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Research Article

Preliminary Findings of Femoroacetabular Impingement Treated Via Anterior Mini-Open Approach and Arthroscopy

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Abstract

Objectives: To compare clinical, functional, and radiographic outcomes of patients subjected to the anterior mini-open approach with those subjected to the outside-in arthroscopic approach for the treatment of femoroacetabular impingement (FAI).

Methods: Retrospective case-control study with clinical and radiographic assessments of patients subjected to surgical treatment of FAI between July 2011 and May 2016. The outcomes were compared between the groups. The assessments were made with the Merle-D'aubigné-Postel, Western Ontario and McMaster Universities Osteoarthritis Index scores and pain visual analog scale, in addition to measurements of internal rotation of the hip and the FAI provocation test. Radiographically, the patients were assessed according to Tönnis classification and to alpha angle measurements. The chi-square and Student's t tests were used for statistical analyses.

Results: Twenty-three patients were included – 10 subjected to the mini-open approach (Group A) and 13 subjected to arthroscopic surgery (Group B). The mean postoperative follow-up of the patients in Group A was 5.5 years and 90% showed clinical and functional improvement. Radiographically, the mean alpha angle improved and Tönnis grade did not deteriorate in any patient. In Group B, the mean postoperative follow-up was 3.6 years and all patients showed clinical and functional improvement. The mean alpha angle improved and no radiographic changes occurred in Tönnis grade. Both groups tested negative for impingement and exhibited improvement of internal rotation of the hip in the postoperative period. The clinical and radiographic outcomes were statistically similar between the groups.

Conclusions: The study demonstrated that surgical treatment of FAI had good clinical, functional, and radiographic outcomes in the midterm follow-up period with a low complication rate in both techniques.

Keywords: Femoroacetabular Impingement; Hip Arthroscopy; Anterior Approach; Complications

Introduction

The assumption that morphological hip joint deformities found between the femur and the acetabular rim could be the underlying cause of painful symptoms was originally made by Smith-Petersen in 1936 and reprinted in 2009 [1]. In his article, Smith-Petersen claimed that hip deformities could be remarkably improved or that there could be some gain in the joint range of motion if they were surgically corrected. This concept had been forgotten for decades and included some citations that were few and far between, however after the publications by the Bern Group [2-4] about the etiology, morphology, diagnosis, and treatment of the femoroacetabular impingement (FAI) syndrome, the subject has been widely investigated and the surgical treatment of this syndrome has been ameliorated in an attempt to postpone or even prevent hip osteoarthrosis, given that such changes could predispose to degenerative joint disease [3,4].

Numerous surgical approaches to FAI have been described, including open surgery and arthroscopy, but the goal is always to reestablish the anatomy in such a way that it prevents the contact between the femoral head-neck junction and the acetabular rim. Ganz., *et al*. [2] described a posterior approach with trochanteric osteotomy and anterior hip dislocation for the treatment of conditions that affect this joint, but they did not find any case of avascular necrosis of the femoral head among 213 surgically treated hips. In 2003, the same research group postulated that FAI could be one of the etiologies of hip osteoarthrosis [3] and, in 2005, they published encouraging results for the treatment of the FAI syndrome after surgical hip dislocation of 302 cases, providing a didactic description of the types of impingement and revolutionizing the method, which has become a benchmark in the treatment of this syndrome, considering that it allows full access to the acetabulum and femoral head [5]. Later on, several authors have published studies that demonstrated the success and safety of the approach [6-9].

Arthroscopic hip surgery for the treatment of FAI is quite recent, but it has improved in the past decades, and many authors have shown good outcomes over the short and intermediate term [10-13]. Two approaches have been described: inside-out [14,15] and outside-in [16-20]. Both approaches have demonstrated good clinical and esthetic outcomes and quicker postoperative recovery. Ribas., *et al*. [21] used a minimally invasive anterior approach with the patient in the supine position on a traction table, inserting an arthroscope through a surgical incision under direct visualization, with distraction of the hip, and they also obtained good outcomes for the treatment of FAI. Their outcomes were reproduced by other authors [22,23], even with the use of a conventional table and without the use of arthroscopic instruments, rendering the technique an intermediate approach between open surgery and arthroscopy.

The classic approach via surgical dislocation described by Ganz., *et al*. [2] while regarded by many authors as the gold standard for the treatment of FAI, is quite invasive, requires a long incision, may lead to labral ossification [6], and requires trochanteric osteotomy, which results in additional trauma to the patients, delaying recovery and exposing them to the risk (albeit low) of pseudoarthrosis [6,9]. In addition, there might be inflammatory processes and residual pain in the screw region used for osteotomy fixation, and that could require a later procedure for their removal [6]. On the other hand, the inside-out arthroscopic approach, even though it is a minimally invasive procedure with excellent cosmetic outcome and quicker recovery, and also appropriate offset restoration, as pointed out by anatomic and clinical studies [10-13], it appears to have a steep learning curve, posing risks of inadequate osteoplasty, causing residual [12,24] or even excessive impingement, which could cause femoral neck fractures or instability [25-27]. Iatrogenic injuries to the articular cartilage and to the labrum could also occur during the insertion of instruments [12,24,28] and the longer traction time could lead to neurological damage and hematomas, especially if performed by inexperienced surgeons [28].

The aim of this study was to compare surgical outcomes in patients with FAI subjected to the minimally invasive mini-open anterior procedure with the outcomes of the arthroscopic approach (outside-in technique). The study also aimed to compare the current outcomes of the mini-open approach with the ones previously published by the author.

Methods

This is a retrospective, longitudinal, observational, and quantitative case-control clinical study with clinical and radiographic assessment of patients surgically treated for FAI via the minimally invasive mini-open anterior approach recommended by Ribas., *et al*. [21] and via the extracapsular outside-in arthroscopic approach [19].

After submission of the research project to Plataforma Brasil and approval by the Research Ethics Committee of the Gaffreé Guinle University Hospital (process no. 58252016.5.0000.5258), all patients with a clinical and radiographic diagnosis of FAI syndrome surgically treated at the Hip Surgery Outpatient Clinic either via the anterior mini-open approach or arthroscopic technique were identified and contacted.

Ten hips of nine patients with FAI were subjected to the anterior approach from July 2011 to November 2012. All patients were contacted by phone and later showed up at the outpatient clinic for clinical and radiographic evaluation. These patients were included in Group A. Twenty-one hip arthroscopies were performed on 19 patients using the outside-in approach between May 2013 and May 2016. Eight patients were excluded from the study; two for having undergone arthroscopy to treat hip conditions other than FAI and six for having been the first cases operated on by the author and by another surgeon with vast experience in the technique. Therefore, 13 arthroscopies performed on 11 patients were eventually included in Group B.

After being informed of the goals of the study and signing the informed consent form, the patients were clinically and functionally evaluated before and after the surgery, using Merle-D'aubigné and Postel[29] (MDP) scores whose reliability has already been demonstrated after their translation into Brazilian Portuguese and subsequent validation [30], assessing pain, mobility, and gait, and using also the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) translated into and validated in Portuguese [31], according to pain, stiffness, and function, each with their subitems. The visual analog scale (VAS) [32] was also employed to quantify pain in the preoperative and postoperative periods. Preoperative clinical data were retrieved from the patients' electronic medical records to assess the hip range of motion related to VAS, as well as radiographic data related to the degree of hip joint degeneration graded according to Tönnis [33] classification and also related to the alpha angle measurement, as described by Nötzli., *et al*. [34] for axial Dunn view at 45º.

All patients, in both groups, were symptomatic at diagnosis and tested positive for FAI (passive motion with painful hip flexion, adduction and internal hip rotation). The clinical suspicion of FAI was confirmed by panoramic radiographs of the pelvis in AP view and axial Dunn view at 45º, to check for bone deformities, following the criteria proposed by Clohisy., *et al*. [35].

The preoperative panoramic radiographs of the pelvis in AP view showed the degree of osteoarticular involvement and degeneration of the hip, according to Tönnis classification [33], deformities in the femoral head-neck junction, changes in the acetabular version, in search of the crossover sign, of the posterior wall sign, characterized by the center of rotation of the femoral head located laterally to the posterior acetabular wall [36] and ischial spine sign, in addition to the presence of protrusio acetabuli (when the femoral head is medially displaced to the ilioischial line) or of coxa profunda (when the acetabular fossa is located medially to the ilioischial line). For appropriate assessment of the crossover and posterior wall signs, proper positioning of the patient was considered, taking into account appropriate pelvic tilt, as described by Siebenrock., *et al*. [37] with a distance between the pubic symphysis and the sacrococcygeal joint close to 32 mm in men and 47 mm in women. The alpha angle described by Nötzli., *et al*. [34] was measured via the axial Dunn view at 45º, considered by Meyer., *et al*. [38] the best view for assessment of cam deformity in the anterolateral aspect of the femoral head-neck junction. An alpha angle greater than 50º was regarded as cam deformity. The alpha angle [34] and Tönnis grade [33] were assessed postoperatively.

In Group A, the minimally invasive approach proposed by Ribas., *et al*. [21] was used, with skeletal traction table and perioperative fluoroscopy (Figures 1A and 1B).

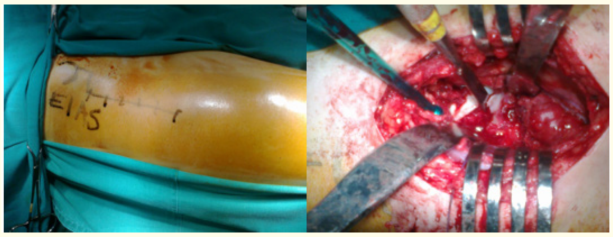

Figure 1: (A) Right thigh and hip of a patient positioned for surgical procedure, with anatomic landmarks for the anterior approach and (B) anterior approach showing femoral osteochondroplasty with osteotome for the treatment of cam deformity.
Source: Patient surgically treated in the present study.

The surgical technique is described in detail by the author when the same 10 patients were evaluated preoperatively and postoperatively in a shorter follow-up period [39].

In Group B, the extracapsular (outside-in) arthroscopic approach was used and the patient was placed on a traction table in dorsal decubitus, with well-positioned perineum supported upon a well-padded perineal post for protection of the genital region and of the pudendal nerve, as described by Horisberger [19] (Figures 2A, 2B, and 2C).

Two arthroscopic portals were used for all cases and the articular capsule was not sutured in any patient. Only the 30º arthroscope was used for the procedures. The procedures on patients from Groups A and B were performed by the same surgeon.

The MDP [29] WOMAC [31], and VAS [32] data, in addition to the measurement of the hip internal rotation angle, were compared between patients from the same group before and after surgery using the chi-square test, which compares same-size samples to assess whether there was any statistically significant change. Student's t test, which can compare different-sized samples, was used for comparison of the means between Groups A and B.

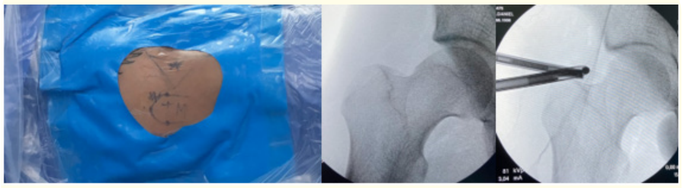

Figure 2: (A) Right thigh and hip positioned for arthroscopy with anatomic landmarks on patient with cam femoroacetabular impingement in the right hip subjected to extracapsular arthroscopy. (B) Image of right hip fluoroscopy in AP view before osteoplasty, and (C) AP view after femoral osteochondroplasty and proper correction of the femoral offset.
Source: Patient treated in the present study.

The clinical and functional outcomes (MDP [29] and WOMAC [31]) observed for those patients subjected to mini-open surgery (Group A) were compared with those of Group B and with those of the same patients previously treated by the author in another study [39], in a shorter follow-up period, assessing whether the outcomes were maintained over the years. All patients from Group A who participated in the previous assessment returned for reassessment. The chi-square test was used again for the analyses.

The alpha angle [34] calculated in the preoperative period was compared with that obtained after the procedure, in both approaches, using the chi-square test. Student's t test was used for comparison of this angle in the postoperative period between Groups A and B. Tönnis grade [33] and the alpha angle [34] in Dunn view at 45º were also compared preoperatively between Groups A and B using Student's t test to determine whether the groups exhibited homogeneous parameters. On the day of the evaluation, an FAI provocation test was carried out on all patients in order to assess whether the outcome would be negative. The statistical significance was set at $p < 0.05$.

Results

The mean postoperative follow-up period for Group A (patients treated with mini-open surgery) was 5.5 years (66.1 months, range from 62 to 78 months) and 3.6 years (43.5 months, range from 21 to 57 months) for Group B (patients subjected to arthroscopy).

Among those patients subjected to mini-open surgery (Group A), most were male (70%), the right side was most commonly affected (70%), and white skin color was the most prevalent (70%). The mean age of patients at the time of surgery was 28.8 years (12 to 44 years) and the mean time of symptom onset referred by the patients up to the day of the surgery was 27.7 months, ranging from 8 to 60 months.

In Group B, the mean age at the time of arthroscopy was 40 years (20 to 57 years), the left side was the most affected, corresponding to 69.23% of the cases, male patients were more prevalent (92.3%), and white skin color was predominant in 84.6% of the patients. The mean time from the onset of symptoms to surgery was 24.1 months, ranging from 6 to 72 months.

In Group A, the mean operative time was 153.4 minutes (107 to 207 minutes). All patients were hospitalized electively one day before surgery. Hospital discharge occurred on postoperative day 2 in nine cases (90%) and on postoperative day 1 only in one case (10%), with a mean hospital stay of 2.9 days (2 to 3 days). After hospital discharge, the patients were referred to the same outpatient clinic for physical therapy and the same protocol was followed.

In the group subjected to arthroscopy (Group B), the operative time ranged from 105 to 180 minutes, with a mean of 130 minutes. All patients were discharged on postoperative day 1, and the mean hospital stay was 2 days, including the day of hospital admission (one day before surgery). After hospital discharge, the patients were referred to the same outpatient clinic for physical therapy and the same protocol applied in Group A was used. All patients in both groups were asked to use crutches for help with their gait, in addition to partial weight bearing on the surgically treated limb for 6 weeks.

In Group A, all patients were subjected to femoral osteoplasty for treatment of cam deformity. Only one patient (10%) was subjected to acetabular osteoplasty for the treatment of pincer impingement associated with labral reattachment using suture anchors in the anterolateral acetabular rim. One patient (10%) was subjected to femoral osteoplasty and resection of an osteochondroma from the posteromedial region of the femoral neck by means of a second medial approach (Figure 3).

Another patient (10%) exhibited cam FAI associated with post-traumatic subspine impingement, which was accessed and treated through the same incision, with resection of the ossification (Figure 4).

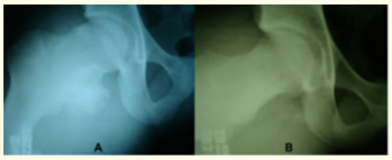

Figure 3: Patient with cam femoroacetabular impingement in right hip associated with osteochondroma in the femoral neck. (A) Preoperative radiograph of right hip in Dunn view at 45o with an alpha angle of 82º and (B) postoperative radiograph in the same view after femoral osteoplasty performed through anterior mini-open approach and tumor resection through medial access, at an alpha angle of 46º.
Source: Patient treated in this study.

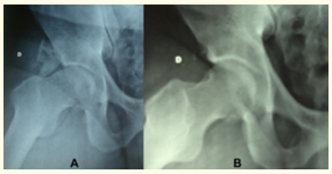

Figure 4: Patient with cam FAI associated with subspine impingement in right hip. (A) Preoperative radiograph of right hip in Dunn view at 45o with an alpha angle of 89º and (B) postoperative radiograph in the same view after femoral osteoplasty and treatment of subspine impingement via the anterior approach at an alpha angle of 45º.
Source: Patient treated in this study.

Of the surgically treated patients, one (10%) was a professional soccer player and two (20%) were amateur soccer players. Epiphysiolysis was considered the cause of FAI in 50% of the cases.

All patients subjected to arthroscopy (Group B) were subjected to femoral osteochondroplasty for the treatment of cam deformity. Three patients (23.08%) required osteoplasty of the acetabular rim, performed via the external region of the acetabulum without labral reattachment. Labral debridement was performed on those three patients. One patient (7.7%) was a professional marathoner and three (23.08%) played amateur soccer. Only one case (7.7%) was regarded as a sequela of Epiphysiolysis, while the remaining cases were unrelated to childhood or adolescent diseases and were therefore considered to be morphological changes of hip development (Figure 5).

In Group A, clinical parameters improved in nine (90%) out of 10 hips, when compared to the preoperative period. The postoperative impingement clinical test was negative in nine hips (90%). The mean score of the modified MDP (Table 1) increased from 11.5

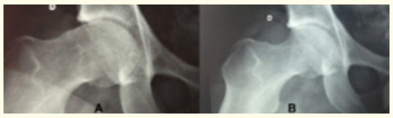

Figure 5: Patient with cam FAI in right hip. (A) Preoperative radiograph of right hip in Dunn view at 45o with an alpha angle of 94º and (B) postoperative radiograph in the same view after femoral osteoplasty via arthroscopy, using the extracapsular technique at an alpha angle of 50º.
Source: Patient treated in this study.

before surgery to 16.3 and, according to the chi-square test, this increase was statistically significant – $p < 0.05$ ($p = 0.00000149$). Only patient #5 (10%) showed a worse mean, with a decrease from 14 to 13 in the score (Table 1). By analyzing the means of the subitems of this score separately (Table 1), there was improvement in pain, from 2.6 before surgery to 5.1 after surgery, which was statistically significant $p < 0.05$ ($p = 0.00000000$); improvement in gait, from 4.2 to 5.6, with $p < 0.05$ ($p = 0.03256096$); and improvement in mobility, from 4.7 to 5.6, which was not statistically significant ($p = 0.96227957$).

	Before surgery				After surgery			
	Pain	Mobility	Gait	Total	Pain	Mobility	Gait	Total
Patient 1	4	6	6	16	6	6	6	18
Patient 2	1	4	2	7	6	6	6	18
Patient 3	1	5	3	9	4	6	5	15
Patient 4	1	4	3	8	6	6	6	18
Patient 5*	5	4	5	14	4	5	4	13
Patient 6	2	6	4	12	4	6	6	16
Patient 7	1	3	2	6	4	3	5	12
Patient 8	4	5	6	15	6	6	6	18
Patient 9	4	5	6	15	6	6	6	18
Patient 10	3	5	5	13	5	6	6	17
Mean	2.6	4.7	4.2	11.5	5.1	5.6	5.6	16.3

Table 1: MéMerle-d'Aubigné-Postel modified by Chanrley – mini-open approach.

Source: Data from the study; * Patient with reduced score

The preoperative mean of the WOMAC score in group A was 25.9, decreasing to 5.4 at the time of the assessments (Table 2), with statistically significant clinical improvement, as demonstrated by the chi-square test, with a p value close to zero ($p = 0.00000000$). When each subitem of the WOMAC score was calculated separately, there was also statistically significant clinical improvement (Table 2). Pain decreased from 5.3 before the procedure to 0.8 thereafter, with $p < 0.05$ ($p = 0.00000048$); stiffness decreased from 1.7 to zero, with $p = 0.0487$; and function went from 18.9 to 4.6, with a p value close to zero ($p = 0.00000000$). Again, only patient #5 did not show clinical improvement, with deterioration of pain and function, going from 11 to 21 in the WOMAC score (Table 2). In the preoperative period, this patient had hip osteoarthrosis classified as Tönnis grade 2 and had been reporting symptoms for approximately 5 years – the case with longer time from symptom onset to surgery. Moreover, excessive femoral osteoplasty was observed.

	Before surgery				After surgery			
	Pain	Stiffness	Function	Total	Pain	Stiffness	Function	Total
Patient 1	0	1	4	5	0	0	0	0
Patient 2	8	4	41	53	0	0	3	3
Patient 3	11	2	16	29	1	0	5	6
Patient 4	9	5	40	54	0	0	0	0
Patient 5*	2	0	9	11	4	0	17	21
Patient 6	8	4	23	35	0	0	8	8
Patient 7	3	1	14	18	2	0	4	6
Patient 8	2	0	9	11	0	0	0	0
Patient 9	1	0	8	9	0	0	0	0
Patient 10	9	0	25	34	1	0	9	10
Mean	5.3	1.7	18.9	25.9	0.8	0	4.6	5.4

Table 2: WOMAC score - mini-open approach

Source: Data from the study.

* Patient with increased score.

A $p < 0.05$ was observed for the MDP and the WOMAC scores. The analysis of the subitems (pain, stiffness, and function) of the WOMAC score also had a $p < 0.05$, which means that all the tested parameters significantly improved when compared with the preoperative and postoperative periods.

The VAS also indicated improvement of pain (Table 3), going from 6.7 before surgery to 1.2, which was statistically significant according to the chi-square test, with $p < 0.05$ ($p = 0.000000333$).

	Before surgery	After surgery
Patient 1	4	0
Patient 2	8	0
Patient 3	10	2
Patient 4	10	0
Patient 5	8	4
Patient 6	8	2
Patient 7	7	3
Patient 8	4	0
Patient 9	3	0
Patient 10	5	1
Mean	6.7	1.2

Table 3: Pain Visual Analog Scale – mini-open approach.

Source: Patient treated in this study

In Group B, the clinical parameters improved in all patients. The impingement clinical test was negative in 100% of the patients during the postoperative period. The mean MDP score (Table 4) rose from 12.62 before surgery to 17.08, a statistically significant increase, with $p = 0.01011971$ in the chi-square test. By assessing the subgroups of this score (Table 4), pain went from 3.46 to 5.38, with $p = 0.02438978$; gait went from 3.92 to 5.69, with $p = 0.03294061$; and mobility went from 5.23 to 6.0, with $p = 0.99395971$ (without statistical significance).

The mean WOMAC score in the preoperative period was 31.54 and decreased to 6.62 at the time of the assessment (Table 5), showing statistically significant clinical improvement, with a p value close to zero ($p = 0.00000000$), as indicated by the chi-square test. The analysis of each subitem of the WOMAC score also demonstrated statistically significant improvement (Table 5). Pain decreased from 5.92 before the procedure to 0.85 in the postoperative period, with a p value close to zero (0.00000004); stiffness went down from 3 to 0.77 ($p = 0.0361003$); and function went from 22.62 to 5 ($p = 0.00000000$).

The VAS (Table 6) shows there was clinical improvement in pain, which went from 5.92 before surgery to 0.92 thereafter, with $p = 0.00000008$, as indicated by the chi-square test.

	Before surgery				
	Pain	Mobility	Gait	Total	Pain
Patient 1	6	4	6	16	6
Patient 2	4	5	5	14	5
Patient 3	3	4	3	10	4
Patient 4	4	5	4	13	6
Patient 5	3	5	5	13	6
Patient 6	4	5	5	14	6
Patient 7	3	5	3	11	6
Patient 8	2	5	3	10	6
Patient 9	3	6	5	14	6
Patient 10	4	6	4	14	5
Patient 11	2	6	2	10	4
Patient 12	3	6	2	11	5
Patient 13	4	6	4	14	5
Mean	3.46	5.23	3.92	12.62	5.38

After surgery		
Mobility	Gait	Total
6	6	18
6	5	16
6	4	14
6	6	18
6	6	18
6	6	18
6	6	18
6	6	18
6	6	18
6	6	17
6	5	15
6	6	17
6	6	17
6.00	5.69	17.08

Table 4: MéMerle-d'Aubigné-Postel score modified by Chanrley – arthroscopic approach.

Source: Patient treated in this study.

		Before surgery			
	Pain	Stiffness	Function	Total	Pain
Patient 1	0	6	9	15	0
Patient 2	5	5	51	61	2
Patient 3	2	0	10	12	1
Patient 4	8	3	16	27	0
Patient 5	5	0	8	13	0
Patient 6	3	6	15	24	0
Patient 7	9	2	22	33	0
Patient 8	7	0	27	34	0
Patient 9	1	0	11	12	0
Patient 10	11	6	37	54	3
Patient 11	6	2	21	29	2
Patient 12	9	3	30	42	0
Patient 13	11	6	37	54	3
Mean	5.92	3.00	22.62	31.54	0.85

After surgery		
Stiffness	Function	Total
2	3	5
1	20	23
0	7	8
0	0	0
0	1	1
2	1	3
0	0	0
0	3	3
0	1	1
2	8	13
1	7	10
0	6	6
2	8	13
0.77	5.00	6.62

Table 5: WOMAC score – arthroscopic approach.

Source: Data from the study.

	Before surgery	After surgery
Patient 1	0	0
Patient 2	5	2
Patient 3	8	4
Patient 4	5	0
Patient 5	2	0
Patient 6	10	2
Patient 7	8	0
Patient 8	8	0
Patient 9	7	0
Patient 10	4	0
Patient 11	8	1
Patient 12	8	2
Patient 13	4	1
Mean	5.92	0.92

Table 6: Pain Visual Analog Scale – arthroscopic approach.

Source: Data from the study.

The postoperative outcomes of patients in Groups A and B were compared by Student's t test, considering the groups have different sample sizes. By looking at the MDP and WOMAC scores and VAS, no statistically significant difference was found for the postoperative outcomes of patients subjected to mini-open surgery when compared with those subjected to arthroscopy. Both groups had good outcomes. Only the subitem "stiffness" in the WOMAC score yielded better outcomes for those patients subjected to mini-open surgery than for those subjected to arthroscopy, with mean values ranging from 0 to 0.77, respectively, with p = 0.00417896 (Table 7).

To verify whether the clinical and functional outcomes were maintained by those patients subjected to mini-open surgery, the outcomes obtained in a previous study published by the author, [39] with a mean follow-up period of only 6 months, were compared with the current outcomes, with a postoperative follow-up of 5 years and a half (66.1 months). The MDP score was maintained after 5 years, going from 16.5 to 16.3 which, according to the chi-square test, was not statistically significant (Table 8). When each parameter of the MDP score (pain, mobility, and gait) were assessed separately, no statistically significant difference was observed. There were no changes in pain and mobility (5.1 and 5.6 at 6 and 66 postoperative months). Gait showed slight deterioration, going from 5.8 to 5.6, without statistical significance (Table 8).

		OPEN APPROACH		ARTHROSCOPIC APPROACH		
		Mean	**Variance**	**Mean**	**Variance**	**Mean difference**
MéMerle-d'Aubigné-Postel modified by Chanrley	Before surgery	11.50	13.61	12.62	3.92	1.12
	After surgery	16.30	5.12	17.08	1.74	0.78
MéMerle-d'Aubigné-Postel modified by Chanrley – PAIN	Before surgery	2.60	2.49	3.46	1.10	0.86
	After surgery	5.10	0.99	5.38	0.59	0.28
MéMerle-d'Aubigné-Postel modified by Chanrley – MOBILITY	Before surgery	4.70	0.90	5.23	0.53	0.53
	After surgery	5.60	0.93	6.00	0.00	0.40
MéMerle-d'Aubigné-Postel modified by Chanrley – GAIT	Before surgery	4.20	2.62	3.92	1.58	-0.28
	After surgery	5.60	0.49	5.69	0.40	0.09
Pain Visual Analog Scale	Before surgery	6.70	6.46	5.92	8.24	-0.78
	After surgery	1.20	2.18	0.92	1.58	-0.28
WOMAC	Before surgery	25.90	323.43	31.54	288.27	5.64
	After surgery	5.40	43.82	6.62	45.26	1.22
WOMAC – PAIN	Before surgery	5.30	16.46	5.92	13.41	0.62
	After surgery	0.80	1.73	0.85	1.47	0.05
WOMAC – STIFFNESS	Before surgery	1.70	3.79	3.00	6.50	1.30
	After surgery	0.00	0.00	0.77	0.86	0.77
WOMAC – FUNCTION	Before surgery	18.90	172.99	22.62	174.26	3.72
	After surgery	4.60	30.27	5.00	29.83	0.40

	t statistic	
Var. sum	**Observed**	**Tabulated**
1.64	0.87	2.18
0.64	0.97	2.16
0.33	1.51	2.14
0.14	0.76	2.12
0.13	1.49	2.12
0.09	1.31	2.26
0.37	-0.45	2.12
0.08	0.33	2.10
1.23	-0.70	2.09
0.33	-0.48	2.11
52.93	0.77	2.10
7.61	0.44	2.09
2.60	0.39	2.10
0.28	0.09	2.10
0.84	1.42	2.08
0.06	3.11	2.16
29.75	0.68	2.09
5.16	0.18	2.09

Table 7: Difference in means test statistics.

Source: Data from the study

		After surgery 1			
	Pain	Mobility	Gait	Total	Pain
Patient 1	6	6	6	18	6
Patient 2	6	6	6	18	6
Patient 3	6	6	6	18	4
Patient 4	6	5	6	17	6
Patient 5	2	6	5	13	4
Patient 6	4	6	6	16	4
Patient 7	4	3	5	12	4
Patient 8	6	6	6	18	6
Patient 9	6	6	6	18	6
Patient 10	5	6	6	17	5
Mean	5.1	5.6	5.8	16.5	5.1

After surgery 2		
Mobility	Gait	Total
6	6	18
6	6	18
6	5	15
6	6	18
5	4	13
6	6	16
3	5	12
6	6	18
6	6	18
6	6	17
5.6	5.6	16.3

Table 8: MéMerle-d'Aubigné-Postel modified by Chanrley – after surgery – mini-open approach.

Source: Data from the study.

When comparing the WOMAC scores (Table 9), the initial value, which was 6.5 in the first assessment at 6 postoperative months, decreased to 5.4 at 5.5 years of follow-up, with statistically significant clinical improvement (p = 0.00685278), as shown by the chi-square test. When evaluating each parameter of the score separately (Table 9), pain went from 1.4 to 0.8; stiffness from 0.1 to 0; and function from 5 to 4.6, demonstrating that the clinical outcomes were maintained and improved slightly in the midterm follow-up.

The alpha angle, calculated for Dunn view at 45º for Group A patients, had a preoperative mean of 91.6º, which dropped to 46.9º in the postoperative assessment. According to the chi-square test, there was significant difference between the alpha angle in the preoperative and postoperative periods, with a tabulated value of 16.92 and an estimated value of 236.04, which indicates that the means were different, with a p value close to zero (Table 10). However, there was suboptimal correction in two cases (20%), with a final value greater than 50º.

In Group B, the alpha angle went from 85.54º before the procedure to 49.77º in the postoperative period, with statistical significance (p close to 0), as the tabulated value was 21.03 and the estimated value was 211.20, indicating different means after application of the same test (Table 11). As with Group A, there was suboptimal correction and five cases (38.46%) had an alpha angle greater than 50º in the postoperative period.

	After surgery 1				
	Pain	Stiffness	Function	Total	Pain
Patient 1	0	0	0	0	0
Patient 2	0	0	7	7	0
Patient 3	2	0	0	2	1
Patient 4	0	0	2	2	0
Patient 5	6	0	8	14	4
Patient 6	2	0	8	10	0
Patient 7	1	1	9	11	2
Patient 8	0	0	0	0	0
Patient 9	0	0	0	0	0
Patient 10	3	0	16	19	1
Mean	1.4	0.1	5	6.5	0.8

After surgery 2		
Stiffness	Function	Total
0	0	0
0	3	3
0	5	6
0	0	0
0	17	21
0	8	8
0	4	6
0	0	0
0	0	0
0	9	10
0	4.6	5.4

Table 9: WOMAC score – after surgery – mini-open approach.

Source: Data from the study.

	Before surgery	After surgery
Patient 1	84°	39°
Patient 2	88°	49°
Patient 3	91°	50°
Patient 4	92°	60°
Patient 5	90°	30°
Patient 6	120°	40°
Patient 7	70°	60°
Patient 8	89°	45°
Patient 9	82°	46°
Patient 10	110°	50°
Mean	91.60°	46.90°

Table 10: Alpha angle – mini-open approach.

Source: Data from the study.

	Before surgery	After surgery
Patient 1	94°	50°
Patient 2	79°	50°
Patient 3	80°	48°
Patient 4	104°	49°
Patient 5	87°	49°
Patient 6	90°	55°
Patient 7	82°	40°
Patient 8	96°	70°
Patient 9	82°	39°
Patient 10	67°	55°
Patient 11	98°	36°
Patient 12	88°	55°
Patient 13	65°	51°
Mean	85.54°	49.77°

Table 11: Alpha angle – arthroscopic approach.

Source: Data from the study.

According to Student's t test, the preoperative values of the alpha angles between Groups A and B were the same, i.e., statistically identical, with a p value of 0.2376. By comparing the mean alpha angles in the postoperative period between the groups using Student's t test, there was no significant difference between the two surgical approaches (p = 0.466), with similar outcomes in both groups (Table 12).

Mini-open approach	**Mean**	**46.90°**
	Standard deviation	9.23°
Arthroscopic approach	Mean	49.77°
	Standard deviation	8.65°
Mean difference		2.87°
Var. sum		14.28
t statistic	Observed	0.76
	Tabulated	2.09

Table 12: Difference in means test statistics for alpha angle between the techniques.

Source: Data from the study.

Regarding the degree of internal rotation of the hip in Group A, the preoperative mean was 9.2º, increasing to 26.2º in the postoperative period, showing statistical significance in the chi-square test, with a p value close to 0 (p = 0.00000) – tabulated value of 16.92 and estimated value of 125.93 (Table 13).

In Group B patients, the mean value for the internal rotation of the hip was 14.69º before the procedure, increasing to 30.15º in the postoperative assessment, with p = 0.00000 in the chi-square test, and tabulated value of 21.03 and estimated value of 151.57, indicating significant change between the preoperative and postoperative outcomes (Table 14).

	Before surgery	After surgery
Patient 1	0°	26°
Patient 2	10°	36°
Patient 3	7°	16°
Patient 4	0°	26°
Patient 5	0°	0°
Patient 6	30°	42°
Patient 7	0°	10°
Patient 8	20°	35°
Patient 9	15°	35°
Patient 10	10°	36°
Mean	9.2°	26.2°

Table 13: Range of motion of internal hip rotation – mini-open approach.

Source: Data from the study.

The Student's t test did not show statistical difference between groups A and B for the range of motion of internal rotation in postoperative assessment, yielding identical outcomes (p = 0.4174), thus having no statistical difference (Table 15).

	Before surgery	After surgery
Patient 1	0°	30°
Patient 2	20°	38°
Patient 3	5°	30°
Patient 4	15°	32°
Patient 5	30°	34°
Patient 6	29°	30°
Patient 7	10°	30°
Patient 8	5°	38°
Patient 9	5°	30°
Patient 10	16°	30°
Patient 11	30°	25°
Patient 12	26°	35°
Patient 13	0°	10°
Mean	14.7°	30.2°

Table 14: Range of motion of internal hip rotation – arthroscopic approach. Source: Data from the study.

Mini-open approach	Mean	26.20°
	Standard deviation	13.54°
Arthroscopic approach	Mean	30.15°
	Standard deviation	7.06°
Mean difference		3.95°
Var. sum		22.16
t statistic	Observed	-0.84
	Tabulated	2.18
Source: Data from the study		

Table 15: Difference in means test statistics for range of motion of internal hip rotation between the techniques.

No cases of infection, osteonecrosis of the femoral head (ONFH), femoral neck fracture, postoperative instability, heterotopic ossification, iatrogenic damage to the labrum or to the articular cartilage of the femoral head were observed in patients from Groups A and B. There were three cases (30%) of lateral femoral cutaneous nerve paresthesia in Group A, but after the final assessment, only two cases (20%) persisted. Hypertrophic scar was detected in three patients (30%) in Group A. The average size of the scar was 10.2 cm (8.2 to 12.7 cm). Excessive femoral osteoplasty was performed in one case (10%) from Group A (patient #5), without femoral neck fracture, but clinical and functional deterioration occurred. Breakage of a bone shaver occurred during the procedure in one case (7.69%) in Group B (patient #12). The instrument was immediately replaced and the surgery was resumed without any other intercurrent events. No patients in Group B presented with paresthesia.

In Group A, Epiphysiolysis was regarded as the etiology of cam FAI in 50% of the cases. Other causes that could be detected were Legg-Calvè-Perthes disease in one case (10%), association of cam impingement with subspine impingement in one case (10%), association of cam FAI with osteochondroma of the femoral proximal third in one case (10%), and three cases of unknown etiology (30%). In Group B, only one case was associated with Epiphysiolysis neglected in adolescence (7.69%). Another case of cam FAI (7.69%) was associated with previous hip trauma. The etiology of FAI could not be identified in the remainder of the patients (84.62%) and the condition was regarded as morphological changes related to hip development. Among 13 patients subjected to arthroscopy, two (15.38%) had already had total hip replacement on the contralateral side. So far, no patients from Groups A and B have required joint replacement surgery.

Concerning the radiographic classification of osteoarthrosis of the hip proposed by Tönnis, [33] in Group A, three patients (30%) had their hips preoperatively classified as grade 0, four (40%) as grade 1, two (20%) as grade 2, and one (10%) as grade 3, with a mean of 1.1. In Group B, the hips were preoperatively classified as grade 0 in seven patients (53.8%), as grade 1 in three (23.1%), and as grade 2 in three (23.1%), but no patient was classified as grade 3, with a mean of 0.69 in Group B. Tönnis grade was homogeneous between the groups, as shown by the Student's t test, with $p = 0.15753904$, without statistically significant difference. No patients showed worsening of degenerative joint disease on the radiographs; hence, Tönnis grade remained unchanged up to the time of the assessments.

Thus, it is possible to say that the groups were statistically homogeneous in preoperative findings and that the clinical, functional, and radiographic outcomes obtained from the surgical treatment of FAI were actually similar and equivalent when mini-open surgery and arthroscopy were compared.

Discussion

Osteoarthritis of the hip affects 5% to 10% of the population [35] and several authors have already shown FAI as an underlying factor in the development of this disease [3,34,40,41].

The Bern Group, led by Dr. Reinhold Ganz, demonstrated in 2001 that it was possible to combine surgical access to the hip with trochanteric osteotomy, followed by anterior dislocation, to treat mechanical changes without compromising the integrity of blood supply to the femoral head. After 213 procedures with this surgical approach, Ganz., *et al*. [2] did not find any case of ONFH, and broke new ground in the history of hip preservation surgery.

The same group described FAI patterns [3] by classifying them into cam, pincer, and combined. The combined type was the most frequent, with over 600 hips treated with surgical dislocation. Beck., *et al*. [5] after performing surgeries in 302 hips with joint diseases using the same technique, selected 26 cases with cam deformity and 16 cases with pincer deformity. They postulated that degenerative joint diseases, once regarded as primary or idiopathic, were actually secondary to those deformities. Joint damage varies with the morphology of FAI. In cam deformity, during hip flexion and especially when associated with internal rotation, there is impingement between the aspherical femoral head and the chondrolabral complex located in the anterosuperior region of the acetabular rim, where the labrum is stretched and pushed outward, while the cartilage is compressed and pushed inward, keeping them apart but maintaining a stable fixation between the labrum and the acetabular rim. In pincer FAI, the mechanism is different, and the major predisposing factor is a deep acetabulum, with limited range of motion of the hip due to acetabular over coverage. With the limited range of motion, the femoral neck abuts against the labrum, and the labrum acts as a shock absorber. It is compressed between the femoral neck and the underlying acetabular bone, and the force is then transmitted to the cartilage. This transmission occurs in a narrow band along the acetabular rim. Recurrent microtraumas induce bone growth at the base of the labrum, which eventually results in ossification. Because flexion is the major direction of the hip range of motion, most lesions are located on the anterosuperior acetabular rim. If greater flexion is exerted, the femoral head begins to dislocate posteriorly and, because of the limited range of motion of the hip joint, the stress between the posteromedial aspect of the femoral head and the posteroinferior region of the acetabulum increases, resulting in a contrecoup injury, observed more often in the femoral head (62%), but also in the acetabulum (31%) [5]. Understanding these mechanisms is crucial for appropriate approach to and treatment of the FAI syndrome so as to prevent or at least delay degenerative joint disease.

Several authors have employed surgical dislocation for the treatment of FAI. Beaulé., *et al*. [6] published their experience after surgically treating 37 hips of 34 patients with a mean age of 40.5 years and mean postoperative follow-up of 3.1 years, and demonstrated clinical and functional improvement according to the WOMAC score, in addition to an improvement in the UCLA (University of California at Los Angeles) score from 4.8 to 7.5, with no case of ONFH. They reported one case of pseudoarthrosis of the trochanteric osteotomy that required new fixation and consolidation; one case of Brooker IV heterotopic ossification that required surgical resection; and nine cases with superficial residual pain, which required the removal of screws from the greater trochanter. All patients resumed their daily activities normally and fully. The authors also reported that six out of 34 patients were dissatisfied with the procedure.

Bizzini., *et al*. [7] used surgical dislocation on five young hockey players with cam FAI, with mean age of 21.4 years. With a mean follow-up of 2.7 years, those authors reported full recovery of the range of motion within 10.3 weeks, in addition to the recovery of hip strength to preoperative level 7.8 months after surgery, allowing the players to go back to the championships within 9.6 months after the procedure. Three players returned to the Premier League in international hockey championships and two had to play in lower leagues. Peters and Erickson [9] performed trochanteric osteotomy on 30 hips of 29 young patients with a mean age of 31 years. With a mean follow-up of 32 months, the Harris Hip Score (HHS) increased from 70 points before the surgery to 87 points in postoperative assessments. There was no case of ONFH, but there were three cases of trochanteric pseudoarthrosis. In 18 cases, they observed major damage to the acetabular cartilage, which had not been detected in preoperative radiographs and magnetic resonance arthrography. Eight of these 18 cases showed radiographic deterioration of osteoarthrosis and four out of these eight cases had already undergone or were awaiting total hip replacement for the treatment of progressive pain.

Even though this technique has been regarded by many surgeons as the gold standard for the treatment of FAI and has provided thriving outcomes, also proving to be reproducible, it produces an unsatisfactory cosmetic outcome and poses some risk (albeit minor) of major trochanter pseudoarthrosis [6,9]. Physical therapy is initially postponed for approximately six weeks because trochanteric osteotomy has to be consolidated first and some patients may have residual pain at the site of screw fixation and a new procedure should be sometimes performed for the removal of the screws [6]. Also, the consequences of *ligamentum teres* resection is still unclear as to the stability of the hip joint.

On the other hand, several authors have demonstrated that it is possible to approach the hip joint via arthroscopy for the diagnosis and treatment of some injuries, including FAI, providing quite satisfactory esthetic outcomes, in addition to quicker recovery [10,11,13], with a relatively small rate of complications that ranges from 1% [42] to 8% [43]. The technique, however, seems to be challenging, and the learning curve is known to be steep.

Two approaches to the hip via arthroscopy are described, regardless of the decubitus positioning used (lateral or supine): the inside-out [14,15] technique and the outside-in technique [16-20]. The inside-out technique requires enough traction to disengage the femoral head from the acetabulum and gain access to the central compartment. Minimum distraction (1 cm) is required for proper insertion of instruments without damaging the articular cartilage of the femoral head or the labrum. In this technique, alterations in the central compartment are usually treated first and pincer impingement is then addressed by distraction. Subsequently, traction is relaxed and cam deformity is approached via the peripheral compartment. Because of the need of hip joint distraction, with the patient lying on a traction table, for approaching the central compartment, complications such as nerve injuries and large periarticular hematomas are common during the learning curve or when longer attention is required for this compartment. Incomplete resection of femoral and acetabular deformities may also occur, possibly influencing the outcomes, given that osteochondroplasty appears to be the main goal in the treatment of FAI syndrome [8,12,26].

In the early 19th century, Sampson [28] described that most complications associated with hip arthroscopy are related to traction and fluid management. He also claimed that they are preventable and fortunately not severe, and more often than not transient, with rare permanent damage. He highlighted that the complications occurred at the initial learning curve and that experience and modifications in the technique reduce the incidence of neuropraxia. He has reported 34 complications of the inside-out technique in 530 hips subjected to arthroscopy since 1977, with transient injuries in 10 peroneal nerves, four pudendal nerves, four sciatic nerves, one lateral femoral cutaneous nerve, and one involving both the sciatic and femoral nerves, all of them associated with traction longer than 5 hours, but resolved within 2 and 3 days, except for the injury that simultaneously involved the sciatic and femoral nerves, which recurred within one week. He also reported nine cases of fluid leakage into the abdominal cavity or into the thigh, in addition to two severe cases of damage to the femoral head cartilage during instrument insertion, which were attributed to insufficient hip distraction (less than 1 cm). One patient who had slipped off a ladder and had developed a labral injury presented with ONFH seven months after the procedure. The author recommended distraction for less than 2 hours using less than 50 lb of traction, but he underscored that at least 1 cm of distraction was needed to prevent severe damage to the femoral head cartilage or labral injuries during insertion of needle and instruments into the central compartment. He concluded that if the procedure lasts more than 2 hours, it is crucial to relieve traction for some time before resuming it.

Inappropriate osteochondroplasty of cam and pincer deformities is a recently recognized complication that affects the outcome of hip arthroscopy and has become increasingly frequent as the number of procedures has been on the rise and been the most widely indicated procedure for the revision of hip joint arthroscopy [26]. May., *et al*. [8] reported on a series of five patients whose hip pain persisted after having undergone arthroscopy for labral debridement and who subsequently underwent surgery for correction of bone anomalies associated with FAI. Three were subjected to surgical hip dislocation, whereas two were subjected to arthroscopy combined with anterior arthrotomy. All patients exhibited residual cam deformity, which was treated with femoral osteochondroplasty, in addition to new labral debridement. No case required labral resection or reattachment. Only one patient was subjected to a new procedure for removal of trochanteric screws because of residual pain associated with internal rotation, which subsided later, but no other postoperative complication was observed. Philippon., *et al*. [12] reassessed 37 cases treated with arthroscopy because of persistent hip pain. They reported clinical and radiographic signs of residual FAI in 36 out of 37 patients who had not been treated or whose first procedure had been insufficient. They recommended proper treatment of bone anomalies for successful arthroscopy. Heyworth., *et al*. [24] reassessed 24 hip arthroscopies in symptomatic patients. Radiographic and intraoperative assessments revealed 19 cases with bone anomalies who had been treated insufficiently or who had not been addressed at all. In eight cases initially treated with labral repair alone, 75% had bone injuries caused by FAI. Those authors suggested that bone impingement was a limiting factor for the success of labral repair.

Recently, Nakano and Khanduja [26], in a review of the literature, described the main complications related to hip arthroscopy. They noted that damage to the articular cartilage and to the acetabular labrum are relatively common and that the labrum, typically in the superior and anterosuperior regions, is at risk during inadvertent punctures when the surgeon seeks to establish the anterolateral portal in the central compartment. The area of the labrum corresponding to the anterior portal could also be injured in case of poor visualization, such as in cases of moderate or severe synovitis. In line with the studies by Dienst., *et al.* [44], they underscore that the injury often occurs in the femoral head cartilage and its main cause is insufficient distraction. For complex cases, when too many portal changes are made, the femoral head is at risk of injury by rigid metal instruments, even during articular distraction. Dienst., *et al.* [44] recommend that, if proper distraction cannot be achieved, the peripheral compartment should be approached previously (outside-in technique) before approaching the central compartment under direct arthroscopic visualization. In the same literature review, Nakano and Khanduja [26] report that distraction-type nerve injury is the most common complication in hip arthroscopy, occurring in 7% of the cases and, according to Simpson., *et al*. [45] most are neuropraxias of the femoral, sciatic, or perineal nerves caused by excessive traction or prolonged traction. Flierl., *et al*. [46] recommend traction less than 50 lb for no longer than 2 hours. On the other hand, nerve injuries may also occur because of compression in the inguinal region against the perineal post, where the pudendal nerve is at risk. This injury was reported when hip arthroscopy was first described in 1987 [15], but other soft tissue injuries, such as those which affect the scrotum and labia majora, also occur, varying from small bruise, as reported by Funke and Munzinger [47], to tissue necrosis, as described by Gedouin [48]. To prevent these injuries, Gedouin [48] recommend careful perineal post padding with at least 9 cm in diameter, ideally positioned in the medial coxal region by means of abduction in order to allow it to act like a lever rather than like a support for the genitals and inguinal region.

Malpositioned anchors during labral reattachment into the acetabular rim is another complication. The anchors should be positioned close to each other in such a way that they do not damage the articular cartilage and do not penetrate into the joint [26]. Conversely, if the anchors are positioned far from the acetabular cartilage, they can evert or medialize the labrum, compromising its function, and if they are positioned too close to the articular cartilage, they can cause iatrogenic damage to it. In a recent multicenter retrospective study, Matsuda., *et al*. [49] have described that the "one-hour position" of the acetabular rim is most often associated with this complication. According to Stanton and Banffy [50], the surgeon should be experienced in using a distal anterolateral accessory portal in order to prevent such complication, allowing the insertion of the anchors at a large distance from the articular surface.

Other complications of hip arthroscopy that are less frequent have been described in the literature, such as fluid extravasation, hypothermia, deep vein thrombosis, instability, ONFH, adhesions, heterotopic ossification, trochanteric bursitis, iliopsoas tendonitis, and femoral neck fractures [27]. The same authors, in a recent systematic review, assessed 12 clinical trials with 31,392 patients subjected to hip arthroscopy between 2009 and 2016 and found 43 cases of femoral neck fractures (0.1%). In all cases, the patients were subjected to femoral osteochondroplasty. The fractures occurred, on average, 40.2 days after the procedure, ranging from 3 to 6 months postoperatively. In six studies (50%), the cause of fracture was associated with early weight bearing before six postoperative weeks. Seven out of 43 fractures occurred by minor traumas or falls in a short postoperative period and one case out of 43 was associated with vigorous running 6 months after the procedure. One study found a correlation of older age and height with a higher risk of fracture. Only 26 out of 43 (60.5%) fractures were classified in the studies, 13 (50%) of which were stress fractures, 12 (46.2%) nondisplaced fractures, and one displaced femoral neck fracture (3.8%). Seven biomechanical studies were included in the systematic review, and six of the studies correlated the increased risk of femoral neck fracture with the depth of the femoral bone resection in the anterolateral quadrant of the femoral head-neck junction, but the depth of bone resection considered safe ranged from 10% to 33%. In one of the biomechanical studies, Mardones., *et al*. [25] performed a case-control study using anatomical specimens and noted that the group with 10% of bone resection showed a change of less than 1% in the mean peak load for fracture when compared to the contralateral side (control group). The group with 30% of bone resection demonstrated a 16% reduction in peak load, whereas the group with 50% of resection had a 43% reduction. Regarding peak load, it was concluded that femoral neck fracture risk in 10% and 30% resections were not statistically significant. Noble., *et al*. [51] demonstrated in a virtual model that only 0.61 mm of resection depth was necessary to restore the full range of motion of hips with cam deformities.

In the present study, all cases treated with arthroscopy (group B) were subjected to the outside-in technique (extracapsular approach) with patients in the supine position, with no complications such as labral injury or femoral head articular cartilage injury, ONFH, femoral neck fracture, infection, heterotopic ossification, postoperative instability, or genital or neurologic soft tissue injuries. The only complication was the breakage of a bone shaver, probably because of insufficient capsulotomy, which was changed during the surgery, with no other intraoperative intercurrent event.

Dorfmann and Boyer [16] were probably the first to describe the outside-in technique and to single out the central compartment, which used to be known as iliofemoral region of the peripheral compartment, referred to as peripheral area. They published their 12-year experience with 413 hip arthroscopies (358 without the use of traction) and concluded that hip arthroscopy was an excellent tool for investigating and treating several hip conditions. Dienst., *et al*. [17] described a safe approach to the central compartment, starting with the peripheral compartment, inserting a wire through the anterior portal between the labrum and the articular cartilage of the femoral head under direct visualization in the anterolateral portal, with lower risk of iatrogenic injury to these structures. They argued that the approach to the peripheral compartment through the anterolateral portal is safe if oriented directly towards the anterior aspect of the femoral head-neck junction, where the femoral head does not have cartilage, the labrum is approximately 2 to 3 cm away, and the articular capsule is a bit far from the femoral neck. Also, this is the safest zone for hip arthroscopy regarding neurovascular bundles both medially and posteriorly. They basically used the traction-free technique.

Sampson [18] published the outcomes of 120 hip arthroscopies performed on 118 patients, and of 38 hips surgically treated by his associate, describing a new approach to the peripheral compartment. He started the procedure in the central compartment and later removed the instruments, resuming the procedure with the extracapsular approach to the peripheral compartment to treat the cam deformity. He reported only one complication related to a nondisplaced femoral head fracture treated with percutaneous pinning. In a prospective study, Horisberger., *et al*. [19] described and published the outside-in technique performed on 88 patients and 105 hip arthroscopies. They described 12 minor complications (11%): nine cases of paresthesia of pudendal nerves and lateral femoral cutaneous nerve, two cases of sciatic neuropraxia, and one case of a patient with obesity who had a small superficial lesion in the labia minora caused by traction. All complications resolved within some months without any specific treatment. No case presented with femoral neck fracture or ONFH, as shown by magnetic resonance imaging in the postoperative period. Those authors also found 91% of improvement in flexion and internal rotation, improvement of pain indicated by the VAS, of the alpha angle, and of the nonarthritis hip score (NAHS). After comparing the outcomes between patients treated for cam FAI alone (54.3%) with those treated for combined impingement (45.7%), they did not observe any difference in preoperative Tönnis grade, chondral injuries, NAHS, range of motion, or pain. Nine patients required total hip replacement, five of whom had been classified before surgery as Tönnis grade 2 and four as Tönnis grade 1. In the intraoperative period, there were stage III osteochondral injuries in four cases and stage II injuries in five cases, and NAHS was lower in those patients in the preoperative period. Those authors highlighted that the technique allows safe penetration into the joint capsule and sufficient visualization of the head-neck region with excellent correction of FAI.

Doron., *et al*. [20] described the extracapsular (outside-in) technique without the use of too much traction to approach the central compartment. After opening the joint capsule from outside in, the anterolateral region of the acetabular rim is subjected to osteoplasty and the joint is distracted without excessive traction, allowing a safe approach to the central compartment and labral reattachment. Gédouin [48], in a review article on arthroscopy for the treatment of FAI, concluded that there exists a learning curve, regardless of the technique used, and that the cases should be well selected so that the surgeon can gradually gain experience, rendering the technique simpler over time, but still technically challenging. Gédouin [48] also claimed that the ideal management of labral and chondral injuries also remains uncertain.

In the present study, femoral osteoplasty in Group B (arthroscopy) was performed on all patients, but acetabular osteoplasty was carried out only on three patients, from outside in, preserving labral attachment, which did not have to be reattached in any case. All patients showed statistically significant clinical and functional improvement, according to the MDP ($p = 0.01011971$) and WOMAC ($p = 0.00000000$) scores, in addition to pain relief indicated by the VAS ($p = 0.00000008$). The preoperative mean MDP score was 12.62 and increased to 17.08 in the postoperative period. The preoperative mean WOMAC score was 31.54 and decreased to 6.62 in the postoperative period, whereas the mean pain VAS went from 5.92 to 0.92. When assessing the MDP subitems, pain and gait showed statistically significant improvement ($p = 0.02438978$ and $p = 0,03294061$, respectively). Mobility also improved but was not statistically significant ($p = 0.99395971$). All subitems of the WOMAC score also improved and were statistically significant (pain – $p = 0.00000004$; stiffness – $p = 0.03361003$, and function – $p = 0.00000000$). The clinical test for FAI was negative in the postoperative period in all cases. The mean alpha angle improved in the postoperative period and was statistically significant, going from 85.54º before the procedure to 49.77º in the postoperative assessment, with a p value closer to zero. However, in five cases (38.46%), the correction of the alpha angle was not sufficient, with suboptimal values, but seemingly no interference in the clinical and functional outcomes. This corroborates the findings of other published articles that demonstrate the existence of a learning curve for gaining experience in the procedure. When assessing the internal rotation of the hip separately, all cases exhibited improvement. The mean went from 14.69º before the procedure to 30.15º in the postoperative period, $p = 0.000000$. Tönnis grade did not change in the postoperative period up to the assessments and no case required total hip replacement. The author considers that approaches to the central compartment are not essential, nor do they alter the outcome in patients surgically treated for FAI, as treating the causes (rather than the consequences) of femoral and acetabular anomalies is what actually matters.

Ribas., *et al*. [21] published their findings after a mean follow-up period of 3.7 years of patients treated for FAI using a minimally invasive anterior approach via intermuscular and internervous plane, combined with the use of arthroscopy with the patient in supine position on the traction table. They recommend the release of the reflex portion of the rectus femoris muscle and T capsulotomy. One-centimeter minimal distraction is applied to the hip and a 70º arthroscope is inserted into the acetabular cavity for inspection. Chondrolabral injuries were treated by labral detachment, acetabular osteoplasty, followed by reattachment with absorbable suture anchors. Traction was released and femoral osteoplasty was performed. After testing the range of motion to check whether the hip was free from impingement, the capsule was sutured. The recommendation was that the patients should use crutches, with partial weight bearing, for 10 days only. The authors described the outcomes obtained for 117 surgically treated hips and observed significant improvement in those patients classified as Tönnis grades 0 and 1 before surgery, based on the MDP and WOMAC scores. Patients with Tönnis grade 2 did not show statistically significant improvement. There were two cases of hematoma that required drainage and 18% of paresthesias of the lateral femoral cutaneous nerve, which persisted in 3% of the patients after a one-year follow-up. No cases of infection, heterotopic ossification, or ONFH were observed. Twenty-seven percent of the patients had hypertrophic scar. Cohen., *et al*. [23] operated 257 hips on 234 young athletes using minimally invasive anterior approach with patients in the supine position on a conventional table and a mean operative time of 75 minutes. Release of the reflex portion of the rectus femoris muscle was not necessary and an I-shaped capsulotomy was performed. Between 60% and 70% of the acetabular cavity was approached via manual traction of the limb, liable to the treatment of chondral injuries. Only 47 patients with at least one year of follow-up were included in their results. None of the athletes needed total hip replacement or had to undergo a new surgery. Only two patients did not show clinical improvement in terms of function and pain according to the HHS and WOMAC scores. Nine patients had paresthesia of the lateral femoral cutaneous nerve, but all of them recovered fully within one year. One patient had femoral nerve injury but recovered within 6 months. No other complications were described.

In the present study, those patients subjected to the minimally invasive anterior mini-open approach (Group A) were treated with a similar technique as that described by Ribas., *et al*. [21] with the patient in the supine position on a traction table, release of the reflex portion of the rectus femoris muscle, T capsulotomy, 70º arthroscopic inspection of the articular cavity, femoroacetabular osteoplasty, and joint capsule suture at the end of the procedure. All hips were subjected to femoral osteoplasty and only one case required acetabular osteoplasty and reattachment of the labrum with suture anchors. Nine cases (90%) exhibited statistically significant clinical and functional improvement according to the MDP and WOMAC scores and pain VAS. The mean MDP score before surgery was 11.5 and increased to 16.3 after surgery ($p = 0.00000149$). The mean WOMAC score went from 25.9 to 5.4 ($p = 0.00000000$) and VAS decreased from 6.7 to 1.2 ($p = 0.00000033$). By analyzing the subitems in the MDP score separately, all criteria improved in the postoperative period, with statistically significant differences for pain ($p = 0.00000000$) and gait ($p = 0.03256096$), but without statistical significance for mobility ($p = 0.96227957$). In WOMAC subitems, all criteria improved as well, with $p < 0.05$ (pain – $p = 0.00000048$; stiffness – $p = 0.04871598$; and function – $p = 0.00000000$). The only patient without any improvement (patient #5) had osteoarthritis classified as Tönnis grade 2 before surgery, confirmed during 70º arthroscopic inspection, having reported symptoms in the affected hip for approximately 5 years. No method was used during the procedure to treat the acetabular or femoral head cartilage in this case, and excessive femoral osteoplasty occurred intraoperatively. According to VAS, all patients showed clinical improvement, including patient #5, with $p < 0.05$. The mean alpha angle decreased from 91.6º to 46.9º in postoperative assessments, with a p value close to zero. As with the cases subjected to hip arthroscopy, there was suboptimal correction of the alpha angle in two cases (20%) approached by open surgery, in which the angle was greater than 50º in the postoperative period. Nevertheless, those patients had good clinical and functional outcomes according to the scores used. Internal hip rotation improved in all patients, going from an average of 9.2º before surgery to 26.2º in the postoperative period, with a p value close to zero ($p = 0.000000$).

The patients in Group A, subjected to mini-open surgery, had been assessed by Futuro., *et al*. [39] in a previous study with a shorter follow-up period and mean postoperative follow-up of 6 months. All those patients from the previous study were found and accepted to participate in the present study. In the current assessment, the mean postoperative follow-up was 66 months and the mean MDP scores were maintained between the previous study (five years before) and the present study, decreasing from 16.5 to 16.3. The chi-square test did not indicate statistical difference. Patient #5 did not have any change in the mean of this score (13 points), without clinical deterioration over 5 years. Pain intensity increased by 2 points, but mobility and gait improved by one point each. The comparison of the mean outcomes obtained for the 6-month and 66-month postoperative follow-up assessments using the WOMAC score showed clinical and functional improvement, which was statistically significant according to the chi-square test ($p = 0.00685278$). The mean decreased from 6.5 to 5.4 over 5 years.

This score revealed, however, that patient #5 had worse outcomes, decreasing from 14 to 21 points.

Three patients (30%) had hypoesthesia of the lateral femoral cutaneous nerve, which persisted in two cases (20%). Hypertrophic scar was observed in three patients (30%). No other complications were found in this group. So far, no abnormal radiographic findings have been observed by the Tönnis method and no patients were subjected to joint replacement surgery.

Few studies have compared the anterior mini-open approach and hip arthroscopy for the surgical treatment of FAI. In a recent retrospective case-control study, published in 2017, similar to the present study but with a larger sample size, Roos., *et al*. [52] compared the outcomes of FAI treatment with the anterior open approach with extracapsular arthroscopy. They observed statistically homogenous groups in the preoperative period. The group treated with arthroscopy had a mean follow-up period of 29.1 months in 40 patients. The HHS showed average improvement by 22.1 points, with 75.6% of good or excellent outcomes, 19.51% of satisfactory outcomes, and only 7.31% of poor outcomes, in addition to a mean improvement by 21.5 points in NAHS. They reported a mean increase in the range of motion of internal rotation from 5º before surgery to 20º in the postoperative period, with statistical significance in all clinical methods. The preoperative mean of the alpha angle in this group was 76º, decreasing to 44º in the postoperative period ($p < 0.001$). There were four cases (9.75%) of Brooker class 1 heterotopic ossification, one case (2.43%) of class 3 ossification, one case of deep vein thrombosis (2.43%), and one patient with transient paresthesia of the pudendal nerve (2.43%). Pain persisted in two patients (both classified as Tönnis grade 2) and one patient had indication for total hip replacement. In the group treated via the anterior mini-open approach, 16 patients were followed up for 52 months. The modified HHS revealed mean increase by 21.7 points, with 70.58% of good or excellent clinical outcomes, 11.76% of satisfactory outcomes, and 17.64% of poor outcomes. NAHS increased, on average, by 20.4 points in the postoperative period, and internal hip rotation went from 5º to 25º in the postoperative period ($p < 0.001$). The mean alpha angle went from 72º to 40º. There were five cases (29.41%) of class 1 heterotopic ossification, four cases (23.5%) of lateral femoral cutaneous nerve injuries, persistent pain in four patients, and two cases subjected to total hip replacement. No major complications were noted. The authors concluded that both groups had similar postoperative clinical, functional, and radiographic outcomes. In a review article, Kuhns., *et al*. [53] compared the open approaches with arthroscopies in the treatment of FAI and concluded that, even though arthroscopy demonstrated slightly better outcomes in the short and intermediate term, it was not risk-free, especially during the learning curve. They also reported that in some cases of complex articular morphology, such as in associations of dysplasia and FAI, the open approach should be preferred over arthroscopy. The authors mention there is a paucity of studies on long-term outcomes and of randomized clinical trials comparing both techniques.

In a systematic review comparing open surgery with arthroscopy for the treatment of FAI, Nwachukwu., *et al*. [54] selected only studies in English, with clinical and therapeutic outcomes, and follow-up of at least three years. They included 16 studies in their review, eight of them about open surgery with surgical dislocation, seven about arthroscopy, and one about the anterior mini-open approach with the aid of an arthroscope. They underscored the measurement of outcomes reported by the patients and conversion to total hip replacement. They found 600 hips of 519 patients with a mean age of 32.1 years treated with the open approach, with a mean follow-up of 57.6 months, and 1,484 hips of 1,461 patients with a mean age of 36.7 years subjected to arthroscopy, with a mean follow-up of 50.8 months. Most patients in both groups were male (64% in the open approach group and 53.9% in the arthroscopy group). The conversion rate for total hip replacement was similar in both groups, with a mean of 7% in the open approach group and 9.5% in the arthroscopy group, without statistical difference between them. The risk factors associated with conversion to total hip replacement were older age, previous chondral injuries or hip osteoarthrosis, high body mass index, and female sex. They concluded that both techniques showed excellent maintenance of outcomes in the intermediate and long term, but long-term studies are still needed.

In the present study, preoperative radiographs for the assessment of hip joint involvement (Tönnis grade) did not show statistically significant difference between Groups A and B, as indicated by the Student's t test ($p = 0.15753904$). Group A (mini-open approach) had a mean of 1.1 before surgery and Group B (arthroscopy) a mean of 0.69. Regarding the alpha angle before surgery, there was no statistical difference between the groups (Student's t test); therefore, the groups were considered radiographically homogeneous. Clinically, the test for impingement was positive in 100% of the patients in both groups and internal hip rotation was not statistically significant according to the Student's t test, thus indicating clinically and radiographically homogeneous samples.

The comparison of clinical and functional postoperative outcomes obtained with MDP and WOMAC scores and VAS between Groups A and B did not reveal statistically significant difference

(Student's t test), with p values equal to 0.17400761, 0.33229530, and 0.68193946, respectively, indicating similar samples. Both groups had good outcomes. The stiffness subitem in the WOMAC score improved in patients subjected to the mini-open approach when compared with those subjected to arthroscopy, with mean values of zero and 0.77, respectively ($p = 0.00417896$). Comparison of mean values for the alpha angle on axial Dunn view at 45º in the postoperative period between the two techniques did not reveal statistically significant difference (Student's t test), with a p value of 0.466. Comparison of the mean values for internal rotation of the hips in the postoperative period between the groups had statistically identical values, according to the Student's t test, with $p = 0.2376$, indicating similar results for both groups.

Mean operative time for the mini-open approach was 153.4 minutes, with mean hospital stay of 2.9 days as compared to 130 minutes, with a mean hospital stay of 2 days in Group B. In both groups, the patients were instructed to maintain partial weight bearing with the aid of crutches, and all patients were referred to the same physical therapy program. Prophylaxis for thrombosis or for heterotopic ossification was not performed.

Limitations of the present study were the small sample size in both groups and the retrospective design. However, the clinical, functional, and radiographic outcomes were homogenous in the control group, with a mean postoperative follow-up period of 5.5 years in the mini-open approach group and of 3.6 years in the arthroscopy group. In addition, the comparison of short-term and midterm outcomes for the mini-open approach group demonstrated maintenance of the outcomes for five years. Long-term follow-up of the cases is needed.

Conclusion

Surgical treatment of FAI showed statistically significant good clinical, functional, and radiographic outcomes for both groups.

There were a low number of complications in the midterm follow-up of both groups and the techniques had similar outcomes.

The anterior mini-open approach showed that the good outcomes were maintained over a five-year period.

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