Triple Pelvic Osteotomy in the Treatment of pincer type Femoroacetabular impingement Syndrome Triple Pelvic Osteotomy for FAI

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Original Article

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Abstract:

Purpose: Femoroacetabular impingement (FAI) syndrome is a dynamic contributor to hip arthritis. It is frequently identified in young adults with no other underlying reasons for hip discomfort. The pincer type of FAI, which is the focus of this study, is usually observed in inactive middle-aged women. This study aimed to assess our group of patients who underwent surgical treatment for pincer or combined types of FAI, examining their clinical and radiological outcomes, as well as any complications arising from the surgery.
Methods: Eighteen patients identified with pincer or combined

type FAI underwent triple pelvic reverse osteotomy from 2011 to 2020, and their progress was tracked in a prospective study for both clinical and radiological assessment. The average age of the patients was 37.3 years, with a range of 28.0 to 45.0 years. Follow-up assessments were conducted at mid-term. MRI scans were utilized to accurately assess the retroversion of the acetabulum both pre- and post-surgery. Subjective evaluations were carried out using Harris Hip Scores (HHS), Visual Analog Scale (VAS) scores, and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores, with Wilcoxon tests applied for paired samples (the significance level was set at 95%, $p<0.05$). A comparison of preoperative and post-operative data was conducted to assess clinical outcomes.

Results: Statistically significant improvement was observed in MRI measurements after triple pelvic osteotomy for the treatment of pincer or combined-type FAI. The HHS improved from 55.1 to 91.4, with preoperative MRIs showing a median retroversion of 5.35 degrees and post-operative MRIs indicating anteversion at 26.35 degrees. WOMAC scores were at a median of 69.9 prior to surgery and increased to 94.15 afterward, with a statistically significant result ($p<7.629$ x 10-6). After surgery, 22% (4 out of 18 patients) showed signs of clinically relevant posterior pelvic femoroacetabular impingement (FAI), although this finding was not considered significant due to the small sample size, which was a limitation of our study.

Conclusion: This surgical approach is a safe method for restoring hip mobility. For patients with pincer or combined-type of FAI, the authors recommend performing surgical pelvic osteotomy rather than hip arthroscopy, as it is an extra-articular operation and may be more effective in addressing intra-articular arthritis.

The authors declare no conflicts of interest.

All experimental protocols were approved by the Ethics Committee of the Faculty Hospital Bulovka.

Introduction

Femoroacetabular impingement (FAI) is characterized by an abnormally shaped hip joint, which can lead to hip arthritis. Pain occurs during certain hip movements, particularly flexion, adduction, and internal rotation, and it is displayed during the anterior impingement test. FAI can have multiple causes, including developmental conditions, hip joint trauma, and changes in the angles of the proximal femur due to osteotomy. Pincer FAI is more common in active, middle-aged women and is caused by extra bone growth on the acetabulum, resulting in overlap between the acetabulum and the femoral head. Combined FAI is a combination of pincer and CAM types. It is the most common type of FAI and is diagnosed by X-ray. In this study, the authors found that pelvic osteotomy is favorable for treating pincer types of FAI.

Treatment options for femoroacetabular impingement (FAI) include lifestyle modifications, over-the-counter pain relievers, physical therapy, and surgical intervention. When conservative measures fail to alleviate pain or if joint

damage is present, surgery is advised. Patients with minor joint and cartilage damage can often undergo arthroscopic procedures, whereas more extensive cases may require open surgery, pelvic osteotomy, or total hip replacement.

The purpose of this study was to assess a series of patients who underwent surgery for pincer or combined-type FAI, examining their clinical and radiological outcomes, along with any surgical complications. We hypothesize that the redirectional triple pelvic osteotomy will correct acetabular retroversion as seen on MRI scans and will lead to improved clinical results in our patient group. We also believe this anatomical correction will not negatively impact joint arthritis.

Materials and Methods

Our patient cohort consisted of consecutive cases from our institution over a specific period. All participants were diagnosed with pincer or combined FAI. These patients had undergone a reverse triple pelvic osteotomy for the treatment of pincer/combined-type FAI at the Orthopedic Clinic, Faculty Hospital Bulovka in Prague between 2011 and 2020. A total of 18 consecutive patients completed the midterm follow-up (1-9 years). The average age of the patients was 37.3 (28.0-45.0) years. All the specifications of the patients are disclosed in Table 1. All the patients were unilateral cases and were sequenced successively.

Patients with clinically symptomatic anterior femoroacetabular impingement, characterized by groin pain and decreased hip flexion, abduction, or internal rotation, were recruited for this study. Most of these patients also tested positive on the anterior FAI test. Initially, they were managed non-surgically through activity modifications; specifically, they were advised to avoid painful activities such as horse riding or motorbiking that could exacerbate symptoms.

Table 1 Patients prior to surgical intervention. Patients experienced pain during activities that involved abduction and flexion, such as ice skating and horse riding. The degree of retroversion was assessed using X-rays, following the methodology outlined by Siebenrock et al. MRI scans were utilized to measure the most retroverted side of the acetabulum.

Patient no.	Sex	Pain VAS during movement	ROM			X-ray retroversion	MRI retroversion
			Sagittal	Rotational	Abd./Add.		
1	M	5	0-0-120	10-0-10	30-0-20	x	5.5°
2	F	6	0-0-120	10-0-0	30-0-10	x	6.9°
3	F	5	0-0-120	10-0-10	30-0-20	x	7.0°
4	F	5	0-0-120	10-0-10	30-0-20	x	6.5°
5	M	7	0-0-110	10-0-0	30-0-10	x	5.2°
6	F	8	0-0-100	10-0-0	20-0-10	x	6.5°
7	F	5	0-0-120	10-0-10	30-0-20	x	5.1°
8	F	5	0-0-120	10-0-10	30-0-20	x	4.8°
9	F	6	0-0-110	10-0-10	30-0-10		3.9°
10	M	6	0-0-120	10-0-10	30-0-10	x	5.2°
11	F	7	0-0-110	10-0-0	20-0-10	x	6.1°
12	F	8	0-0-110	10-0-0	20-0-10	x	6.3°
13	F	9	0-0-110	10-0-0	20-0-10	x	6.0°
14	F	10	0-0-100	10-0-0	20-0-10	x	6.2°
15	F	7	0-0-120	10-0-10	30-0-10	x	3.4°
16	F	7	0-0-120	10-0-10	30-0-10		3.2°
17	M	7	0-0-120	10-0-10	30-0-10	x	5.0°
18	M	5	0-0-120	10-0-10	30-0-20		3.4°

This treatment period is often not limited, frequently extending beyond a year, until patients begin to experience progressive or intolerable pain that limits daily activities and ultimately leads to a surgical indication. All patients were evaluated using the Harris Hip Score (HHS) before and after surgery. Additionally, X-rays and MRI scans were performed to assess the acetabular retroversion—either focal or global—and to distinguish between retroversion and anterior rim prominence [21]. Pre- and post-operative X-ray measurements were compared following Siebenrock's criteria [20] (see Figures 1, 7, and 8). Retroverted acetabulum was identified based on three signs: 1) a crossover sign with a retroversion index over 30%, 2) a posterior wall sign, and 3) an ischial sign. These same radiographs were used to evaluate pincer FAI. Figure 3 il-

Figure 1 The typical crossover sign observed in combined FAI cases. A: Indicates focal retroversion of the acetabulum accompanied by a crossover sign. B: Shows the frontal edge highlighted in red and the reverse edge in yellow.

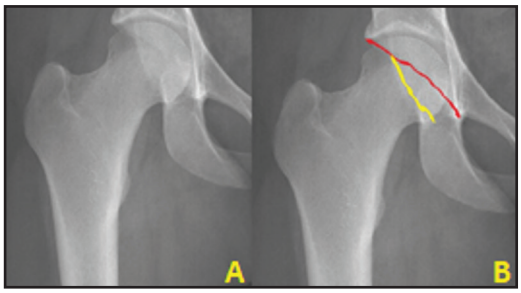
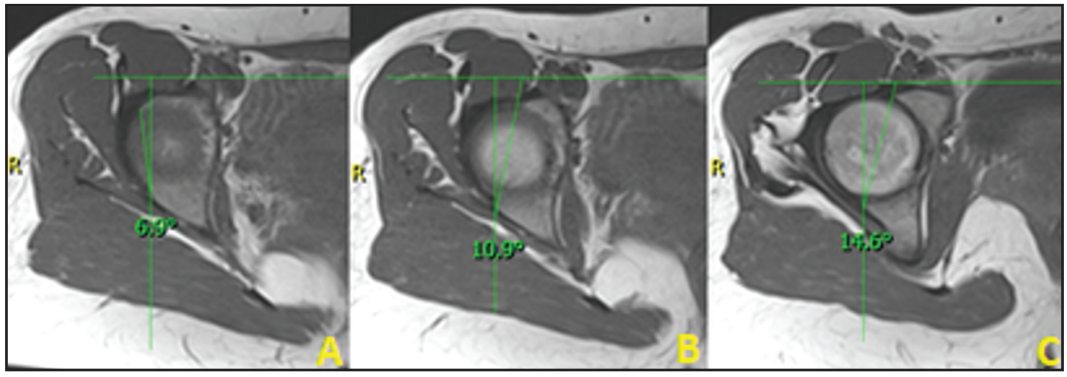


Figure 3 An image of the osteotomy procedure. It illustrates a triple pelvic osteotomy as a treatment for pincer femoroacetabular impingement (FAI) syndrome. The osteotomy lines are highlighted in yellow.



Figure 2 Transverse MRI sections of the acetabulum at various levels prior to surgery A: Focal retroversion measuring 6.9°. B: Middle portion of the acetabulum exhibiting an anteversion of 10.9°. C: Caudal part of the acetabulum in anteversion 14.6° [13]. A transverse cut of the acetabulum was performed preoperatively to accurately assess acetabular retroversion and pincer FAI and to ensure there was no damage to the cartilage.



lustrates the osteotomy lines and the post-operative X-rays. Follow-ups occurred at 6 and 12 months, then annually.

Anteversion/retroversion of the acetabulum were measured on transverse T1 MRI scans before surgery and when the osteotomy (OT) were healed. All MRI scans were done on the same MRI machine in our hospital using the same protocol. The highest measured angles were used (Fig 2 and 4).

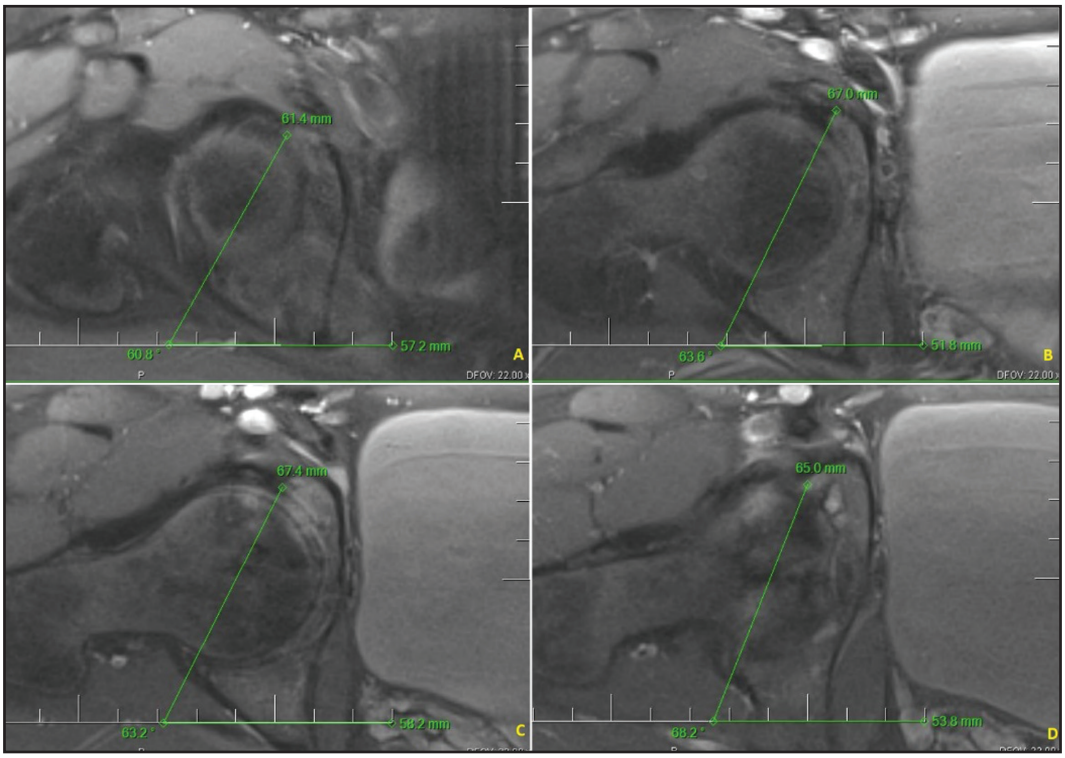
MRI scans were also used to determine the status of the cartilage and signs of arthritis before and after surgery and at the last follow up (Figure 2).

The surgical technique of a triple pelvic osteotomy, as described by Steel, is performed to change the orientation of the acetabulum. Retroversion of the pelvic bone, as identified on preoperative MRI scans, is usually performed to prevent posterior FAI clinical signs. This surgery only involves the reorientation of the acetabulum, so no bone graft was used (as in another pelvic osteotomies) and there was no lower-leg prolongation. During the operation, an extraction of part of the bone was performed from the os ischii (segment of 0.5 cm). An internal rotation of the acetabular segment of approximately 30 degrees was also performed (see Table 2 for exact values of each retroversion) with Kirschner wire fixation. The amount of inner rotation was approximately 30 degrees. Since there are no standardized reference points for degree measurements, we estimated angles based on the MRIs to achieve acetabular anteversion between approximately 10 and 20 degrees (±15 degrees).

Surgical intervention was only indicated for patients with symptomatic pincer or combined FAI that were unresponsive to conservative therapy, especially if radiographic signs of joint degeneration were present.

We opted for this extra-articular procedure to effectively address intra-articular arthritis, with

Figure 4 Transverse MRI scans of the acetabulum at various levels post-surgery. There is no retroversion present at any level.



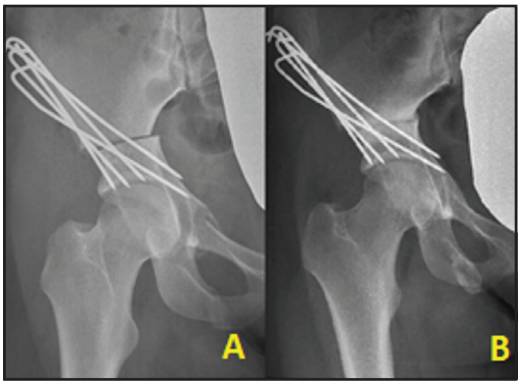
the operation typically lasting around 90 minutes. Post-surgery, patients were advised to begin physiotherapy immediately to prevent periarticular adhesions. Recommendations included continuous passive motion, using two crutches for at least 8 weeks, and limiting hip flexion to 70° for 3 to 6 months.

Cartilage damage was monitored via MRI during follow-up. X-rays were examined for signs of non-union at osteotomy sites (Figure 5).

Once complete bone healing was confirmed after two years, the Kirschner wires were removed from all patients (Figure 6A). At the 3-year follow-up, we checked for any signs of femoral head damage or necrosis (Figure 6B).

By the end of this study, patients had been followed for up to 9 years post-surgery. We analyzed the follow-up data for patients in their middle age, focusing on HHS as a clinical outcome. Additionally, frontal and dorsal impingement tests were repeated to assess the surgical results, along with X-rays and MRIs to evaluate surgical success. MRIs specifically assessed whether the osteotomy had healed and the displayed the positioning of the reverted acetabulum without using classification tests.

Figure 5 X-rayimages taken after the osteotomy. A: The postsurgical view of the pelvis after the procedure. B: The pelvic X-ray one year after the surgery indicates that proper alignment has been maintained, with no Kirschner wires observed in the joint during passive hip movement.



Results

The average retroversion was 5.34 degrees (details are in Table 2). Postoperative MRI scans were used to assess the orientation of retroversion. Patient satisfaction was measured using the Visual Analog Scale (VAS), rating pain during daily activities from 0 (no pain) to 10 (the worst pain) [12]. The Harris Hip Score (HHS) evaluated pain, gait, daily activity function, deformity absence, and range of motion, with scores categorized as poor (<70), fair (70–79), good (80–89), and excellent (90–100) [9]. The WOMAC [11] score was also recorded (Table 3).

Figure 6 X-ray images of the pelvis after the removal of the Kirschner wires. A: Taken two years post-surgery when the wires were extracted. B: Taken one year after their removal, demonstrating no defects in the femoral head, no signs of necrosis, and proper alignment. The yellow lines in the final image illustrate the technique used for the triple pelvic osteotomy.

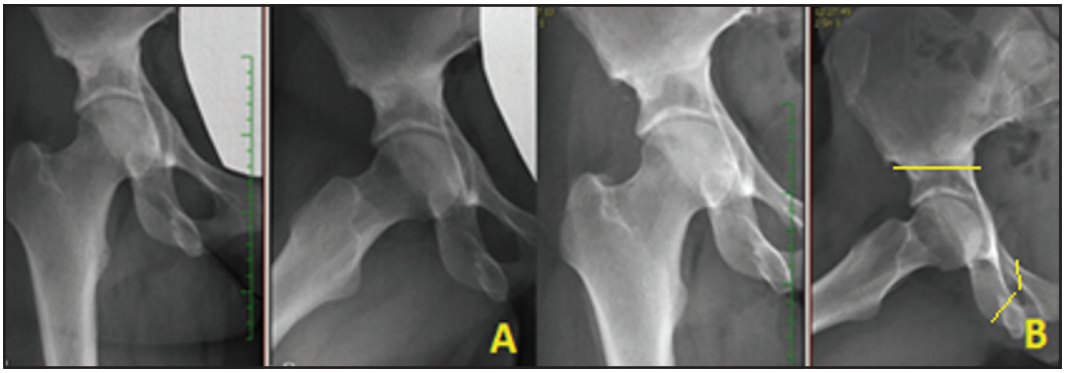


Table 2 MRI findings prior to the operation revealed an average acetabular retroversion of 5.34°, measured at the most prominent edge of the acetabulum. After the operation, the average anteversion was recorded at 26.75°.

Patient no.	MRI before operation	MRI after operation
1	5.5°	29.2°
2	6.9°	26.4°
3	7.0°	26.8°
4	6.5°	25.8°
5	5.2°	25.2°
6	6.5°	26.3°
7	5.1°	27.2°
8	4.8°	26.3°
9	3.9°	25.7°
10	5.2°	26.3°
11	6.1°	25.9°
12	6.3°	26.2°
13	6.0°	27.3°
14	6.2°	28.2°
15	3.4°	28.1°
16	3.2°	25.3°
17	5.0°	27.2°
18	3.4°	28.1°
Statistics		
average	5.34	26.75
median	5.35	26.35

Table 3 Statistical analysis was conducted using the Wilcoxon test for paired samples on the WOMAC scores. Statistical analysis showed that the scores before and after the operation were not identical. With a confidence level of 95%, the analysis indicated that the post-operative WOMAC scores were significantly improved compared to the preoperative scores ($p<7.629*10-6$).

Patient no.	WOMAC before operation	WOMAC after operation
1	67.2	96.9
2	62.5	94.5
3	64.5	89.8
4	74.2	93.5
5	68.3	95.3
6	71.9	95.2
7	73.4	93.0
8	60.8	92.7
9	71.8	95.3
10	75.0	95.3
11	68.0	92.2
12	72.7	93.5
13	69.5	96.9
14	79.7	95.3
15	71.1	94.5
16	68.0	93.8
17	70.3	93.0
18	69.5	93.8
Statistics		
average	69.91	94.14
median	69.90	94.15

Overall, all patients improved into the excellent HHS category, with scores rising from an average of 55.1 to 91.4 (Figure 7).

Hip impingement tests showed no signs of anterior impingement or pain similar to preoperative symptoms. Some patients experienced mild discomfort during prolonged walking, but overall, there was complete relief from painful hip movements (Figure 9).

We observed a significant reduction in clinically positive signs for ventral FAI, regardless of the surgical approach. All patients exhibited positive signs for ventral FAI before surgery, and postoperative treatment reduced clinically positive FAI tests to less than 1%. This outcome suggests that conservative therapy was beneficial for all patients. In our cohort treated with triple pelvic osteotomy, 22% (4 out of 18 patients) exhibited clinically relevant rear pelvic FAI post-operation, which is a limitation of our study. Our goal was to correct the retroversion of the acetabulum, as measured by post-operative MRIs. Changes to the labrum or cartilage defects were not assessed since all patients were considered too young to have such complications and did not report any arthritic issues.

When we look more precisely at the version levels of acetabulum before and after surgery (Figure 10), we can clearly see a significant of difference preoperative and postoperative MRI measurements, expressed in degrees.

Figure 7 Data on median Harris Hip Scores (HHS) for patients after reverse pelvic osteotomy

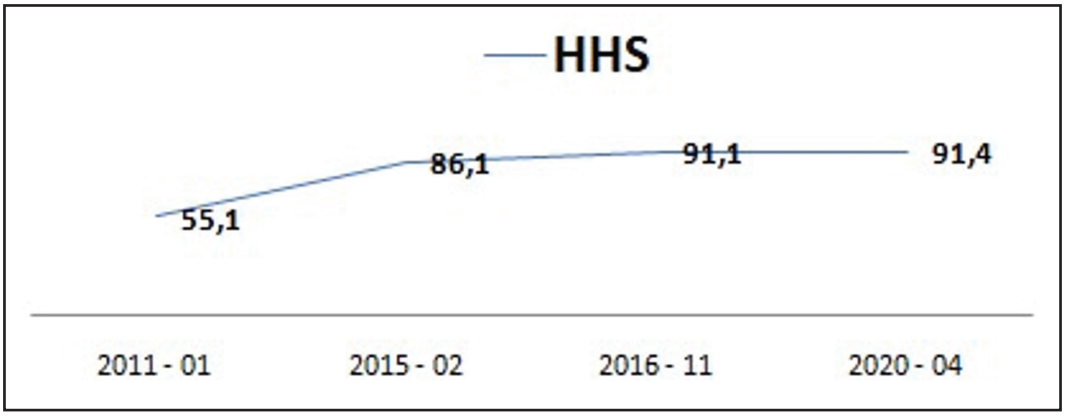
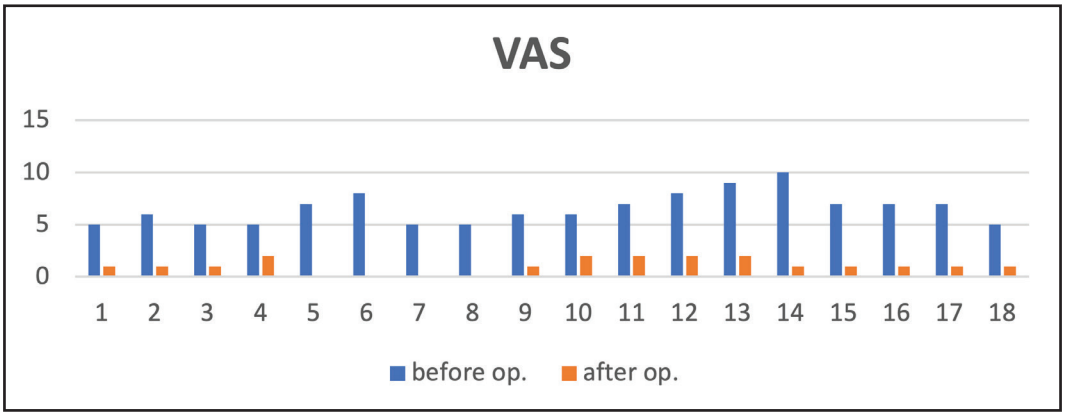


Figure 8 The average Visual Analog Scale (VAS) scores for the participants. Measured before the operation (blue line) and one year after (red line), clearly showing the benefits of the surgery.



Discussion

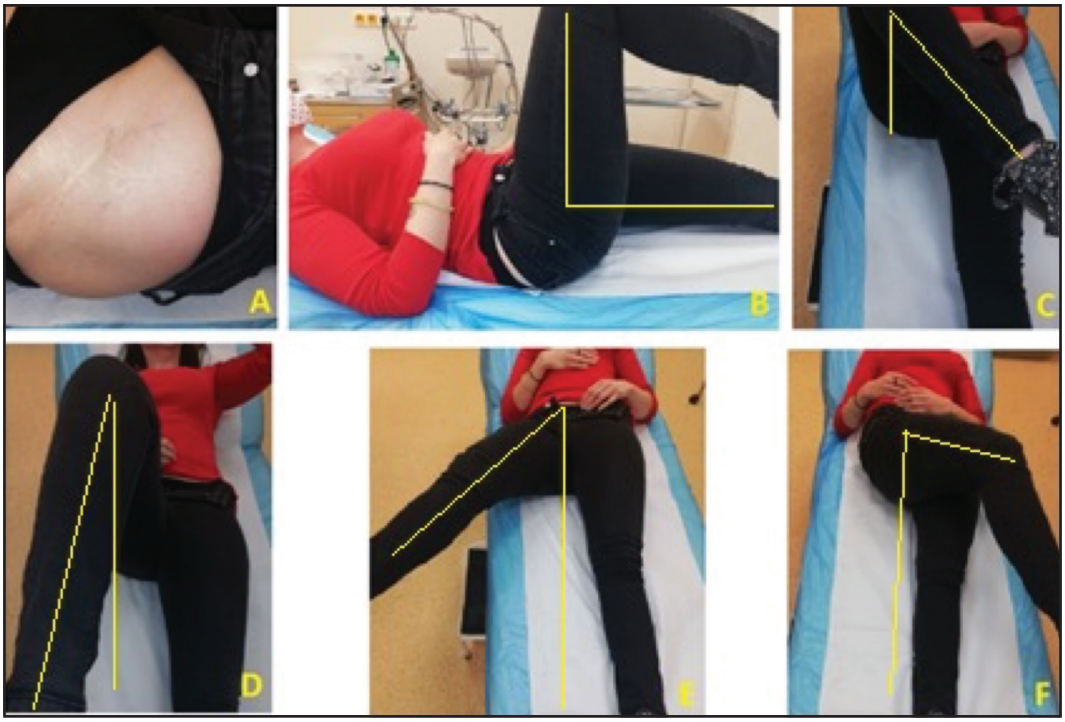
Since FAI is a dynamic factor contributing to hip arthritis, accurate diagnosis and timely treatment are crucial. Surgical intervention is indicated when patients have persistent symptoms, characteristic FAI radiographic features, and evidence of labral or cartilage damage [2]. For cases of only pincer FAI with total or global retroversion of the acetabulum, we opted for a primary reverse pelvic osteotomy, as it is the only technique capable of altering the acetabular orientation.

Various surgical options exist when a prominent anterior rim is present—these include hip dislocation with rim abrasion and redirectional pelvic osteotomy if retroversion is identified. Our findings suggest that significant acetabular retroversion in young (up to age 35) symptomatic patients with pincer FAI is most effectively treated with anteverting periacetabular osteotomy. Kirschner wires were used to stabilize the bones during the healing process. At the one-year follow-up, all the hips remained properly aligned, indicating no osteotomy displacement or femoral head necrosis. The majority of the participants were women (73%).

Siebenrock et al. [21] previously reported that 90% of patients who underwent periacetabular osteotomy for acetabular retroversion correction experienced excellent results. We built upon these findings and performed osteotomies to correct FAI before considering total hip replacement. Furthermore, we avoided surgical hip dislocation as an intra-articular procedure to prevent intra-articular complications.

It is crucial to position the patient correctly (with inner rotation and flexion) during the osteotomy, as improper positioning can lead to secondary rear FAI. Additional capsulotomy and

Figure 9 A clinical photograph of a patient taken eight years post-surgery (March 2020). A: The access point to the hip. B: Complete hip flexion (90 degrees) without pain. C: Hip outward rotation (30 degrees). D: Slight limitation in inward rotation (10 degrees). E: Hip abduction (40 degrees). F: Hip adduction (20 degrees).



enhancement of the anterior head-neck offset are generally not performed [20].

In our patient group, no total hip replacements were required during the follow-up period. Most studies report no complications related to femoral head necrosis, and our patients experienced clinical relief, as evidenced by the reduction in the VAS scores. Our ongoing long-term follow-up will yield further insights. The early correction of FAI appears to enhance hip function, and we aim to explore how often this correction prevents arthritis in future studies.

Surgical hip dislocation [6] was the initial technique described for femoroacetabular osteoplasty (FEO) and labral repair. However, due to its relatively high complication rates, long learning curve, and complexity, numerous alternative surgical approaches have emerged [14, 16]. Ultimately, addressing the acetabular abnormality remains the critical goal, tailored to the source and etiology of the impingement [8]. This aligns with the primary aim of any hip preservation surgery, which is to prevent, or at least delay, total hip arthroplasty while allowing patients to maintain the symptom-free function of their native hip.

The literature describes reverse periacetabular osteotomy (PAO) as an effective method to correct underlying deformities, improve hip pain and range of motion, and achieve favorable outcomes [19, 18]. Combined FAI, which includes true acetabular retroversion and associated cam lesions, can be treated with reverse PAO. In such scenarios, the incision is extended distally for anterior hip capsulotomy, femoral head-neck osteoplasty, and the management of labral pathology [19]. It is essential to correct the reoriented acetabulum while carefully avoiding an increased lateral edge angle or a negative Tonnis angle during the anteversion maneuver of the mobile fragment. Overcorrection of the acetabular fragment must be avoided to prevent excessive anteversion, posterior acetabular impingement, and suboptimal clinical results [18].

Peters et al. [17] previously noted that the failure rate of hip preservation procedures increases by 4% per year. While our findings show a decreasing incidence rate with extended follow-up, this inconsistency may be clarified in future studies.

We propose that significant acetabular retroversion in young symptomatic patients (up to 35 years of age) is best managed with triple pelvic osteotomy. Generally, the outcomes of acetabular rim trimming for treating retroversion appear to be inferior to those of pelvic osteotomy. Since acetabular retroversion results from malorientation rather than excessive anterior rim and insufficient posterior rim, reorienting the acetabulum is a more logical approach. Rim trimming could potentially lead to inadequate acetabular coverage [20].

Figure 10 A box diagram of the medial 50% of the difference in degrees of retroversion and post operative anteversion, a dotted line of the minimum and maximum levels.

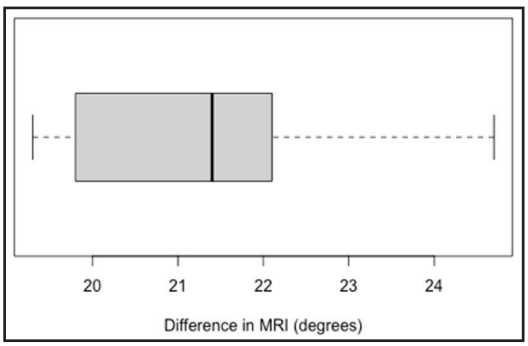
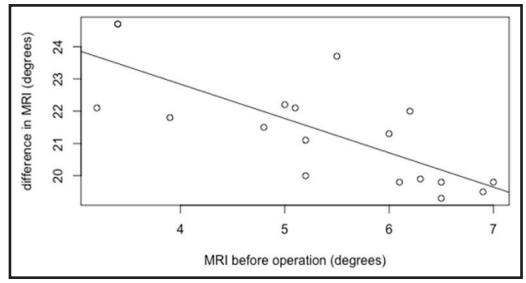


Figure 11 Displays a regression model of the differences in MRIs (degrees) based on MRIs before surgery (degrees), Shapiro-Wilk test – p=0.68, Breusch-Pagan test – p=0.23. This is a statistically significant relationship.



Conclusion

The triple pelvic osteotomy represents a favorable option among various surgical treatments for pincer/combined FAI of the acetabulum without affecting intra-joint arthritis. One advantage of this procedure is that it is the only method capable of changing the acetabulum's orientation. It is also simpler to perform than periacetabular osteotomy. However, our study's limitations include a small sample size, necessitating a larger cohort over a longer duration. Additionally, the middle-aged follow-up is another area for improvement, with 22% of patients in our control group testing positive for rear FAI, indicating that one in five patients displayed this issue. Nonetheless, the management of rear FAI with triple pelvic osteotomy is uncommon, which may be of interest to the hip preservation surgical community.

Declaration

Ethics Approval and Consent to Participate: All procedures were conducted in compliance with applicable guidelines and regulations. The experimental protocols received approval from our institution for postgraduate orthopedic surgery. Informed consent was secured from all participants.

Consent for Publication: This study does not require consent for publication.

Availability of Data and Materials: The datasets utilized and/or analyzed during this study are available from the corresponding author upon reasonable request.

Competing Interests: There are no competing interests to disclose.

Funding: This study did not receive any funding.

Authors' Contributions: Not applicable.

Acknowledgments: Not applicable.

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