Prevalence and Preoperative Demographic and Radiographic Predictors of Bilateral Femoroacetabular Impingement

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Prevalence and Preoperative Demographic and Radiographic Predictors of Bilateral Femoroacetabular Impingement

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Background: Patients with symptomatic femoroacetabular impingement (FAI) frequently have bilateral deformity and inquire about the prognosis of their contralateral, asymptomatic hip. Idiopathic coxarthrosis has been established as an independent risk factor for joint failure on the other side.

Purpose: To determine the prevalence of bilateral arthroscopic treatment for FAI and to identify predictive patient demographics and radiographic findings for bilateral, symptomatic disease.

Study Design: Case control study; Level of evidence, 3.

Methods: Over a 2-year period, patients receiving single-sided FAI surgery for pain and radiographic deformity were identified as unilateral. In the same period, patients undergoing their second side were labeled bilateral, regardless of when the first surgery was performed. Proximal femoral alpha angle; lateral center edge angle; sagittal center edge angle; acetabular version at 1, 2, and 3 o'clock; and femoral torsion were measured on preoperative computed tomography scans.

Results: The unilateral group included 514 patients, and the bilateral group included 132 patients. Women composed 48% of the unilateral group but only 35% of the bilateral group ($P = .006$). The mean age of unilateral patients was 30.3 (±10.7) years and 27.6 (±9.7) years for the first side of bilateral patients ($P = .010$). The bilateral hips had higher alpha angles (63.8° vs 59.8°, $P = .004$), less acetabular anteversion at the 3-o'clock position (13.0° vs 15.9°, $P < .001$), and similar femoral torsion (15.1° vs 15.5°, $P = .793$) compared with unilateral hips. A multivariable logistic regression model found that for every 5 years of younger age, 5° higher alpha angle, and 5° decrease in 3-o'clock acetabular version, patients were more likely to undergo bilateral treatment for FAI, by 13.5%, 14.5%, and 25.5%, respectively. In a side-to-side comparison of both hips in bilateral patients, alpha angle ($r = 0.72$) and acetabular version at 1 o'clock ($r = 0.73$) showed high correlation.

Conclusion: Male sex, younger age, higher alpha angles, and reduced acetabular anteversion at initial presentation are significant risk factors for identifying patients who may ultimately require bilateral surgery for symptomatic FAI. Among bilaterally treated patients, no radiographic parameters were predictive of which side would require treatment first. Patients with FAI requiring surgery should be closely monitored for contralateral hip disease.

Keywords: bilateral; FAI; hip arthroscopy; hip preservation

Femoroacetabular impingement (FAI) is a major cause of hip pain and restricted range of motion (ROM) in adolescents and adults.[37,39] The spectrum of bony abnormalities associated with FAI—cam and pincer impingement—can frequently lead to labral tears, articular cartilage degeneration, and subsequent osteoarthritis.[3,13,14] Current surgical treatment of FAI includes open, arthroscopic, and combined techniques.[9,12,23,30] These procedures aim to alleviate hip pain, improve range of motion, and preserve the long-term health of the joint.[21]

As the field of hip preservation evolves, patients and physicians frequently inquire about the prognosis of asymptomatic hips, contralateral to hips treated for FAI. Recent studies suggest that the presence of bilateral FAI is common.[9,20,32] Allen et al[1] reported a 77.8% incidence of bilateral FAI among patients with symptomatic cam impingement in at least 1 hip. In addition, idiopathic coxarthrosis has been established as an independent risk factor for degenerative joint disease on the contralateral side.[16] This is perhaps due to genetics acting through

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both joint structure and biological factors affecting the progression of the disease.[32]

Because patients undergoing surgical correction of FAI frequently inquire if their contralateral hip will also require hip arthroscopy, we posed the following questions: (1) What is the prevalence of bilateral arthroscopic treatment in a large, consecutive series of patients undergoing arthroscopic hip surgery to treat FAI? (2) Are there any patient demographic factors that increase the odds of eventual bilateral surgical treatment? (3) What radiographic findings are associated with hip joints that are treated bilaterally? (4) Among bilaterally treated patients, does the initial symptomatic hip operated on first have more advanced FAI than the second side?

Although there is a growing amount of evidence supporting the occurrence of bilateral FAI, the prevalence of bilateral hip arthroscopy to treat FAI remains poorly defined. On the basis of our observations, we hypothesized that younger, male patients would be more likely to undergo bilateral hip arthroscopies for FAI.

METHODS

All hip arthroscopies were prospectively tracked in our institutional review board–approved hip preservation registry. Specific information regarding patient demographics, radiographic measurements, and preoperative and intraoperative clinical findings was collected and reviewed. Over a 2-year period from January 2010 to December 2011, 516 patients receiving single-sided arthroscopic surgery to treat FAI were identified as unilateral. In the same period, 132 patients undergoing surgery on their second side were labeled as bilateral, regardless of when the first surgery was performed. All patients undergoing hip arthroscopy to treat pigmented villonodular synovitis, synovial chondramatosis, Legg-Calvé-Perthes disease, and slipped capital femoral epiphysis were excluded from the study. Patients with severe dysplasia or protrusio acetabuli were not considered arthroscopic candidates in the senior author's (B.T.K.) practice.

Relevant patient demographics were automatically collected through our electronic medical records system. Of the 514 unilateral patients, 248 were female and 266 were male. The average age for unilateral patients at the time of surgery was 30.77 ± 11.26 years (range, 10.96-70.27 years). In contrast, the bilateral patients were 65.2% male (86/132 patients) and had an average age of 27.6 ± 9.72 years (range, 17.13-56.78 years) at the time of the second, contralateral surgery. The average time between surgeries was 7.13 ± 10.5 months (range, 0.5-59.3 months).

All patients had standardized radiographs (anterior-posterior pelvis and elongated femoral neck views) and preoperative computed tomography (CT) scans with 3-dimensional (3D) volume-rendered reconstruction. Proximal femoral alpha angle; lateral center edge angle;[8] sagittal center edge angle; acetabular version at 1, 2, and 3 o'clock; and femoral version were measured on CT scans through the hip utilizing 0.625 mm slice thicknesses.[3] Musculoskeletal radiologists on staff measured these values preoperatively utilizing GE Advantage Windows Workstation, Volume Viewer software (General Electric Co, Fairfield, Connecticut). Axial oblique image sequences from the CT scan were used to measure alpha angles.[27]

Diagnosis of FAI was based on a combination of clinical and radiographic tests. A positive impingement test—pain with passive hip flexion, adduction, and internal rotation—and limited internal rotation (less than 15°) at 90° of hip flexion were both considered clinical signs of FAI. Radiographs were evaluated for the presence of an abnormal alpha angle (>50°)[2,19,27] and an acetabular crossover sign,[34] which were considered indicative of cam and pincer impingement, respectively.[26,40] Normal femoral anteversion was considered to be between 10° and 25°.[41] In addition, high-resolution, noncontrast magnetic resonance imaging (MRI) was frequently used to evaluate the extent of labral and chondral injury.[25,33]

All patients with symptoms related to FAI were first treated nonoperatively through activity modification, physical therapy, and intra-articular injection of anesthetic and corticosteroid. If nonoperative treatment failed to resolve symptoms, patients were then considered candidates for surgical treatment. Before surgery, all patients received an intra-articular injection to further localize the pain source, if not done previously. Acetabular dysplasia, posterior extension of cam lesions, and osteoarthritis greater than Tönnis grade 1 were all considered contraindications for arthroscopic treatment.

A single surgeon performed all hip arthroscopies. Patients were positioned supine on a traction table under spinal anesthesia. All procedures were performed through a standard (anterolateral, midanterior, and distal accessory) portal technique with arthroscopic and fluoroscopic visualization. The central compartment was addressed first after an interportal capsulotomy was made. The decision to perform an acetabuloplasty was based on bony structure defined by plain radiographs and 3D CT scans, as well as MRI findings. Intraoperatively, the need for decompression of the acetabular rim or anterior inferior iliac spine (AIIS) region was confirmed by the damage pattern of the labrum, observation of capsular-sided inflammation, and the presence of contre-coup lesions. Depending on the type and severity of labral injury, either a selective labral debridement or labral refixation was performed. In the peripheral compartment, exposure to the femoral neck was achieved through a "T" shaped capsulotomy. Decompression of the cam lesion was then performed to normalize head-neck offset. At the end of the case, the capsule was closed with nonresorbable sutures in a side-to-side fashion.

All patients were managed with a standardized postoperative rehabilitation program after hip arthroscopy. This included continuous passive motion and physical therapy geared toward restoring hip ROM and strength. Nonsteroidal anti-inflammatory drugs were administered as prophylaxis for heterotopic ossification (HO).[4] Patients were seen for follow-up at 10 days, 6 weeks, 3 months, 1 year, and 2 years. During follow-up visits, range of motion and manual resisted strength testing was performed on the involved

and contralateral hip. At 6 weeks and 1 year, radiographic images of the involved hip were obtained to rule out the presence of HO and confirm sufficient surgical correction of preoperative bony abnormalities.

Patients experiencing similar preoperative symptoms on their contralateral, nonoperative side were also evaluated for FAI. The indications for treatment of the contralateral side were determined by the same protocol utilized to diagnose the initial side. Bilateral FAI was managed with a staggered approach, with the most symptomatic and painful hip operated on first. The second side of bilateral surgery was performed at least 6 weeks later to minimize the risk of neurapraxia and other traction-related complications. The rationale for 6 weeks is based on typical progression through physical therapy and the observation that the majority of patients have regained near full range of motion, ambulatory strength, and a normal gait pattern without pain. Furthermore, at 6 weeks patients can safely proceed to full weightbearing on the initial surgical side, as required for surgery on the contralateral hip.

Descriptive statistics were calculated to examine demographic variables in the unilateral and bilateral cohorts. Means and standard deviations were reported for continuous variables, such as age and angle measurements, and the Wilcoxon rank sum test was used to examine differences in these variables between unilateral and bilateral patients. Frequencies and percentages were reported for categorical variables, with comparisons between groups performed using the Fisher exact test. A multivariable logistic regression model was developed to determine potential predictors of bilateral surgery. Pearson correlation coefficients were calculated to examine the relationship between CT measurements of each hip for bilateral patients. All analyses were performed using SAS Software version 9.2 (SAS Institute, Cary, North Carolina).

RESULTS

There were 514 patients in the unilateral group and 132 patients in the bilateral group, making 20.4% of all hip arthroscopies during the study period the second side treated in symptomatic patients. Women composed 48% of the unilateral group but only 35% of the bilateral group (P = .006). The odds ratio of male subjects treated for both hips compared with females was 1.7 (95% confidence interval [CI], 1.16-2.54). The mean age of unilateral patients was 30.3 (±10.7) years and 27.6 (±9.7) for the first side of bilateral patients (P = .010). There was no difference in age between men and women within either the unilateral (P = .313) or bilateral (P = .343) groups. A summary of the demographic data is presented in Table 1.

The mean alpha angle for bilateral patients was 63.8° (±13.1°; range, 33°-96°), compared with 59.8° (±12.4°; range, 28°-95°) in the unilateral group (P = .004). The bilateral group had significantly less acetabular anteversion at the 1-o'clock, 2-o'clock, and 3-o'clock positions. There was no significant difference in average femoral version and lateral center edge angle between the unilateral and bilateral patients. In a multivariable logistic regression model, higher alpha angle and less acetabular version at 3 o'clock were most predictive of bilateral surgery. Specifically, for every 5 years of younger age, 5° higher alpha angle, and 5° decrease in 3-o'clock acetabular version, patients were 13.5% (95% CI, 0.950-0.996), 14.5% (95% CI, 1.010-1.048), and 25.5% (95% CI, 0.919-0.980) more likely to undergo bilateral treatment for FAI, respectively. Focusing on men younger than 25 years and with alpha angle greater than 65°, 33% were in the bilateral group (odds ratio 2.1, P = .005). The CT-based radiographic parameters are summarized in Table 2.

TABLE 1
Patient Demographics

	Unilateral	Bilateral
Number of patients	514	132
Sex		
Male, % (No. of males/total)	51.8 (266/514)	65.2 (86/132)
Female, % (No. of females/total)	48.2 (248/514)	34.8 (46/132)
Age, mean ± standard deviation	30.32 ± 10.65	27.58 ± 9.72

Side-to-side comparison of CT measurements in the bilateral group showed that the bony deformity was not more pronounced in hip treated first. In fact, the alpha angle of the first side was highly correlated with the alpha angle of the contralateral hip, r = 0.72. The r values for acetabular anteversion at 1 o'clock, 2 o'clock, 3 o'clock, and femoral version were 0.73, 0.68, 0.65, and 0.62, respectively. Conversely, there was poor correlation in LCE and neck-shaft angle between the 2 sides in the bilateral patients. These findings are summarized in Table 3.

DISCUSSION

Femoroacetabular impingement is a well-established cause of hip pain and limited range of motion in adolescents and adults. In recent years, hip arthroscopy has become an increasingly popular method to surgically treat FAI because of favorable outcomes[5,6,18,22,29] and low complication rates.[4,7,35] Although the field of hip preservation has developed considerably, there is still a lack of information regarding the prevalence of bilateral hip arthroscopy to treat FAI. To characterize bilateral arthroscopic hip surgery, we posed the following questions: (1) What is the incidence of bilateral arthroscopic treatment in a large, consecutive series of patients undergoing arthroscopic hip surgery to treat FAI? (2) Are there any patient demographic factors that increase the odds of eventual bilateral surgical treatment? (3) What radiographic findings are associated with hip joints that are treated bilaterally? (4) Among bilateral patients, does the initial symptomatic hip operated on first have more advanced FAI than the second side?

The primary limitation for this study is the brief study period. Because of the 2-year window of our study design, there is a possibility that unilateral patients could undergo an additional surgery on their contralateral side at some point in the future. In this way, a segment of the unilateral group would cross over to bilateral over time. It is possible

TABLE 2
Summary of Computed Tomography Scan Analysis[a]

Variable	Unilateral Group		Bilateral Group (First Side)		P Value
	No. of Patients	Mean ± SD, deg	No. of Patients	Mean ± SD, deg	
Acetabular version					
At 1 o'clock	424	2.97 ± 9.44	100	–0.06 ± 9.14	.003
At 2 o'clock	426	10.79 ± 9.77	100	7.31 ± 9.77	.001
At 3 o'clock	425	15.86 ± 7.02	99	13.03 ± 7.42	<.001
Femoral version	422	15.46 ± 9.78	99	15.11 ± 7.8	.793
Alpha angle	426	59.77 ± 12.38	101	63.76 ± 13.07	.004
Sagittal center edge angle	427	54.25 ± 9.89	101	55.01 ± 9.23	.811
Lateral center edge angle	428	34.42 ± 14.59	101	32.75 ± 6.81	.907
Femoral neck shaft angle	426	131.07 ± 12.01	100	131.83 ± 4.54	.554

[a]SD, standard deviation.

TABLE 3
Side-to-Side Comparison of Patients Receiving Bilateral Arthroscopic Treatment of Femoroacetabular Impingement[a]

Variable	First Side		Second Side		No. of Patients With Measurements for Both Sides	Correlation Coefficient ($r \leq 1$)
	No. of Patients	Mean ± SD, deg	No. of Patients	Mean ± SD, deg		
Acetabular version						
At 1 o'clock	100	–0.06 ± 9.14	104	0.93 ± 9.2	83	0.73
At 2 o'clock	100	7.31 ± 9.77	104	9.29 ± 9.63	83	0.68
At 3 o'clock	99	13.03 ± 7.42	103	14.58 ± 6.39	83	0.65
Femoral version	99	15.11 ± 7.8	103	14.38 ± 8.16	82	0.62
Alpha angle	101	63.76 ± 13.07	104	63.88 ± 12.37	84	0.72
Sagittal center edge angle	101	55.01 ± 9.23	104	54.46 ± 9.30	84	0.62
Lateral center edge angle	101	32.75 ± 6.81	105	32.96 ± 6.77	84	0.23
Femoral neck shaft angle	100	131.83 ± 4.54	105	132.05 ± 4.04	84	0.21

[a]SD, standard deviation.

that the differences between the 2 groups would be even more pronounced in a longer, longitudinal study. Thus, a more accurate determination of the incidence of bilateral arthroscopy to treat FAI would likely follow patients for a longer period of time.

The overall prevalence of bilateral patients was 20.4% (132/646). Although various studies have commented on the occurrence of bilateral arthroscopy to treat FAI,[9,11,24,31,36] the prevalence in a large consecutive series of patients has yet to be reported in the literature. In a review of 2628 hip arthroscopies, Haviv and O'Donnell[17] identified 82 patients who underwent bilateral hip arthroscopy to treat cam-type impingement with at least 12 months of follow-up. Since the total amount of patients is not included, the prevalence of bilateral patients can only be roughly estimated. In future studies, depending on the surgeon's indications for treating bilateral FAI, the prevalence of bilateral patients may have varying values.

With regard to patient demographics, our findings indicate that male sex and younger age are good clinical markers for identifying patients who may require bilateral surgery. While the number of unilateral male patients (51.7%) and female patients (48.2%) were comparable, 65.2% (86/132) of the bilateral patients were male (Table 1). In the study by Haviv and O'Donnell,[17] 81.7% (67/82) of the bilateral patients were male. The higher prevalence among male patients is most likely related to the association between male sex and more severe FAI.[1,20,26] In addition, the mean age of bilateral patients on the date of surgery of the first side was approximately 3 years younger than the mean age of unilateral patients. This may suggest that bilateral patients develop symptoms that necessitate surgery at an earlier age than unilateral patients.

Our analysis of CT scan measurements demonstrates that increased alpha angles (63.8° vs 59.8°, $P = .004$) and decreased acetabular anteversion at 3 o'clock (13.0 vs 15.9, $P < .001$) are radiographic findings associated with bilateral patients. The alpha angle measures the asphericity of the femoral head and is a quantification of the degree of cam impingement. Higher alpha angles are associated with labral tears, hip pain, and on a long-term scale, more severe intra-articular disease.[10,13,26,27,42] Allen et al[1] reported that patients with bilateral FAI had a significantly higher mean alpha angle (70.4° vs 63°, $P < .001$) than patients with unilateral FAI. In addition, reduced acetabular anteversion can also cause impingement via

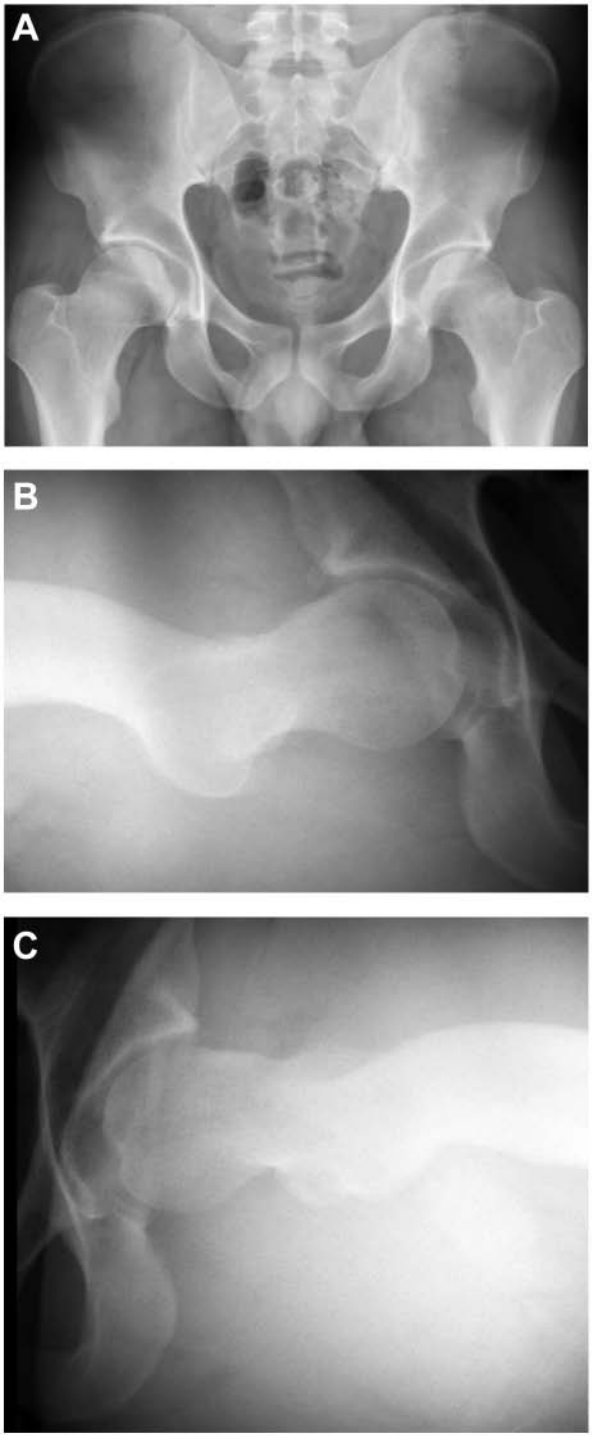

Figure 1. Preoperative radiographs. (A) Anteroposterior view of the pelvis and Dunn lateral view of the (B) right and (C) left hip. This is a 19-year-old male patient who had bilateral femoroacetabular impingement. There is marked acetabular retroversion and cam-type impingement, with a high degree of symmetry from side to side.

Figure 2. Postoperative radiographs. (A) Anteroposterior view of the pelvis and Dunn lateral view of the (B) right and (C) left hip. Bilateral labral repair, acetabular and femoral osteoplasties were performed. The right side was operated on first, followed by the left side approximately 6 weeks later. The patient experienced complete resolution of pain and improved hip range of motion in both hips.

an impaction-type mechanism.[14,15,38,41] Past literature reports that many patients with cam-type impingement also have reduced acetabular anteversion and other bony abnormalities of the acetabulum.[1,3,28] This study suggests that along with a higher alpha angle, reduced acetabular anteversion at 3 o'clock will predispose a unilateral patient to develop contralateral symptoms that require bilateral arthroscopic treatment.

Among patients with bilateral hip abnormalities, there was considerable similarity between the first operative side and second operative side (Table 2). FAI is often congenital and bilateral.[1,9,32,40] However, patients with bilateral FAI do not always show symptoms. Allen et al[1] reported 77.8% (88/113) of patients had bilateral cam deformity, but only 26.1% of those patients (23/88) experienced bilateral pain. The development of hip pain is multifactorial (eg, biological, lifestyle, trauma) and may or may not include predisposing bony pathomorphologic abnormalities. For instance, athletic patients will most likely develop symptoms on the hip that experiences more torque during sports-specific activity. For this reason, despite similar structure from side to side, FAI may present asynchronously.[40] Considering there are no radiographic parameters to predict which side should be treated first, surgeons should treat whatever side is more symptomatic during the physical examination.

Overall, the 20.4% prevalence of patients receiving bilateral arthroscopic treatment for FAI is noteworthy. While we recognize that this number may vary for different surgeons, we believe that patients with hip pain should be closely monitored for contralateral disease.[40] Hartofilakidis et al[16] found that a patient with idiopathic coxarthrosis is 2.3 times (95% CI, 0.1-9.4) more likely to develop coxarthrosisis in the contralateral hip. Male sex, younger age, higher alpha angles, and reduced acetabular anteversion at 3 o'clock are good clinical markers for identifying patients who may benefit from bilateral surgery (Figures 1 and 2). In patients with symptomatic bilateral FAI, the decision of which hip to treat first should be based on severity of pain and chance of successful hip preservation surgery. Our study indicated that there are no radiographic parameters found to predict which side should be operated on first. The goal of this study was to begin to define the prevalence and factors associated with bilateral arthroscopic treatment of FAI. We anticipate that future long-term studies will provide even more information about this important population of patients within the field of hip preservation.

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REFERENCES

1. Allen D, Beaule PE, Ramadan O, Doucette S. Prevalence of associated deformities and hip pain in patients with cam-type femoroacetabular impingement. *J Bone Joint Surg Br*. 2009;91:589-594.
2. Beaule PE, Zaragoza E, Motamedi K, Copelan N, Dorey FJ. Three-dimensional computed tomography of the hip in the assessment of femoroacetabular impingement. *J Orthop Res*. 2005;23:1286-1292.
3. 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.
4. Bedi A, Zbeda RM, Bueno VF, Downie B, Dolan M, Kelly BT. The incidence of heterotopic ossification after hip arthroscopy. *Am J Sports Med*. 2012;40:854-863.
5. Byrd JW, Jones KS. Arthroscopic femoroplasty in the management of cam-type femoroacetabular impingement. *Clin Orthop Relat Res*. 2009;467:739-746.
6. Byrd JW, Jones KS. Prospective analysis of hip arthroscopy with 10-year followup. *Clin Orthop Relat Res*. 2010;468:741-746.
7. Clarke MT, Arora A, Villar RN. Hip arthroscopy: complications in 1054 cases. *Clin Orthop Relat Res*. 2003;406:84-88.
8. Clohisy JC, Carlisle JC, Beaule PE, et al. A systematic approach to the plain radiographic evaluation of the young adult hip. *J Bone Joint Surg Am*. 2008;90(suppl 4):47-66.
9. Clohisy JC, Zebala LP, Nepple JJ, Pashos G. Combined hip arthroscopy and limited open osteochondroplasty for anterior femoroacetabular impingement. *J Bone Joint Surg Am*. 2010;92:1697-1706.
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. Fabricant PD, Heyworth BE, Kelly BT. Hip arthroscopy improves symptoms associated with FAI in selected adolescent athletes. *Clin Orthop Relat Res*. 2012;470:261-269.
12. 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.
13. Ganz R, Leunig M, Leunig-Ganz K, Harris WH. The etiology of osteoarthritis of the hip: an integrated mechanical concept. *Clin Orthop Relat Res*. 2008;466:264-272.
14. 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.
15. Hansen BJ, Harris MD, Anderson LA, Peters CL, Weiss JA, Anderson AE. Correlation between radiographic measures of acetabular morphology with 3D femoral head coverage in patients with acetabular retroversion. *Acta Orthop*. 2012;83:233-239.
16. Hartofilakidis G, Bardakos NV, Babis GC, Georgiades G. An examination of the association between different morphotypes of femoroacetabular impingement in asymptomatic subjects and the development of osteoarthritis of the hip. *J Bone Joint Surg Br*. 2011;93:580-586.
17. Haviv B, O'Donnell J. Arthroscopic treatment for symptomatic bilateral cam-type femoroacetabular impingement. *Orthopedics*. 2010;33:874.
18. Ilizaliturri VM Jr, Villalobos FE Jr, Chaidez PA, Valero FS, Aguilera JM. Internal snapping hip syndrome: treatment by endoscopic release of the iliopsoas tendon. *Arthroscopy*. 2005;21:1375-1380.
19. Johnston TL, Schenker ML, Briggs KK, Philippon MJ. Relationship between offset angle alpha and hip chondral injury in femoroacetabular impingement. *Arthroscopy*. 2008;24:669-675.
20. Kang AC, Gooding AJ, Coates MH, Goh TD, Armour P, Rietveld J. Computed tomography assessment of hip joints in asymptomatic individuals in relation to femoroacetabular impingement. *Am J Sports Med*. 2010;38:1160-1165.
21. Kelly BT, Bedi A, Robertson CM, Dela Torre K, Giveans MR, Larson CM. Alterations in internal rotation and alpha angles are associated with arthroscopic cam decompression in the hip. *Am J Sports Med*. 2012;40:1107-1112.
22. Larson CM, Giveans MR. Arthroscopic management of femoroacetabular impingement: early outcomes measures. *Arthroscopy*. 2008;24:540-546.

23. Laude F, Sariali E, Nogier A. Femoroacetabular impingement treatment using arthroscopy and anterior approach. *Clin Orthop Relat Res*. 2009;467:747-752.
24. McCarthy J, Barsoum W, Puri L, Lee JA, Murphy S, Cooke P. The role of hip arthroscopy in the elite athlete. *Clin Orthop Relat Res*. 2003;406:71-74.
25. Mintz DN, Hooper T, Connell D, Buly R, Padgett DE, Potter HG. Magnetic resonance imaging of the hip: detection of labral and chondral abnormalities using noncontrast imaging. *Arthroscopy*. 2005;21:385-393.
26. Nepple JJ, Carlisle JC, Nunley RM, Clohisy JC. Clinical and radiographic predictors of intra-articular hip disease in arthroscopy. *Am J Sports Med*. 2011;39:296-303.
27. Notzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. *J Bone Joint Surg Br*. 2002;84:556-560.
28. 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.
29. Philippon MJ, Briggs KK, Yen YM, Kuppersmith DA. Outcomes following hip arthroscopy for femoroacetabular impingement with associated chondrolabral dysfunction: minimum two-year follow-up. *J Bone Joint Surg Br*. 2009;91:16-23.
30. Philippon MJ, Stubbs AJ, Schenker ML, Maxwell RB, Ganz R, Leunig M. Arthroscopic management of femoroacetabular impingement: osteoplasty technique and literature review. *Am J Sports Med*. 2007;35:1571-1580.
31. Philippon MJ, Yen YM, Briggs KK, Kuppersmith DA, Maxwell RB. Early outcomes after hip arthroscopy for femoroacetabular impingement in the athletic adolescent patient: a preliminary report. *J Pediatr Orthop*. 2008;28:705-710.
32. Pollard TC, Villar RN, Norton MR, et al. Genetic influences in the aetiology of femoroacetabular impingement: a sibling study. *J Bone Joint Surg Br*. 2010;92:209-216.
33. Potter HG, Schachar J. High resolution noncontrast MRI of the hip. *J Magn Reson Imaging*. 2010;31:268-278.
34. Reynolds D, Lucas J, Klaue K. Retroversion of the acetabulum. A cause of hip pain. *J Bone Joint Surg Br*. 1999;81:281-288.
35. Sampson TG. Complications of hip arthroscopy. *Clin Sports Med*. 2001;20:831-835.
36. Sekiya JK, Martin RL, Lesniak BP. Arthroscopic repair of delaminated acetabular articular cartilage in femoroacetabular impingement. *Orthopedics*. 2009;32:pii.
37. Shindle MK, Voos JE, Nho SJ, Heyworth BE, Kelly BT. Arthroscopic management of labral tears in the hip. *J Bone Joint Surg Am*. 2008;90(suppl 4):2-19.
38. Siebenrock KA, Schoeniger R, Ganz R. Anterior femoro-acetabular impingement due to acetabular retroversion. Treatment with periacetabular osteotomy. *J Bone Joint Surg Am*. 2003;85:278-286.
39. Sink EL, Gralla J, Ryba A, Dayton M. Clinical presentation of femoroacetabular impingement in adolescents. *J Pediatr Orthop*. 2008;28:806-811.
40. Tannast M, Siebenrock KA, Anderson SE. Femoroacetabular impingement: radiographic diagnosis—what the radiologist should know. *AJR Am J Roentgenol*. 2007;188:1540-1552.
41. Tonnis D, Heinecke A. Acetabular and femoral anteversion: relationship with osteoarthritis of the hip. *J Bone Joint Surg Am*. 1999;81:1747-1770.
42. Wenger DE, Kendell KR, Miner MR, Trousdale RT. Acetabular labral tears rarely occur in the absence of bony abnormalities. *Clin Orthop Relat Res*. 2004;426:145-150.