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Open Treatment of Femoroacetabular Impingement is Associated with Clinical Improvement and Low Complication Rate at Short-term Followup

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Abstract

Background Since the modern description of femoroacetabular impingement (FAI) a decade ago, surgical treatment has become increasingly common. Although the ability of open treatment of FAI to relieve pain and improve function has been demonstrated in a number of retrospective studies, questions remain regarding predictability of clinical outcome, the factors associated with clinical failure, and the complications associated with treatment.

Questions/purposes We therefore described the change in clinical pain and function after open treatment, determined whether failure of treatment and progression of osteoarthritis was associated with Outerbridge Grade IV hyaline cartilage injury, and described the associated complications.

Methods We retrospectively reviewed all 94 patients (96 hips) (55 males and 39 females; mean age, 28 years) who underwent surgical dislocation for femoroacetabular impingement between 2000 and 2008. Seventy-two of the 96 hips had acetabular articular cartilage lesions treated with a variety of methods, most commonly resection of damaged hyaline cartilage and labral advancement. Patients were followed for a minimum of 18 months (mean, 26 months; range, 18–96 months).

Results Mean Harris hip scores improved from 67 to 91 at final followup. Six of the 96 hips (6%) were converted to arthroplasty or had worse Harris hip score after surgical recovery. Four of these six had Outerbridge Grade IV acetabular cartilage lesions and two had Legg-Calvé-Perthes disease or slipped capital epiphysis deformities. Two hips (2%) had refixation of the greater trochanter.

Conclusions At short-term followup, open treatment for femoroacetabular impingement in hips without substantial acetabular hyaline cartilage damage reduced pain and improved function with a low complication rate. Treatment of Outerbridge Grade IV acetabular cartilage delamination remains the major challenge.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Femoroacetabular impingement (FAI), or abutment of the anterior femoral head-neck junction against the anterior acetabular rim or labrum [5, 15, 19, 20, 29, 39], has been the focus of increasing research in the past decade and is reportedly an etiologic factor in osteoarthritis (OA) of the hip [5, 10, 15, 24, 25, 31, 32, 40–42]. Because of this apparent relationship, Ganz et al., among others, have advocated early surgical intervention in symptomatic hips [15, 23, 31, 36, 40]. The surgical goal is to eliminate impingement of the femoral head-neck junction on the anterior acetabular rim by débriding the excessive osseous-chondral tissue from the femoral head-neck junction and/or the acetabular rim. Additionally, several investigators have

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described treatment of the associated chondrolabral injury frequently encountered in the anterosuperior quadrant of the acetabulum. Indeed, the prognosis of the hip may be directly related to the extent and severity of chondrolabral injury [5, 6, 12, 28, 31, 33, 36].

To allow for complete visualization of the intraarticular proximal femur and acetabulum, Ganz et al. [13, 16] described a safe method surgically dislocating the femoral head via a trochanteric flip osteotomy and anterior capsulotomy. The specific advantages of the approach are complete visualization and access for treating intraarticular femur and acetabulum without compromising the posterior-based blood supply to the femoral head [13, 16]. Since the original description of the surgical dislocation and osteochondroplasty (SDO) procedure, several investigators have reported low failure rates with minimal complications [3, 6, 8, 28, 33]. Beck et al. [6] reported five failures and no complications in 19 hips. Similarly, Bizzini et al. [8] reported no failures or complications in a small series of five professional hockey players while Murphy et al. [28] reported on 23 hips with seven failures and no complications. In our original series of 30 hips, we reported four failures and no complications [33]. Beaule et al. [3] reported six failures and no complications in his series of 37 hips. More recently, Graves and Mast [18] reported on 48 hips noting improvement in clinical scores in 96% without osteonecrosis or trochanteric nonunion.

In this study, we (1) describe the change in clinical pain and function after open treatment and determine whether failure rates are higher with increasing severity of hyaline cartilage injury noted at the time of surgery; (2) describe the progression of radiographic osteoarthrosis after open treatment and determine whether radiographic progression was related to Outerbridge Grade IV hyaline cartilage injury; and (3) describe the complications associated with open treatment.

Patients and Methods

We retrospectively reviewed all 94 patients (96 hips) with FAI treated with open surgical dislocation between 2000 and 2008. The type of impingement was predominately cam impingement in 33 hips, pincer impingement in six hips, and combined cam and pincer impingement in 57 hips. There were 39 females and 55 males with an average age of 28 years (range, 14–51 years) (Table 1). The right hip was involved in 56 patients, and the left in 40 patients. Two patients had bilateral staged procedures. The average patient height was 68.5 inches (range, 62–75 inches) and the average body mass index was 27.2 (range, 16.8–35.9). Eighteen patients (18 hips) had undergone prior procedures. The mean followup was 26 months (range, 18–96 months). Nine patients had less than 18 months of followup.

Table 1. Demographics and radiographic findings

Variable	Value
Age (years)*	28 (14–51)
Gender	56 males, 40 females
Cam	33
Pincer	6
Combined	57
Acetabular version	
Anteversion	48
Neutral	21
Retroversion	27
Positive posterior wall sign	40
Anterior center-edge angle*	34° (0°–90°)
Lateral center-edge angle*	33° (0°–63°)
Acetabular index*	6.9° (−16°–38°)
Alpha angle*	
AP	72° (32°–118°)
False profile lateral	66° (25°–150°)
Groin lateral	70° (32°–103°)
Tönnis grade	
Preoperative	
0	29
1	44
2	23
3	0
Final followup	
0	21
1	38
2	33
3	4

* Values are expressed as mean, with range in parentheses.

All patients with FAI presented with anterior groin pain with flexion activities such as sitting, squatting, or certain work-specific maneuvers. The impingement test, performed at 90° of flexion with internal rotation and adduction of the femur, produced pain in all patients [33, 35, 37]. Fluoroscopically guided intraarticular hip injection with local anesthetic and corticosteroid was used in most patients to corroborate an intraarticular source of pain.

Surgical dislocation was performed utilizing a lateral incision with greater trochanteric flip osteotomy with the patient in the lateral position on a radiolucent table. The short external rotators including the piriformis and posterior capsule were left intact. A Z-shaped anterior capsulotomy was performed with the superior limb of the capsulotomy taken from the acetabular origin and the inferior limb from the femoral attachment. The femoral head was dislocated anteriorly [13]. The proximal femur

was retracted posteriorly and the integrity of the acetabular labrum and hyaline cartilage was assessed.

The integrity of the acetabular labrum was assessed and damage was classified by the primary surgeon (CLP) as a labral tear, degeneration, detachment, calcification, or labral absence. Labral and acetabular cartilage lesions were described using the clock classification system [5, 26]. Eight-two of the 96 hips (85%) had an abnormal labrum: 44 detached labra, 15 tears, nine with labral degeneration, 10 calcified labra, and four absent labra secondary to débridement at prior arthroscopy. Fourteen hips had normal labra. Damage to the acetabular labrum or underlying articular cartilage consistently involved, but was not necessarily contained within, the anterosuperior quadrant (12 to 3 o'clock) of the acetabulum at the region of abutment of the femoral head-neck junction against the acetabulum. No contrecoup lesions [5] beyond Outerbridge Grade I or II were noted intraoperatively.

One of us (CLP—the operating surgeon) graded the size, character, and location of the acetabular articular cartilage damage according to the Outerbridge grading system of chondral injury [30]. Particular attention was paid to assess for acetabular hyaline cartilage delamination including wave phenomenon-type lesions without a free edge [2, 4]. Specific treatment of damaged acetabular articular cartilage evolved over the course of the study period as we gained experience in treating the chondral lesion most commonly associated with FAI [2].

Fifty-three of 72 acetabula with cartilage lesions underwent resection of the damaged or delaminated hyaline cartilage and the underlying subchondral bone to establish a stable edge of intact hyaline cartilage. Forty-three of these underwent concurrent labral refixation [11, 33]. The remaining 10 acetabula had thin, degenerative labra or deficient anterior labra from previous arthroscopy that could not be repaired. Of the 48 hips with Outerbridge Grade III or IV cartilage delamination, 11 underwent débridement of the delaminated articular cartilage and either microfracture of the acetabular subchondral bone (seven hips) or no specific bony treatment; the remaining 37 hips underwent rim resection [11, 33]. Osteochondroplasty of the femoral head-neck junction to improve femoral head-neck offset was performed in 95 of 96 hips (99%).

Five hips underwent planned, staged procedures commencing with SDO to address the cam impingement and associated acetabular hyaline cartilage damage, followed by periacetabular osteotomy (PAO) to reorient the position of the acetabulum [1, 14]. Three of these five hips had large acetabular delamination lesions diagnosed preoperatively by MR arthrography that were treated by resection of the acetabular rim and labral advancement [11, 33]. The resulting iatrogenic deficiency of acetabular coverage was treated by a planned staged PAO. The remaining two patients had Legg-Calvé-Perthes or Legg-Calvé-Perthes-like hips with severe cam deformities of the proximal femur, impingement of the greater trochanter, and deficient acetabular coverage. These patients were treated with SDO to address the femoral deformity followed by PAO to address the acetabular deficiency.

Patients were hospitalized an average of 3 days (range, 2–5 days). No drains were used, and dressings were removed on the second postoperative day. Anticoagulation included enoxaparin and foot compression boots as an inpatient. Patients were prescribed aspirin for 6 weeks after hospital discharge. Partial weightbearing was encouraged for 6 weeks with two crutches; then full weightbearing was allowed with one crutch or a cane until ambulation could be accomplished without a limp.

Patients were followed prospectively according to a clinical and radiographic protocol we have used for all patients treated for hip preservation since 1997. Clinical results were graded using the Harris hip score (HHS), measured by authors (JE, KS, LA) other than the operating surgeon preoperatively, at 6 months and 1 year postoperatively, and yearly thereafter. Clinical failure was defined as pending or actual progression to arthroplasty or a lower HHS at final followup when compared to the preoperative score.

All 96 hips had preoperative, postoperative, and followup (6-week, 6-month, and yearly) standing AP pelvis, false profile, and cross-table groin lateral radiographs [22, 27, 39]. We observed morphologic heterogeneity of the acetabulum and femur. Twenty-eight percent of hips were retroverted and 42% of hips had a posterior wall sign. The average lateral center-edge angle had a wide range (0°–63°) and it was greater than 15° in 90 of 96 hips, less than 20° in nine (eight of which were Legg-Calvé-Perthes hips), 20°–24° in 11, and greater than 24° in 85 hips. An os acetabuli [24] was present on seven of 96 hip radiographs (two acetabula were anteverted, two were neutral, and three were retroverted). There was relatively even distribution of preoperative Tönnis radiographic grade for OA for Grades 0 through 2 (Table 1). No acetabular delamination cysts were observed in retrospective review of preoperative radiographs [17], which may be related to patient selection for THA versus SDO in our series.

We compared the preoperative and postoperative HHS and the age of failed versus non-failed hips using Student's t test. We used Fisher's exact test to determine whether patients with Grade IV articular cartilage damage were more likely to have radiographic progression of OA than those with less grades and whether patients with Grade IV damage were more likely to have clinical failure. All of the collected data were analyzed using a commercially available software package (FileMaker® Pro 7.0, FileMaker,

Inc, Santa Clara, CA; and Microsoft® Excel®, Microsoft Corp, Redmond, WA).

Results

The average HHS improved ($p < 0.0001$) from a preoperative value of 67 (range, 43–87) to 91 (range, 48–100) at final followup. Six patients (six of 96 hips, 6.25%) were considered clinical failures because of worsening HHS or conversion to arthroplasty. Five of the six failures were among the first 30 patients treated. Five of the six failures were converted to arthroplasty (two at 3 months and one each at 1, 2, and 3 years postoperatively) (Table 2). A higher percentage ($p = 0.06$) of hips that had failed had Grade IV cartilage damage than those that survived: four of the six failed hips (Table 2) had severe acetabular articular cartilage delamination (Outerbridge Grade IV) while 35 of the 90 surviving hips had Outerbridge Grade IV changes. Treatment of the acetabular hyaline cartilage in the failed cases was as follows: two lesions were treated with cartilage flap resection and microfracture while two were treated with labral takedown, lesion resection, and labral advancement. The fifth failure had Outerbridge Grade 0 at time of SDO with combined impingement that went on to THA at an outside facility 3 years after SDO. The sixth failure was a patient with Legg-Calvé-Perthes disease with multiple previous surgeries who had deterioration of HHS at latest followup. When the one hip with slipped capital femoral epiphysis and one with Legg-Calvé-Perthes were eliminated, the average age at surgery of the patients with hips that went on to failure was older ($p = 0.017$) than that for the entire study group: 38.5 years versus 28 years, respectively. Only three of the six failures demonstrated worsening Tönnis grade before THA, and of those, one worsened one grade (Table 2).

At last followup, the Tönnis grade worsened in 25 of 96 hips (Table 3). Seventeen of these 25 hips (70.4%) had

Table 2. Clinical failures

Failure	Gender	Age (years)	Outcome	Outerbridge diagnosis	Cartilage treatment	Labrum diagnosis	Treatment	Tönnis grade	
								Preoperative	Postoperative
1	Female	41	THA	IV	Rim débridement	Normal	Takedown and repair	2	3
2	Male	32	THA	IV	Débridement and microfracture	Detached	Débridement only	1	1
3	Female	50	THA	IV	Microfracture	Normal		1	2
4	Male	20	Resurfacing arthroplasty	IV (slipped capital femoral epiphysis)	Rim débridement	Tear	Takedown and repair	2	2
5	Male	47	THA	0	None	Tear	Repair	1	2
6	Female	19	Decreased Harris hip score	I (Legg-Calvé-Perthes)	None	Detached	None	2	2

Table 3. Acetabular lesions by Outerbridge grade

Outerbridge grade	Number of hips with lesions	Cam	Pincer	Combined	Harris hip scores*		Tönnis grade change†
					Preoperative	Postoperative	
0	26	10	2	14	69 (53–87)	92 (71–100)	0–1 (2)
							1–2 (1)
I	15	7	2	6	60 (43–83)	86 (53–100)	0–1 (1)
II	7	3	0	4	67 (55–87)	88 (68–99)	1–2 (2)
III	9	5	0	4	66 (55–78)	85 (68–100)	1–2 (1)
							2–3 (1)
IV	39	19	2	18	68 (51–87)	91 (48–100)	0–1 (6)
							0–2 (2)
							1–2 (8)
							2–3 (1)

* Values are expressed as mean, with range in parentheses; †values are expressed as preoperative grade to postoperative grade, with number of hips in parentheses.

severe acetabular articular cartilage delaminations (Outerbridge Grade IV) at arthrotomy. Twenty-three of these 25 hips (92%) continue to function well with an improved HHS. In the 71 hips without radiographic progression, 24 had Outerbridge Grade IV lesions, seven had Grade III, and 40 had Grade 0 to II. We found a lower incidence ($p = 0.11$) of Outerbridge Grade IV lesions in the hips without radiographic progression of OA (24 of 71 hips, 35%) than those with progression (17 of 25 hips, 70%).

There were two complications related to fixation of the greater trochanter: one early failure of fixation due to failure to acquire cortical screw purchase distally in a female patient and one nonunion in a male patient. Both cases were treated with revision fixation with subsequent full recovery and improved HHS. There were no nerve palsies, infections, osteonecroses of the femoral head, or femoral neck fractures in the series. Estimated blood loss for the operations averaged 325 mL (range, 100–1500 mL).

Discussion

Recent evidence suggests altered hip morphology may be the primary etiology of hip OA in young adults [15, 23, 38, 40]. Impingement of the proximal femoral head-neck junction on the anterolateral acetabular rim results from abnormal morphology: primarily reduced femoral head-neck offset or a maloriented acetabulum or both [5, 15, 23, 25, 32, 33, 40, 41]. Treatment of FAI has focused on relief of femoroacetabular abutment and repair or débridement of damaged chondrolabral tissue [6, 7, 9, 11, 15, 28, 31–34]. In 2006, we reported on the first 30 patients treated by us with surgical dislocation [33]. This report represents an update of that series and includes a review of 96 consecutive hips treated from 2000 to 2008. The purposes of the current study were to (1) describe the change in clinical pain and function after open treatment and determine whether failure rates would be higher with increasing severity of hyaline cartilage injury at the time of surgery; (2) describe the progression of radiographic osteoarthrosis after open treatment and determine whether progression rates would be higher with increasing severity of hyaline cartilage injury; and (3) describe the complications associated with open treatment.

The major limitations of this report are twofold. First, this is an observational study of a case series of patients treated with an evolving surgical approach over an 8-year time period with no true control population. Second, although limited numbers of patients render the study underpowered to make strong statistical correlations between variables such as clinical improvement and severity of articular cartilage damage, the data suggest a trend for failed hips having Grade IV acetabular cartilage damage compared to those hips which did not fail. Moreover, because the study of FAI in general, and treatment methodology of FAI in particular, is relatively new, with little existing literature regarding treatment outcomes and predictors of failure, the current study should provide relevant information to individuals involved in the surgical treatment of patients with FAI.

Improvement of clinical pain and function after open treatment of FAI has been documented by several authors. Beck et al. [6] reported improved pain and function based on the Merle d'Aubigné-Postel hip score in 13 of 19 patients at a mean 4.7-year followup. Espinosa et al. [12] reported similarly improved Merle d'Aubigné-Postel hip scores in 60 hips treated with surgical dislocation and noted superior clinical results in hips with labral refixation rather than labral resection. In our original report of the first 30 patients treated with surgical dislocation, we noted an improvement in the HHS from 70 to 87 points at a minimum 2-year followup [33]. In the current series, the HHS improved from 67 to 91 at a mean 24-month followup. All of the aforementioned studies cited postulated that high grade acetabular hyaline cartilage damage was likely to be present in failed hips although none of the conclusions were statistically confirmed. We also observed a higher percentage of failed hips had Grade IV acetabular cartilage damage than those hips that did not fail and given the consistent findings in the studies suspect this relationship would be statistically significant with a greater numbers of hips.

The factors associated with radiographic deterioration of the hip in terms of arthrosis progression are less straightforward. In the original report of our first 30 patients, there was one Tönnis grade of progression in nine hips and two Tönnis grades of progression in one hip; eight of 10 hips with radiographic evidence of progression had Outerbridge IV hyaline cartilage delamination [33]. In the report of Espinosa et al. [12], there were more radiographic signs of OA in the patients treated with labral refixation (and presumably more aggressive treatment of the injured hyaline cartilage) than in the patients treated with labral resection. In the midterm result paper from Beck et al. [6], radiographic degenerative changes remained stable or improved in 17 of 19 hips, although several of these hips were converted to arthroplasty despite temporary radiographic improvement or stability. The apparent fact that radiographic progression of OA is a less precise indicator of impending failure of hip preservation surgery is paralleled by our data, which indicate some correlation between radiographic osteoarthrosis progression and more severe acetabular cartilage injury (Outerbridge Grade IV)

($p = 0.11$) but is confounded by the fact that 23 of the 25 hips (92%) with radiographic evidence of progression of OA continue to function well with an improved HHS (Table 3).

The low complication rate (2%) is also somewhat counterintuitive and yet reflected in the overall body of literature related to open treatment of FAI. If the reported results from the studies by Ganz et al. [13], Murphy et al. [28], Peters and Erickson [33], Beck et al. [6], Bizzini et al. [8], Beaule et al. [3], and Graves and Mast [18] on open treatment of FAI are combined, 148 hips are reported on with zero major complications. In the current series, the two complications were related to trochanteric fixation and were perhaps avoidable with better technique. Nevertheless, the low complication rate is comparable to what has been reported for less invasive arthroscopic treatment of FAI [7, 9, 21].

In summary, at short-term followup, open treatment for FAI in hips without substantial acetabular hyaline cartilage damage reduced pain and improved function with a low complication rate. Treatment of Outerbridge Grade IV acetabular cartilage delamination remains the major challenge. We believe multicenter studies evaluating the outcomes of débridement, microfracture, or rim resection with labral advancement are needed to fully characterize the best approach to treatment of damaged hyaline cartilage. Additionally, further research on the viability of the delaminated acetabular hyaline cartilage and cartilage restoration techniques may broaden and improve the options for joint restoration and salvage for the young patient with FAI.

References

1. Anderson LA, Crofoot CD, Erickson JA, Peters CL. Staged surgical dislocation and redirectional periacetabular osteotomy: a report of five cases. *J Bone Joint Surg Am.* 2009;91:2469–2476.
2. Anderson LA, Peters CL, Park BB, Stoddard GJ, Erickson JA, Crim JR. Acetabular cartilage delamination in femoroacetabular impingement. Risk factors and magnetic resonance imaging diagnosis. *J Bone Joint Surg Am.* 2009;91:305–313.
3. Beaule PE, Le Duff MJ, Zaragoza E. Quality of life following femoral head-neck osteochondroplasty for femoroacetabular impingement. *J Bone Joint Surg Am.* 2007;89:773–779.
4. Beaule PE, Zaragoza E, Copelan N. Magnetic resonance imaging with gadolinium arthrography to assess acetabular cartilage delamination. A report of four cases. *J Bone Joint Surg Am.* 2004;86:2294–2298.
5. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. *J Bone Joint Surg Br.* 2005;87:1012–1018.
6. Beck M, Leunig M, Parvizi J, Boutier V, Wyss D, Ganz R. Anterior femoroacetabular impingement: part II. Midterm results of surgical treatment. *Clin Orthop Relat Res.* 2004;418:67–73.
7. Bedi A, Chen N, Robertson W, Kelly BT. The management of labral tears and femoroacetabular impingement of the hip in the young, active patient. *Arthroscopy.* 2008;24:1135–1145.
8. Bizzini M, Notzli HP, Maffiuletti NA. Femoroacetabular impingement in professional ice hockey players: a case series of 5 athletes after open surgical decompression of the hip. *Am J Sports Med.* 2007;35:1955–1959.
9. Byrd JW, Jones KS. Prospective analysis of hip arthroscopy with 2-year follow-up. *Arthroscopy.* 2000;16:578–587.
10. Ecker TM, Tannast M, Puls M, Siebenrock KA, Murphy SB. Pathomorphologic alterations predict presence or absence of hip osteoarthrosis. *Clin Orthop Relat Res.* 2007;465:46–52.
11. Espinosa N, Beck M, Rothenfluh DA, Ganz R, Leunig M. Treatment of femoro-acetabular impingement: preliminary results of labral refixation. Surgical technique. *J Bone Joint Surg Am.* 2007;89 Pt 1 Suppl 2:36–53.
12. Espinosa N, Rothenfluh DA, Beck M, Ganz R, Leunig M. Treatment of femoro-acetabular impingement: preliminary results of labral refixation. *J Bone Joint Surg Am.* 2006;88:925–935.
13. Ganz R, Gill TJ, Gautier E, Ganz K, Krugel N, Berlemann U. Surgical dislocation of the adult hip a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. *J Bone Joint Surg Br.* 2001;83:1119–1124.
14. Ganz R, Klaue K, Vinh TS, Mast JW. A new periacetabular osteotomy for the treatment of hip dysplasias: technique and preliminary results. 1988. *Clin Orthop Relat Res.* 2004;418:3–8.
15. Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res.* 2003;417:112–120.
16. Gautier E, Ganz K, Krugel N, Gill T, Ganz R. Anatomy of the medial femoral circumflex artery and its surgical implications. *J Bone Joint Surg Br.* 2000;82:679–683.
17. Gdalevitch M, Smith K, Tanzer M. Delamination cysts: a predictor of acetabular cartilage delamination in hips with a labral tear. *Clin Orthop Relat Res.* 2009;467;4:985–991.
18. Graves ML, Mast JW. Femoroacetabular impingement: do outcomes reliably improve with surgical dislocations? *Clin Orthop Relat Res.* 2009;467:717–723.
19. Ito K, Minka MA, II, Leunig M, Werlen S, Ganz R. Femoroacetabular impingement and the cam-effect. A MRI-based quantitative anatomical study of the femoral head-neck offset. *J Bone Joint Surg Br.* 2001;83:171–176.
20. Kassarjian A, Yoon LS, Belzile E, Connolly SA, Millis MB, Palmer WE. Triad of MR arthrographic findings in patients with cam-type femoroacetabular impingement. *Radiology.* 2005;236:588–592.
21. Larson CM, Giveans MR. Arthroscopic management of femoroacetabular impingement: early outcomes measures. *Arthroscopy.* 2008;24:540–546.
22. Lequesne M, de S. False profile of the pelvis. A new radiographic incidence for the study of the hip. Its use in dysplasias and different coxopathies [in French]. *Rev Rhum Mal Osteoartic.* 1961;28:643–652.
23. Leunig M, Beck M, Dora C, Ganz R. Femoroacetabular impingement: trigger for the development of coxarthrosis [in German]. *Orthopade.* 2006;35:77–84.
24. Leunig M, Beck M, Woo A, Dora C, Kerboull M, Ganz R. Acetabular rim degeneration: a constant finding in the aged hip. *Clin Orthop Relat Res.* 2003;413:201–207.
25. Leunig M, Ganz R. Femoroacetabular impingement. A common cause of hip complaints leading to arthrosis [in German]. *Unfallchirurg.* 2005;108:9–10, 12–17.
26. Leunig M, Werlen S, Ungersbock A, Ito K, Ganz R. Evaluation of the acetabular labrum by MR arthrography. *J Bone Joint Surg Br.* 1997;79:230–234.

27. Mast JW, Brunner RL, Zebrack J. Recognizing acetabular version in the radiographic presentation of hip dysplasia. *Clin Orthop Relat Res.* 2004;418:48–53.
28. Murphy S, Tannast M, Kim YJ, Buly R, Millis MB. Debridement of the adult hip for femoroacetabular impingement: indications and preliminary clinical results. *Clin Orthop Relat Res.* 2004;429: 178–181.
29. Myers SR, Eijer H, Ganz R. Anterior femoroacetabular impingement after periacetabular osteotomy. *Clin Orthop Relat Res.* 1999;363:93–99.
30. Outerbridge RE. The etiology of chondromalacia patellae. 1961. *Clin Orthop Relat Res.* 2001;389:5–8.
31. Parvizi J, Leunig M, Ganz R. Femoroacetabular impingement. *J Am Acad Orthop Surg.* 2007;15:561–570.
32. Peters CL, Erickson J. The etiology and treatment of hip pain in the young adult. *J Bone Joint Surg Am.* 2006;88 Suppl 4:20–26.
33. Peters CL, Erickson JA. Treatment of femoro-acetabular impingement with surgical dislocation and debridement in young adults. *J Bone Joint Surg Am.* 2006;88:1735–1741.
34. Philippon M, Schenker M, Briggs K, Kuppersmith D. Femoro-acetabular impingement in 45 professional athletes: associated pathologies and return to sport following arthroscopic decompression. *Knee Surg Sports Traumatol Arthrosc.* 2007;15:908–914.
35. Philippon MJ, Maxwell RB, Johnston TL, Schenker M, Briggs KK. Clinical presentation of femoroacetabular impingement. *Knee Surg Sports Traumatol Arthrosc.* 2007;15:1041–1047.
36. Pulido L, Parvizi J. Femoroacetabular impingement. *Semin Musculoskelet Radiol.* 2007;11:66–72.
37. Siebenrock KA, Wahab KH, Werlen S, Kalhor M, Leunig M, Ganz R. Abnormal extension of the femoral head epiphysis as a cause of cam impingement. *Clin Orthop Relat Res.* 2004;418: 54–60.
38. Tannast M, Goricki D, Beck M, Murphy SB, Siebenrock KA. Hip damage occurs at the zone of femoroacetabular impingement. *Clin Orthop Relat Res.* 2008;466:273–280.
39. Tannast M, Siebenrock KA, Anderson SE. Femoroacetabular impingement: radiographic diagnosis—what the radiologist should know. *AJR Am J Roentgenol.* 2007;188:1540–1552.
40. Tanzer M, Noiseux N. Osseous abnormalities and early osteoarthritis: the role of hip impingement. *Clin Orthop Relat Res.* 2004;429:170–177.
41. Wagner S, Hofstetter W, Chiquet M, Mainil-Varlet P, Stauffer E, Ganz R, Siebenrock KA. Early osteoarthritic changes of human femoral head cartilage subsequent to femoro-acetabular impingement. *Osteoarthritis Cartilage.* 2003;11:508–518.
42. Wenger DR, Kishan S, Pring ME. Impingement and childhood hip disease. *J Pediatr Orthop B.* 2006;15:233–243.