Radiographic Risk Factors for Labral Lesions in Femoroacetabular Impingement

Thomas Kappe MD, Tugrul Kocak MD,
Ralf Bieger MD, Heiko Reichel MD, Christian R. Fraitzl MD

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Abstract

Background Tears of the acetabular labrum can lead to pain, disability, and osteoarthritis. Several pathomechanisms have been proposed, including femoroacetabular impingement (FAI). Labral tears have been reported to occur in the presence of even subtle deformities of the acetabulum and femoral head-neck junction.

Questions/purposes We analyzed the association of the extent of bony deformity and presence and extent of labral lesions in hips with FAI.

Patients and Methods Radiographs of 123 hips in 116 patients receiving surgical treatment for FAI were analyzed and correlated to the presence and extent of labral lesions. Radiographic parameters of the acetabulum included acetabular index of the weightbearing zone, center-edge angle, inclination of the acetabulum, lateral head extrusion index, and retroversion. On the femoral side, neck-shaft angle, asphericity of the femoral head, superior and anterior alpha angle, offset, and offset ratio were measured. Osteoarthritis was graded according to Tönnis and Kellgren and Lawrence. Labral lesions were graded according to the modified Beck classification. A correlation between labral lesions and age,

gender, affected side, type of impingement, and presence and extent of chondromalacia also was tested.

Results No correlation was found between presence or extent of labral lesions and any radiographic parameter tested, except osteoarthritis classification. The severity of labral lesions correlated to the severity of acetabular chondromalacia as well as patient age (Beck Grade 0 versus Grade 1, Beck Grade 0 versus Grades 1 and 2).

Conclusions In the presence of impingement-inducing deformity, the extent of deformation is not associated with the incidence of labral lesions. Labral lesions are associated with early degenerative hip disease in FAI.

Level of Evidence Level I, diagnostic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Tears of the acetabular labrum can lead to pain and disability in the young and active adult [3]. Loss of labral function can lead to osteoarthritis of the hip [18, 24]. Various pathomechanisms leading to labral tearing have been proposed, including femoroacetabular impingement (FAI) [6]. In cam-type FAI, an aspheric junction of the femoral head and neck will lead to more localized detachment of the labrum and tearing in an inside-out direction, whereas the labrum will sustain more circumferential fraying in an outside-in direction in pincer-type FAI [1].

Sharp groin pain provoked by strenuous labor or prolonged sitting may raise suspicion for a labral tear that can be strengthened by MRI [3]. Labral tears have been reported to be rare in the absence of bony abnormalities. Cutoff values have been proposed for radiological

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

T. Kappe (✉), T. Kocak, R. Bieger, H. Reichel, C. R. Fraitzl
Department for Orthopaedic Surgery, University of Ulm,
Oberer Eselsberg 45, 89081 Ulm, Germany
e-mail: thkappe@gmx.de

measures of the proximal femur (e.g., the alpha angle) and the acetabulum to distinguish hips with a deformity predisposing to FAI from those without [9, 21]. Ganz et al. [6] proposed that even slight deformities of either the proximal femur (especially offset reduction) or the acetabulum might result in substantial intraarticular damage, but conversely, not every hip with a deformity predisposing to FAI will experience labral tearing [1].

Therefore, we analyzed the relationship between the extent of proximal femoral and acetabular impingement-related deformity and the presence and extent of labral lesions in hips with FAI. Our hypothesis was that hips with labral tears would show more pronounced femoral offset reduction and more excessive coverage of the femoral head than hips with labral fraying or without labral lesions. Furthermore, we expected a higher prevalence of early radiographic signs of osteoarthritis in hips with labral tears.

Patients and Methods

For inclusion in this retrospective, cross-sectional study, we reviewed the surgical reports and preoperative radiographs of 149 consecutive hips of patients who received osteochondroplasty for femoral offset reduction either by surgical hip dislocation or via an anterior approach from November 2003 through January 2010. The indication for surgery was FAI in all cases. The diagnosis of FAI was based on patient history (especially groin pain during strenuous physical activities and prolonged sitting), clinical (especially a positive impingement test), and radiographic findings (offset reduction in cam-type and either acetabular retroversion or excessive global femoral head coverage in pincer-type FAI). An anterior approach was used if the indication was only to restore anterior femoral offset either alone or in combination with a partial anterior labral resection or débridement. All patients with marked deformity of the proximal femur necessitating wider exposure, suspected cartilage lesions, or planned rim trimming received surgical hip dislocation. Additional inclusion criteria for the study included a comprehensive description of the condition of the labrum in the surgical records and a complete set of preoperative radiographs, consisting of an AP view of the pelvis and an axial Lauenstein view. The latter is the standard axial view at our institution and is about comparable to the 45° Dunn view, which was the most sensitive axial projection for detection of offset reduction in the study by Meyer et al. [20]. The Lauenstein view has been used at other institutions for similar purposes [17, 25]. Patients with malrotated (foramen obturatum index < 0.56 or > 1.8) [27] or malinclined pelvic radiographs (distance between tip of coccygeum and symphysis pubis < 0 or > 2 cm) and those who have had

previous surgical treatment of the affected hip during adulthood were excluded from the study. We excluded 12 patients with previous operations (including pelvic osteotomies in seven patients and intertrochanteric osteotomies in two) and 14 patients with inadequate preoperative radiographs. Thus, 123 hips in 116 patients, 44 women and 72 men, with a mean age of 37.4 ± 9.5 years (range, 18–57 years), were included in the analysis. There were 51 left and 72 right hips affected. Twenty-one hips had cam-type, 17 hips had pincer-type, and 85 hips had mixed-type FAI. No patient had a history of major trauma preceding clinical symptoms. Ninety-two hips were operated on via surgical dislocation and 31 via an anterior approach.

We screened the surgical reports forms for the status of the acetabular labrum. A hook probe was used routinely intraoperatively to identify tears in the substance of the labrum or at the junction between the labrum and cartilage. Using an anterior approach, the undersurface of the labrum could be probed by rotating the hip with varying degrees of flexion in slight abduction. This sometimes was possible only after offset reduction. The presence, size, and location of labral tears were documented in the surgical reports. In the first step of the statistical analysis, the labrum was classified to be intact or flawed (torn, severely degenerated, or frayed). The classification scheme of Beck et al. [1] also was used and modified for statistical analysis: an intact labrum received Grade 0, a labrum with degeneration or ossification received Grade 1, and a labrum with a full-thickness tear or detached from the acetabulum was labeled Grade 2 (Table 1). Acetabular chondromalacia was graded according to Outerbridge [22]. As the anterior approach does not allow inspection of the acetabular cartilage, patients treated by the anterior approach were not included in the subanalysis on the coincidence of cartilage and labral lesions.

The radiographic measurements were made by an orthopaedic surgeon trained in hip-preserving surgery (TK). From the AP pelvis, the acetabular index of the weightbearing zone [2], center-edge angle [30], inclination of the acetabulum [26, 28], lateral head extrusion index [10], neck-shaft angle, asphericity of the femoral head [4], superior alpha angle [21], superior offset, and superior offset ratios [5] were acquired using commercially available software (DiagnostiX-32, Version 3.8.6, 2003; Gemed, Ulm, Germany). Asphericity was determined to be present when the junction of the femoral head and neck lay outside a circle matching the surface of the femoral head [4]. The alpha angle according to Nötzli et al. [21] is the angle between a line connecting the narrowest point of the femoral neck to the center of the femoral head and a line connecting the latter to the point where the surface of the femoral head leaves a circle at the head-neck junction. Femoral offset was measured according to the original

Table 1. Modification of the classification scheme of Beck et al.

Grade	Beck's description	Beck's criteria
0	Normal	Intact
1	Degeneration Ossification	Thinning or localized hypertrophy, fraying, discoloration
2	Full-thickness tear Detachment	Complete avulsion from the acetabular rim Separation between acetabular and labral cartilage, preserved attachment to bone

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definition of Eijer et al. [5] as the distance between a line parallel to the femoral neck axis at the cortex of the femoral neck and a parallel tangent to the femoral head. The offset ratio was defined as the ratio between the femoral offset and the diameter of the femoral head [5]. Retroversion of the acetabulum was assumed when the anterior and posterior acetabular rim crossed (crossover sign) [14] or the ischial spine projected into the pelvic cavity (ischial spine sign) [12]. The posterior wall sign was assumed to be present when the center of the femoral head lay lateral to the posterior acetabular rim [14].

On the axial view, asphericity of the femoral head, anterior alpha angle, anterior offset, and anterior offset ratio were determined in a similar fashion. The extent of radiographic osteoarthritis was assessed according to Tönnis [27] and Kellgren and Lawrence [13]. In a previous study, the 95% confidence interval of radiographic measurements for the same observer and the identical measuring technique had been determined to be -0.5° and $+0.9^\circ$ for acetabular index of the weightbearing zone, -1.9° and $+0.9^\circ$ for center-edge angle, -0.5° and $+1.5^\circ$ for acetabular inclination, -0.02 and $+0.06$ for lateral head extrusion index, -1.0° and $+1.3^\circ$ for neck-shaft angle, -1.7° and $+1.5^\circ$ for superior and -1.5° and $+1.9^\circ$ for anterior alpha angle, -1.2 and $+1.1$ mm for superior and -0.7 and $+1.3$ mm for anterior offset, and -0.03 and $+0.03$ for superior and -0.03 and $+0.04$ for anterior offset ratio. We determined Kappa values to be 1.000 for the assessment of asphericity, 1.000 for the Tönnis classification, and 0.750 for the Kellgren and Lawrence classification (Kappe T, Kocak T, Fraitzl CR, Reichel H. Radiological risk factors for cartilage lesions in femoroacetabular impingement. Poster presentation P028, San Diego, CA, AAOS Annual Meeting February 15–19, 2011.).

Radiographic measurements in patient groups with and without labral alterations or tears were compared using one-way ANOVA for multiple groups, Student's t test (metrical data), and the chi square test (nominal data). Established cutoff values were used to delineate pathologic from nonpathologic groups: less than 0° and greater than

Table 2. Results of radiographic measurements

Measurement	Value
AIWZ ($^\circ$)*	2.9 ± 4.1 (-6.4 – 12.2)
CEA ($^\circ$)*	29.5 ± 6.6 (13.7 – 49.1)
Acetabular inclination ($^\circ$)*	39.3 ± 3.5 (28.2 – 48.2)
LHEI*	0.20 ± 0.06 (0.04 – 0.32)
CCD ($^\circ$)*	131.5 ± 5.6 (114.8 – 142.8)
Superior alpha angle ($^\circ$)*	62.5 ± 17.7 (37.8 – 105.4)
Anterior alpha angle ($^\circ$)*	64.3 ± 14.1 (32.6 – 100.5)
Superior offset (mm)*	6.9 ± 2.3 (0 – 12.2)
Anterior offset (mm)*	5.6 ± 3.0 (0 – 13.2)
Superior offset ratio*	0.12 ± 0.04 (0.00 – 0.25)
Anterior offset ratio*	0.11 ± 0.05 (0.00 – 0.23)
Crossover sign [†]	71 (58%)
Posterior wall sign [†]	45 (37%)
Ischial spine sign [†]	53 (43%)
Superior asphericity [†]	83 (68%)
Anterior asphericity [†]	110 (89%)
Tönnis OA classification [†]	
Grade 0	61 (50%)
Grade 1	37 (30%)
Grade 2	25 (20%)
Kellgren and Lawrence OA classification [†]	
Grade 0	34 (28%)
Grade 1	47 (38%)
Grade 2	22 (18%)
Grade 3	20 (16%)

* Values are expressed as mean $\pm$ SD, with range in parentheses;

[†] values are expressed as number of hips, with percentage in parentheses; AIWZ = acetabular index of the weightbearing zone; CEA = center-edge angle; LHEI = lateral head extrusion index; CCD = neck-shaft angle; OA = osteoarthritis.

10° for acetabular index of the weightbearing zone, greater than 39° and less than 25° for center-edge angle, less than 0.10 and greater than 0.25 for lateral head extrusion index, less than 126° and greater than 139° for neck-shaft angle, greater than 50° for alpha angle, less than 9 mm for offset, and less than 0.17 for offset ratio [9]. SPSS[®] software

(Version 17.0; SPSS Inc, Chicago, IL, USA) was used for statistical analysis and significance assumed for a *p* value less than 0.05. In an a priori power analysis (G*Power, Version 3.1.2; Universität Kiel Dusseldorf, Germany), the necessary sample size for an effect size of 0.5, an alpha of 0.05, and a beta of 0.2 was determined to be 51.

Results

No differences could be found comparing radiographic criteria between hips with and without labral lesions or hips with or without labral tears (Tables 2, 3). Sixty hips had lesions to the acetabular cartilage diagnosed during surgical hip dislocation. According to the modified Beck classification, 56 hips had intact labra, 39 had labral fraying or ossification, and 28 had labral tears. The overall incidence of labral lesions was 55% and the incidence of labral tears was 23%. No differences in Beck grades were found comparing gender, affected side, or type of FAI. Patients with labral lesions were older (*p* = 0.025) than patients with an intact labrum (Tables 3, 4).

Associations were observed between osteoarthritis grades according to Tönnis (Fig. 1) and Kellgren and Lawrence (Fig. 2) and the presence and severity of labral lesions (*p* = 0.023 and 0.005, respectively). There was a correlation between the presence of labral and cartilage lesions (chi square = 9.372; *p* = 0.02). Also, an association was found between the severity of acetabular chondromalacia and the presence and severity of labral lesions (*p* = 0.003).

Discussion

Tears of the acetabular labrum can lead to pain, disability, and osteoarthritis. Several pathomechanisms have been proposed, including FAI. Labral tears have been reported to occur in the presence of even subtle deformities of the acetabulum and femoral head-neck junction. We therefore analyzed the relationship between the extent of proximal femoral and acetabular deformity and the presence and extent of labral lesions in hips with FAI. It was our hypothesis that labral lesions, especially tears, would be

Table 3. Comparison of hips with and without labral lesions according to the classification scheme of Beck et al. [1]

Parameter	Grade 0 (n = 56)	Grade 1 (n = 39)	Grade 2 (n = 28)	p Value			
				All grades	Grade 0 vs 1	Grade 0 vs 2	Grade 0 vs 1 + 2
Age (years)*	35.3 ± 9.6	39.2 ± 8.2	39.0 ± 10.3	0.079	0.034	0.117	0.025
Gender†				0.446	0.182	0.256	0.332
Female	24	15	8				
Male	32	24	20				
Side†				0.578	0.936	0.269	0.654
Left	34	24	14				
Right	22	15	14				
FAI type†				0.810	0.781	0.817	0.452
Cam	8	7	5				
Pincer	10	4	3				
Mixed	37	28	20				
AIWZ (°)*	3.1 ± 4.1	3.2 ± 3.7	2.3 ± 4.6	0.640	0.948	0.436	0.678
CEA (°)*	28.9 ± 6.8	29.3 ± 6.5	30.8 ± 6.4	0.475	0.806	0.229	0.422
Inclination (°)*	39.7 ± 3.4	38.7 ± 3.1	39.2 ± 4.2	0.384	0.135	0.597	0.210
LHEI*	0.20 ± 0.06	0.20 ± 0.03	0.20 ± 0.05	0.936	0.920	0.750	0.938
CCD (°)*	132.2 ± 5.7	130.5 ± 5.5	131.5 ± 5.3	0.314	0.132	0.575	0.191
Superior alpha angle (°)*	61.8 ± 17.8	64.3 ± 19.4	61.6 ± 15.4	0.762	0.524	0.971	0.664
Anterior alpha angle (°)*	62.1 ± 13.0	66.7 ± 15.9	65.4 ± 13.6	0.269	0.140	0.295	0.110
Superior offset (mm)*	7.1 ± 2.0	7.2 ± 2.2	6.3 ± 2.9	0.276	0.834	0.227	0.526
Anterior offset (mm)*	6.0 ± 2.6	5.1 ± 3.5	5.4 ± 3.1	0.303	0.129	0.376	0.130
Superior offset ratio*	0.13 ± 0.03	0.13 ± 0.04	0.11 ± 0.05	0.203	0.949	0.095	0.338
Anterior offset ratio*	0.11 ± 0.05	0.11 ± 0.05	0.12 ± 0.05	0.144	0.936	0.076	0.291

* Values are expressed as mean ± SD; † values are expressed as number of hips; AIWZ = acetabular index of the weightbearing zone; CEA = center-edge angle; LHEI = lateral head extrusion index; CCD = neck-shaft angle.

Table 4. Comparison of nominal data between hips with (Beck Grades 1 and 2) and without (Beck Grade 0) labral lesions

Parameter	Hips with labral lesions (n = 67)	Hips without labral lesions (n = 56)	Chi square value	Odds ratio (95% CI)
Crossover sign	42 (63%)	25 (45%)	0.152	0.836 (0.411, 1.812)
Posterior wall sign	40 (60%)	27 (48%)	0.013	1.043 (0.505, 2.154)
Ischial spine sign	32 (48%)	25 (45%)	0.122	1.141 (0.543, 2.400)
Superior asphericity	46 (69%)	37 (66%)	0.093	1.125 (0.528, 2.397)
Anterior asphericity	62 (93%)	48 (86%)	1.502	2.067 (0.636, 6.720)
AIWZ $\leq 0^\circ$	15 (22%)	9 (16%)	0.775	1.506 (0.603, 3.764)
AIWZ $\geq 10^\circ$	2 (3%)	2 (4%)	0.033	0.831 (0.113, 6.095)
CEA $\geq 39^\circ$	4 (6%)	5 (9%)	0.394	0.648 (0.165, 2.538)
CEA $\leq 25^\circ$	17 (25%)	18 (32%)	0.687	0.718 (0.327, 1.575)
LHEI ≤ 0.10	2 (3%)	2 (4%)	0.048	0.800 (0.109, 5.874)
LHEI ≥ 0.25	15 (22%)	11 (20%)	0.103	1.154 (0.481, 2.769)
CCD $< 126^\circ$	10 (15%)	6 (11%)	0.478	1.462 (0.496, 4.309)
CCD $> 139^\circ$	5 (8%)	5 (9%)	0.088	0.823 (0.226, 3.000)
Superior alpha angle $> 50^\circ$	47 (70%)	32 (57%)	2.246	1.763 (0.837, 3.710)
Anterior alpha angle $> 50^\circ$	54 (81%)	44 (79%)	0.077	1.133 (0.470, 2.731)
Superior offset < 9 mm	56 (84%)	49 (88%)	0.375	0.727 (0.262, 2.021)
Anterior offset < 9 mm	54 (81%)	50 (89%)	1.763	0.498 (0.176, 1.412)
Superior offset ratio < 0.17	58 (87%)	51 (91%)	0.614	0.632 (0.199, 2.008)
Anterior offset ratio < 0.17	56 (84%)	51 (91%)	1.512	0.499 (0.162, 1.535)

95% CI = 95% confidence interval; AIWZ = acetabular index of the weightbearing zone; CEA = center-edge angle; LHEI = lateral head extrusion index; CCD = neck-shaft angle.

Fig. 1 A bar graph shows distribution of the Tönnis osteoarthritis classification according to modified Beck grades.

more prevalent in hips with marked offset reduction or femoral head coverage or both.

Our study has several weaknesses. First, this is a retrospective review of patients' radiographs and surgical reports. However, as we included only patients with complete sets of preoperative radiographs with adequate exposure and we routinely describe labral and cartilage lesions in the surgical report forms, we do not think this is a

Fig. 2 A bar graph shows distribution of the Kellgren and Lawrence osteoarthritis classification according to modified Beck grades.

major drawback of the study. Furthermore, only plain radiographs were analyzed in this study. Although almost every patient undergoes MRI before surgical treatment for FAI at our institution, these MR images are not uniformly performed at our institution and thus were not available for all patients. In our experience and that of others, plain

radiographs are representative and depict the extent and location of the deformity sufficiently in most cases [4]. In a recent study of CT for assessment of femoral offset reduction, Konan et al. [15] found the alpha angle to be greater on frog-leg lateral radiographs than on CT, highlighting the importance of correct location of the three-dimensional reconstruction slices in CT and the value of plain radiographs. Furthermore, the finding that no hip in our study had a Grade 1 cartilage lesion could be related to the fact that all patients were operated on via open approaches and not arthroscopically. Therefore, Grade 1 cartilage lesions might have been underdiagnosed in our study. Finally, incomplete undersurface lesions to the labrum in hips operated on via the anterior approach might have escaped recognition in our study. A hook probe was used routinely as described above, thereby allowing identification of tears at the undersurface of the labrum. Fraying of the labrum and superficial disease affecting the undersurface exclusively might have escaped this method, however.

In our study, we found no correlation between measures of acetabular retroversion, coverage of the femoral head, or extent of cam deformity with the presence of labral lesions. Labral lesions were encountered in hips regardless of the extent of FAI-promoting deformity. This does not contradict the relation between bony deformity and labral lesions in general, as we did not intend to prove what already has been shown. All hips included in our study had FAI with either acetabular or femoral deformity or a mixture of both. Some studies suggest labral tears rarely occur in the absence of structural deformity [8, 30]. One study [29] analyzed the radiographs of patients with labral tears diagnosed either on MRI or CT arthrography or confirmed during surgery and found plain radiographic abnormalities in 87% of these cases. Structural abnormalities were present in all hips in our study, as this was a premise for the diagnosis of FAI and part of the indication for surgery. In another study [7] which used the contralateral asymptomatic hip for comparison, a lower center-edge angle and higher acetabular index of the weightbearing zone, lateral head extrusion index, and inclination of the acetabulum evident in the symptomatic hip were associated with the presence of a labral tear confirmed during surgery. This was true for dysplastic and nondysplastic hips, indicating hips with lesser coverage of the femoral head were more likely to have a symptomatic labral tear. The presence of a crossover sign was more common in hips with labral tears than on the unaffected side in nondysplastic hips and vice versa for dysplastic hips. Unfortunately, in the study by Guevara et al. [7], the presence of FAI was not verified by established clinical or radiographic criteria (eg, the alpha angle) and the absence of a labral tear of the asymptomatic contralateral sides was not confirmed radiographically (eg, with MRI). Nevertheless, the incidence of labral tears in

hip dysplasia has been determined to range between 48% and 72% [8, 18], and the association of a smaller center-edge angle with labral tears in hip dysplasia was confirmed by Jessel et al. [11]. Peelle et al. [23] also found hips with labral tears to have a smaller center-edge angle and higher lateral head extrusion index in comparison to asymptomatic controls, but no differences in femoral offset, offset ratio, or the incidence of acetabular retroversion were found. Similar to the study by Guevara et al. [7], labral lesions were not excluded by further diagnostic workup.

Our data further confirm the association of labral and cartilage lesions [19]. Furthermore, by converting the classification scheme of labral lesions described by Beck et al. [1] to an ordinal scale, a correlation between the degree of labral damage and the grade of acetabular chondromalacia was found. Finally, an association between the radiographic grade of osteoarthritis and the severity of labral lesions was found. The latter finding is in apparent contrast to Locher et al. [16], who found 20% of hips with relevant cartilage lesions to have unsuspecting radiographs. This leads to the assumption that, although the extent of labral alteration can be estimated from the radiographic osteoarthritis grade, the extent of cartilage alteration cannot. This hypothesis is supported by Wenger et al. [29], who found osteophytes to be present on plain radiographs in 55% of hips with labral tears. Lesions to the acetabular labrum are reported to be common in osteoarthritis and may occur rather early and enhance the arthritic process [18, 24].

No association was found between the extent of femoral or acetabular deformity in hips with FAI and the presence and extent of labral lesions. Labral lesions were found to be associated with age and the radiographic grade of osteoarthritis, alluding to the pivotal role the labrum has in cartilage preservation.

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