RADIOGRAPHIC HIP OSTEOARTHRITIS IS PREVALENT, AND IS RELATED TO CAM DEFORMITY 12-24 MONTHS POST-HIP ARTHROSCOPY

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ABSTRACT

Background: The prevalence of radiographic hip osteoarthritis (OA), and its relationship with outcomes after hip arthroscopy is unclear.

Objectives: The aims of this study were to: (i) describe the prevalence of OA and cam deformity 12-24 months post hip arthroscopy; (ii) to determine the association between radiographic OA and cam deformity, surgical and clinical findings and symptoms; and (iii) describe the differences between legs for radiological and clinical findings.

Study Design: Cross sectional study

Methods: Seventy patients, mean age 36.7(range 18-59) years, 12-24 months post-arthroscopy.

Main outcome measures: Outcomes were collected prospectively via clinical and radiographic examination. (i)Prevalence of OA and cam deformity measured on and anteroposterior pelvic radiographs; (ii)Hip disability and Osteoarthritis Outcome Score (HOOS) and International Hip Outcome Tool (iHOT-33) patient-reported outcomes (PROs); (iii) hip internal and external rotation range of motion (ROM). Associations between OA and surgical findings, PROs and clinical findings were determined using generalized estimated equations, between operated and non-operated sides.

Results: The prevalence of OA was 37%. The likelihood of OA 12-24 months after surgery was positively associated with alpha angle size 12-24 months post-hip arthroscopy surgery ($p=0.010$). There were no differences between operated and non-operated legs in radiographic or clinical findings.

Conclusion: Radiographic OA is prevalent in a population which has undergone hip arthroscopy. Increased OA severity is associated with a higher alpha angle 12-24 months post-surgery.

Level of evidence: Cross-sectional study Level IV

Key words: Alpha angle, femoroacetabular impingement, hip arthroscopy, osteoarthritis

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Conflicts of Interest: None

INTRODUCTION

Hip osteoarthritis (OA) is a common joint disease, with an estimated overall prevalence in the general adult population of 11%.^{1,2} It is a significant cause of pain, stiffness and reduced function in the elderly.³ Symptomatic OA affects 9.6% of men and 18% of women aged 60 years or older, and with an aging population, the prevalence of OA will increase substantially,⁴ which is associated with growing economic, health and personal costs⁵. To date, no cure for hip OA has been found⁶. After OA onset, treatment options, involving non-pharmacological, and surgical treatment, are based on controlling pain, improving function and improving health-related quality of life.^{3,6-9}

Cam deformity is caused by extra bone formation in the anterolateral femoral head-neck junction and associated with an increased risk of OA.^{10,11} Femoro-acetabular impingement (FAI) is a clinical condition of hip and/or groin pain, associated with abnormal contact between the femoral head-neck junction and the acetabulum, due to a bone shape abnormality on either the femoral (cam impingement) or acetabular (pincer impingement) side.¹² Repeated abutment may cause pain and a cascade of structural damage, resulting in labral tears and cartilage degeneration, ultimately progressing to osteoarthritis of the hip.¹³⁻¹⁵ Therefore, cam deformity and associated impingement has been proposed as a biomechanical risk factor for the development of hip OA.¹³

Hip arthroscopy is now routinely performed for intra-articular hip pathology, including FAI, labral, and chondral pathology.^{16,17} The short term aim of arthroscopic surgery is to relieve pre-operative symptoms including pain and reduced physical function. The long term aim is prevention of repetitive injury to articular cartilage and thus, possibly reducing the risk of subsequently developing OA.¹⁸ Studies have indicated that the prevalence of chondropathy at surgery is 72%.¹⁹ The presence, and severity of chondropathy at the time of surgery is generally associated with poorer outcomes.^{20,21,22} As FAI is associated with an increased risk of hip OA¹¹ and its associated symptoms, it is important to determine whether morphology and pathology are also associated with hip OA in people who have undergone hip arthroscopy.

The aims of this study were to: (i) describe the prevalence of osteoarthritis (OA) and cam deformity 12-24 months post hip arthroscopy; (ii) to determine the association between radiographic OA and cam deformity, surgical and clinical findings and symptoms; and (iii) describe the differences between legs for radiological and clinical findings.

MATERIALS AND METHODS

Study design and participants

The study was of cross-sectional design. This study was funded by The Australian Physiotherapy Association, Physiotherapy Research Foundation Beryl Haynes Memorial Fund and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. This study was approved by The University of Melbourne Human Research Ethics Committee (HREC number 1033063) and The University of Queensland Medical Research Ethics Committee (MREC number 2012000708). The recruitment procedure has been described in detail previously.¹⁹ Between January 2009 and July 2011 all consecutive hip arthroscopy patients, aged between 18-60 years old, of one single orthopaedic surgeon (MGP) were invited to participate in the study. Letters of invitation were sent to patients 12-24 months after their surgery. Participants were excluded if their surgery converted to a total hip arthroplasty (THA), if they had further hip or other surgery or concurrent other lower limb injury, if they were unable to walk without assistance, or if they were unable to speak or read English. From this cohort participants, those who did not consent to have a radiograph taken post-arthroscopy were excluded. All participants provided written informed consent prior to commencing the study.

Procedure

Hip arthroscopy was performed by a single surgeon (MGP) in Hobart, Australia, with the patient in lateral decubitus position, with the hip abducted and slightly flexed while traction was applied. An arthroscope entered the central and peripheral compartments of the hip via a viewing mid-trochanteric portal and an instrument anterior trochanteric portal. The surgical technique used in this study has been reported previously, and used a standardized and systematic technique for the assessment and treatment of

intra-articular pathology, including labral pathology, FAI and chondropathy.¹⁹

Collection of this surgical data and collection of clinical, PRO and radiographic data was completed by a single investigator (JLK in a private physiotherapy clinic 12-24 months post-surgery, who was blinded to the surgical findings. Information regarding whether a surgical intervention was performed for intra-articular pathology, including cam deformity, labral pathology and chondropathy, was recorded from surgical notes. The presence of cam deformity at surgery was also noted. Clinical data included hip joint range of motion (ROM). This was measured as internal and external rotation (in 90 degrees of flexion), with a Plurimeter V gravity inclinometer (Dr Rippstein Company, Zurich, Switzerland) described in detail previously.²³ Patient-reported outcome questionnaire data collected included the Hip Osteoarthritis and Disability Outcome Score (HOOS) and the International Hip Outcome Tool (iHOT-33), which have both been shown to be reliable and valid tools for use in a hip arthroscopy population²².

Primary outcome measures: Radiographic measures of hip OA and FAI prevalence

Radiographic imaging 12-24 months post-arthroscopy consisted of scoring anterior-posterior pelvic radiographs for OA severity, using the Kellgren and Lawrence (KL) score and FAI, using the alpha angle. Radiographs were scored by a single investigator (FG) who was blinded to surgical, PRO and clinical data.

Kellgren and Lawrence score:

The hip images were graded from the anteroposterior view of the femoroacetabular joint on a scale from 0-4 using the Kellgren and Lawrence (KL) grading system.²⁴ Grade 1 and grade 2 K&L grade were classified as early OA, as detectable radiographic OA is considered to represent degenerative joint disease equivalent to OARSI grade 3.²⁵

Alpha angle

A cam deformity was quantified by using the alpha angle, which measures the degree of which the femoral head deviates from spherical. The alpha angle was calculated using a point set along the contour of the proximal femur, from which the alpha

angle was automatically calculated. This technique has been described previously²⁶ and ensures an unbiased measurement of the alpha angle. The alpha angle is measured by first drawing the best fitted circle around the femoral head and then drawing a line through the center of the neck and the center of the head. A second line is drawn from the center of the head to the point where the superior surface of the head-neck junction first departs from the fitted circle. The angle between these two lines is the alpha angle.²⁷ The radiographic cam-type deformity is considered to be present when the alpha angle is greater than 60°.²⁸

Reliability

The KL scoring and the point set of the SSM software were positioned in all radiographs by one investigator (FG, who was blinded to the other collected data. Reliability of this investigator was tested in 30 randomly selected radiographs of this study against a highly skilled investigator (10+ years experience) from the Erasmus Medical Center (Rotterdam) for the KL score. Reliability for the alpha angle measurements was tested in 40 randomly selected radiographs from the CHECK (Cohort Hip and Cohort Knee) study in Rotterdam, prior to the commencement of this study

Statistical analysis

All statistical calculations were performed using SPSS, version 20.0.0, (SPSS, Chicago, IL). The demographic and clinical characteristics of patients and PRO scores were recorded as means (standard deviation [SD]) and percentages. Multivariate stepwise regression analysis was utilised to determine the adjusted association between patient characteristics, surgical findings, radiographic findings, clinical ROM findings and radiographic OA prevalence. All analyses included covariates of age and gender. Bilateral surgery was accounted for in the analyses where appropriate, using a generalized estimating equation (GEE). The use of generalized estimating equations ensured every hip was an independent subject. Given the multiple testing in a small number of subjects, $p < 0.01$ was considered *a priori* as being statistically significant in regression analyses. The difference between the operated and non-operated leg for radiological and clinical measures

were determined using paired t-tests, in patients who underwent unilateral surgery only. In order to determine a difference between legs of $d=0.40$ and power of 0.80, a sample of 78 hips was required.

RESULTS

Three hundred, fifty-five patients were identified who underwent hip-arthroscopy between January 2009 and July 2011. 152 responded to the invitation, however 52 were excluded (one deceased, nine had moved away, 28 were too busy and four for other reasons); or they had further surgery or other injuries precluding their involvement (four underwent THA, three had other surgery, three had low back pain). Therefore 100 patients fulfilled eligibility criteria for the study. Of the 100 patients who entered the study cohort, 30 were excluded as they did not consent to x-ray post-arthroscopy. Seventy patients were included in this study (78 hips) (Figure 1). Sixty-two patients underwent unilateral surgery and eight patients underwent bilateral surgery). Patient characteristics are summarised in Table 1. The mean age at surgery was 36.7 years (range 18 to 59 years). The median alpha angle was 43 degrees 12-24 months

Figure 1. *Prisma Flow Chart.*

Table 1. Example of six week post operative interventions.	
Baseline characteristics	All participants (n=70) Mean (SD)
Age (y) at surgery	37 (12)
Gender (female), No (%)	38 (54)
Height (m)	1.73 (0.09)
Weight (kg)	77 (13)
BMI (kg/m2)	25.7 (3.7)
Waist (cm)	81 (9)
Physical activity (hours/week)	6 (5)
Labral surgery, No (%)	43 (61)
Cam deformity at surgery (presence of cam deformity on radiograph requiring surgical intervention), No (%)	31 (49)
Chondral intervention, No (%)	52 (74)
Bilateral surgery, No (%)	8 (11)
α angle in degrees, Median [IQR]	43 [37-49]
ROM(degrees)	
ER (90 degrees flexion)	37 (11)
IR (90 degrees flexion)	31 (10)
HOOS Symptoms	72 (18)
HOOS Pain	79 (17)
HOOS ADL	85 (16)
HOOS Sport and Recreation	69 (24)
HOOS Quality of Life	59 (24)
iHOT-33	67 (21)

SD = standard deviation; y = years; m = metres; kg = kilograms; BMI = body mass index (kg/m²); cm = centimetre; Nm/kg = Newton metres/kilograms; α =alpha; ROM = range of motion; ER = external rotation; IR = internal rotation; HOOS – Hip disability and Osteoarthritis Outcome Score; iHOT-33 = International Hip Outcome Tool.

post-arthroscopy. There were 38 female patients (54%). Eight patients (11%) had bilateral surgery, 75% of whom were men with a mean age of 21 years.

Radiology Findings

Reliability

The kappa score for inter-observer reliability was 0.75 for the KL score. The ICC score for inter-observer reliability for the alpha angle was 0.91.

Osteoarthritis

The overall prevalence of early hip OA (K&L grade 1 or 2) was 37%. Of the 78 included hips, 63% (n = 49) had no radiographic signs of hip OA (K&L grade 0), 35% (n = 27) had very mild radiographic hip OA (K&L

grade 1) and 3% (n=2) had mild radiographic hip OA (K&L grade 2) 12-24 months post-arthroscopy.

Cam impingement

Thirty one of 78 hips underwent femoral osteoplasty during arthroscopy to treat cam-type FAI diagnosed prior to or at surgery. At 12-24 months post-arthroscopy two men (5%) and one woman (3%) still had a cam deformity out of the group that underwent femoral osteoplasty.

As illustrated in Table 2, post-arthroscopic radiographs showed a statistically significant positive relationship between size of alpha angle and radiographic hip OA post-operatively (p=0.010). A positive trend towards chondral intervention at surgery (p=0.018), labral pathology at surgery (p=0.011) and radiographic hip OA post-arthroscopy was seen (where p<0.01 as determined *a priori*). Patient characteristics, clinical findings and symptoms were not significantly related to hip OA in this population. The odds ratios (% CIs) for clinical findings ranged from 0.90(0.83 to 1.02) to 0.99(0.95 to 1.02); while those for symptoms ranged from 0.98(0.96 to 1.01) to 1.00(0.98 to 1.02) (Table 2).

The differences between operated and non-operated leg (n=62 patients who underwent unilateral surgery) for the radiological and ROM outcomes are described in Table 3. There were no significant

Table 3. Differences between operated and non-operated leg for radiographic and ROM outcomes (n = 62).

measured	(mean[SD])	side (mean[SD])	sides (95% confidence interval; p)
Alpha angle	44[8]	47[11]	-3 (-6 to 1; p=0.055)
External rotation	36[10]	36[9]	0 (-2 to 2; p=0.799)
ROM			
Internal rotation	31[11]	33[9]	-2 (-4 to 1; p=0.223)
ROM			
SD = standard deviation; p=0.05; K&L – Kellgren and Lawrence; ROM = range of motion			

differences between sides for OA grade, alpha angle, IR ROM and ER ROM.

DISCUSSION

The results of this study indicate that radiographic hip OA in its early stages is common, affecting 37% of patients 18-60 years of age post-hip arthroscopy. A larger alpha angle was positively associated with severity of radiographic hip OA post-operatively. Despite unilateral surgery being performed in 62 participants, the operated and non-operated sides had similar ranges of motion and rates of hip OA, with a trend towards lower alpha angles in the operated legs.

Radiographic signs of early onset OA (K&L grade 1&2) were observed in 37% of the patients. Given that detectable radiographic OA (K&L grade 1&2) is considered to represent degenerative joint disease equivalent to at least OARSI grade 3²⁵, these findings suggest that the prevalence of early hip OA in this young to middle aged population is high, and has potential to impact pain, function and quality of life in this patient group in the future. Importantly, these findings indicated that older age was not associated with an increased likelihood of OA. In addition, a recent systematic review indicated that patients with mild to moderate hip OA are at greater risk of progressing to THA within two years of the primary hip arthroscopic procedure ²¹. Patients in this study are at an age of peak work and family commitments yet may be facing a future of degenerative hip disease, associated poor quality of life and eventually THA. Our findings indicate a higher prevalence of radiographic hip OA than the CHECK study, where 24% of the participants were diagnosed with early OA at baseline.¹¹ Given the

Table 2. Association between parameters and early radiographic OA (n = 78 hips).

OA parameters		value	OR	Lower	Higher
Surgical	Labral pathology	0.011	4.25	1.39	12.95
	Chondral intervention	0.018	5.03	1.31	19.30
	Osteotomy	0.468	1.40	.57	3.47
Radiographic	Alpha angle (in degrees)	0.010	1.08	1.02	1.15
Clinical	ROM; ER (90° flexion)	0.483	0.99	.95	1.02
	ROM; IR (90° flexion)	0.289	0.90	.83	1.02
Symptomatic	HOOS Symptoms	0.237	0.99	.96	1.01
	HOOS Pain	0.486	0.99	.96	1.02
	HOOS ADL	0.280	0.98	.96	1.01
	HOOS Sport and Recreation	0.503	0.99	.98	1.01
	HOOS Quality of Life	0.924	1.00	.98	1.02
	iHOT33	0.475	0.99	.97	1.02
ROM = range of motion; ER = external rotation; IR = internal rotation; P = P-value; OR = Odds Ratio; CI = Confidence interval; * p<0.01.					

mean age of this cohort (37 years), and our recent finding of a risk of progression to THA in patients with hip OA at arthroscopy,²¹ these findings raise concerns regarding the long-term hip joint health in this patient group.

Patient-reported outcomes of pain and function in this study were not associated with radiographic hip OA in the current study. Previous studies have reported an inconsistent relationship between early radiographic OA and patient characteristics, clinical findings and symptoms. Given previous findings where more severe cartilage disease predicted worse PROs¹⁹ in patients post hip arthroscopy, and patients with chondrolabral pathology had worse impairments in strength and range of motion,²³ it appears that more sensitive imaging measures to early stages of disease may be required, in order to identify factors that can alter hip joint disease progression. Imaging using 3.0T magnetic resonance imaging (MRI), scored using a semi-quantitative system such as the Scoring Hip OA with MRI (SHOMRI) can identify features of early hip OA.^{29,30} These include bone-marrow oedema, subchondral cysts, articular cartilage defects, paralabral cysts, and labral pathologies, all of which correlate with clinical features of hip OA.²⁹ The application of such measures into clinical practice may assist in this process in future.

A larger alpha angle was significantly associated with greater hip OA post-surgery. While the odds ratio was small (8% increased likelihood of OA in larger alpha angles), the narrow confidence intervals suggest the findings are precise, with the true effect somewhere between 1% and 15%. Future studies may choose to follow patients up beyond 24 months to explore this relationship. In post-operative knee injured groups, the onset of radiographic knee OA generally occurs 10-years after surgery,^{31,32} and it is possible similar time periods are needed to observe the onset of radiographic hip OA in people with cam morphology after hip arthroscopy surgery. In addition, when chondral or labral interventions were performed at the time of surgery, patients were four to five times more likely to have early radiographic OA, although these findings were not statistically significant (where $p < 0.01$). Given the wide confidence intervals associated with these findings, it is likely that the

true association may be closer to the lower CI (30%) for each of these findings. These findings appear to support previous work, which indicated a greater likelihood of chondral pathology when FAI or labral pathology were present at surgery, suggesting that patients with FAI and labral pathology represent hip OA in its early stages.¹⁹ To date, the efficacy of surgical and non-surgical interventions for altering hip joint disease progression remain unknown. These interventions require further investigation in high quality randomised controlled trials in order to determine the most efficacious treatments to slow hip joint disease progression in these patients.

There were no significant differences between the operated and non-operated leg for radiographic and ROM outcomes in the current study. Interestingly, there was also no association between ROM outcomes and radiographic hip OA. To the best knowledge of the authors, these findings have not been reported previously. Hip arthroscopy surgery may aim to reduce the size of the cam deformity (alpha angle) and thus improve hip joint ROM in patients with cam-type FAI.³³ Given that we found no difference between operated and non-operated sides after unilateral hip arthroscopy surgery, in either alpha angle or joint ROM, and no relationship between ROM and radiographic hip OA, it is possible that limits to joint range may be influenced by factors other than cam deformity size. These could include soft-tissue structures around the joint, and other morphological variants such as acetabular or femoral version. This study finding of reduced ROM not being associated with radiographic OA is in contrast to other studies.³⁴ This may be because the study quantified radiographic OA only, and did not classify patients based on measures of clinical OA, that were used in previous studies.³⁴ Studies measuring pre-operative to post-operative change in these parameters are needed to confirm this hypothesis.

The current study has some limitations. Firstly, the authors did not obtain pre-operative radiographs and therefore could not compare the pre-arthroscopic with the post-operative radiographs to compare osteoarthritic changes, or changes to the alpha angle following osteoplasty. Future studies should attempt to examine the change in OA between

the pre- and post-operative time points. Second, surgical outcomes were retrieved from the surgical notes of a single surgeon, potentially limiting the generalizability of these findings. However, a standardised and previously published surgical technique was used¹⁹ enhancing the reproducibility of these findings. Third, there were a small number of participants with radiographic hip OA (n=29) included in the regression analyses. Given this number, it was decided to use a p-value of 0.01 to delineate statistical significance. Associations between radiographic hip OA, and chondral or labral intervention neared statistical significance. Future studies with larger numbers may determine stronger associations between radiographic hip OA and these other parameters in this patient group. Patients were excluded from the study who had undergone total hip arthroplasty following the hip arthroscopy procedure. If these patients were included, the prevalence of hip OA may have been higher than that reported. Finally, 30 out of 100 people did not consent to x-ray, creating the possibility of inclusion bias. However, between-group analysis of participant characteristics of those included to those not included revealed no differences, providing confidence that the cohort included is representative of the whole group.

CONCLUSION

In conclusion, radiographic early OA is prevalent in a population who are 12-24 months post-hip arthroscopy and is positively associated with a larger alpha angle post-arthroscopy. Further prospective longitudinal studies are required to determine the influence of FAI and the arthroscopic intervention on the development of hip OA.

REFERENCES

1. Buckwalter JA, Saltzman C, Brown T. The impact of osteoarthritis: implications for research. *Clin Orthop Rel Res.* 2004(427 Suppl):S6-15.
2. Pereira D, Peleteiro B, Araujo J, Branco J, Santos RA, Ramos E. The effect of osteoarthritis definition on prevalence and incidence estimates: a systematic review. *Osteoarthritis Cart.* 2011;19(11):1270-85.
3. Zhang W, Moskowitz RW, Nuki G, Abramson S, Altman RD, Arden N, et al. OARSI recommendations for the management of hip and knee osteoarthritis, Part II: OARSI evidence-based, expert consensus guidelines. *Osteoarthritis Cart.* 2008;16(2):137-62.

4. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. *Bulletin of the World Health Organization.* 2003;81(9):646-56.
5. Reginster JY. The prevalence and burden of arthritis. *Rheumatology.* 2002;41 Supp 1:3-6.
6. Zhang W, Nuki G, Moskowitz RW, Abramson S, Altman RD, Arden NK, et al. OARSI recommendations for the management of hip and knee osteoarthritis: part III: Changes in evidence following systematic cumulative update of research published through January 2009. *Osteoarthritis Cart.* 2010;18(4):476-99.
7. Zhang W, Doherty M, Arden N, Bannwarth B, Bijlsma J, Gunther KP, et al. EULAR evidence based recommendations for the management of hip osteoarthritis: report of a task force of the EULAR Standing Committee for International Clinical Studies Including Therapeutics (ESCISIT). *Annals Rheum Dis.* 2005;64(5):669-81.
8. Bijlsma JW, Berenbaum F, Lafeber FP. Osteoarthritis: an update with relevance for clinical practice. *Lancet.* 2011;377(9783):2115-26.
9. Fernandes L, Hagen KB, Bijlsma JW, Andreassen O, Christensen P, Conaghan PG, et al. EULAR recommendations for the non-pharmacological core management of hip and knee osteoarthritis. *Annals Rheum Dis.* 2013;72(7):1125-35.
10. Ganz R, Leunig M, Leunig-Ganz K, Harris WH. The etiology of osteoarthritis of the hip: an integrated mechanical concept. *Clin Orthop Rel Res.* 2008;466(2):264-72.
11. Agricola R, Waarsing JH, Arden NK, Carr AJ, Bierma-Zeinstra SMA, Thomas GE, et al. Cam impingement of the hip-a risk factor for hip osteoarthritis. *Nat Rev Rheumatol.* 2013;9(10):630-4.
12. Gosvig KK, Jacobsen S, Sonne-Holm S, Gebuhr P. The Prevalence of Cam-Type Deformity of the Hip Joint: A Survey of 4151 Subjects of the Copenhagen Osteoarthritis Study. *Acta Radiologica.* 2008;49(4):436-41.
13. Doherty M, Courtney P, Doherty S, Jenkins W, Maciewicz RA, Muir K, et al. Nonspherical femoral head shape (pistol grip deformity), neck shaft angle, and risk of hip osteoarthritis: a case-control study. *Arthritis Rheum.* 2008;58(10):3172-82.
14. 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 Jt Surg (B)* 2005;87(7):1012-8.
15. Tannast M, Siebenrock KA, Anderson SE. Femoroacetabular impingement: radiographic diagnosis-what the radiologist should know. *AJR.* 2007;188(6):1540-52.

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16. Weber AE, Jacobson JA, Bedi A. A review of imaging modalities for the hip. *Current Rev Musculoskel Med*. 2013.
 17. Byrd JW, Jones KS. Prospective analysis of hip arthroscopy with 10-year followup. *Clin Orthop Rel Res*. 2010;468(3):741-6.
 18. Bardakos NV, Vasconcelos JC, Villar RN. Early outcome of hip arthroscopy for femoroacetabular impingement: the role of femoral osteoplasty in symptomatic improvement. *J Bone Jt Surg(Br)*. 2008;90(12):1570-5.
 19. Kemp JL, Makdissi M, Pritchard MG, Schache AG, Pollard TCB, Crossley KM. Chondropathy of the hip at arthroscopy: prevalence and relationship to labral pathology, femoro-acetabular impingement and patient-reported outcomes. *Br J Sports Med*. 2014;48(11):1102-7.
 20. Kemp JL, Collins NJ, Makdissi M, Schache AG, Machotka Z, Crossley K. Hip arthroscopy for intra-articular pathology: a systematic review of outcomes with and without femoral osteoplasty. *Br J Sports Med*. 2012;46(9):632-43.
 21. Kemp JL, MacDonald D, Collins N, Hatton AL, Crossley KM. Hip Arthroscopy in the Setting of Hip Osteoarthritis: Systematic Review of Outcomes and Progression to Hip Arthroplasty. *Clin Orthop Rel Res*. 2014;473:1055-1073.
 22. Kemp JL, Collins NJ, Roos EM, Crossley KM. Psychometric Properties of Patient-Reported Outcome Measures for Hip Arthroscopic Surgery. *Am J Sports Med*. 2013.
 23. Kemp JL, Schache A, Makdissi M, Pritchard M, K. S, Crossley K. Is hip range of motion and strength impaired in people with hip chondrolabral pathology? *J Musculoskel Neur Interact*. 2014;14(3):334-42.
 24. Altman RD, Gold GE. Atlas of individual radiographic features in osteoarthritis, revised. *Osteoarthritis Cart*. 2007;15 Suppl A:A1-56.
 25. Pritzker KP, Gay S, Jimenez SA, al e. Osteoarthritis cartilage histopathology: grading and staging. *Osteoarthritis Cart*. 2006;14:13-29.
 26. Agricola R, Bessems JH, Ginai AZ, Heijboer MP, van der Heijden RA, Verhaar JA, et al. The development of Cam-type deformity in adolescent and young male soccer players. *Am J Sports Med*. 2012;40(5):1099-106.
 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 Jt Surg(Br)*. 2002;84(4):556-60.
 28. Agricola R, Waarsing JH, Thomas GE, Carr AJ, Reijman M, Bierma-Zeinstra SM, et al. Cam impingement: defining the presence of a cam deformity by the alpha angle: data from the CHECK cohort and Chingford cohort. *Osteoarthritis Cart*. 2014;22(2):218-25.
 29. Schwaiger BJ, Gersing AS, Lee S, Nardo L, Samaan MA, Souza RB, et al. Longitudinal assessment of MRI in hip osteoarthritis using SHOMRI and correlation with clinical progression. *Seminars in Arthritis Rheum*. 2016;45(6):648-55.
 30. Lee S, Nardo L, Kumar D, Wyatt CR, Souza RB, Lynch J, et al. Scoring hip osteoarthritis with MRI (SHOMRI): A whole joint osteoarthritis evaluation system. *J Magn Reson Imaging*. 2015;41:1549-57.
 31. Øiestad BE, Engebretsen L, Storheim K, Risberg MA. Knee osteoarthritis after anterior cruciate ligament injury: A systematic review. *Am J Sports Med*. 2009;37(7):1434-43.
 32. Øiestad BE, Holm I, Engebretsen L, Risberg MA. The association between radiographic knee osteoarthritis and knee symptoms, function and quality of life 10-15 years after anterior cruciate ligament reconstruction. *Br J Sports Med*. 2011;45(7):583-8.
 33. Ross JR, Larson CM, Adeoye O, Kelly BT, Bedi A. Residual deformity is the most common reason for revision hip arthroscopy: a three-dimensional CT study. *Clin Orthop Rel Res*. 2015;473(4):1388-95.
 34. Holla JFM, Steultjens MPM, van der Leeden M, Roorda LD, Bierma-Zeinstra S, den Broeder AA, et al. Determinants of range of joint motion in patients with early symptomatic osteoarthritis of the hip and/or knee: an exploratory study in the CHECK cohort. *Osteoarthritis Cart*. 2011;19:411-9.
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