Original article

The anterior mini-open approach for femoroacetabular impingement: Gait and functional assessment at one year post-surgery

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Keywords: Femoroacetabular impingement Rehabilitation Outcome assessment Minimally invasive surgery Gait Hip

ARTICLE INFO

Article history:
Received 9 February 2014
Received in revised form 20 September 2014
Accepted 20 September 2014

ABSTRACT

Objective: This study aimed to evaluate the outcome of the anterior mini-open approach of the hip for femoroacetabular impingement (FAI) at one year post-surgery by use of questionnaires, functional capacity tests and biomechanical studies.

Design: This is a case series prospective study. A total of 14 patients diagnosed of FAI were included. Patients were classified according to Tönnis scale. Hip joint mobility, Faber distance, pain levels (assessed on a visual analog scale [VAS]), 6-minute walking test (6MW), Timed up & go test (TUGT), Stairs climbing test, Lequesne functional index, and gait analysis were assessed prior to and 12 months after surgery.

Results: Pain significantly improved following surgery. An improvement of 80% or more was found in 6 patients (42.85% of cases). Improvements were also seen in time support of the affected limb and in the braking force of the contralateral limb, although these are not clinically significant. No statistically significant changes were seen in functional capacity tests. At 12 months after surgery, meralgia paraesthetica presented in 3 patients (21.4%), and a total hip arthroplasty was performed in 1 patient.

Conclusions: There was significant reduction in pain intensity 12 months following mini-open approach for FAI compared to preoperatively. Improvement in gait analysis and functional capacity was also seen, although not statistically significant.

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1. Introduction

Femoroacetabular impingement (FAI) was described by Ganz et al. [1] as a condition caused by an abnormal contact between the proximal femur and the acetabular rim, especially in the extremes of range of motion. This can cause chondral and acetabular labrum injuries. Three types have been described (pincer, cam and mixed) [1], and all have morphological variants on the hip. The condition of FAI has been recognized as a common cause of hip pain and osteoarthritis in young adults [2,3]. With improved imaging techniques presently available, the diagnosis of FAI and labral injury has increased [3–5].

After surgical treatment of FAI it is important to assess the anatomical and functional outcome of the hip. This can be done using biomechanical assessment tests as well as functional and pain scales. The advantage of biomechanical assessment is that it allows an objective measurement of changes in patients.

There are currently few published studies that evaluate prospective short and long-term results for FAI [6,7]. This study is the first to evaluate the outcome of surgery using biomechanical and functional testing in the same cohort.

The purpose of this study is to evaluate the outcome of patients who underwent FAI surgery by mini-anterior approach of the hip, by use of questionnaires, tests of functional capacity and biomechanical studies.

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http://dx.doi.org/10.1016/j.rehab.2014.09.013
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2. Materials and methods

A prospective study was designed to assess functional results of FAI surgical treatment in active patients at a minimum of one year following surgical intervention. The diagnosis of FAI was confirmed clinically and by radiology. The radiological investigations performed were plain X-rays (AP pelvis, AP and axial Dunn views of the affected hip) as well as magnetic resonance arthrogram (MRA). All patients undergoing treatment for FAI at our institution between November 2009 and January 2012 (total of 48) were assessed to determine whether they were eligible for inclusion in the study.

The inclusion criteria for the study were patients with a primary diagnosis of FAI operated by an anterior mini-open approach and functional requirements (measured by sports practice). The exclusion criteria were signs of osteoarthritis (Tönnis 2 and above), insignificant level of sports practice and surgical treatment differing from anterior mini-open approach of the hip (i.e. surgical hip dislocation or arthroscopy). From the original cohort of 48 patients, 14 were eligible for inclusion. Of the 34 patients excluded, 15 denied any sports practice, 11 were treated by arthroscopy, four had femoral fractures in the past, two underwent femoral osteotomies during childhood, one patient declined to sign the informed consent and another had to be revised and underwent surgery for total hip replacement 8 months following the index FAI surgery (Fig. 1). All patients included in the study signed the informed consent meeting the principles of the WMA Declaration of Helsinki and approval was obtained from the Ethics Committee in our institution.

2.1. Procedure and rehabilitation

All procedures were performed by a single surgeon. The procedure involved femoral osteoplasty by means of an anterior mini-open approach. All patients underwent rehabilitation following the same protocol established in our health center.

2.1.1. Surgical technique

The procedure consisted of an anterior mini-open incision of 6–8 cm following the description of Ribas et al. [8]. After capsulotomy is performed full visualization of the joint is obtained without any muscle detachment. The labrum and cartilage were assessed for pathologic changes with intermittent use of traction. When labral tears are identified, labral debride- ment and partial excision are performed to treat the lesion. In our cases no significant chondral lesions were found to warrant operative treatment. No cases needed acetabular resection and impingement was corrected by different amounts of femoral osteochondroplasty. The capsule and ligaments are closed and the incision sutured leaving a suction drain for the first 24 hours postoperatively. DVT prophylaxis was given as per protocol during 10 days.

2.1.2. Rehabilitation treatment

The rehabilitation protocol in our hospital for patients who undergo surgery for FAI without labral repair is as follows:

- during the first 3 weeks post-surgery: ambulation with 2 crutches, active and auto-assisted flexo-extension hip movements, to gain range of motion; isometric quadriceps and gluteus exercises, to gain muscular strength; seated proprioception exercises;
- after 3 weeks post-surgery: isotonic hip muscles exercises, to gain muscular strength; bipodal and unipodal proprioception exercises, progressively.

2.2. Variables

After designing a protocol specifically for the study, the patients were assessed before the surgical operation and at 12 months postoperatively.

At the time of the first assessment demographic variables were collected: gender, age, profession and sport(s) participated. Pain characteristics, including onset (acute or chronic), laterality and any previous recalled trauma were registered. The past medical history and any predisposing hip conditions for FAI like Legg Calve Perthes, Developmental Dysplasia of the hip (DDH), Slipped Upper Femoral Epiphysis (SUFE), Protrusio Acetabuli and Retroverted acetabulum were registered. By means of preoperative plain films the presence of the crossover sign, coxa profunda or protrusio acetabuli were assessed, all of them predisposing conditions for Pincer type FAI; as well as the Pistol grip sign, Cervical-Diaphyseal Angle (CDA), Alpha Angle (AA), Head-neck offset (HNO) and Modified proximal femoral angle (MPFA), predisposing for Cam type FAI. Every patient was classified according to Tönnis classification. MRI arthrogram was studied to rule out any further
pathologic disease paying attention to the labrum and articular cartilage.

The main variable in this study was the pain level assessed on VAS. Secondary variables were hip range of motion, measurements of functional capacity, Lequesne functional index and gait analysis variables.

The intra and postoperative complications were noted as well as whether any further surgery was required within the first 12 months following the procedure and time until return to sports.

2.2.1. Pain measurement
To assess the subjective intensity of pain the VAS was used, which is considered to be a valid and reliable element to assess the degree of pain. It ranges from 0 (absence of pain) to 10 (unbearable pain). Depending on the pain intensity it is classified into 3 categories: 0–3, mild pain; 4–6, moderate pain; 7–10, intense pain [9,10].

2.2.2. Hip range of motion
On physical examination, flexion, extension, abduction, adduction, internal and external rotation at 90° of flexion, as well as impingement test and Faber distance were recorded for the affected and non-affected hips. The Faber test or distance is measured with the patient lying supine and the affected extremity placed in the figure-four position of flexion, abduction, and external rotation. Gentle downward force is then applied to the affected leg while a stabilizing force is applied to the contralateral side of the pelvis. The vertical distance from the lateral aspect of the knee to the examination table is recorded [11]. Every examination was performed by the same team using an electronic goniometer and every patient was always assessed by the same examiner for consistency.

2.3. Measurement of functional capacity

2.3.1. Six-minute walking test
The Six-minute walking test (6MWT) is the distance the patient is able to walk in a 6-minute period. This test was initially considered a valid test to measure endurance but more recently considered to measure motion and function in a widest sense related with activities of daily living [12,34]. The 6MWT in our study was performed in a corridor marking 24 meters in total. Patients walked at a “comfortable pace”, were advised not to talk during the test, and were notified of the remaining minutes. When 6 minutes was reached the total distance walked was recorded.

2.3.2. Timed up and go
The Timed up and go (TUG) is a test that records the time required for the patient to stand up from a chair with armrest, walk 3 meters, turn round and walk back to the chair and sit down. The patients walked around a small cone placed at the 3 meters landmark. The participants were instructed to proceed “as fast as possible with security and without running” [12,34].

2.3.3. Stairs climbing test
The Stairs climbing test (SCT) is a measurement of the time spent by a participant to walk up and down stairs made of twelve steps each of a height of 18 cm and a depth of 28 cm [14,15,34]. The patients were advised to complete the test as fast as they felt safe and comfortable. They were allowed to use the stairs’ handrail as needed, although encouraged to use only their legs.

2.4. Questionnaire

2.4.1. Lequesne functional index for hip osteoarthritis
The Lequesne functional index is a questionnaire that measures the functional impact of hip and knee osteoarthritis. It can also be used to evaluate the effectiveness of therapeutic interventions. It consists of 10 items in three different sections: pain or discomfort, maximum walked distance, and daily activities. Every section has a score range of 0 to 8. The total score of this index ranges from 0 to 24. Depending on the severity of osteoarthritis, the result might be 0 points: unaffected, 1–3 points: mild, 5–7 points: moderate, 8–10 points: severe and 11–13: very severe; scores of 14 points and higher: extremely severe [16,17].

2.5. Biomechanical tests

2.5.1. Gait analysis
The analysis was conducted with the Dinascan600/IBV system. This system, used with the Dinascan600/IBV dinamometric platform, biomechanically analyses human gait to functionally evaluate the ability and regularity of the patient’s gait pattern. The following variables were collected: gait speed (m/s²); support time (seconds); and braking force (Nw). The platform Dinascan 600/IBV (Instituto Biomecanico de Valencia, Universidad Politécnica de Valencia. Camino de Vera s/n 46022 Valencia, Spain) is formed by an active rectangular surface measuring 600 x 370 mm with 4 extensometric anchors in each corner, embedded in the floor, equipped with an A-D converter and controlled by 32 bit applications developed on LabWindows under C++. NedAMH/IBV and NedSVE/IBV interface. NedAMH/IBV is a software application to assist the specialist in biomechanical assessment of the human gait. A functional assessment of the capacity and regularity of gait is compared to normal standards. This system allows for analysis of ground reaction forces and moments performed by the individual on the floor during any human activity.

2.6. Statistical study

For the descriptive analysis, means (standard deviations [SD]) were used for quantitative variables and percentages for qualitative variables. The non-parametric Mann-Whitney U test was used to analyze the association between dependent quantitative variables, whereas the Wilcoxon test was used to study the association between independent quantitative variables. The adjustment was done taking the prognostic value of the variable when the bivariate analysis presented a P < 0.05. Unless otherwise indicated, the statistical significance of P < 0.05 was established.

3. Results

The final sample consisted of 14 patients who were followed up 12 months following surgical operation of mini-open anterior approach of the hip for FAI.

The mean age at time of operation was 40.75 years (± 6.84). The majority were male patients (9; 64.3%), without previous trauma history (13; 92.9%) and with ongoing pain for more than 3 months (13; 92.9%). All patients (14; 100%) practiced at least one sport at a recreational level previous to the onset of symptoms. The most affected side was the right (10; 71.4%), and only one case was found to be bilateral, in which only the right side was operated, and therefore it was included in the statistical analysis as right side. Regarding the past medical history and predisposing conditions, only one patient (1; 7.1%) was diagnosed of DDH and one patient (1; 7.1%) SUFE. Sports undertaken by patients included cycling in 5 cases, swimming in 3, aerobics in 2, jogging in 2, football in 1, and basketball in 1. Prior to surgery patients had only undergone symptomatic treatment involving analgesia and activity modification.

With regard to Tönnis classification, the majority of the patients were type I (9, 64.3%), and type 0 for the rest (5; 35.7%). In 100% (14) of our sample the “pistol grip” sign was present, with a mean CDA of 127.58° ± 5.55°, AA of 81.08° ± 5.73°, MPFA of
81.17 ± 5.75, and HNO of 6.58 ± 1.73. In 4 patients (28.6%) there was coxa vara. The crossover sign was present in 10 patients (71%) although very mild in all of them. None of the patients had coxa profunda nor protrusio acetabuli.

3.1. Main variable

The most important improvement was noticed in pain assessed on VAS (6.47 ± 2.71 to 2.06 ± 1.68), this change was statistically significant (P < 0.05). 42.85% of the cohort (6 patients) experienced an improvement in pain levels equal to or above 80% of the initial value.

3.2. Secondary variables

With regard to range of motion (ROM) of the affected hip, most patients showed improvement. The Faber distance also improved although, like ROM, it was not statistically significant (Table 1). All the functional capacity tests improved at 12 months after surgery, but none were statistically significant (Table 2).

The results of gait analysis prior to surgery and at 12 months after surgery showed improvement. The patients were analyzed separately according to right and left involvement. In the group of patients with the affected right side, the support time of the right lower limb and the braking force of the left lower limb prior and at 12 months after surgery showed statistically significant changes, from 0.64 ± 0.03 seconds to 0.66 ± 0.04 seconds and from 0.20 ± 0.04 to 0.18 ± 0.03 Nw respectively (Table 3).

The impingement sign remained positive at 12 months after surgery in 4 patients (28.6%). Regarding postoperative complications, 3 patients (21.4%) developed meralgia paraestethica within 12 months following surgery. No cases of heterotopic ossification were found in our series. All patients returned to sports at a recreational level at an average of 4.3 months (range 2.8 months–9 months).

4. Discussion

The results of this study show a statistically significant decrease in the subjective pain intensity at 12 months, with improvement, although not statistically significant, in gait analysis and functional capacity tests after FAI surgical treatment.

The intention of this study was to evaluate outcomes after FAI surgery from a functional and objective perspective. Important aspects were studied such as time until return to sports, functional capacity tests and biomechanical changes (gait analysis). All patients in this cohort practiced sports at least at a recreational level. It is known that individuals are more prone to develop symptomatic FAI depending on the sports discipline practiced. Various movements performed during sports, particularly flexion combined with internal rotation (i.e., hockey goalkeepers, ballet dancers and martial arts), have been suggested as potential causes of hip injury due to overload [1,18,19].

In this study, the performed mini-open anterior approach technique allows a prompt beginning of the rehabilitation program and is ideal for patients with important FAI deformities and lesions [13,20] whilst avoiding the risks of dislocation [21]. The rate of conversion to arthroplasty in this study is low (n = 1, 6.6%) and comparable to other published arthroscopic (0.5 to 40%) and open (5.3 to 26%) series [22–25]. Similarly return to sports (average 4.3 months) is comparable to studies performed within a cohort of athletes (average 3.8 months) [26]. At the time this study was set up, we were at the beginning of the learning curve of arthroscopic surgery and these good results have encouraged us to progressively switch to a full arthroscopic technique.

At 12 months after surgical operation functional capacity tests showed a trend to improvement, but not statistically significant. These results could be explained by two reasons: firstly, the limited number of patients in the cohort; secondly, the values show great heterogeneity. Regarding hip range of motion, results showed non statistically significant improvement in the Faber distance and in 5 of 6 directions of movement.

On gait analysis the study showed changes of longer support time of the affected limb and higher braking force of the contralateral, nevertheless, these are not clinically significant results. No significant differences were found in functional capacity tests nor in gait speed. We believe this is due to our cohort of patients who had an excellent functional capacity, mainly because of a young mean age and sports practice. For instance, gait speed prior to surgery (> 1.3 m/s) can be considered a very fast speed. Consequently, we believe that pain is a variable, which gives much more information than functional capacity tests in this cohort of patients. The functional studies performed might involve a relatively low demand for our cohort of young active patients and the performance time is short being therefore tolerable with regards to pain. We know that in this mechanical condition patients experience pain especially during high demand activities, i.e., when they practice sports. We believe that although hip pain might have had an impact on functional studies it might have not reached the level of sports practice.

Only one study has previously analyzed the biomechanical effects of FAI surgery during gait [27]. Their results suggested that gait mechanics did not return to normal after surgery. Contrary to our trend to improvement in time support of the affected limb and braking force of the contralateral they found no statistical

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**Table 1** Evaluation of the range of motion (ROM) in the affected and non affected hips.

<table>
<thead>
<tr>
<th>Examination</th>
<th>Affected side</th>
<th>Non-affected side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>12 months</td>
<td>Preoperative</td>
</tr>
<tr>
<td></td>
<td>12 months</td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>99.58 ± 21.05</td>
<td>106.25 ± 17.06</td>
</tr>
<tr>
<td>Extension</td>
<td>15.88 ± 10.03</td>
<td>16.59 ± 10.52</td>
</tr>
<tr>
<td>Abduction</td>
<td>28.75 ± 9.08</td>
<td>36.88 ± 7.99</td>
</tr>
<tr>
<td>Adduction</td>
<td>25.83 ± 10.41</td>
<td>25.00 ± 7.56</td>
</tr>
<tr>
<td>External rotation</td>
<td>26.67 ± 13.20</td>
<td>29.38 ± 7.29</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>16.25 ± 9.32</td>
<td>25.00 ± 12.54</td>
</tr>
<tr>
<td>Faber distance</td>
<td>21.40 ± 6.47</td>
<td>20.81 ± 7.98</td>
</tr>
</tbody>
</table>

ROM expressed in degrees, Fabere distance in centimeters.

**Table 2** Functional tests analysis.

<table>
<thead>
<tr>
<th>Test</th>
<th>Preoperative</th>
<th>12 months after</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS</td>
<td>6.47 ± 2.71</td>
<td>2.06 ± 1.68</td>
<td>P &lt; 0.01</td>
</tr>
<tr>
<td>6MWTa</td>
<td>480.75 ± 115.64</td>
<td>523.25 ± 111.69</td>
<td>NS</td>
</tr>
<tr>
<td>TUGc</td>
<td>8.34 ± 3.08</td>
<td>6.78 ± 2.01</td>
<td>NS</td>
</tr>
<tr>
<td>Stairs climbing testb</td>
<td>15.52 ± 10.40</td>
<td>9.97 ± 10.89</td>
<td>NS</td>
</tr>
<tr>
<td>Lequesne index</td>
<td>11.42 ± 4.63</td>
<td>6.94 ± 5.67</td>
<td>NS</td>
</tr>
</tbody>
</table>

6MWT: 6-minute walking test; TUG: Timed up & go; VAS: visual analogic scale.

a Distance expressed in meters.

b Time in seconds.

**Table 3** Gait analysis in patients affected of FAI in the right lower limb (n=10).

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Preoperative</th>
<th>12 months after</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT: gait speed</td>
<td>1.35 ± 0.25</td>
<td>1.32 ± 0.18</td>
<td>NS</td>
</tr>
<tr>
<td>RT: gait speed</td>
<td>1.36 ± 0.26</td>
<td>1.32 ± 0.20</td>
<td>NS</td>
</tr>
<tr>
<td>LT: support time</td>
<td>0.66 ± 0.08</td>
<td>0.66 ± 0.04</td>
<td>NS</td>
</tr>
<tr>
<td>RT: support time</td>
<td>0.64 ± 0.03</td>
<td>0.66 ± 0.04</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>LT: braking force</td>
<td>0.20 ± 0.04</td>
<td>0.18 ± 0.03</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>RT: braking force</td>
<td>0.17 ± 0.06</td>
<td>0.16 ± 0.04</td>
<td>NS</td>
</tr>
</tbody>
</table>

Time expressed in seconds; LT: left; RT: right.
differences between pre and postoperative results in their gait variables. However, the variables analyzed and the gait analysis system in that study were different from ours and they also used a different operative procedure. They include 10 patients and used an open approach in 4 and a combined approach in 6 with non-controlled rehabilitation protocols. Although not described in detail their approaches seem to require higher muscle splitting than the mini-open anterior approach. By using the same operative technique and rehabilitation protocol in the present study we tried to standardize the treatment in order to draw more consistent conclusions.

It is important to discuss the complication experienced in this approach. Meralgia paraesthetica had a relatively high incidence (21.3%). All patients showed improvement in symptoms at follow up which suggests that the lesion was a neurapraxia. Treatment should be considered as a multidisciplinary team approach, involving rehabilitation and pain control physicians and surgeons [28].

The review by Papalia et al. [24] studied the scientific evidence of 31 studies regarding clinical, functional and radiological outcome after treatment of FAI by arthroscopy or open surgery. Based on the study it has been shown that the different techniques are comparable in terms of functional, biomechanical and time to return to sports results. The mini-open anterior or anterolateral approaches have been proven effective in the treatment of this pathology in large number of patients [7,8,13] and likewise with arthroscopy. The outcomes by Sampson [29] who assessed 183 patients treated arthroscopically, showed a 94% impingement sign disappearance and high level of satisfaction, without tests or measurements of outcome. Larson and Giveans [5], reported a significant improvement of the Modified Harris Hip Score in 100 hips with a mean follow-up of 10 months. Three patients required THR out of these 100. Philippin et al. [25] also published a significant improvement in the Modified Harris Hip Score in 122 cases with a minimum follow-up of 2 years, finding predictors for better outcome as: higher preoperative hip grade, lower articular space narrowing and labral repair. Very few series included more than 100 cases [6,7,30], and even fewer [6,7] were studied prospectively. To our knowledge, we present the first prospective study that includes gait analysis and functional capacity tests.

Most of the previous authors evaluated the results with items like the Harris hip score, which was designed to evaluate the outcome after hip dislocations [23] or Merle d’Aubigné, which was developed to evaluate the results of THR [8,31]. In this study the Lequesne Index was used, which was designed as a questionnaire to assess hip function and the effects of surgery.

The treatment for FAI, open or arthroscopic, pursues two aims. In the short term to ease the clinical symptoms, and in the long term to prevent the repetitive injury to the articular cartilage and labrum, and therefore reduce the consequent possibility of developing osteoarthritis [1,32]. This study lacks the sufficient follow up to address the latter, but strongly contributes to reassure clinicians of the benefits of surgical treatment.

This study has some limitations. First the patients’ follow-up was performed at 12 months after surgery. This length of time does not allow us to evaluate further osteoarthritic changes but enables us to report an improvement on the symptoms. Secondly no isolated pincher cases were found in our cohort although this is known to have a low prevalence of presentation. Thirdly the techniques to treat impingement were being developed at the beginning of our study, and we did not compare the mini-open approach to other techniques such as arthroscopy. Finally the number of patients in the study is limited, although it enables to show some significant results.

Biomechanic tests offer the rehabilitation physician an objective measure of the patients’ functional status. In addition to the subjective pain score and although not statistically significant, the patients in this study showed an improvement in gait analysis, which can be considered as an objective pain improvement. This represented a more physiologic gait at 12 months after surgery.

Further studies with longer follow up are required to study the effect of FAI surgery in depth. Different surgical approaches might play a role in hip biomechanics and gait postoperatively. We encourage others to include gait analysis and functional capacity tests in the evaluation of FAI patients.

5. Conclusions

In conclusion, in this study we found an improvement in subjective pain intensity at 12 months following surgical intervention for FAI, with no significant improvements in functional capacity nor clinically significant changes in gait analysis. This was at the expense of a 21.4% rate of meralgia paraesthetica due to neurapraxia and 28.6% of the patients with residual positive impingement sign.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

Acknowledgements

Authors would like to thank the contribution of Ernesto Ortiz-Jr for the language guidance and of Elisabet Palomera, statistician of Consorci Sanitari del Maresme, for statistical consultation.

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