Midterm Follow-Up and Assessment of Cartilage Thickness by Arthro-Magnetic Resonance Imaging After Arthroscopic Cam Resection, Labral Repair, and Rim Trimming Without Labral Detachment

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Purpose: To evaluate the clinical and radiological outcome, sum of acetabular and femoral cartilage thickness, and rate of failure in the midterm after arthroscopic treatment of femoroacetabular impingement (FAI) syndrome with femoral osteoplasty, labral repair, and rim trimming without labral detachment. **Methods:** This retrospective case series included patients with FAI syndrome who had undergone hip arthroscopy from January 2009 to December 2010 by a single surgeon, with a minimum follow-up of 55 months. Data from patients who had undergone arthroscopic hip procedures with labral repair, rim trimming, and femoral osteoplasty were analyzed pre- and postoperatively. Clinical outcome (nonarthritic hip score [NAHS], Short Form 36 [SF-36]), range of motion, progression of osteoarthritis (Tönnis grade), radiological parameters (α angle, lateral center-edge angle [LCEA], Tönnis angle), femoral and acetabular cartilage thickness (using magnetic resonance imaging [MRI]), and intraoperative findings were evaluated. **Results:** Of 148 hip arthroscopies performed, 97 included rim trimming, labral refixation, and femoral osteoplasty. Ten cases were lost to follow-up, leaving 87 hips. Arthroscopic revision was performed on 4 hips and total hip replacement on 4 hips, and 1 hip underwent both arthroscopic revision and total hip replacement. Excluding these 9 cases of revision, for which follow-up was not possible (retrospective study), the remaining 78 hips were followed up for a minimum of 55 months (77 ± 11.4, mean ± SD; range 55 to 124). Mean NAHS (65 to 88, $P < .001$), SF-36 physical subscale (65 to 85, $P < .001$), and the numerical pain rating scale (NRS) (5 to 1, $P < .001$) improved significantly. Outcome scores of minimal clinical importance (NAHS) were achieved in 67.6% of the patients. Mean range of movement improved significantly in flexion (109 to 122, $P < .001$) and internal rotation (10 to 22.7, $P < .001$). NAHS was positively associated with flexion of the hip postoperatively ($r = 0.307$, $P = .011$). In 16 cases, microfracture was performed (15 acetabular and 1 femoral). Preoperative α angles (anteroposterior and modified Dunn) were significantly higher in this cohort ($P < .001$, 95% confidence interval 8.9 to 25.2, $P = .001$). Twenty hips (28 %) progressed to worse Tönnis grades. Initial Tönnis grades were grade 0, 38; grade 1, 48; grade 2, 8. Pre- or postoperative Tönnis grades did not show any correlation with pre- or postoperative NAHS and NRS. MRI measurements at the latest follow-up (69 patients) of the femoral and acetabular cartilage thickness did not reveal any significant reduction at the 12 o'clock position. **Conclusion:** Arthroscopic cam resection, rim trimming, and labral repair without detachment of the labrum provides good or excellent outcome in 77.1% of hips based on NAHS in the midterm. Higher range of motion in flexion is associated with higher NAHS postoperatively. Arthroscopic cam resection, rim trimming and labral repair without detachment of the labrum is a successful method for the treatment of FAI syndrome in the midterm. **Level of Evidence:** IV, retrospective case series.

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The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received August 12, 2019; accepted October 11, 2020.

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0749-8063/19941

https://doi.org/10.1016/j.arthro.2020.10.012

Recent evidence has shown that surgical hip dislocation and hip arthroscopy are valid methods for the treatment of femoroacetabular impingement (FAI) syndrome in the mid- to long term.[1-3] An unstable labrum should be repaired in a case of chondrolabral tear. When less extensive incomplete tears or pincer or mixed-type impingements occur, the acetabular rim can be accessed by detachment of the labrum or the over-the-top technique.[4,5] Minimal rim trimming is often performed to generate a healing response for labral repair.

Short-term follow-up studies on the over-the-top technique have been reported[6]; however, midterm follow-up investigations have been rare. Furthermore, no comparative studies have been published regarding labral detachment. The chondral layer preserved in junction with the labrum can act as an extra cuff of tissue supporting the suction-seal effect.

Reducing cartilage wear is the main goal of joint-preserving surgery. Currently, however, there is no widely accepted classification system for categorizing intra-articular damage in patients with FAI syndrome.[7] Very few studies have been conducted to assess cartilage thickness using magnetic resonance imaging (MRI) scans.

The aims of this study were to evaluate the clinical and radiological outcome, sum of acetabular and femoral cartilage thickness, and rate of failure in the midterm after arthroscopic treatment of FAI syndrome with femoral osteoplasty, labral repair, and rim trimming without labral detachment.[4,5] The hypothesis was that the outcome would be significantly better at the final follow-up compared with preoperative values, cartilage thickness would not be reduced, and the revision rate would be acceptable. A further hypothesis was that the α angle and acetabular retroversion index would be reduced and that low femoral antetorsion would be associated with worse outcome, as reported previously.[8]

Methods

Data of patients who had undergone an arthroscopic hip procedure with labral repair, variable amount of rim trimming, and femoral osteoplasty from January 2009 to December 2010 with hip arthroscopy were collected in a prospective fashion and retrospectively analyzed. The study was approved by the Ethics Board of the North-West and Central Switzerland (EKNZ) (registration number: 2015-213).

Inclusion Criteria

A consecutive series of symptomatic patients undergoing hip arthroscopy, with labral repair and femoral osteoplasty in all cases and rim trimming as required by patient anatomic characteristics, were included in the study. Further enrollment criteria were failed nonsurgical management, such as physiotherapy, oral analgesia, and occasional intraarticular cortisone injections, for 6 months; mixed-type or pincer morphology; and minimum clinical and radiological follow-up of 55 months.

Exclusion Criteria

Patients were excluded with <55 months' follow-up, advanced level of osteoarthritis (Tönnis grade 3), previous ipsilateral hip surgery, Perthes disease, or not having undergone labral repair.

Indication for Surgery

FAI syndrome was diagnosed by symptoms (motion- or position-related symptoms), clinical examination (positive impingement test and exclusion of extra-articular causes of pain), and diagnostic imaging. The cam component of mixed type impingement was defined as follows: >50° on radial reconstruction of MRI scans or x-ray (modified Dunn view).[9,10] This threshold was chosen for the α angle in cases of mixed-type or pincer impingement, because the α angle may not necessarily be as high as in pure cam-type impingement.

Sclerotic subcortical bone at the neck–head transition was also considered suggestive of impingement. Pincer was diagnosed by the presence of the crossover sign (on the x-ray) and the analysis of the acetabular version in the proximal 50% on the axial section of the pelvis observed on MRI scans, intraoperative impingement test after sufficient cam correction, coxa profunda morphology, or lateral center-edge angle (LCEA) ≥35°.

Operative Technique

The operative technique has been previously described (Fig 1).[11] The joint capsule was opened in an extensive manner, mostly in the area of the iliofemoral ligament, to ensure good access. The capsule was then left open without closure.

Acetabuloplasty and Labral Repair

Minimal rim trimming without detachment of the labrum was performed for labral refixation without significant pincer morphology to support healing. The decision to repair the labrum was based on intra-operative findings, such as a the lack of a proper suction seal by the labrum when distracting the joint or significant chondrolabral dissociation with unstable labrum to probing. In all other cases, correction of pincer morphology was performed (Fig 1).

Femoral Osteoplasty

Femoral osteoplasty was performed in all cases regardless of the initial α angle, to allow for more impingement-free range of motion (ROM). If significantly positive posterior wall sign was present,

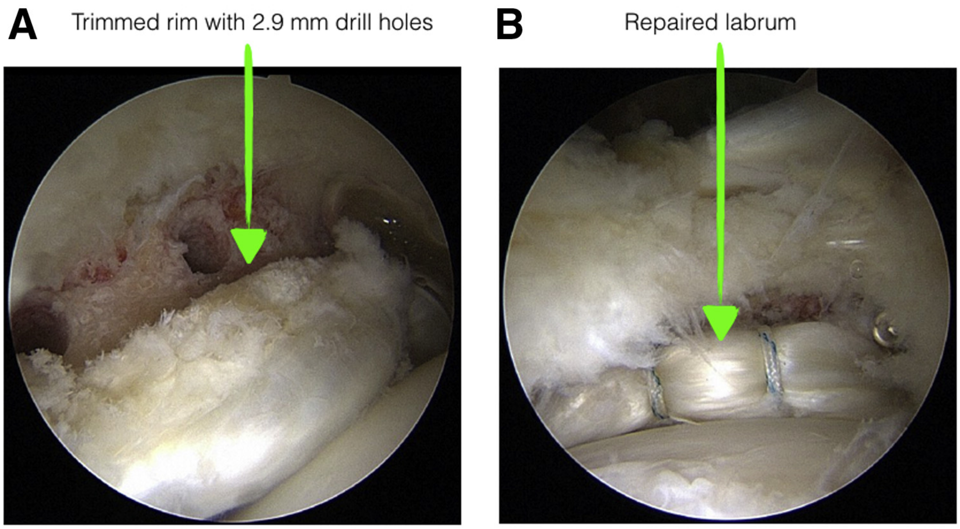

Fig 1. Acetabular rim trimming (A) and labral refixation without detachment of the labrum (B). Right hip, distal anterolateral portal, 70° arthroscope, without traction. (B) Drilled for 2.9-mm PEEK push lock anchors from 12 to 1:30 o'clock. Note the reflected head of the rectus tendon at 12 o'clock.

compensatory femoral osteoplasty was performed instead of anterosuperior rim trimming.

Clinical Findings

Patient-reported outcomes were assessed by the nonarthritic hip score (NAHS, scale 0 to 100), Short Form 36 (SF-36, physical and mental subscale, scale 0 to 100), and numerical pain rating scale (NRS, scale 0 to 10). Minimal clinical importance was determined based on the methodology of Thorborg et al.[12] ROM was assessed using a goniometer; internal and external rotation was measured in 90° flexion with the contralateral hip in 0° flexion. Gait was assessed by checking whether limping occurred (Duchenne gait, antalgic gait), and 1-leg stance was assessed in terms of Trendelenburg positivity (0, negative; 1, unstable; 2, positive). Pain intensity during anterior impingement testing was evaluated on a subjective scale (0 to 3) at the final follow-up (≥55 months postoperatively). The applied scales to assess gait and pain intensity during anterior impingement testing are not validated.

Intraoperative Findings

Acetabular cartilage lesions were assessed using the Outerbridge and Acetabular Labral Articular Disruption (ALAD) classification.[13] The Seldes[14] and Outerbridge classifications were used to assess labral and femoral cartilage lesions, respectively. Intraoperative procedures were also recorded (number of anchors, size of the trimmed acetabular rim, and area of microfracture).

Radiographic Analysis

Conventional radiographs were analyzed according to Tönnis grade and the anteroposterior LCEA, Tönnis angle, anteroposterior (AP) α angle, and α angle on modified Dunn x-rays (AD)[15,16] preoperatively, at 6 weeks, and at the final follow-up postoperatively. α Angle was measured on the radial reconstruction of the MRI scans according to the sagittal view in cases of suboptimal x-rays. The mean medial proximal femoral angle,[17] the posterior wall sign (PWS), and the ischial spine sign (ISS) were also evaluated.[18] The acetabular retroversion index (ARI) was quantified as described previously.[19,20]

Where measurements of 2 independent readers were available, a 2-way mixed-effects model intraclass correlation coefficient (ICC) was calculated to measure interrater reliability. The level of reliability was categorized as poor (ICC <0.5), moderate (ICC 0.5 to 0.75), good (ICC 0.75 to 0.90), or excellent (ICC >0.90).[21]

MRI

MRI was performed with intraarticular Gadolinium contrast agent. MRI scans were performed with a Siemens Achieva 3-Tesla preoperatively with a standard protocol and with a Siemens Area 1.5 Tesla at the final follow-up (≥55 months postoperatively), applying additional radial reconstruction.

To assess cartilage thickness, coronal proton density (PD) images across the greatest diameter of the femoral head were analyzed in the weightbearing area at 12 o'clock, in 3 subregions, from lateral to medial (1, 2, and 3). With radial reconstruction, based on PD sequences, the cartilage thickness was also measured in the weightbearing zone at 12 o'clock and posteroinferiorly on the facies lunata, using the 3 subregions. Femoral antetorsion was measured in relation to the posterior condylar line of the knee according to Lee et al.[22]

Definition of Failure

Failure was defined as revision hip arthroscopy, conversion to total hip replacement (THR), and <80 points on the NAHS at the latest follow-up.

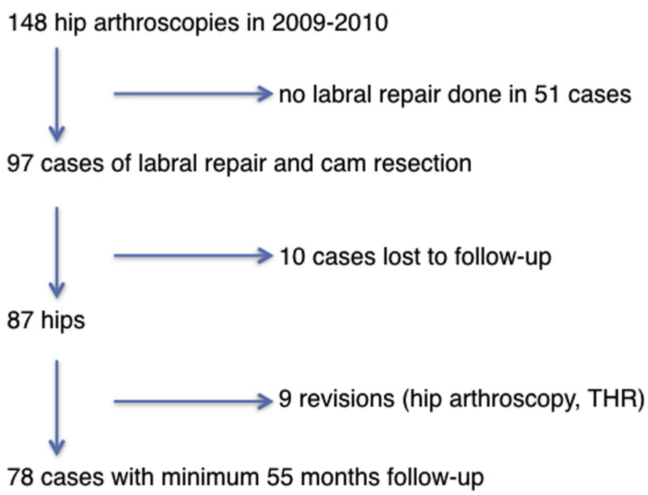

Fig 2. Flowchart: Selection of studied cases.

Statistical Analysis

All statistical analyses were performed with IBM SPSS Statistics, version 25. Descriptive statistics, including means and standard deviation (SD), were calculated for all continuous variables. Frequency counts and percentages were calculated for categorical variables. Paired *t* test was used to assess differences between pre- and postoperative data. Bivariate linear correlations were analyzed with the Pearson test for continuous variables and the Spearman test for categorical variables. The correlation effect sizes were classified as poor ($r = 0.1$), medium ($r = 0.3$), or strong ($r = 0.5$).[23] All tests were performed 2-tailed, P values $\leq .05$ were considered statistically significant, and 95% confidence intervals (CIs) are reported where appropriate.

Results

Arthroscopic femoral osteoplasty was carried out in 148 cases. Additional rim trimming and labral repair was performed in 97 cases (83 patients, 49 male). Altogether, 10 hips were lost to follow-up (10.3%), leaving 87 hips. Arthroscopic revision was performed on 4 hips and THR on another 4 hips, and 1 hip underwent both arthroscopic revision and THR. Excluding these 9 cases of revision, for which follow-up was not possible owing to the study being retrospective, the remaining 78 hips were followed up for a minimum of 55 months (77 ± 11.4 months [mean ± SD]; range 55 to 124).

In unilateral cases, the right or left sides were operated in 40 and 25 cases, respectively. There were 16 staged bilateral cases. Among the bilateral cases, 1 side of 2 patients were lost to follow-up and 1 side of 3 patients were excluded owing to short follow-up (Fig 2). The interval between bilateral operations was 10.1 ± 11.3 months (range 0 to 34). Age at surgery was 33.1 ± 11.7 years (range 16 to 66), and body mass index (BMI) was 22.7 ± 3.3 kg/m^2 (range 15.2 to 31.4)

The hips that were lost to follow-up were not different from those with follow-up data in terms of sex, age, BMI, preoperative NAHS, NRS, ALAD classification, and Tönnis grade; however, they had a higher mean α angle on the modified Dunn view (see Limitations).

Patient-Reported Outcome Measures (PROMs)

Results regarding NAHS, SF 36, and NRS are shown in Table 1. The minimal clinically important nonarthritic hip score, based on the methodology of Thorborg et al.,[12] was achieved by 67.6% of the patients. Pre- and postoperative NAHS showed a positive correlation with SF-36 physical subscale before ($r = 0.671$, $P < .001$) and after ($r = 0.771$, $P < .001$) surgery, and 77.1% of cases were rated good or excellent. The change in NAHS showed a medium to strong correlation with BMI, preoperative α angle on Dunn and AP views, change of the α angle on the modified Dunn view, and the Beighton score (Table 2).

The Beighton score was positively correlated with the changes in NAHS (Spearman $\rho = 0.419$, $P = .002$) and was negatively associated with acetabular chondropathy (Spearman $\rho = -0.259$, $P = .049$). The Beighton score was significantly higher in females ($P < .001$). ROM is shown in Table 3. There was a positive correlation between NAHS and flexion at follow-up ($r = 0.307$, $P = .011$). Internal rotation showed a significant correlation with flexion postoperatively ($r = 0.456$, $P < .001$) (Table 3). The results of impingement testing (flexion, adduction, internal rotation) are shown in Table 4.

Table 1. Patient-reported outcome measures and Beighton score (paired *t* test)

Measure	Baseline	Follow-up	Difference	95% CI	*P* Value
NAHS	65 (19.3)	88 (11.9)	21 (17.8)	17.0 to 25.4	**<0.001**
SF 36 Mental	78 (17.3)	82 (12.6)	4 (16.6)	0.3 to 8.6	.068
SF 36 Physical	65 (21.8)	85 (14.4)	20 (19.6)	14.2 to 24.7	**<0.001**
NRS pain[a]	5 (2.0)	1 (1.2)	−4 (2.2)		**<0.001**
Beighton	1 (1.3)				

NOTE. Boldface indicates statistical significance. Data are mean (standard deviation).

CI, confidence interval; NAHS, nonarthritic hip score; NRS, numerical pain rating scale; SF 36, short form 36.

[a]Wilcoxon test.

Table 2. Correlation of change in NAHS (preoperative versus last follow-up)

Measure	n	Pearson *r*	*P* Value	Correlation
BMI	68	−0.260	.033	Medium
Preoperative α angle, AP pelvis	65	−0.412	.001	Strong
Preoperative α angle, modified Dunn view	62	−0.303	.018	Medium
Change in α angle, modified Dunn view	59	0.320	.014	Medium
Beighton score	54	0.419[a]	.002	Strong

AP, anteroposterior; BMI, body mass index.
[a]Spearman ρ.

Intraoperative Findings and Treatment

The distribution of the ALAD lesions were grade I, 36%; grade II, 28%; grade III, 22%; and grade IV, 12%; those of the acetabular Outerbridge lesions were grade I, 53%; grade II, 30%; grade III, 10%; and grade IV , 5%. Labra showed lesions of Seldes 1, 52%; Seldes 2, 28%; or both, 14% in the indicated proportions. No labral pathology was found in 6% of the hips. In these hips, pincer correction was performed. Femoral Outerbridge lesions were grade I, 13%; grade II, 4%; grade III, 1%; and grade IV, 1% in the indicated distribution. No pathology was seen in 81% of the cases.

Rim trimming was performed from 0.6 to 7 mm (area 161.74 ± 50.56 mm^2; range 45 to 350). Microfracturing was performed in 16 cases on the acetabular side (area 215 ± 145.86 mm^2; range 90 to 600). Femoral microfracturing was done in 1 case (mean area 75 mm^2).

Preoperative AP and AD were both significantly higher for hips with microfracture (66.0° versus 48.9°, 95% CI 8.9 to 25.2, $P < .001$; 70.5° versus 58.2°, 95% CI 5.0 to 19.5, $P = .001$, respectively), as was the change of AD (−23.3° versus −13.3°, 95% CI −15.6 to −4.4, $P = .001$). There were no significant differences in PROMs between the 2 cohorts.

Radiological Outcome and MRI Assessment

The comparison of radiological parameters preoperatively and at the final follow-up are shown in Table 5. Mean femoral antetorsion was 8.68° ± 8.07°; range −6° to 29.7°; 95% CI 6.39 to 10.98). Correlations of PROMs, postoperative internal rotation, and flexion with femoral antetorsion are presented in Table 6. No correlation could be found between femoral antetorsion and any of the assessed PROMs (Table 6). Postoperative internal rotation (Pearson $r = 0.392$, $P = .006$) and flexion (Pearson $r = 0.354$, $P = .014$) showed an association with femoral antetorsion.

Quantitative comparisons of cartilage thickness preoperatively and at the latest follow-up were performed. The most relevant subregions, regarding cam impingement, were found at the margin of the acetabulum (Cor PD 1 and 2 and Rad 1 and 2). No statistically significant differences were found in these subregions. However, at the most medial subregions (Cor PD 3 and Rad 3), there was a significant difference compared with preoperative values, showing slightly thicker cartilage. Cartilage thickness in any of the examined subregions at any time point failed to show a correlation with NAHS. SF-36 showed no correlation with cartilage thickness either pre- or postoperatively.

Table 3. Range of motion, gait, and 1-leg stand (paired *t* test)

Measure	Baseline	Follow-Up	Difference	95% CI	*P* Value
Extension	1 (3.6)	11 (6.2)	10 (7.1)	8.4 to 11.7	<.001*
Flexion	109 (10.0)	122 (11.4)	12 (13.3)	9.2 to 15.5	<.001*
Abduction	39 (6.9)	46 (9.8)	7 (11.6)	3.7 to 9.5	<.001*
Adduction	25 (4.5)	26 (7.8)	1 (9.0)	−1.3 to 3.2	.410
External rotation	36 (12.0)	39 (9.3)	4 (11.7)	1.2 to 6.9	.006*
Internal rotation	10 (12.6)	22.7 (10.7)	12 (14.5)	8.7 to 15.6	<.001*
Gait					.001*[a]
0	62 (80)	67 (97)			
1	4 (5)	2 (3)			
2	11 (14)				
3	1 (1)				
1-leg stand					.408[a]
0	73 (95)	69 (99)			
1	3 (4)	1 (1)			
2	1 (1)				

Data are mean (standard deviation) or n (%).
[a]Wilcoxon test.
*Statistically significant.

Table 4. Anterior impingement test preoperatively and at follow-up (Wilcoxon test)

Measure	Baseline	Follow-up	*P* Value
Impingement			<.001
0	2 (3)	45 (64)	
1	13 (17)	13 (19)	
2	41 (54)	10 (14)	
3	20 (26)	2 (3)	

Data are n (%).

Despite preserved cartilage thickness on the MRI, Tönnis classification showed progression. Results are presented in Table 7. Twenty hips (28%) progressed to worse Tönnis grades, and 52 hips (72%) showed no change. Tönnis classification pre- or postoperatively did not show any correlation with pre- or postoperative NAHS and NRS scores, nor did it correlate with the changes of these scores or radiologic indices such as PWS, ISS, or ARI.

Failure

Failure was defined as THA, revision hip arthroscopy for any reason, and postoperative NAHS <80. Five patients (5 hips, 4 female, 2 of them on the right side) received THR after a mean of 2.4 years postoperatively at the age of 47.2 ± 6.0 years; range 37 to 52. These patients were significantly older (P = .009) and had a significantly higher Tönnis grade (Tönnis 2, 3 hips; Tönnis 1, 2 hips; P = .003) and more severe acetabular chondropathy (Outerbridge 2, 3 hips; Outerbridge 3, 2 hips; P = .007) before surgery. Sex, BMI, preoperative NAHS, NRS, ALAD classification, and microfracturing did not show significantly different results for this cohort.

Four revision hip arthroscopies were performed after nonsurgical treatment. Time to revision was 14.8 ± 5.76 months. Residual bony impingement, capsulolabral and capsulofemoral adhesions, or acetabular chondropathy were identified as the causes of failure. All except 1 patient, who received a THR, did better postoperatively. The period after which no pain medication was needed varied from 2 to 12 months. These cases included significantly more labral damage (Seldes classification, P = .003) and significantly more frequent microfracturing at the time of the index operation (3 of 5 versus 13 of 91 cases; P = .017).

There were 14 patients with a postoperative NAHS <80. These patients were slightly but not significantly older (35.4 versus 32.3 years, P = .393) and had significantly lower mean preoperative NAHS scores (52 versus 70 points, P = .001). There was no significant difference in the improvement in NAHS between the 2 groups (13 versus 23 points, P = .74). There was also no significant difference in sex distribution (P = .38). Hips with postoperative NAHS <80 were significantly different in terms of femoral chondropathy (P = .004), NRS (P < .001), preoperative gait (P < .001), and 1-leg stand postoperatively (P = .038).

The only radiological parameter that was significantly different for hips with NAHS <80 was the LCEA. Mean LCEA was significantly higher preoperatively (30.8 versus 26.4, 95% CI 0.8 to 7.8, P = .016) and postoperatively (30.1 versus 26.0, 95% CI 0.24 to 7.96, P = .038) for hips with NAHS <80. The extent of chondrolabral disruption (ALAD) (P = .764), labral lesion (Seldes) (P = .454), acetabular chondropathy (Outerbridge) (P = .362), and pre- and postoperative Tönnis grade (P = .281 and P = .642, respectively) were not significantly different in these patients (NAHS <80). Overall failure rate was 22.9%.

Discussion

After the arthroscopic treatment of FAI syndrome with femoral osteoplasty, labral repair and rim trimming without labral detachment in a consecutive series of patients, the PROMs (NAHS and SF-36 physical), hip ROM (except adduction), and impingement test positivity improved significantly by the final follow-up date (minimum 55 months). The hypothesis that the outcome would be significantly better at the final follow-up compared with preoperative values was confirmed.

Table 5. Comparison of radiologic parameters pre- and postoperatively (paired *t* test)

Parameter	Baseline n	Baseline Mean (SD) or n (%)	Baseline ICC	Follow-Up n	Follow-Up Mean (SD)	Follow-Up ICC	Difference n	Difference Mean (SD)	Difference 95% CI	*P* Value
Lateral center edge angle	74	27.2 (5.6)	0.798	73	26.8 (6.1)	0.814	73	−0.5 (3.7)	−1.4 to 0.4	.277
Tönnis angle	74	2.8 (5.1)		74	3.4 (5.3)		74	0.6 (3.4)	−0.2 to 1.4	.131
α angle on AP pelvis	73	51.5 (13.8)	0.987	73	46.7 (9.6)	0.993	73	−4.8 (14.2)	−8.1 to −1.4	.006
α angle on Dunn view/MRI radial reconstruction	78	59.9 (11.9)	0.979	74	42.9 (4.1)	0.823	65	−14.7 (8.5)	−16.8 to −12.6	<.001
Acetabular retroversion index	56	14.9 (13.3)	0.999	56	8.1 (12.5)		56	6.7 (13.7)	10.4 to 3	.001
Medial proximal femoral angle	72	86.9 (7.1)								
Ischial spine sign	72	26 (36)								
Posterior wall sign	68	28 (41)								

AP, anteroposterior; CI, confidence interval; ICC, intraclass correlation coefficient; SD, standard deviation.

Table 6. Correlation of the femoral antetorsion

Measure	n	Pearson *r*	*P* Value	Correlation
NAHS preoperative	46	−0.127	.402	No
NAHS postoperative	46	0.015	.920	No
SF-36 Physical preoperative	36	−0.040	.816	No
SF-36 Physical postoperative	43	−0.075	.633	No
Internal rotation postoperative	48	0.392	.006	Medium
Flexion postoperative	48	0.354	.014	Medium

NAHS, nonarthritic hip score; SF 36, short form 36.

The directly measured thickness of the femoral and acetabular cartilage did not decrease significantly, and the revision rate was 9.3%, with a relatively high percentage of Tönnis 1 and 2 cases at baseline after the arthroscopic treatment of FAI syndrome with femoral osteoplasty, labral repair, and rim trimming without labral detachment. Thus, the hypotheses that the cartilage thickness would not decrease and the revision rate would be acceptable were confirmed.

A further hypothesis was that the α angle and acetabular retroversion index would be reduced. The α angle and acetabular retroversion index were reduced significantly. Therefore, this hypothesis was also supported by the study's results. However, the hypothesis that femoral antetorsion would be associated with worse outcome was rejected, as femoral antetorsion did not correlate with any of the PROMs.

PROMs

The investigated PROMs (NAHS and SF-36) improved significantly postoperatively (final follow-up at minimum 55 months) and were comparable to those of other studies.[2] Arthroscopic labral repair with the over-the-top technique yielded good and excellent midterm results in 77.1% of the hips, and minimal clinically important difference was achieved in 67.6% of the patients based on NAHS.

The changes in NAHS showed medium to strong correlations with the BMI and the Beighton score. The role of BMI has been considered controversial in previous studies. Two reports could not detect a negative prognostic value of BMI, although the study of Saltzman et al.[25] may have been underpowered.[24,25] However, in line with the current study, Krych et al.[26] identified BMI as a negative prognostic factor. This result appears plausible, since a higher BMI may reduce patients' ability to perform postoperative physiotherapy exercises, thus negatively influencing improvement of PROMs.

Preoperative cartilage thickness measured by MRI did not show any correlation with PROMs. This may be due to the small sample size and the difficulty to perform exact measurements on areas with thin cartilage layers.[27] Studies have shown that patients with grade 3 and 4 cartilage lesions have worse outcomes.[28]

Table 7. Tönnis grade postoperatively and at latest follow-up (Wilcoxon test)

Tönnis Grade	Baseline	Follow-Up
0	38 (40)	26 (36)
1	48 (51)	33 (45)
2	8 (9)	12 (16)
3		2 (3)

Data are n (%).

Range of Motion

Hip ROM improved significantly in all directions except adduction.[11] The increase in extension, abduction, and external rotation may be explained by the extensive capsulotomy without repair.[24] No revisions were performed for instability, subluxations, or dislocations. This may be due to labrum repair carried out in each case instead of labral debridement or resection and the lack of dysplastic hips. However, the latter does not necessarily preclude subluxations or dislocations without capsular repair.[29] The postoperative degree of flexion correlated with postoperative NAHS. This finding is indirectly supported by Krauetler et al.,[30] who found that cam morphology was responsible for the limitation of flexion rather than internal rotation.

Surprisingly, no direct link between ROM and PROMs could be found in the literature of arthroscopic hip preservation until now, although it seems plausible. An association between postoperative flexion and internal rotation at final follow-up was found, which may be explained by simultaneous cam and pincer correction, leading to higher flexion and, to a lesser extent, internal rotation based on the data of Kelly et al.[31] Internal rotation in 90° flexion did not show any significant correlation with NAHS, SF-36 physical, or NRS, possibly owing to type II error.

Radiologic Parameters

Preoperative α angle on AP pelvis and modified Dunn views were shown to negatively correlate with the change of NAHS. The reduction of the α angle on the modified Dunn view was associated with the improvement of NAHS. These findings suggest that severe cam morphology was more difficult to correct, which is in accordance with the results of Lansdown et al.,[32] who found that femoral-side measurements were the strongest independent predictors of postoperative outcome.

Hips with a posterior wall sign were associated with less improvement in NAHS. This may be due to a potential instability as a result of decreased posterior coverage combined with a reduced anterior coverage due to rim trimming. Lack of capsule closure may have contributed to this issue. Tannast et al.[18] found, however, that PWS was a normal phenomenon.

In spite of rim trimming, the LCEA was not reduced significantly. This could be because rim trimming was initiated more anteriorly than the 12 o'clock position; thus the LCEA and Tönnis angle did not change significantly. Reduction of the ARI showed only a weak association with the change in ROM or NAHS. This may be due to a type 2 error.

Femoral Antetorsion

In contrast to a previous report,[33] femoral antetorsion did not correlate with any PROMs, but was associated with ROM (postoperative internal rotation and flexion). This finding was partially supported by Krauetler et al.,[30] who showed that femoral antetorsion outweighed cam morphology in terms of internal rotation.

Cartilage Thickness

Cartilage thickness was measured on MRI scans pre- and postoperatively. Slightly thicker cartilage was found postoperatively in 4 subregions. No significant differences between cartilage thickness could be detected in 2 subregions. Despite the limitations of the applied assessment, significant reduction in cartilage thickness could not be found in the examined subregions.

Impingement Test

Flexion-adduction-internal-rotation test results showed significant improvement postoperatively. It must be noted, however, that the sensitivity and specificity of this test has been found to be low, and thus it is recommended as a screening tool only, according to previous reports.[34] The foot progression angle walking test has been described and recommended recently to improve diagnostic accuracy.[35]

Treatment of Cartilage Lesions

The mean surface area of microfracture was 215 mm^2. This was larger than in other studies dealing with microfracture.[36] In spite of this, the cases with microfracture did not differ from the rest in terms of PROMs, but had significantly higher preoperative AP, AD, and reduction of AD. The latter serves as an explanation for more advanced chondral lesions on the acetabular side, which reflects the natural history of cam morphology.

These results are similar to other studies, in which no differences were found in patient-reported outcomes between cases with or without microfracture.[37,38] Moreover, none of these cases were revised to THR, which seems to support the efficacy of this technique of cartilage regeneration.

Tönnis Grade

A large proportion of hips progressed to worse Tönnis grades. The inclusion criteria reflected the routine indication of surgery by the senior author in 2009 and 2010. Even Tönnis grade 2 hips were operated on in the study period, and the proportion of operated Tönnis 1 hips was also high, which would not occur in today's practice. There is a clear discrepancy between the progression of Tönnis grade and measured cartilage thickness pre- and postoperatively on MRI. As suggested previously,[39] this may be due to the fair to moderate inter- and intraobserver reliability of the Tönnis classification, especially in cases of less advanced degenerative changes.[39]

Failure

Revision surgery, including THR and arthroscopy, and a final NAHS <80 were considered failure. The overall failure rate was 22.9%, which may be partly explained by the application of rather strict criteria (NAHS <80).

Revision to THR

Revision rate to THR was similar[40] or slightly lower compared with other reports; however, Tönnis 2 hips were also included in the current study. Assuming that all hips that were lost to follow-up had received a THR, the revision rate (15.6%) would still remain comparable to other midterm studies.[1,2] Age, Tönnis grade, and acetabular chondropathy appear to be risk factors for THR, which has been extensively studied in the literature. Microfracturing was not performed in this cohort, as opposed to the rest of the cases.

Arthroscopic Revision

The 4 cases with arthroscopic revision had significantly more labral damage and underwent microfracture more frequently at the index operation. Revision was performed for persistent bony deformity and chondrolabral adhesions. Minor chondral damage was also noted near the acetabular rim. Adhesiolysis was performed in nearly 40% of the revision cases, according to previous data, whereas residual impingement was cited as the no. 1 reason for revision.[41,42]

Postoperative NAHS <80

There were 14 patients with a postoperative NAHS <80. These hips were significantly different in terms of femoral chondropathy, NRS, preoperative gait, and 1-leg stand. More patients said they would not be willing to undergo surgery again in this group. Patients in this cohort had lower baseline NAHS but showed comparable improvement postoperatively. The sex distribution, age, extent of chondrolabral disruption (ALAD), labral lesion (Seldes), acetabular chondropathy (Outerbridge), and pre- and postoperative Tönnis grades were not significantly different in this cohort. These results do not reflect the findings of previous studies, which reported worse outcomes for cases with chondral lesions.[28]

We also found higher lateral coverage (LCEA) of the femoral head in these patients, although it was still within the normal range. The effect on outcome is unclear. NRS and the cohort of hips with NAHS <80 did not show any association with Beighton score.[43]

Limitations

The study has several limitations. This is a single-surgeon case series study with a small patient cohort without a control group. The hips that were lost to follow-up had significantly higher preoperative α angles on the modified Dunn view (77.5° versus 59.9°, $P < .001$) than those with follow-up data. This may have biased the results. Cartilage thickness measurements were biased, since pre- and postoperative measurements were performed on 2 different MRI scanners, and no semiquantitative scores such as the hip osteoarthritis MRI scoring system (HOAMS)[44] were applied.

Furthermore, no multivariate linear regression analysis was performed; thus, no independent predictors of failure could be identified. In analyses where parameters and their relationships were not found to be significant and correlation effect sizes were classified as low, the results may have been due to type 2 error. Correlation effect sizes were classified as low between the following parameters:

- microfracture and PROMs;
- Tönnis grade and NAHS;
- THR and microfracture, ALAD classification, and preoperative NAHS;
- ARI and ROM, impingement test, and NAHS; and
- NAHS <80 and ALAD classification, Seldes classification, Outerbridge grade, and Tönnis grade pre- and postoperatively.

Conclusion

Arthroscopic cam resection, rim trimming and labral repair without detachment of the labrum provides good or excellent outcome in 77.1% of hips based on NAHS in the midterm. Higher ROM in flexion is associated with higher NAHS postoperatively. Arthroscopic cam resection, rim trimming, and labral repair without detachment of the labrum is a successful method for the treatment of FAI syndrome in the midterm.

Acknowledgments

We thank Michael Thomas for his valuable language help and proofreading.

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