthritic hip score, MHHS = Modified Harris hip score, HOS = hip outcome score, SFS = Sports Frequency Score, VAS = visual analog scale score, NR = not reported.