A traffic light grading system of hip dysplasia to predict the success of arthroscopic hip surgery.

ABSTRACT

Background: The role of hip arthroscopy in dysplasia is controversial.

Purpose: Determine the 7-year joint preservation rate following hip arthroscopy in hip dysplasia and identify anatomical and intra-operative features that predict success of hip preservation with arthroscopic surgery allowing formulation of an evidence-based classification.

Study Design: Cohort Study; Level of evidence: 3

Methods: Between 2008 and 2013, 111 hips with dysplastic features [acetabular index (AI) > 10° and/or centre-edge angle (CEA) <25°] having undergone an arthroscopy were identified. Clinical, radiological and operative findings and type of procedure performed were reviewed. Radiographic evaluations of the operated hip [acetabular index (AI), centre-edge angle (CEA), extrusion index] were performed. Outcome measures included whether the hip was preserved at follow-up, pre- and post-operative NAHS and HOOS scores.

We calculated AI and CEA factored (AI_f and CEA_f respectively) by a measure of articular wear as follows:

AI_f = AI x (number of UCL wear zones +1)

CEA_f = CEA / (number of UCL zones + 1)

A contour plot of the resulting probability value of failure for every combination of AI_f and CEA_f allowed for the determination of the zones with the lowest and highest incidence of failure to preserve the hip respectively.

Results: The mean AI and CEA were 7.8**°** and 18.0**°,** respectively. At a mean follow-up of 4.4 years, 33 hips had failed requiring a hip arthroplasty. The 7- year joint survival was 68%. The mean improvement in NAHS and HOOS were 7.8 and 23 points respectively.

The zone with the greatest chance of joint preservation (odds ratio: 10, p<0.001) was AI_f: 0 – 15 and CEA_f: 15 – 25 (Green Zone); on the contrary the zone with the greatest chance of failure (odds ratio: 10, p<0.001) was AI_f: 20 – 100 and CEA_f : 0 – 10 (Red Zone).

Conclusion: Overall, the 7- year hip survival in hip dysplasia appears inferior compared to reports of Femoro-Acetabular Impingement cases. Hip arthroscopy is associated with excellent chance of hip preservation in mild (Green Zone) dysplasia (AI< 15° & CEA: 15 – 25°) and no (or little) articular wear. Hip arthroscopy should not be performed in cases with severe (Red Zone) dysplasia (AI> 20° & CEA< 10°).

Keywords: hip arthroscopy; dysplasia; hip preservation; outcomes

What is known about the subject:

Acetabular dysplasia presents in great variability. Arthroscopic treatment of dysplastic hips is controversial, with mixed results in early-term studies. To-date no evidence-based guidelines exist in order to quantify the degree of Dysplasia.

What this study adds to existing knowledge:

The 7-year preservation rate with arthroscopy in hip dysplasia is 68% (inferior to FAI treatment). Articular wear and extent of dysplasia predicted failure to preserve the hip. This study provides the reader with an evidence-based algorithm on when hip arthroscopy can be offered in the setting of hip dysplasia. Hips with AI <15° and CEA ≥15° have good chances of joint preservation with arthroscopy provided no articular wear exists and no labral debridement takes place.

Introduction

The desire to achieve hip preservation with symptomatic hip conditions has been associated with a steep rise in the uptake of hip arthroscopy over recent years[7]. Numerous reports have demonstrated the effectiveness of arthroscopic hip surgery in dealing with a variety of femoral and acetabular deformities and their associated pathological features (e.g. chondro-labral lesions)[4, 25, 35, 42]. However, up to 37% of these hips may subsequently 'fail' and require an arthroplasty within 10-yrs[29]. Factors associated with an increased risk of arthroscopic failure include advanced age, established degenerative changes within the joint and the presence of dysplasia[2, 17, 29].

Although hip arthroscopy can effectively address the bony deformities of femoro-acetabular impingement (FAI) (e.g. acetabular rim-trim, cam- and subspinous-resection), it does not allow for augmenting the deficient acetabulum, the primary pathology in the dysplastic hip. Accordingly, in a recent study reviewing all causes of failed hip arthroscopy, dysplasia was the second most common cause (24%) after persistent/unaddressed FAI (43%)[2].

Acetabular hip dysplasia covers a spectrum of deformity and is considered to be present when the centre-edge angle (CEA) is less than 25° and/or acetabular index [(AI) or Tönnis angle] is greater than 10°[3, 14]. In severe cases, a peri-acetabular osteotomy may be necessary in order to alleviate symptoms; a treatment associated with very good chance of joint preservation and restoration of function, albeit associated with significant peri-operative risks[19, 39]. In contrast, the ideal treatment modality (i.e. osteotomy or not) for the moderate/mild case is not as well defined.

Arthroscopic treatment in the dysplastic hip has been associated with mixed results[3, 9, 11-13, 21, 26, 32, 37]. Some authors describe little symptomatic improvement and high failure rates within 3 years post-surgery[34]. These cases were associated with debridement of the labrum, which provides a significant contribution to joint stability in dysplastic hips, and so is now not recommended practice. In contrast, others have demonstrated that symptomatic improvement can be achieved in particular when labral repair and capsular plication takes place, in addition to addressing any other pathology (e.g. cam resection)[9, 26]. This may be because the pathology primarily contributing to the patient's symptoms may not be the dysplasia. It has been shown that the presence of a cam lesion and the associated FAI can be the predominant pathology even in hips with shallow acetabulae[10, 31].

Defining the role of arthroscopy in dysplasia and identifying the parameters that increase the chances of success would aid surgical decision-making and therefore potentially improve outcomes. The aims of this study were to: 1. Determine the 7-year joint preservation rate following hip arthroscopy in a cohort of dysplastic hips, 2. Identify anatomical and peri-operative features predictive of success in preserving the hip with arthroscopic surgery in such cohort and 3. Create an evidence-based algorithm for the treatment of the symptomatic dysplastic hip.

Methods

This is a retrospective, single-surgeon, consecutive, case series from a tertiary referral centre. This was a service evaluation and so did not require NHS Research Ethics Committee (REC) or NHS/HSC R&D office or HRA Approval (http://www.hra.nhs.uk/research-community/before-you-apply/determine-whether-your-study-is-research/#sthash.UDz6enkk.dpuf). The senior author set up the hip arthroscopy service in 2002, and in January 2008 a hospital database was set up that prospectively records data on all hip arthroscopies performed. We retrieved from this database all hip arthroscopies (n=377) performed between 2008 and 2013, by the senior author, ensuring a minimum 2-year follow-up period. Inclusion criterion for this study was the presence of radiographic features of dysplasia (AI > 10° and/or CEA <25°). Exclusion criteria included previous history of Legg-Calve-Perthes' Disease, advanced degenerative changes based on radiographic evaluation (<2 mm joint space). From the retrieved cases, we identified 112 hips (108 patients) that fulfilled the above criteria and these formed the study cohort.

Demographic data was obtained for all patients and is detailed in Table 1. All procedures were performed in the supine position using a two portal (antero-lateral and anterior) technique. Typically, following the diagnostic round, a limited capsulotomy to enlarge each portal (but not join them) was performed to aid the carrying out of therapeutic interventions. No T-capsulotomy or limb extension to the capsulotomy took place in any of the cases. The peripheral compartment was fully assessed in all cases. The operative findings are detailed in Table 2. The most common finding was that of labral tear (n=105, 95%) followed by acetabular cartilage wear in 54 hips (49%), the extent of which was graded using the UCL system[24]. The type of therapeutic intervention performed is detailed in Table 2. The most common intervention was femoral osteochondroplasty (81%). The limited capsulotomy was not repaired at the end of the procedure and no ligamentum teres reconstruction nor capsular plication took place in any of the cases. Labral repair was always carried out in preference to debridement (Figure 1). Post-operatively, patients were allowed to fully weight bear unless a microfracture took place, when weight bearing was restricted for up to 6 weeks. All patients were reviewed by a physiotherapist with a specialist interest in hip pathology prior to discharge and were provided with dedicated hip and abdominal core exercises. They were regularly reviewed in the outpatients setting by both the physiotherapy and surgical team for at least 1-year following surgery.

Factor		**Cohort (n=111)**	**Groups**		**p-value**
			Preserved (n=78)	**Failed (n=33)**	
Age/ years (mean, range)		40.9 (16 – 65)	39.6 (16 – 65)	44.0 (23 – 63)	0.04*
Age Group	<40 years old	33	34	9	0.1
	≥ 40 years old	68	44	24	
Gender	Male	33	27	6	0.08
	Female	78	51	27	
Follow-up/ years (mean, range)		4.4 (0.4 – 8.3)	5.5 (3.3 – 8.3)	1.8 (0.4 – 6.8)	<0.001*
Side	Right	56	37	19	0.3
	Left	55	41	14	

Table 1: Demographics as per whole cohort and per group (hip preserved or failed). *: Statistical significant difference

Factor		**Cohort (n=111)**	**Groups**		**p-value**
			Preserved (n=78)	**Failed (n=33)**	
Labral Tear	No	6 (5)	3 (4)	3 (9)	0.3
	Yes	105 (95)	75 (96)	30 (91)	
Location of labral tear	Anterior	37 (33)	27 (35)	10 (30)	0.02*
	AS	25 (23)	22 (28)	3 (9)	
	Superior	23 (21)	18 (23)	5 (15)	
	PS	1 (1)	0	1 (3)	
	Posterior	8 (7)	4 (5)	4 (12)	
	Circumferential	11 (10)	4 (5)	7 (21)	
Labral Repair	No	59 (56)	40 (53)	19 (63)	0.35
	Yes	46 (44)	35 (47)	11 (37)	
Femoral head cartilage wear	No	70 (63)	56 (72)	14 (42)	0.003*
	Yes	41 (37)	22 (28)	19 (58)	
Acetabular cartilage wear	No	57 (51)	49 (63)	8 (24)	<0.001*
	Yes	54 (49)	29 (37)	25 (76)	
No. of acetabular zones with wear		0.9 (1 – 5)	0.7 (0 – 5)	1.4 (0 – 3)	<0.001*
Zone location of acetabular wear	2	8 (7)	5 (6)	3 (9)	0.01*
	3	11 (10)	7 (9)	4 (12)	
	4	2 (2)	2 (3)	0	
	5	2 (2)	1 (1)	1 (3)	
	6	2 (2)	2 (3)	0	
	2-zones	15 (14)	4 (5)	11 (37)	
	≥3 –zones	14 (13)	8 (10)	6 (18)	
Microfracture	No	83 (75)	59 (76)	24 (73)	0.75
	Yes	28 (25)	19 (24)	9 (27)	
Osteochondroplasty	No	21 (19)	11 (14)	10 (30)	0.046*
	Yes	90 (81)	67 (86)	23 (70)	

Table 2: Operative findings and surgical procedure performed for the whole cohort and sub-divided by outcome.

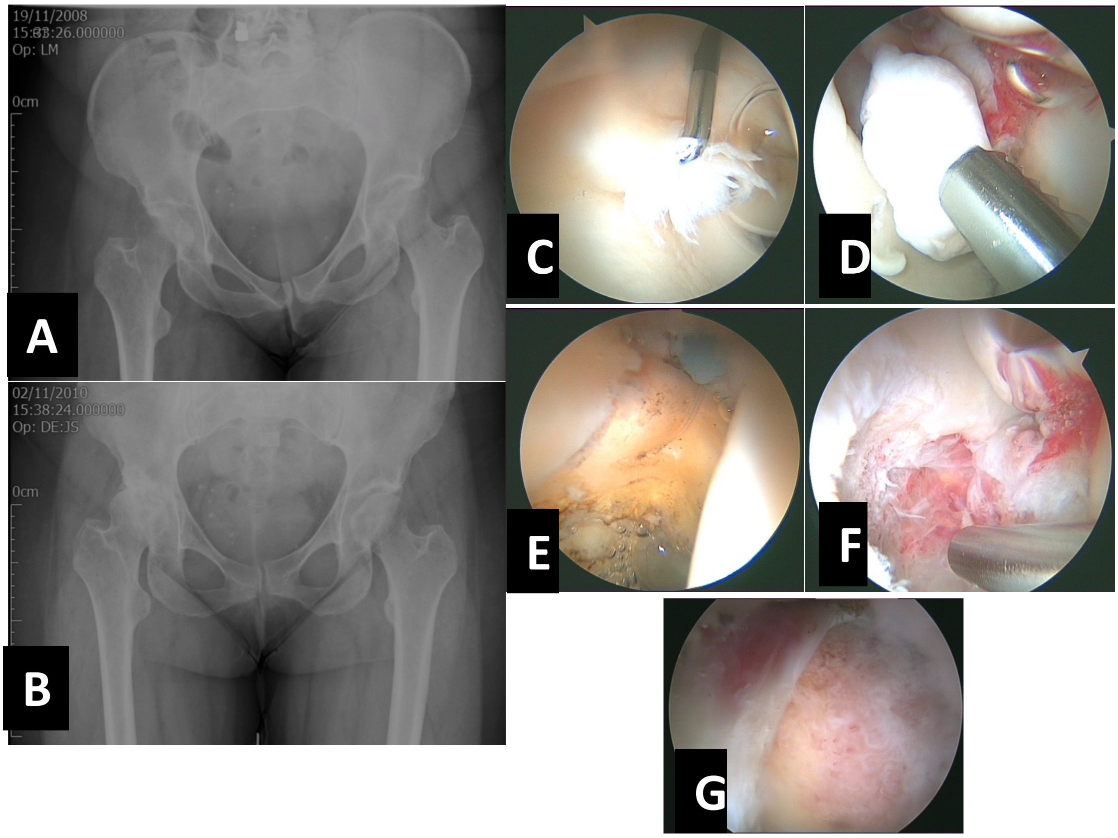


Figure 1: Pre-operative (A) and Follow-up (B) radiographs of a mildly dysplastic case that failed at 2-years post surgery. Intra-operative findings are detailed in C-G, illustrating a labral tear (C), a loose cartilaginous piece within the joint (D), the labrum repaired (E), debridement of the cotyloid fossa (F) and finally the CAM resection ensuring satisfactory seal.

Radiographic assessments

Radiographic evaluations of the operated hip were performed using a validated (HipMorf) software programme using Antero-Posterior Pelvic radiographs[33]. Parameters recorded included AI, CEA, extrusion index (EI) and alpha angle. An orthopaedic resident performed the assessments in all cases. Intra-observer reliability was established by repeating the measurement in 10 cases. Similarly, inter-observer reliability was tested with an orthopaedic fellow performing the measurements in 10 cases and comparing the results of the two assessors.

Outcome

Patient outcome was determined for all patients from hospital records and questionnaires. Outcome measures included whether any complications or revision surgery took place. Furthermore, whether the hip was preserved at follow-up was established. Pre- and post-operative patient reported outcome measures were obtained using the Non-Arthritic Hip[5] and the Hip-disability and Osteoarthritis Outcome[23] Scores (NAHS, and HOOS) at 1-year post-op. The differences between pre- and post-operative scores were defined as Δ and were calculated as:

$\Delta NAHS = NAHS_{post\text{-}operatively} - NAHS_{Pre\text{-}operatively}$

$\Delta HOOS = HOOS_{post\text{-}operatively} - HOOS_{Pre\text{-}operatively}$

Analyses

The effect of different patient- and surgical- related factors on the ability to preserve the hip with an arthroscopy were assessed. Factors tested included: age, gender, AI, CEA, HEI, degree of intra-articular wear, labral pathology and labral surgery (debridement or repair) performed.

The extent of articular surface wear and dysplasia are factors that have been associated with increased failure following hip arthroscopy and are interlinked[11]. A greater degree of dysplasia (greater AI and smaller CEA) is associated with a smaller contact area between the acetabular and femoral surfaces and would therefore result in greater wear. Therefore, both factors needed to be taken in account for any analysis. In order to account for the interaction of these 2 factors, we defined AI and CEA factored by the extent of acetabular wear (AI_f and CEA_f) and calculated them using the following equations:

AI_f = AI *(number of UCL wear zones + 1)

CEA_f = CEA/ (number of UCL wear zones + 1)

The following 2 different methods were used to identify which degrees of dysplasia are associated with hip preservation and failure respectively. For both methods a scatter plot of CEA_f on the x-axis and AI_f on the y-axis was plotted.

Method 1: Lowest/highest incidence of failure based on degree space Euclidean distance.

The Euclidean distance in the scatter plot degree space (r) of each acetabulum from any point P, with factored acetabular index value of P_{AIf} and factored centre-edge angle of P_{CEAf}P, can be calculated using the following equation:

$$r= \sqrt{[(AI_f - P_{AIf})^2 +(CEA_f - P_{CEAf})^2]}$$

The mean distances from any given point of the scatter plot from the preserved ($r_{preserved}$) and failed (r_{failed}) cases, were calculated separately. The distance ratio

($r_{preserved}/r_{failed}$) was calculated for every possible combination of each degree increment in AI_f and CEA_f. This was then plotted as a contour plot; the larger the value of the distance ratio the nearer to the points of all preserved hips and the further away from all those that failed. The optimal degree of dysplasia, which was at the maximum value of the distance ratio was then determined for hips that were preserved.

Method 2: Zones with lowest/highest incidence of failure to preserve the hip.

In order to identify the zones with the lowest and highest incidence of failure to preserve the hip, for every combination of AI_f and CEA_f a 2x2 contingency table was constructed. This consisted of the number of failed and preserved cases within a ± 2° about the considered location on the scatter plot. Fisher's exact test was then applied to the contingency table. This was repeated for every combination of each degree increment in AI_f and CEA_f. A contour plot of the resulting probability values allowed for the location of the zones with the lowest and highest incidence of failure to preserve the hip respectively.

Analyses were performed using custom routines written in Matlab (version 2009a, The MathWorks Inc., Natick, Massachusetts, USA).

Statistics

Statistical analysis was performed using SPSS v22 (IBM). Intra- and inter-observer reliability were evaluated using single measure intra-class correlation coefficients (ICC) with a two-way random effects model for absolute agreement. Cross-tabulation, the chi-squared and Fisher's exact tests were used for categorical data.

Intergroup comparisons were made using non-parametric tests (Mann-Whitney U, Kruskal Wallis, log-rank). Survival analysis taking into account time to arthroplasty was performed using Kaplan-Meier survival analysis with 95% confidence intervals (CI). A p-value ≤0.05 was considered significant.

Results

Excellent intra- (k: 0.73 to 0.85, p=0.001 to 0.003) and inter- (k: 0.71 to 0.82, p= 0.002 to 5) observer reliability was detected for radiographic parameters measured. The mean AI was 9.8° (0.2 to 26.6°), the mean CEA was 17.9° (1.8 to 24.9°) and the mean head extrusion index was 0.5 (0.2 to 0.9) (Table 3). Strong and significant correlations (rho: 0.2 to 0.7, p<0.001) between the measured parameters were detected (Table 4, Figure 2). The mean improvement in NAHS and HOOS was 7.8 (-52 to 66) and 23 (-24 to 80) points respectively.

Factor (mean, range)	**Cohort**	**Groups**		**p-value**
		Preserved	**Failed**	
Acetabular index (AI) /°	9.8 (0.2 – 27)	8.9 (0.2 – 24.7)	11.8 (2.5 – 26.6)	0.004*
Anterior Centre-Edge Angle (ACEA) /°	17.8 (1.8 – 25.0)	18.8 (7.4 – 25.0)	16.0 (1.8 – 22.2)	0.003*
Alpha Angle/°	44.3 (3.4 – 82.5)	43.9 (3.4 – 77.7)	45.3 (34.4 – 82.5)	0.4
Extrusion Index/°	0.47 (0.2 – 0.9)	0.45 (0.2 – 0.9)	0.50 (0.2 – 0.9)	0.07

Table 3: Radiographic parameters made on Antero-Posterior Pelvic Radiographs.

*: Statistical significant difference

	Acetabular Index	**Anterior Centre-Edge Angle**	**Head- Extrusion Index**
Acetabular Index	1.00	Rho=-0.57 p<0.001	Rho=0.23 p=0.01
Anterior Centre Edge Angle	Rho=-0.57 p<0.001	1.00	Rho=-0.68 p<0.001
Head- Extrusion Index	Rho=0.23 p=0.01	Rho=-0.68 <0.001	1.00

Table 4: Correlation of radiographic parameters of cohort.

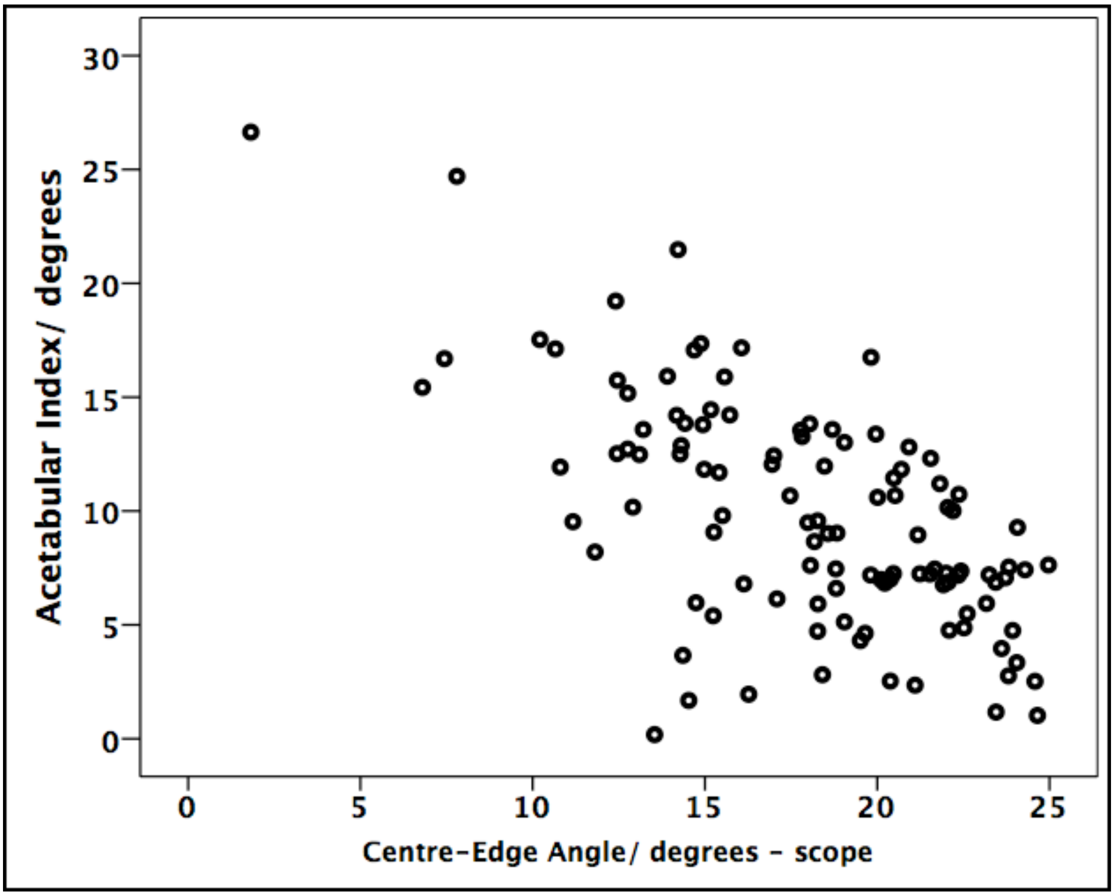


Figure 2: Scatter plot of Acetabular Index measured plotted against the Centre-Edge angle measured.

At a mean follow-up of 5.5 years [3.1 to 8.3 years], 33 hips (29%) had failed requiring a hip arthroplasty, whilst the remaining 79 (71%) remained preserved. The overall 3, 5- and 7- year joint survivorship was 73% (95%CI: 65 to 81%), 71% (95% CI: 64 to 79%) and 68% (95% CI: 58 to 78%) respectively (Figure 3). There were no gender (p=0.09), nor age (p=0.06) differences between the failed and preserved cases. Failed cases had more severe features of dysplasia compared to preserved hips, with higher acetabular index [11.9, SD: 5.5 (failed) Vs. 8.9, SD: 4.5 (preserved)] (p=0.004) and lower centre-edge-angle [16.0, SD: 4.5 (failed) Vs. 18.7, SD: 4.2 (preserved)] (p=0.004).

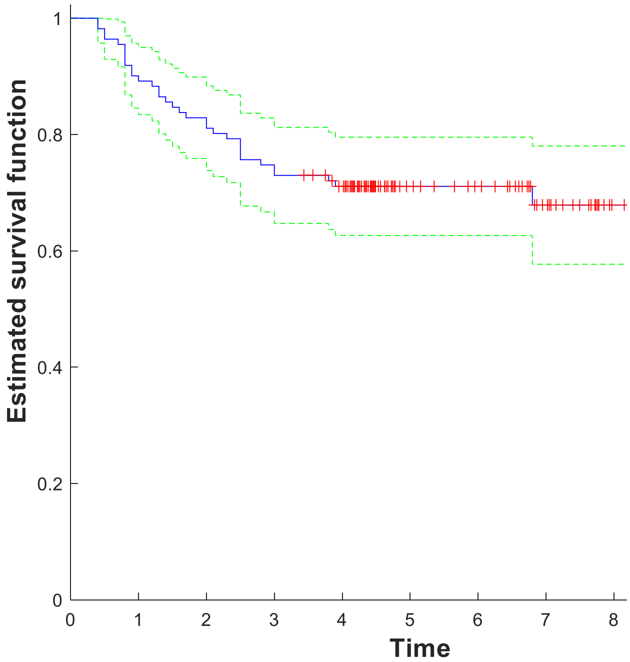


Figure 3: Kaplan Meier survival analysis plot for the whole cohort

The importance of intra-articular wear and the degree of dysplasia parameters on subsequent outcome (preservation or not) are illustrated in Figure 4.

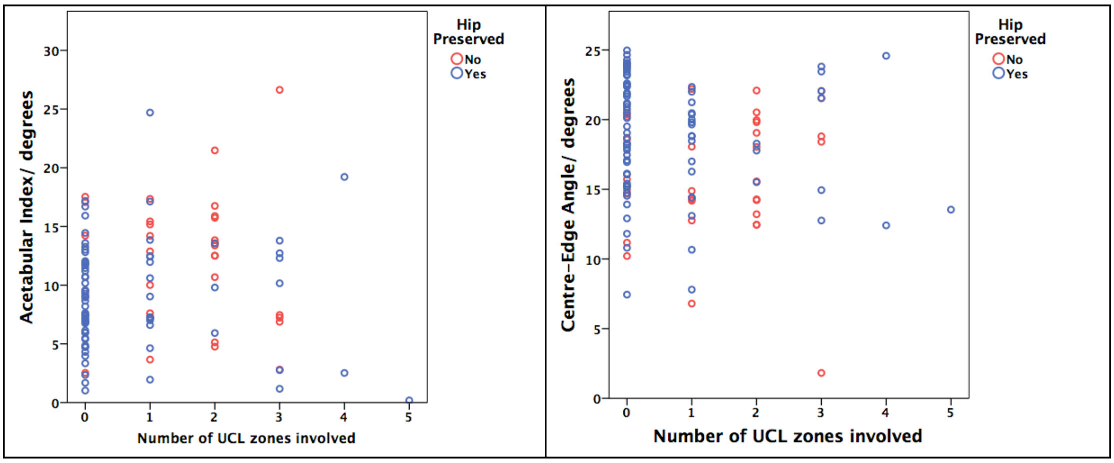


Figure 4: Scatter plots of Acetabular Index (A) and Centre Edge Angle (B) measured against the number of UCL Zones with evidence of cartilaginous damage. Note colour coding as per fate of operated hip.

The mean AI_f was 18.8 (1 to 106.6) and the mean CEA_f was 12.9 (0.5 to 25.0). The location on the scatter plot with the maximum value of the distance ratio was AI_f of 7.4 and CEA_f of 19.8 (Figure 5).

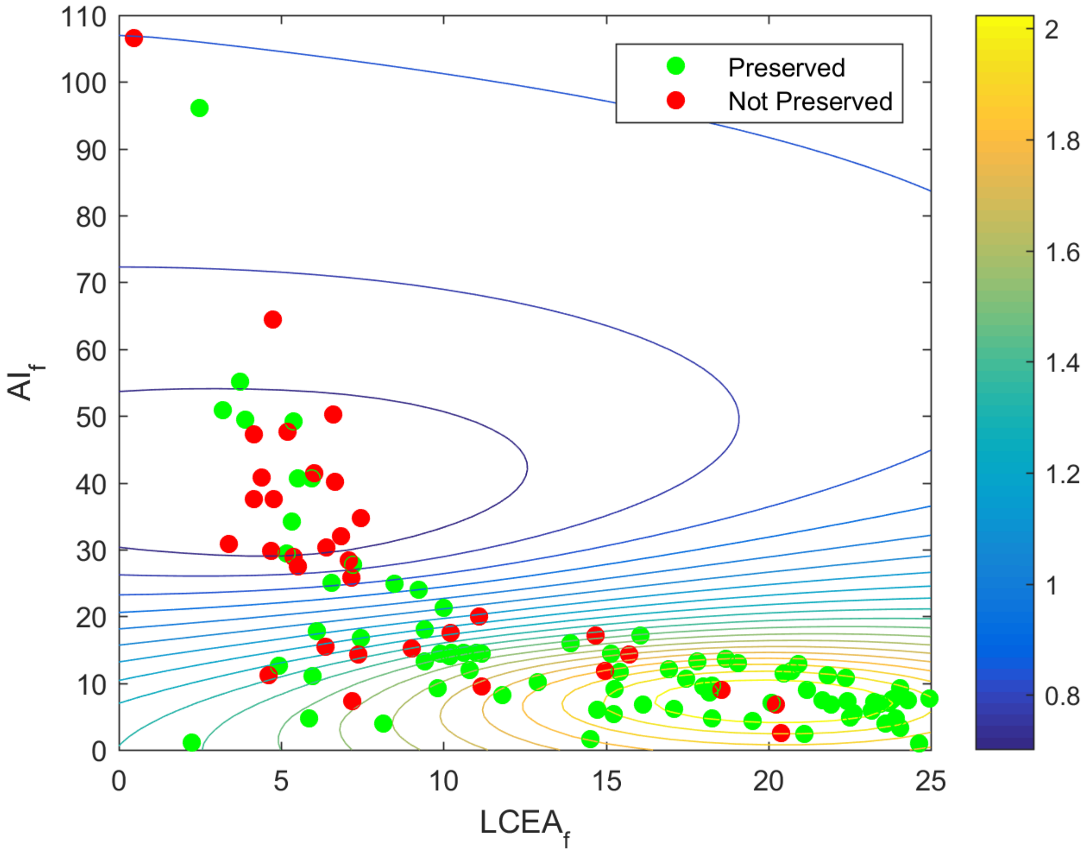


Figure 5: Scatter plot of AI_f against CEA_f colour coded for fate of hip. The colours of the contour plot define the distance ratio ($r_{preserved}/r_{failed}$). The larger the value of the distance ratio (closer to yellow) the nearer to the points of all preserved hips and the further away from all those that failed.

The optimal zone with the greatest chance of joint preservation (odds ratio: 10, $p<0.001$) was AI_f:0 to 14 and CEA_f: 15 to 25 (this was termed the Green Zone); in contrast the zone with the greatest chance of failure (odds ratio: 10, $p<0.001$) was AI_f: 20 to 100 and CEA_f: 0 to 10 (Red Zone) (Figure 6).

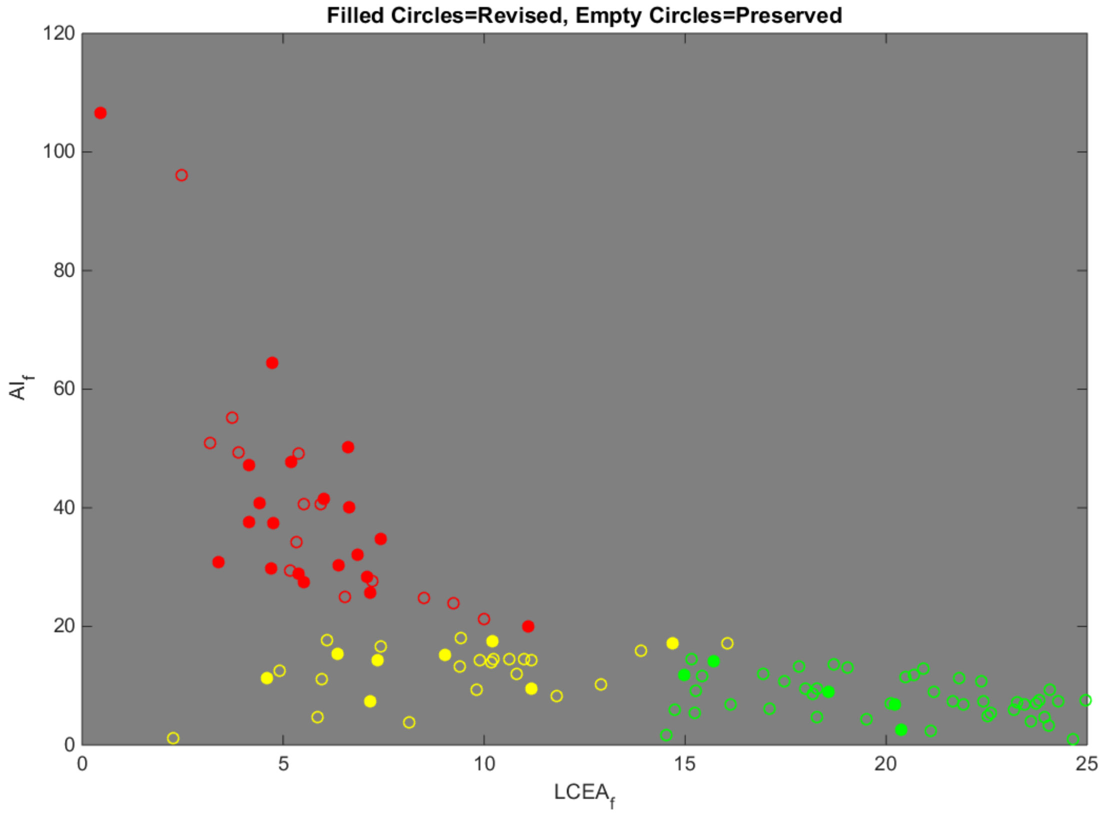


Figure 6: Scatter plot of AI_f against CEA_f colour coded for Zone each case belongs to. Filled circles are cases that had undergone arthroplasty by follow-up. Hollow circles were preserved by follow-up.

The 7-year survival of cases in the Green Zone was significantly superior (89.6%, range: 80.9 to 98.3), compared to the Amber (71.9%, 66.9 to 87.9) and the Red Zone (35.3%, 14.8 to 55.8) ($p<0.001$) (Figure 7). Functional outcome 1-year post-arthroscopy was similar for the three zones (Table 5). Preserved cases (in all three zones) had superior $NAHS_{post\text{-}operatievely}$ and $HOOS_{post\text{-}operatively}$ (71, SD: 20; 61 SD: 20) at 1-year compared to the failed cases (60, SD: 15; 44, SD:23) ($p=0.03$).

Factor (mean, range)	Cohort	Groups			p-value
		Green (n=48)	Amber (n=29)	Red (n=34)	
AIf	19. 1(1 – 107)	8 (1 – 14)	13 (1 – 18)	40 (20 – 107)	<0.001
ACEAf	12.8 (1 – 25)	20 (15 – 25)	9 (2 – 16)	6 (0 – 11)	<0.001
n (%) of hips preserved	78 (70)	43(90)	21 (72)	14 (41)	<0.001
NAHSpre	49 (4 – 90)	46 (0 – 84)	51 (6 – 77)	52 (19 – 90)	0.3
NAHSpost	58 (0 – 100)	62 (13 – 100)	57 (0 – 95)	52 (9 – 85)	0.3
ΔNAHS	7.8 (-52 to 66)	14 (-29 to 62)	4 (-20 to 23)	1 (-52 to 66)	0.1
HOOSpre	45 (4 – 96)	46 (13 – 96)	39 (4 – 82)	48 (11 – 91)	0.4
HOOSpost	67 (21 – 100)	71 (27 – 100)	66 (34 – 100)	63 (21 – 91)	0.4
ΔHOOS	23 (-24 to 80)	25 (-24 to 80)	27 (-1 to 77)	15 (-11 to 76)	0.5

Table 5: AIf, ACEAf and functional outcome parameters for the whole cohort and for the three different types of dysplasia severity. AI: Acetabular Index factored for wear, ACEAf: Anterior Centre Edge Angle factored for wear. NAHS: Non-Arthroplasty Hip Score, HOOS: Hip disability Osteoarthritis Outcome Score

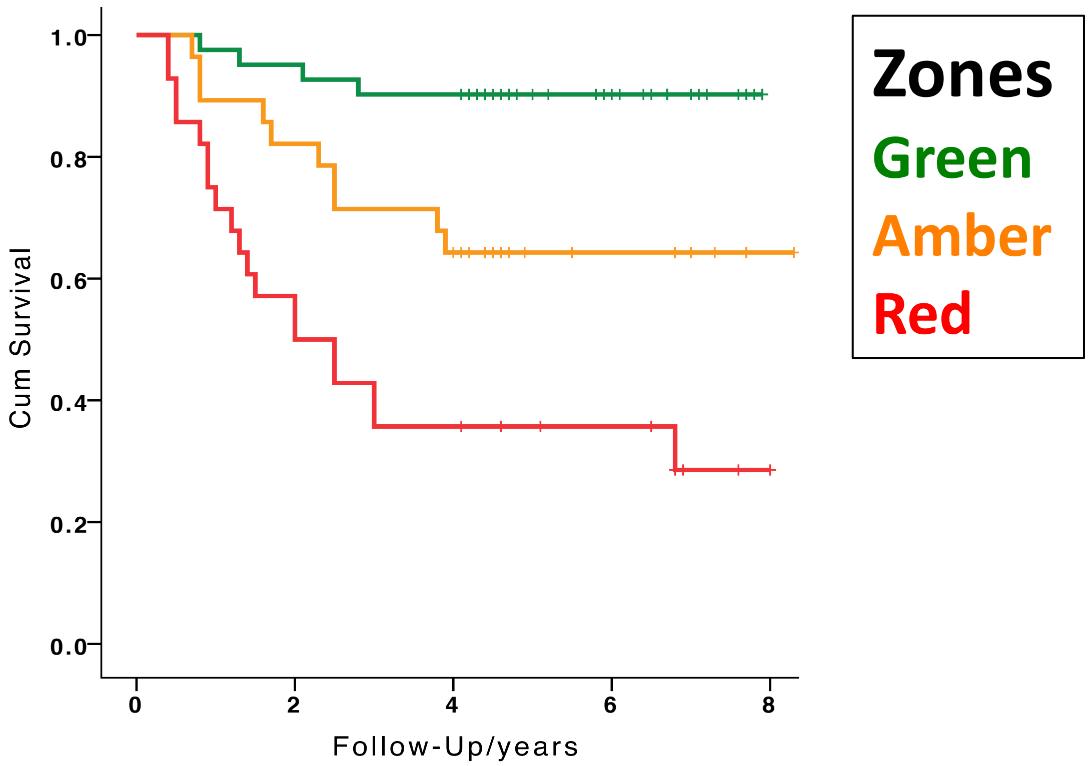


Figure 7: Kaplan Meier survival analysis plot colour-coded for the three different Zones.

Discussion

The last decade has seen significant advances in the understanding of failure mechanisms in the young adult hip, an improved understanding of which surgical procedures are appropriate for particular morphological abnormalities, and an evolution in the safety and effectiveness of these procedures.

Painful hips with evidence of some degree of dysplasia can represent a significant proportion of patients seen in a young adult hip practice, as seen in this study (30%). However, the role of hip arthroscopy in the presence of dysplasia remains controversial, due to conflicting results. Byrd *et al* reviewed their arthroscopic results in 48 dysplastic hips, categorising them into borderline dysplastic (CEA: 20 to 25°) or dysplastic (<20°)[3]. At an average follow-up of 2 years, 2 hips had been converted to arthroplasty and no statistical difference was detected between the 2 severity groups. Parvizi *et al* reported on the outcome of 34 hips with acetabular morphological abnormalities (30 dysplastic) that underwent arthroscopy and labral debridement.[34] At an average follow-up of 3 years, the authors reported accelerated arthritis in 14 cases and/or migration of the femoral head in 13 cases with 16 hips requiring further intervention. The authors emphasised the importance of not debriding the labrum in such cohort, as this would likely accelerate the degenerative process. Larson *et al* reviewed 88 dysplastic hips (CEA: 8.7 to 24.5° and AI: 0 to 22.2°) that underwent arthroscopic treatment and compared outcome with an age-matched FAI cohort[26]. The authors reported inferior clinical results in the dysplastic cohort and higher failure rate; they noted that labral repair and capsular plication resulted in superior clinical results. In addition to the above studies, cases with catastrophic results following rim resection, labral debridement, extensive[30] capsulotomy[36] and psoas tenotomy[38] have been reported. The present study has greater length of follow-up compared to the aforementioned ones hence allowed for determination of the medium-term (5 and 7 year) joint preservation rates and identification of factors that improve chances of preservation. The rate of joint preservation in this dysplastic series is inferior to other reports on FAI patients ([18, 20]). It is evident, therefore, that patient selection should be stratified. Based on the analyses the following 2 factors had a detrimental effect on the chances of joint preservation: pre-existing wear and greater degree of dysplasia as per radiographic assessment.

There is an overall consensus that corrective osteotomy, such as a PAO, should be the treatment of choice in severely dysplastic hips. Very good 10-year hip joint preservation (over 85%) and functional outcome have been reported by many authors, with correction of the bony anatomy with a PAO[16, 19, 39]. Young age, minimal intra-articular wear and an impingement-free environment post-correction are important factors for optimal outcome following PAO. A PAO is a technically challenging procedure with a steep learning curve. In 2008, PAO was a very significant intervention requiring an extensive surgical approach, associated with a potentially large blood loss (up to 2,500mls), and considerable peri-operative risks (up to 46%) and inevitably had cosmetic implications[1, 8, 15, 43]. It was, therefore, important to offer a PAO to appropriately selected patients; however grading of the degree of deformity in order to judge optimal treatment is not always straightforward[41]. Consequently, hip arthroscopy presented an attractive alternative for such patients. In 2016, minimally-invasive PAO is well established, and associated with low blood loss, rapid discharge, and a cosmetically satisfactory result[22, 27, 28]. Considering this evolution, it is clear that many of the patients in this historical cohort would perhaps not be offered arthroscopy in 2016. However, this cohort has provided a unique and valuable opportunity to study the natural history of arthroscopy in hips with a range of severity of hip dysplasia, and therefore define evidence-based thresholds to aid management. Furthermore, hip arthroscopy can be a very useful way to assess the integrity of the articular cartilage even prior to considering a PAO.

Ross et al, analysing data from the ANCHOR group, reviewed characteristics of 30 dysplastic hips that required PAO following a 'failed' hip arthroscopy and compared the results with 30 cases that underwent a PAO, without a prior arthroscopy[37]. The authors described lesser pre-operative radiographic dysplasia values for the failed-arthroscopy-PAO group [(AI: 16.3°, 0 to 31°) and (CEA: 14.7°, -4 to 37°)] compared to the PAO-alone group [(AI: 21.7°, -15 to 75°) and (CEA: 8.8 (-44 to 65°)]. They reported that having a prior hip arthroscopy did not affect outcome following PAO.

It is also important to understand that patients with acetabular dysplasia frequently demonstrate femoral abnormalities that may require correction. These can manifest as torsional and cam deformities, the latter of which are common in dysplastic patients, demonstrating both femoral head asphericity and also poor anterior femoral head-neck offset[6, 40]. This may cause symptoms by causing impingement against a bulky and at-risk labrum. Thus correction of cam morphology, which is eminently achievable through arthroscopic techniques, may improve symptoms in dysplastic hips and potentially improve the longevity of the joint. In this cohort, 81% of patients underwent femoral osteochondroplasty to correct cam deformity. Determining the relative importance of this aspect of the procedure is difficult from our data, however, it would seem an appropriate intervention when a cam deformity is present.

It would therefore seem very timely to develop evidence-based guidelines based on radiographic characteristics of who should be considered for a hip arthroscopy and who should be a candidate for bony correction. Review of this historic cohort, allowed us to study a large number of dysplastic hips with great variation in both radiographic and operative findings. As both these factors affect chances of success we calculated AI_f and CEA_f and determined the zones with greatest chance of joint preservation and failure respectively. When no intra-articular wear is present AI_f and CEA_f, are of the same values as AI and CEA. Both methods of analysis allowed us to develop a grading system for hip dysplasia, which would help guide treatment.

In our cohort, the 5 and 7 year hip survival appears inferior to series reporting on patients with FAI[18, 20] and therefore arthroscopy should be considered with caution, especially when intra-articular wear is detected on pre-operative imaging. We have been able to develop an evidence-based traffic light grading system that can help guide surgeons when considering arthroscopic treatment in dysplastic hips.

Hip arthroscopy can be associated with an excellent chance of hip preservation with mild dysplasia (Green Zone: AI< 15° & CEA: 15 to 25°) providing there are no signs of instability or articular wear on pre-operative imaging. Hip arthroscopy should not be performed in cases with severe (Red Zone) dysplasia (AI> 20° & CEA< 10°), where other options should be considered. Hip arthroscopy may be offered, with caution, in moderate dysplasia (Amber Zone) provided there is no articular wear, the labrum is repairable and the soft tissues are respected during the procedure.

We recommend that this traffic light system should only be used as a guide; as even when in the Green Zone and with no intra-articular wear, failure to preserve the joint can occur. In this cohort, the five failures in the Green Zone had deterioration in their hip symptoms following arthroscopy but improved dramatically with a hip arthroplasty.

This study has a number of limitations. Firstly, it is a retrospective review and hence suffers from all the inherent faults of such a design. Secondly, as the cohort was not homogeneous (both dysplasia and wear in some cases) we had to account for both factors contributing to failure. However, we defined and calculated AI_f and CEA_f, and based the analyses on these pragmatic values accounting for both radiographic (pre-operative) and arthroscopic (intra-operative) assessments. Therefore, our findings and subsequent recommendations on management reflect a holistic assessment. Thirdly, the study period covers a number of years, during which the surgical attitude and approach towards hip preservation, and the treatment of dysplasia, has seen significant evolutionary changes. Never the less, such a relatively long study period allowed us to evaluate different predictors of outcome and allowed for inclusion of severely dysplastic cases (Red Zone) that would not have been considered as suitable candidates by today's standards. Lastly, we did not perform a radiological assessment of all hips at follow-up in order to determine which hips are radiologically at-risk of failure.

Conclusion

Arthroscopic management of hip dysplasia is associated with an overall 7- year joint survival rate of 68% and a moderate improvement in functional outcome. We were able to determine an evidence-based classification system, based on the degree of dysplasia, extent of intra-articular wear and chances of joint preservation. We have demonstrated an excellent chance of hip preservation with arthroscopic treatment for the symptomatic dysplastic hip with an AI< 15° & CEA: 15 to 25° (the Green Zone), without signs of instability and rim overload.

References

1. Biedermann R, Donnan L, Gabriel A, Wachter R, Krismer M, Behensky H. Complications and patient satisfaction after periacetabular pelvic osteotomy. *Int Orthop.* 2008;32(5):611-617.
2. Bogunovic L, Gottlieb M, Pashos G, Baca G, Clohisy JC. Why do hip arthroscopy procedures fail? *Clin Orthop Relat Res.* 2013;471(8):2523-2529.
3. Byrd JW, Jones KS. Hip arthroscopy in the presence of dysplasia. *Arthroscopy.* 2003;19(10):1055-1060.
4. Byrd JW, Jones KS. Hip arthroscopy for labral pathology: prospective analysis with 10-year follow-up. *Arthroscopy.* 2009;25(4):365-368.
5. Christensen CP, Althausen PL, Mittleman MA, Lee JA, McCarthy JC. The nonarthritic hip score: reliable and validated. *Clin Orthop Relat Res.* 2003(406):75-83.
6. Clohisy JC, Nunley RM, Carlisle JC, Schoenecker PL. Incidence and characteristics of femoral deformities in the dysplastic hip. *Clin Orthop Relat Res.* 2009;467(1):128-134.
7. Cvetanovich GL, Chalmers PN, Levy DM, et al. Hip Arthroscopy Surgical Volume Trends and 30-Day Postoperative Complications. *Arthroscopy.* 2016;32(7):1286-1292.
8. Davey JP, Santore RF. Complications of periacetabular osteotomy. *Clin Orthop Relat Res.* 1999(363):33-37.
9. Domb BG, Stake CE, Lindner D, El-Bitar Y, Jackson TJ. Arthroscopic capsular plication and labral preservation in borderline hip dysplasia: two-year clinical outcomes of a surgical approach to a challenging problem. *Am J Sports Med.* 2013;41(11):2591-2598.
10. Duncan ST, Bogunovic L, Baca G, Schoenecker PL, Clohisy JC. Are there sex-dependent differences in acetabular dysplasia characteristics? *Clin Orthop Relat Res.* 2015;473(4):1432-1439.
11. Dwyer MK, Lee JA, McCarthy JC. Cartilage Status at Time of Arthroscopy Predicts Failure in Patients With Hip Dysplasia. *J Arthroplasty.* 2015;30(9 Suppl):121-124.
12. Fujii M, Nakashima Y, Jingushi S, et al. Intraarticular findings in symptomatic developmental dysplasia of the hip. *J Pediatr Orthop.* 2009;29(1):9-13.
13. Fukui K, Trindade CA, Briggs KK, Philippon MJ. Arthroscopy of the hip for patients with mild to moderate developmental dysplasia of the hip and femoroacetabular impingement: Outcomes following hip arthroscopy for treatment of chondrolabral damage. *Bone Joint J.* 2015;97-B(10):1316-1321.
14. Gala L, Clohisy JC, Beaule PE. Hip Dysplasia in the Young Adult. *J Bone Joint Surg Am.* 2016;98(1):63-73.
15. Ganz R, Klaue K, Vinh TS, Mast JW. A new periacetabular osteotomy for the treatment of hip dysplasias. Technique and preliminary results. *Clin Orthop Relat Res.* 1988(232):26-36.

16. Grammatopoulos G, Wales J, Kothari A, Gill HS, Wainwright A, Theologis T. What Is the Early/Mid-term Survivorship and Functional Outcome After Bernese Periacetabular Osteotomy in a Pediatric Surgeon Practice? *Clin Orthop Relat Res.* 2016;474(5):1216-1223.

17. Griffin DW, Kinnard MJ, Formby PM, McCabe MP, Anderson TD. Outcomes of Hip Arthroscopy in the Older Adult: A Systematic Review of the Literature. *Am J Sports Med.* 2016.

18. Haefeli PC, Albers CE, Steppacher SD, Tannast M, Buchler L. What Are the Risk Factors for Revision Surgery After Hip Arthroscopy for Femoroacetabular Impingement at 7-year Followup? *Clin Orthop Relat Res.* 2016.

19. Hartig-Andreasen C, Troelsen A, Thillemann TM, Soballe K. What factors predict failure 4 to 12 years after periacetabular osteotomy? *Clin Orthop Relat Res.* 2012;470(11):2978-2987.

20. Hufeland M, Kruger D, Haas NP, Perka C, Schroder JH. Arthroscopic treatment of femoroacetabular impingement shows persistent clinical improvement in the mid-term. *Arch Orthop Trauma Surg.* 2016;136(5):687-691.

21. Kalore NV, Jiranek WA. Save the torn labrum in hips with borderline acetabular coverage. *Clin Orthop Relat Res.* 2012;470(12):3406-3413.

22. Khan OH, Malviya A, Subramanian P, Agolley D, Witt JD. Minimally invasive periacetabular osteotomy using a modified Smith-Petersen approach: technique and early outcomes. *Bone Joint J.* 2017;99-B(1):22-28.

23. Klassbo M, Larsson E, Mannevik E. Hip disability and osteoarthritis outcome score. An extension of the Western Ontario and McMaster Universities Osteoarthritis Index. *Scand J Rheumatol.* 2003;32(1):46-51.

24. Konan S, Rayan F, Meermans G, Witt J, Haddad FS. Validation of the classification system for acetabular chondral lesions identified at arthroscopy in patients with femoroacetabular impingement. *J Bone Joint Surg Br.* 2011;93(3):332-336.

25. Larson CM, Giveans MR. Arthroscopic management of femoroacetabular impingement: early outcomes measures. *Arthroscopy.* 2008;24(5):540-546.

26. Larson CM, Ross JR, Stone RM, et al. Arthroscopic Management of Dysplastic Hip Deformities: Predictors of Success and Failures With Comparison to an Arthroscopic FAI Cohort. *Am J Sports Med.* 2016;44(2):447-453.

27. Leunig M, Ganz R. Evolution of technique and indications for the Bernese periacetabular osteotomy. *Bull NYU Hosp Jt Dis.* 2011;69 Suppl 1:S42-46.

28. Luo D, Zhang H, Zhang W. Comparison of three approaches of Bernese periacetabular osteotomy. *Ther Clin Risk Manag.* 2016;12:67-72.

29. McCarthy JC, Jarrett BT, Ojeifo O, Lee JA, Bragdon CR. What factors influence long-term survivorship after hip arthroscopy? *Clin Orthop Relat Res.* 2011;469(2):362-371.

30. Mei-Dan O, McConkey MO, Brick M. Catastrophic failure of hip arthroscopy due to iatrogenic instability: can partial division of the ligamentum teres and iliofemoral ligament cause subluxation? *Arthroscopy.* 2012;28(3):440-445.

31. Nassif NA, Schoenecker PL, Thorsness R, Clohisy JC. Periacetabular osteotomy and combined femoral head-neck junction osteochondroplasty: a minimum two-year follow-up cohort study. *J Bone Joint Surg Am.* 2012;94(21):1959-1966.

32. Nawabi DH, Degen RM, Fields KG, et al. Outcomes After Arthroscopic Treatment of Femoroacetabular Impingement for Patients With Borderline Hip Dysplasia. *Am J Sports Med.* 2016;44(4):1017-1023.

33. Nicholls AS, Kiran A, Pollard TC, et al. The association between hip morphology parameters and nineteen-year risk of end-stage osteoarthritis of the hip: a nested case-control study. *Arthritis Rheum.* 2011;63(11):3392-3400.

34. Parvizi J, Bican O, Bender B, et al. Arthroscopy for labral tears in patients with developmental dysplasia of the hip: a cautionary note. *J Arthroplasty.* 2009;24(6 Suppl):110-113.

35. 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(1):16-23.

36. Ranawat AS, McClincy M, Sekiya JK. Anterior dislocation of the hip after arthroscopy in a patient with capsular laxity of the hip. A case report. *J Bone Joint Surg Am.* 2009;91(1):192-197.

37. Ross JR, Clohisy JC, Baca G, Sink E. Patient and disease characteristics associated with hip arthroscopy failure in acetabular dysplasia. *J Arthroplasty.* 2014;29(9 Suppl):160-163.

38. Sansone M, Ahlden M, Jonasson P, Sward L, Eriksson T, Karlsson J. Total dislocation of the hip joint after arthroscopy and ileopsoas tenotomy. *Knee Surg Sports Traumatol Arthrosc.* 2013;21(2):420-423.

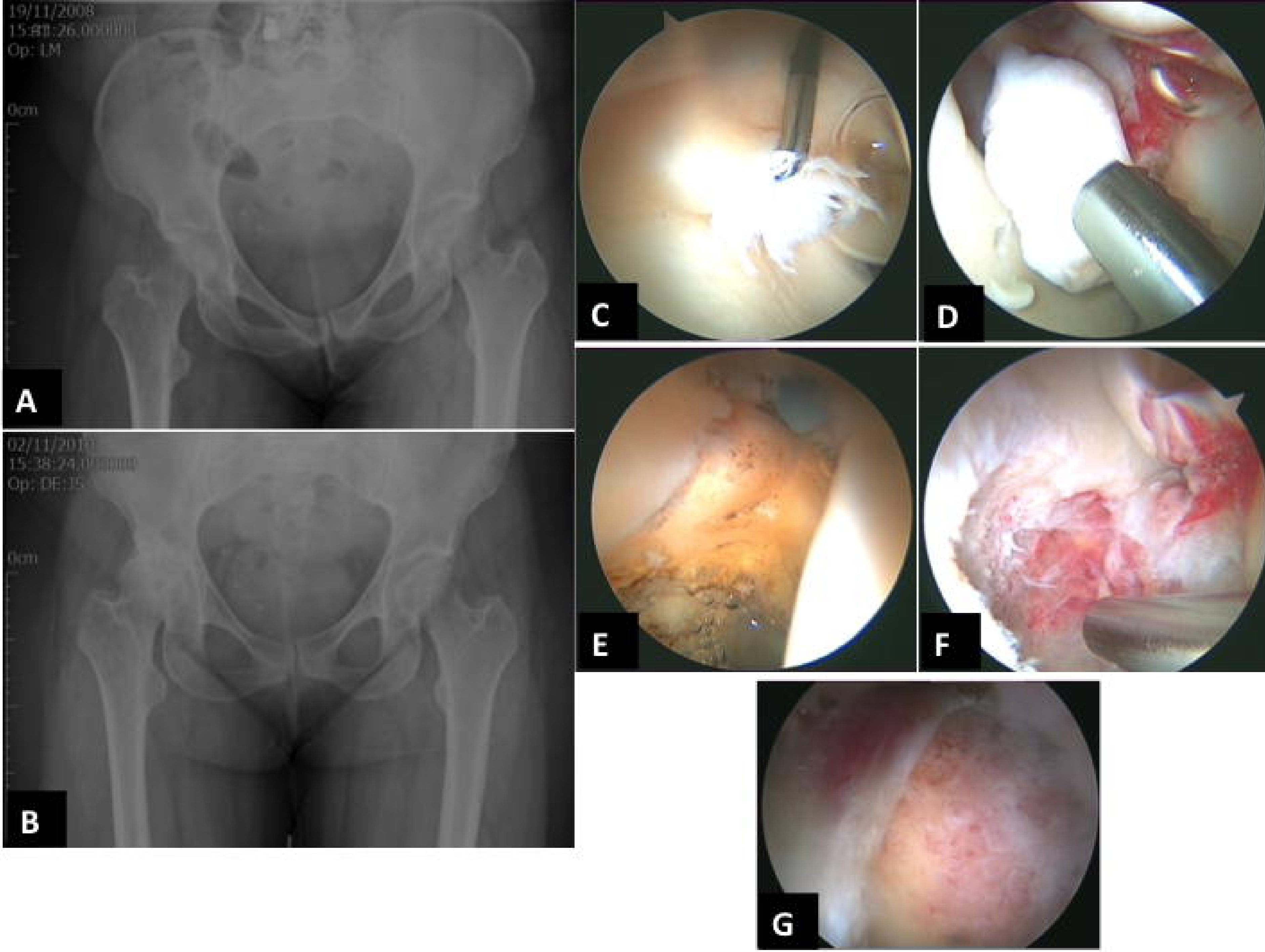
39. Steppacher SD, Tannast M, Ganz R, Siebenrock KA. Mean 20-year followup of Bernese periacetabular osteotomy. *Clin Orthop Relat Res.* 2008;466(7):1633-1644.

40. Wells J, Nepple JJ, Crook K, et al. Femoral Morphology in the Dysplastic Hip: Three-dimensional Characterizations With CT. *Clin Orthop Relat Res.* 2016.

41. Witt MJ. Hip arthroscopy of Peri-acetabular Osteotomy (PAO) for mild and moderate acetabular dysplasia - some perspectives. *ISHA Newsletter*; 2016.

42. Yen YM, Kocher MS. Chondral lesions of the hip: microfracture and chondroplasty. *Sports Med Arthrosc.* 2010;18(2):83-89.

43. Zaltz I, Baca G, Kim YJ, et al. Complications associated with the periacetabular osteotomy: a prospective multicenter study. *J Bone Joint Surg Am.* 2014;96(23):1967-1974.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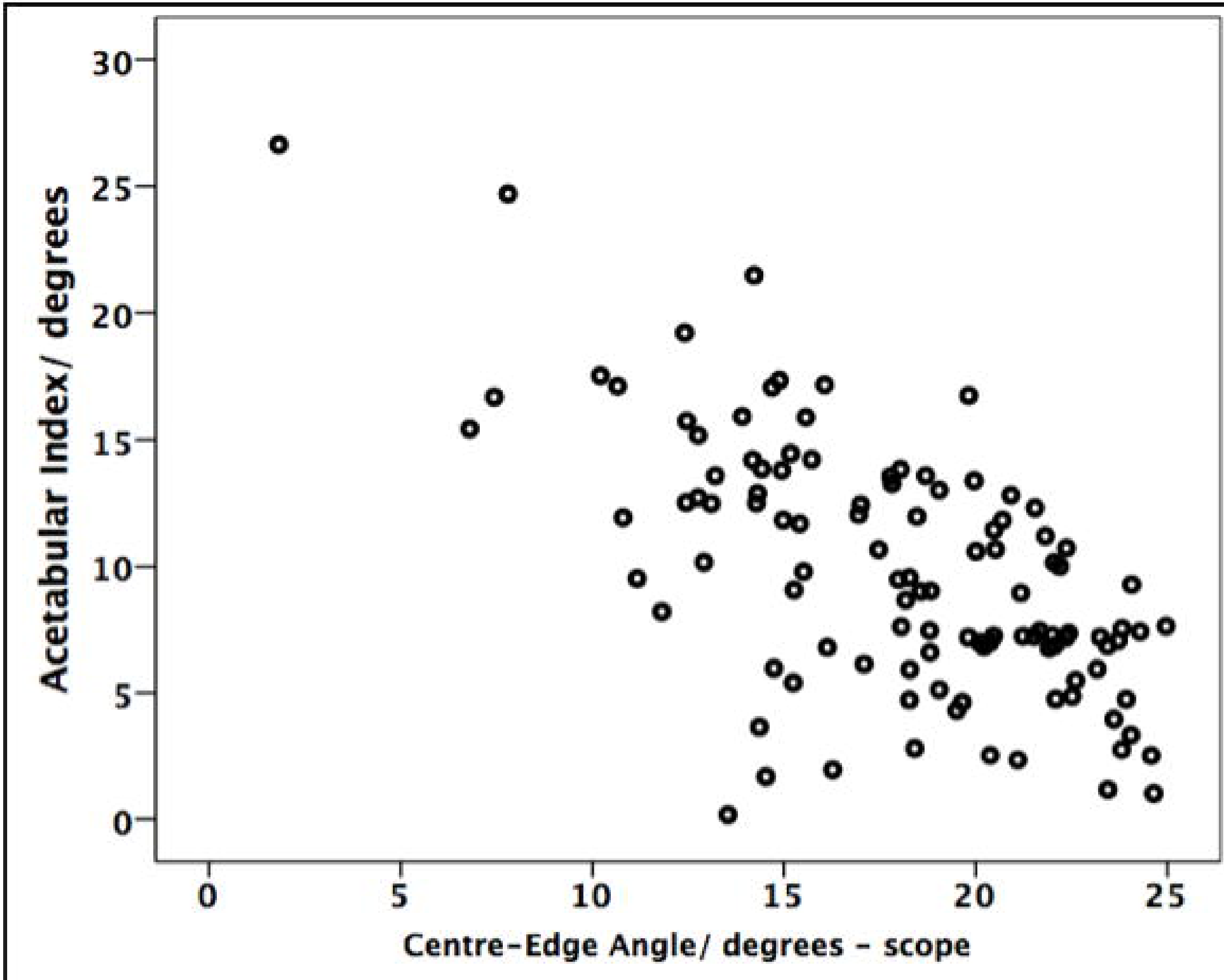

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10
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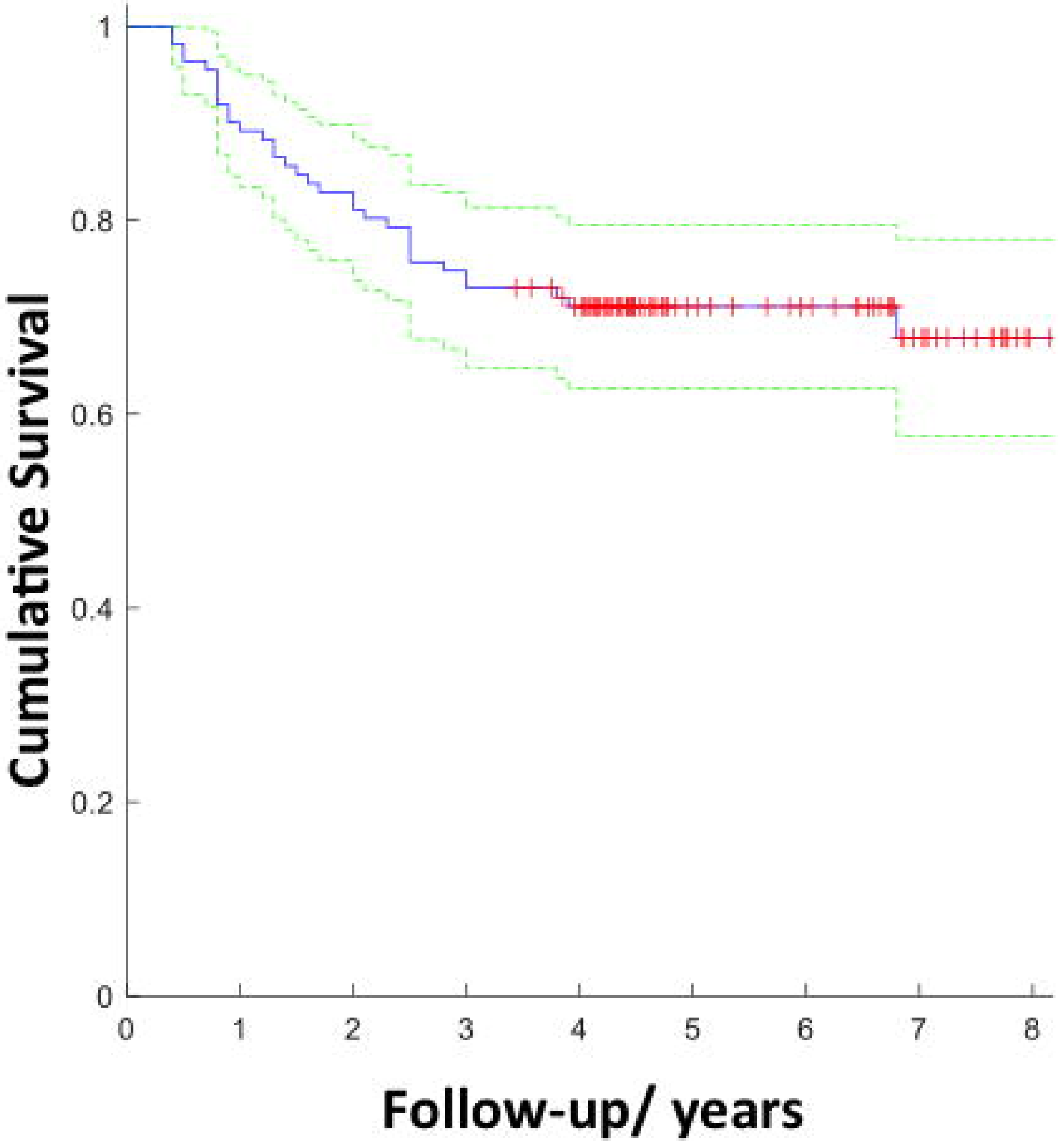
Centre-Edge Angle/ degrees - scope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Follow-up/ years
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4
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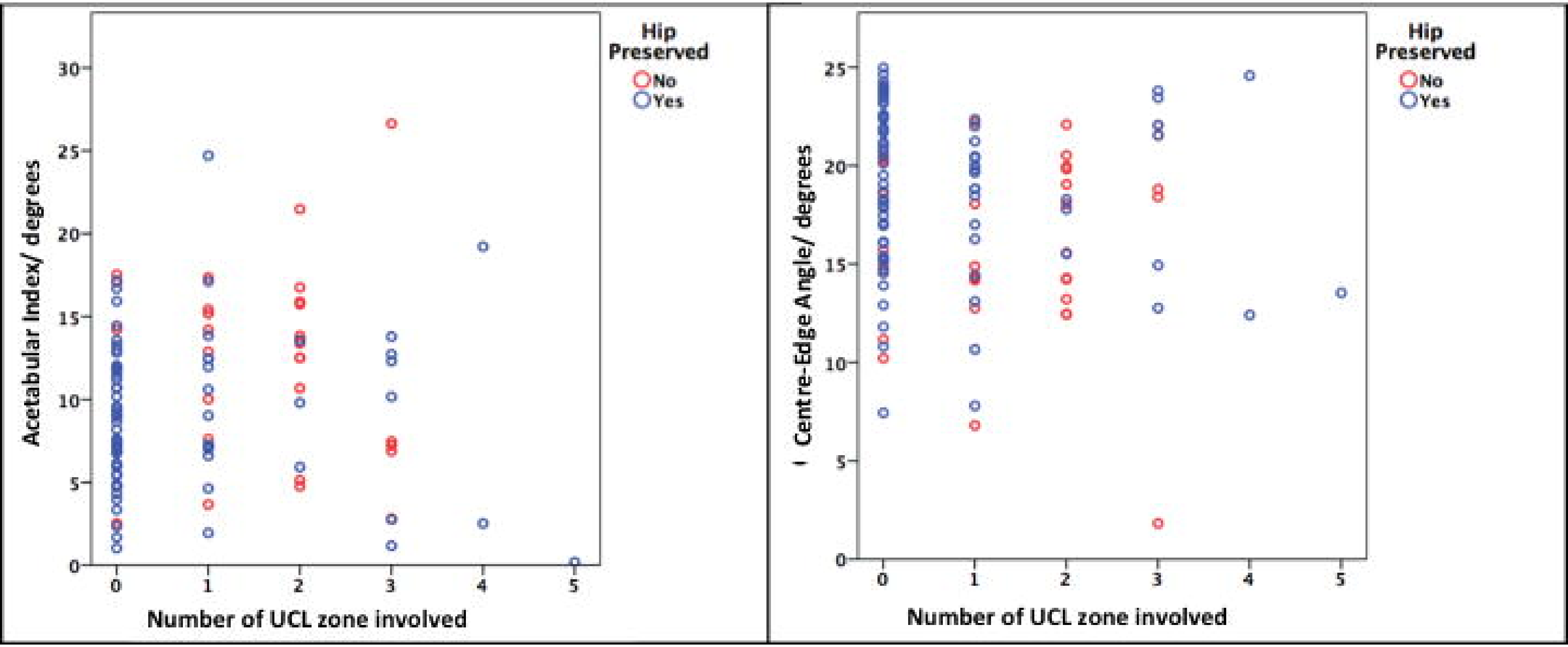
6
7
8


Acetabular Index/ degrees
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25
20
15
10
5
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0
1
2
3
4
5
Number of UCL zone involved
Hip Preserved
No
Yes
Centre-Edge Angle/ degrees
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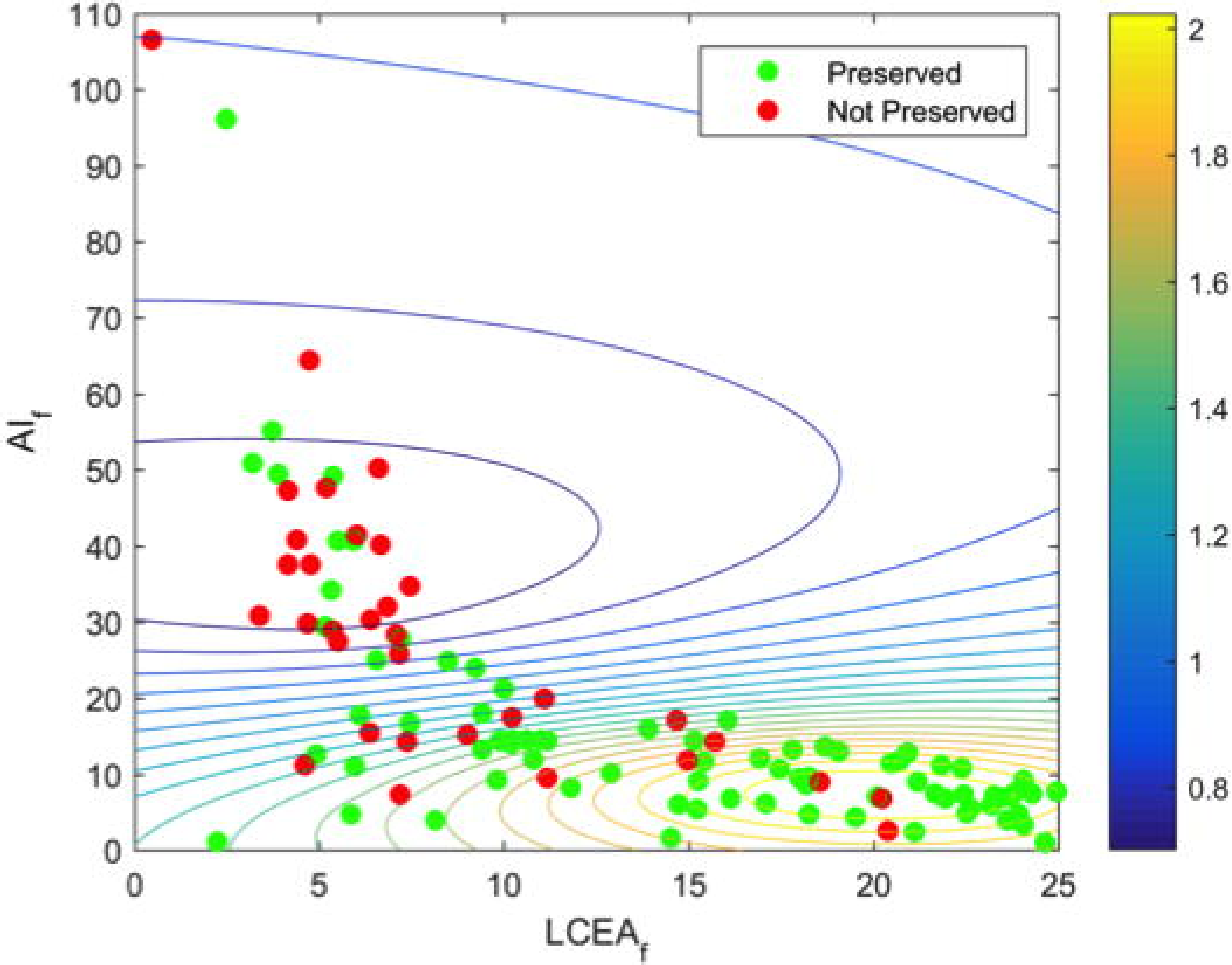
Number of UCL zone involved
Hip Preserved
No
Yes



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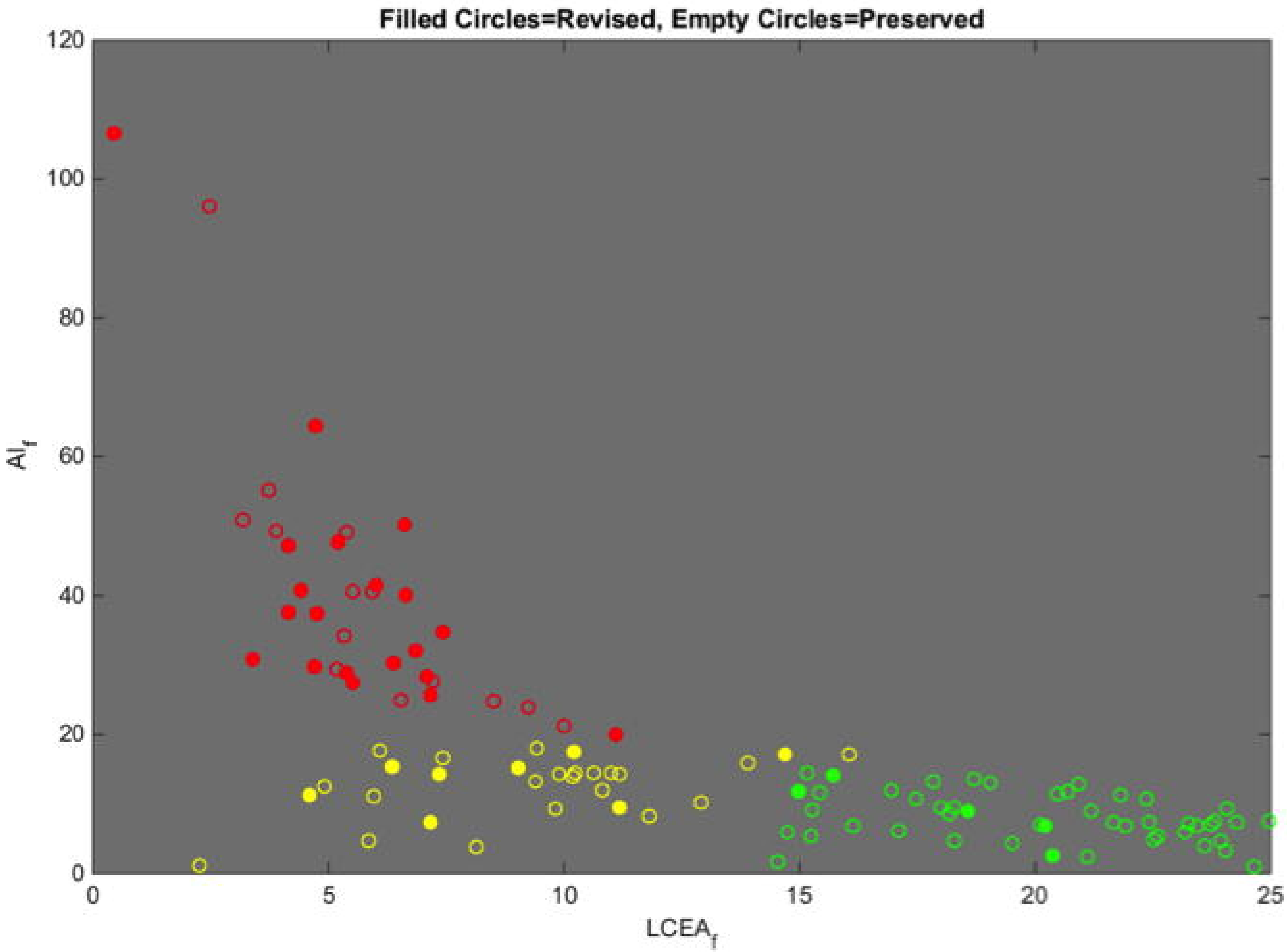
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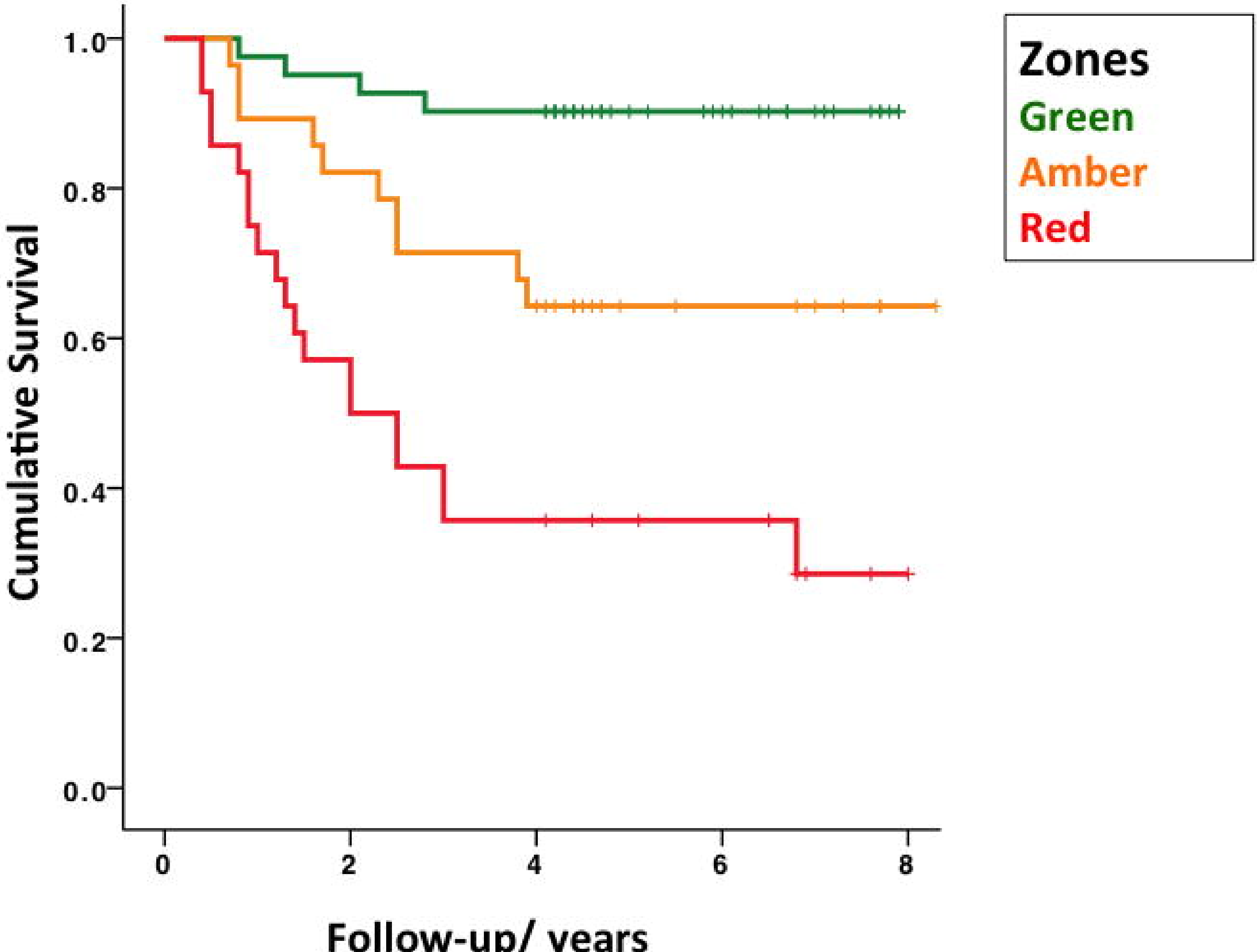
Cumulative Survival
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Follow-up/ years
Zones
Green
Amber
Red