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ORIGINAL ARTICLE

Is acetabular osteoplasty always required in mixed impingement?

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Abstract
Background Mixed femoroacetabular impingement (FAI) is typically managed with both femoral and acetabular rim osteoplasties, but it has not been reported if the rim osteoplasty is always required.
Hypothesis/purpose We hypothesized that mixed FAI managed by femoral or combined femoral and acetabular osteoplasties will both attain satisfactory clinical results, provided intraoperative impingement-free functional motion is attained.
Methods We retrospectively reviewed 30 hips (23 patients, mean age at surgery 24.3 years, mean follow-up time 1.6 years) with mixed FAI who underwent surgical dislocation of the hip and had femoral osteochondroplasty with rim trim (RT, $n = 21$) or no rim trim (NRT, $n = 9$). Physical examination results and Western Ontario and McMaster Universities Osteoarthritis (WOMAC) scores were evaluated.
Results Mean (±SD) WOMAC pain scores improved from 6.56 (±2.96) to 2.33 (±3.64) in the NRT group ($p = .002$) and from 6.86 (±4.15) to 3.86 (±3.95) in the RT group ($p = .014$). Function improved in both groups, but the difference was significant only for the NRT group ($p < .001$). Over 50 % of patients in both groups had resolution of impingement sign. Internal rotation increased from 8.6° (±11.8) to 20.0° (±10.4) in the NRT group ($p = .043$) and from 4.0° (±12.1) to 18.6° (±14.0) in the RT group ($p < .001$). Both groups had increased flexion post-operatively to normal range, but the change was only significant for the RT group ($p = .02$). Both groups had insignificant decreases in external rotation.
Conclusion Satisfactory clinical outcomes were seen in hips with mixed impingement, regardless of whether RT was performed, provided impingement-free functional motion was attained and no severe cartilage damage was seen.

Keywords Femoroacetabular impingement (FAI) · Open surgical dislocation · Crossover sign · Mixed impingement · Femoral osteoplasty · Acetabular osteoplasty

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Introduction

Femoroacetabular impingement (FAI) is recognized as a source of pain and a risk factor for premature osteoarthritis (OA) in active adults [1–5]. The pathoanatomy of FAI involves: (1) cam impingement due to an aspherical femoral head–neck junction; (2) pincer impingement due to acetabular overcoverage from an excessively deep or retroverted socket; or (3) mixed impingement from combined cam and pincer morphology [4]. Repetitive microtrauma from impingement causes damage to the anterior acetabular labrum and adjacent articular cartilage, which can lead to early OA [1–9].

Surgical dislocation of the hip is a safe and effective technique to address symptomatic impingement [10]. In patients with minimal arthrosis at the time of surgery, surgical dislocation with osteoplasty consistently reduces pain and improves function [11–14]. Based on the type of deformity, osteochondroplasty of the femoral head–neck junction and/or trimming of the anterior acetabular rim is performed to reduce pathological contact and improve motion [15, 16]. Although 110°–115° hip flexion has been recommended as a goal for motion after resection [17], and a minimum of 20° internal rotation at 90° flexion has been used as a baseline for normal combined motion [18], there are no established guidelines for resection. Patients with mixed impingement are typically managed with both femoral and rim osteoplasty. The latter requires takedown of an often intact labrum and labrochondral attachment. An ovine model has shown that the labral body heals to bone after labral takedown, but a cleft remains at the labrochondral junction [19]. The effect on the labral sea and the long-term consequences of this iatrogenic labrochondral disruption are unknown [20, 21].

At our institution, the intraoperative goal for motion is flexion >100° and a minimum of 20° internal rotation at 90° flexion. For patients with mixed impingement, no acetabular rim trim is performed if this motion is achieved with femoral osteoplasty alone and if acetabular cartilage damage is <2 mm in depth. The purpose of this study was to compare retrospectively the clinical, radiographic, and functional results of treating patients with mixed impingement by femoral osteoplasty versus femoral osteoplasty with acetabular rim trim.

We focused specifically on patients whose pincer impingement was due to acetabular retroversion, based on positive crossover [22] and ischial spine signs [23]. We hypothesize that there is no difference in clinical outcome between patients with mixed impingement managed by femoral osteoplasty alone compared with femoral and acetabular osteoplasties, as long as impingement-free functional motion is attained.

Materials and methods

After Institutional Review Board approval, a surgical database query identified 124 patients (153 hips) who underwent surgical dislocation of the hip to treat FAI between August 2006 and August 2010. The indications for surgery were persistent pain, mechanical symptoms, and radiographically confirmed structural abnormalities of the hip. All patients had failed 6 months of conservative treatment, including activity modification, restriction of athletics, and avoidance of symptomatic motion. Patients with open growth plates, age >45 years, prior hip surgery, and incomplete clinical or radiographic documentation were excluded from the study. Mixed impingement was defined with the following criteria: an alpha angle >50° [18], positive crossover [22] or ischial spine [23] signs, and an lateral center edge angle [24] of >25° on properly positioned anteroposterior (AP) pelvis radiographs. Radiographic evaluation included AP pelvis and cross-table lateral views of the involved hip. Pelvic inclination was standardized to a distance of 2–6 cm between the sacrococcygeal junction and the superior border of the pubic symphysis [25]. Neutral pelvic rotation was achieved when the tip of the coccyx was aligned with the middle of the pubic symphysis and the radiographic teardrops, the obturator foramina, and the iliac wings were symmetric.

The surgical dislocation approach was performed according to the technique described by Ganz et al. [26] (Fig. 1). Prior to dislocation, range of motion was noted; then, offset correction with femoral osteoplasty was carried out in all hips. If dynamic examination achieved at least 100° flexion and 20° internal rotation at 90° flexion and cartilage damage of <2 mm in depth was seen, no rim trim was performed (Fig. 2). If impingement persisted or acetabular cartilage damage ≥2 mm in depth was seen, it was addressed with labral takedown, acetabular rim trim, and labral refixation (Fig. 3). The integrity of the acetabular labrum was assessed intraoperative.

Subjects were grouped according to whether they had acetabular rim trim (RT) or no rim trim (NRT). Clinical results were measured by physical examination tests of: (1) impingement sign; (2) flexion; (3) combined flexion-internal rotation (flex-IR); and (4) combined flexion-external rotation (flex-ER). Radiographic assessment was based on post-operative decrease in alpha angle. Functional scores were measured by the Western Ontario and McMaster Universities Osteoarthritis (WOMAC) [27] patient-reported outcome tool obtained pre-operatively and at 1-year post-surgery.

Statistical analysis

Distributions are summarized descriptively with mean (±SD) or number (%). The RT and NRT groups were compared with respect to pre-operative characteristics and duration of follow-up using the two-sample t test. To evaluate pre- to post-operative changes in continuous outcomes, we used a paired t test on the differences and also report the corresponding 95 % confidence interval. We compared the pre- and post-operative prevalences of

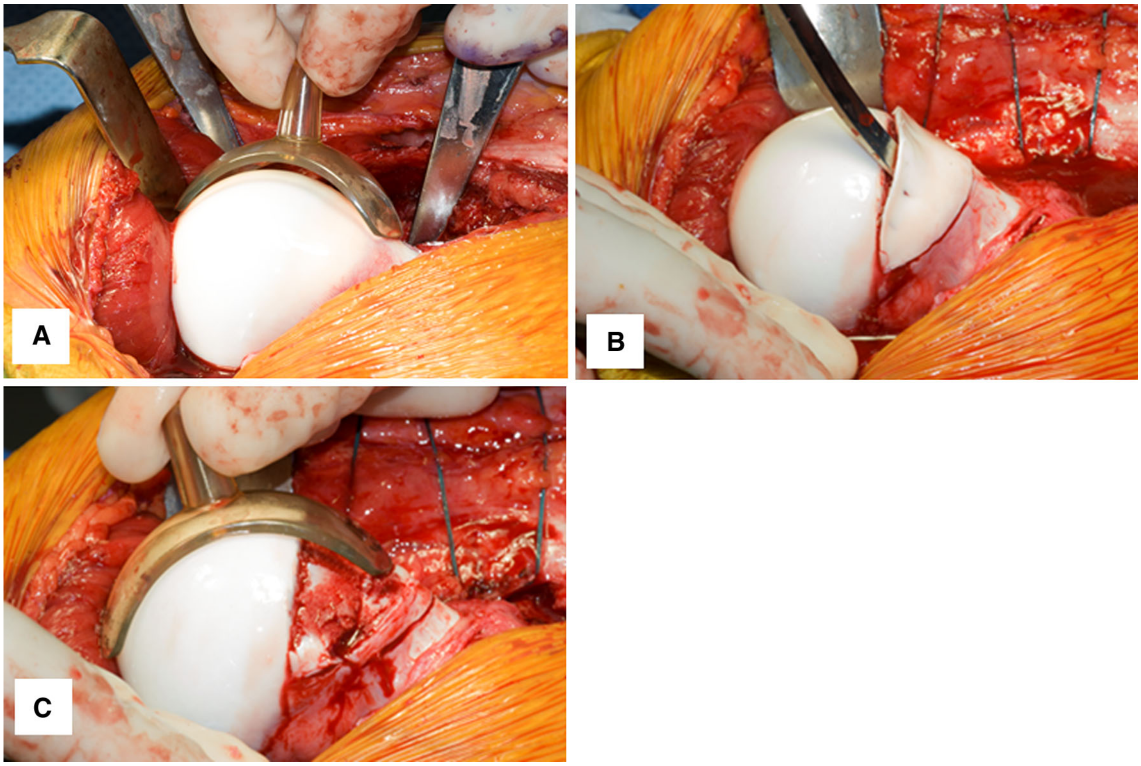

Fig. 1 Intraoperative photographs are shown. The non-spherical portion of the femoral head–neck junction is assessed by using a spherical template (**a**). The prominent bump at the femoral head–neck junction is handled with a femoral osteoplasty. In order to minimize the amount of bone resection needed to restore femoral head sphericity, intraoperative impingement tests are performed and a spherical template is used after each resection step (**b**). After osteochondroplasty, the sphericity of the femoral head–neck junction is confirmed with a spherical template (**c**)

impingement sign using an exact McNemar's test. Some of the outcomes did not have symmetric distributions and 7 of the 23 patients contributed data from both hips. Therefore, we conducted sensitivity analyses to evaluate the robustness of our statistical analyses to possible violations of assumptions. For each two-sample t test comparing the RT and NRT groups, we performed a Wilcoxon rank-sum test and also a mixed model analysis with a random subject effect. Similarly, for each paired t test, we performed a signed rank test and constructed the corresponding test from a mixed model. The results of these different analyses were substantively similar, and we report only the t tests. Two-sided p values are reported throughout and are considered significant when <.05.

Results

Thirty hips in 23 patients met the criteria of mixed FAI due to acetabular retroversion and a cam lesion. There were 18 men (23 hips) and 5 women (7 hips). The right side was involved in 16 cases, and the left side, in 14 cases. Seven patients had bilateral staged procedures. All patients with positive ischial spine signs also had positive crossover signs. In 24 hips (19 patients), the crossover sign was seen at the cranial third of the acetabulum and in 6 hips (4 patients) at the middle third.

Further, only in 2 hips (one in each group) a posterior wall sign was seen. This is when the center of the femoral head lies lateral to the posterior wall and implies a retroverted acetabulum on AP pelvic radiographs. There were 14 patients (21 hips) in the RT group and 9 patients (9 hips) in the NRT group.

The average age at surgery was 24.3 years (SD 7.5 years) with a mean follow-up time of 1.6 years (range from 0.8 to 3.0 years). There were no differences in gender-ratio, age, or length of follow-up as well as pre-operative clinical and radiographic parameters between groups (Table 1). Specifically, there were no pre-operative differences with respect to: WOMAC pain, stiffness and function scores; alpha, Tönnis and lateral center edge angles; and hip flexion, flex-IR, flex-ER, or percentage of patients with positive impingement sign.

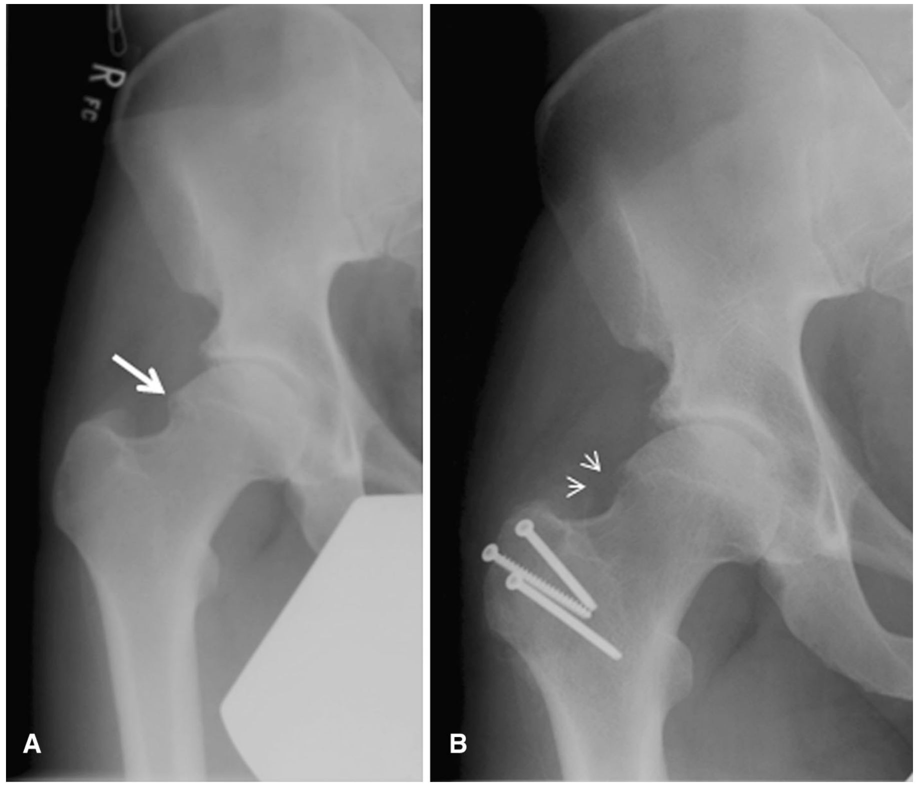

Fig. 2 Pre (**a**)- and post (**b**)-operative standard anterior–posterior radiographs are shown of a patient who underwent open surgical dislocation and femoral osteoplasty alone. Please note the bony prominence on the femur (*arrow*) and the improved femoral head–neck offset after surgery (*arrowhead*)

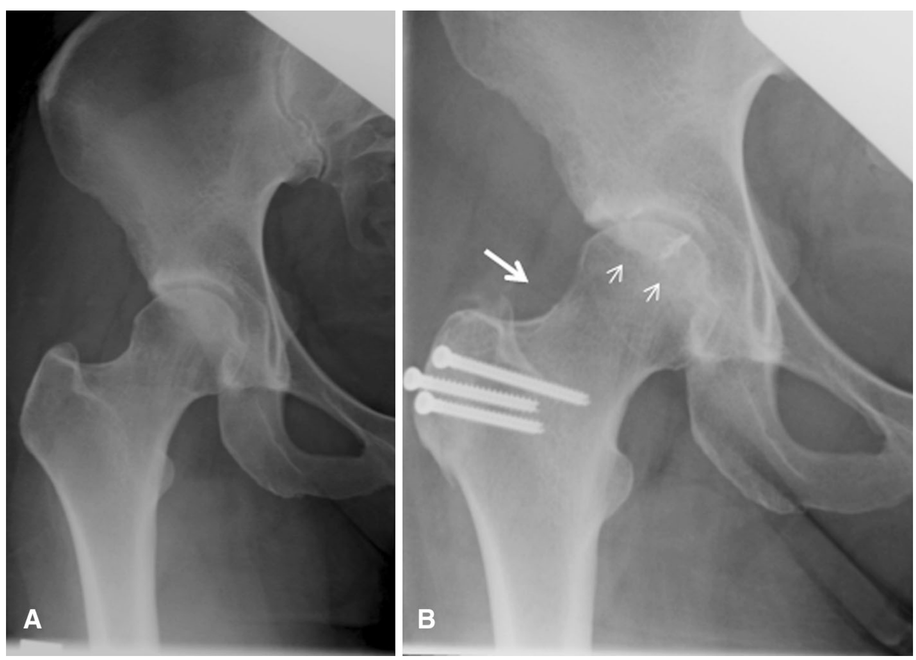

Fig. 3 Pre (**a**)- and post (**b**)-operative standard anterior–posterior radiographs are shown of a patient who underwent open surgical dislocation, acetabular rim trim, labral refixation, and femoral osteoplasty. The abnormal bone was resected on the edge of the femoral head (*arrow*), and the acetabulum was also trimmed back (*arrowhead*) to eliminate the abnormal contact

Successful open surgical dislocation was achieved in every case, and no complications were reported. In the NRT groups in 2 hips, slight labral degeneration was seen and treated with labral debridement.

In the RT group, 8 of the 21 hips had no labral lesion and the labrum was reattached after rim trimming. In 13 hips, labral tear or labral degeneration was seen and treated with partial labral excision and debridement. For refixation, bone anchors were used and stitches were passed through the labrum via a mattress stitch. Average anchors used were 3.1 per hip.

There were no cases of post-operative femoral neck fracture or osteonecrosis.

Table 1 Pre-operative characteristics and extent of follow-up

Characteristics	Rim trim			
	No ($N = 9$)	Yes ($N = 21$)	All ($N = 30$)	p value
Follow-up (years)[a]	1.7 (±.9)	1.6 (±.6)	1.6 (±.7)	.71
Age at surgery (years)	24.3 (±9.1)	24.3 (±7.1)	24.3 (±7.5)	.98
Male gender	7 (78 %)	16 (76 %)	23 (77 %)	.93
Surgery on left side	6 (67 %)	8 (38 %)	14 (47 %)	.15
LCE angle (°)	29.9 (±3.3)	30.4 (±4.6)	30.2 (±4.2)	.77
Tonnis angle (°)	4.2 (±4.2)	5.0 (±2.4)	4.7 (±3.0)	.55
Alpha angle (°)	72.6 (±18.2)	70.3 (±15.1)	71.0 (±15.8)	.73
Impingement sign	9 (100 %)	20 (95 %)	29 (97 %)	.51
Delamination depth (mm)	.2 (±.7)	2.5 (±1.4)	1.8 (±1.6)	<.001
Delamination length (mm)	1.1 (±3.3)	13.3 (±7.6)	9.7 (±8.7)	<.001
Flexion (°)	95.6 (±13.1)	89.3 (±13.3)	91.2 (±13.3)	.24
External rotation (°)	45.0 (±10.4)	43.6 (±10.5)	44.0 (±10.2)	.77
Internal rotation (°)	8.6 (±11.8)	4.0 (±12.1)	5.2 (±12.0)	.39
WOMAC pain	6.56 (±2.96)	6.86 (±4.15)	6.77 (±3.79)	.85
WOMAC stiffness	1.78 (±1.86)	2.43 (±1.99)	2.23 (±1.94)	.41
WOMAC function	12.9 (±12.2)	15.4 (±20.1)	14.6 (±17.9)	.73

Data are summarized with mean (±SD) or number (%)

LCE lateral central edge

[a] Follow-up from surgery to post-operative WOMAC evaluation

Table 2 Pre- and post-operative WOMAC scores

	N	Pre-op	Post-op	Change		
		Mean (±SD)	Mean (±SD)	Mean (±SD)	(95 % CI)	p value
Pain (0–20 scale)						
All	30	6.77 (±3.79)	3.40 (±3.87)	−3.37 (±4.52)	(−5.06, −1.67)	<.001
No rim trim	9	6.56 (±2.96)	2.33 (±3.64)	−4.22 (±2.82)	(−6.39, −2.06)	.002
Rim trim	21	6.86 (±4.15)	3.86 (±3.95)	−3.00 (±5.10)	(−5.32, −.68)	.014
Stiffness (0–8 scale)						
All	30	2.23 (±1.94)	1.97 (±1.69)	−.27 (±1.91)	(−.98, .45)	.45
No rim trim	9	1.78 (±1.86)	.78 (±1.39)	−1.00 (±1.80)	(−2.39, .39)	.13
Rim trim	21	2.43 (±1.99)	2.48 (±1.57)	.05 (±1.91)	(−.82, .92)	.91
Function (0–68 scale)						
All	30	14.6 (±17.9)	9.9 (±11.2)	−4.7 (±15.3)	(−10.5, 1.0)	.10
No rim trim	9	12.9 (±12.2)	7.3 (±12.2)	−5.6 (±2.8)	(−7.7, −3.4)	<.001
Rim trim	21	15.4 (±20.1)	11.0 (±10.8)	−4.4 (±18.4)	(−12.7, 4.0)	.29

Self-reported clinical outcome scores

WOMAC pain scores improved in both groups (Table 2). Function improved in both groups, but the difference was significant only for the NRT group. Stiffness improved in the NRT group and was slightly worse in the RT group, but neither change was statistically significant.

Clinical results

The post-operative alpha angle was substantially improved in all patients (Table 3). Over 50 % of patients in both groups had resolution of impingement sign. Both groups had significant increases in post-operative flex-IR. Both groups had increased flexion post-operatively, and all but one patient (in the RT group) achieved flexion >90°, but the change was not significant for the NRT group because the pre-operative flexion was higher than in the RT group. Both groups had decreases in post-operative flex-ER that were not statistically significant. Post-operative in the RT group in almost all hips the crossover sign disappeared. Only in two hips a crossover sign was still seen after surgery.

Discussion

The results of the present study are consistent with previous studies, demonstrating that the open approach is a safe and

Table 3 Radiographic measurements and physical exam findings

	N[a]	Pre-op	Post-op	Change		
		Mean (±SD)	Mean (±SD)	Mean (±SD)	(95 % CI)	p value
Alpha angle (°)						
All	30	71.0 (±15.8)	40.4 (±12.5)	−30.6 (±17.1)	(−37.0, −24.3)	<.001
No rim trim	9	72.6 (±18.2)	38.3 (±10.9)	−34.2 (±17.6)	(−47.7, −20.7)	<.001
Rim trim	21	70.3 (±15.1)	41.2 (±13.2)	−29.1 (±17.0)	(−36.8, −21.3)	<.001
Impingement sign[b]						
All	30	29 (97 %)	13 (43 %)	−53 %		<.001
No rim trim	9	9 (100 %)	4 (44 %)	−56 %		.06
Rim trim	21	20 (95 %)	9 (43 %)	−52 %		.003
Flexion (°)						
All	30	91.2 (±13.3)	97.5 (±6.5)	6.3 (±14.4)	(.9, 11.7)	.023
No rim trim	9	95.6 (±13.1)	97.8 (±5.1)	2.2 (±13.7)	(−8.3, 12.8)	.64
Rim trim	21	89.3 (±13.3)	97.4 (±7.2)	8.1 (±14.7)	(1.4, 14.8)	.020
External rotation (°)						
All	19	44.0 (±10.2)	39.8 (±8.9)	−2.4 (±9.3)	(−6.9, 2.1)	.28
No rim trim	5	45.0 (±10.4)	40.0 (±7.9)	−3.0 (±4.5)	(−8.6, 2.6)	.21
Rim trim	14	43.6 (±10.5)	39.7 (±9.4)	−2.1 (±10.7)	(−8.3, 4.0)	.47
Internal rotation (°)						
All	27	5.2 (±12.0)	18.9 (±13.0)	14.3 (±14.2)	(8.6, 19.9)	<.001
No rim trim	7	8.6 (±11.8)	20.0 (±10.4)	11.4 (±11.8)	(.5, 22.3)	.043
Rim trim	20	4.0 (±12.1)	18.6 (±14.0)	15.3 (±15.1)	(8.2, 22.3)	<.001

[a] Number with internal and external rotation data varied across visits. Numbers with data at both time points are given

[b] For impingement sign, data are summarized as number (%) at pre- and post-operative visits and the change in prevalence

successful procedure for the treatment of FAI [11, 13, 14, 28]. We found, when analyzing all patients, significant improvement in almost all outcomes measures after surgery.

Given the published outcome studies about hip impingement, including all different types of deformity, our purpose was to specifically investigate the outcome of hips with mixed impingement depending on whether femoral osteoplasty alone or additional acetabular rim trimming was performed. To the best of our knowledge, there is no study published that evaluated those two approaches in hips with combined impingement. While the understanding of the pathomorphology of mixed type impingement is well understood, the appropriate treatment strategy is still evolving and widely debated. There is a controversy in the literature over whether the assessment of acetabular retroversion based on the presence of a crossover sign alone is adequate. On the one hand, there is a study reporting that the crossover sign is a reliable tool for quantification of cranial acetabular retroversion [29], but on the other hand, a number of studies reported that the low specificity [30] or low positive predictive value [31] limit the usefulness of the crossover sign and therefore suggested to use CT or MRI for the quantification of AV, rather than plain radiographs. Given these findings, it remains a matter of discussion how accurately static radiographs reflect acetabular version. In addition, the decision regarding the best surgical management based on a crossover sign alone may result in errant rim resection based on a presumption of focal cranial retroversion and therefore has the potential to result in failures or only moderate improvement in clinical outcomes.

Comparing the two groups, our findings support our hypotheses that both surgical procedures lead to satisfactory clinical results if impingement-free motion is achieved and no severe acetabular cartilage damage is present (in our series, no cases had more than 5 mm in depth from the acetabular rim). However, minor differences were seen between the two groups. WOMAC function score improved in both groups but was only significant in the NRT group, perhaps due to small sample size. In contrast, in both groups, flexion increased post-operatively, but the difference was not significant for the NRT group where the mean pre-operative grade of flexion was already 95° and almost considered to be in the normal range; thus, we did not expect to see much of a change after surgery. For most outcomes, patients in the RT had slightly worse results, even though not all were statistically significant, than patients in the NRT group. We speculate that this may be due to the labral takedown required to access the rim and violation of the pristine labrochondral junction. However, this is compelling, and thus, further studies are needed to confirm our findings.

The present study has limitations. First, the evident heterogeneity in cartilage damage between the treatment groups is a major weakness of this study. Several studies [13, 14] proposed that substantial acetabular cartilage delamination at surgery could lead to unsatisfactory outcomes, but a significant statistical association has not yet been proven [28, 32]. However, because the groups were similar in terms of baseline WOMAC scores, physical examination test results, age, and sex, we believe that they were comparable. Second, this is a retrospective study of patients with a special surgical procedure selected out of a surgical database with a relatively small number of patients and no true control population. Third, intraoperative decision making was subjective and based on surgeons judgment.

In summary, we have underlined our hypotheses and can report, based on our findings, that hips with mixed impingement managed by femoral osteoplasty alone or combined femoral and acetabular osteoplasties, both lead to satisfactory clinical outcomes, as long as intraoperative impingement-free functional motion is attained. Most importantly, due to the fact that unnecessary resection of acetabular hyaline cartilage has the potential to result in iatrogenic hip instability and production of iatrogenic acetabular dysplasia, we suggest that the decision regarding acetabular rim trimming should not be made based on the presence of radiographic findings alone. Rather, intraoperative findings of hip joint ROM restriction and the severity of articular cartilage damage should give direction to the appropriate surgical approach in hips with mixed impingement. Certainly, further prospective clinical trials are required to confirm our finding, and obviously, extrapolation to arthroscopic treatment of combined impingement is needed, but that can be challenging since dynamic motion is difficult to assess.

Conflict of interest None.

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