Ganz Periacetabular Osteotomy for the Treatment of Developmental Dysplasia of the Hip: Initial Experience and Results From the First 44 Cases

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ABSTRACT
Objective: To describe the surgical technique, indications, and initial results of the Bernese periacetabular osteotomy (PAO) for the treatment of developmental dysplasia of the hip. **Materials and Methods:** Between May 2011 and May 2020, 44 PAOs were performed in 44 patients (35 women) with an average age of 30 years (23-38). All patients had a diagnosis of symptomatic hip dysplasia. The average center-edge angle was 17 (9 to 20) and the average acetabular index was 18 (15 to 20). In 22 cases, the intra-articular findings were evaluated and repaired by arthroscopy in the same surgical stage. The correction obtained, the consolidation of the osteotomy, and the functional outcomes at the end of the follow-up were evaluated. **Results:** Hypertrophy and rupture of the acetabular labrum associated with hip dysplasia were evidenced in 22 patients. Paralabral cysts were found in 10 patients in the series. The average postoperative center-edge angle was 32º (27º to 35º) and the acetabular index was 6º (4º to 9º). The surgical time for PAO was 130 minutes; in patients where an arthroscopic procedure was added, the time was 148 minutes. **Conclusions:** PAO is technically demanding, but has predictable outcomes in patients with articular cartilage integrity and correctable deformities. Arthroscopy before osteotomy allows assessing cartilage conditions, diagnosing and treating intra-articular lesions associated with this pathology, and deciding on the need to correct the soft tissue deficit
Key words: Dysplasia; hip; osteoarthrosis; labrum; osteotomy; Ganz.
Level of Evidence: IV

Osteotomía periacetabular de Ganz para el tratamiento de la displasia del desarrollo de la cadera: experiencia inicial y resultados de los primeros 44 casos

RESUMEN
Objetivo: Describir la técnica quirúrgica, indicaciones y resultados iniciales de la osteotomía periacetabular bernesa para tratar la displasia del desarrollo de cadera. **Materiales y Métodos:** Entre mayo de 2011 y mayo de 2020, se realizaron 44 OPAB en 44 pacientes (35 mujeres, edad promedio 30 años [rango 23-38]). Todos tenían diagnóstico de displasia de cadera sintomática. El ángulo centro-borde promedio fue de 17° (rango 9°-20°) y el índice acetabular promedio, de 18° (rango 15°-20°). En 22 casos, se evaluaron y repararon los hallazgos intrarticulares por artroscópica en el mismo acto quirúrgico. Se evaluaron la corrección obtenida, la consolidación de la osteotomía y los resultados funcionales al final del seguimiento. **Resultados:** En 22 pacientes, se detectó hipertrofia y rotura del labrum acetabular asociadas a displasia de cadera. Diez pacientes tenían quistes paralabrales. El ángulo centro borde promedio posoperatorio fue de 32º (rango 27°-35°) y el índice acetabular, de 6° (rango 4°-9°). El tiempo quirúrgico para la osteotomía periacetabular bernesa fue de 130 min, cuando se sumó un procedimiento artroscópico, el tiempo fue de 148 minutos. **Conclusiones:** La osteotomía periacetabular bernesa es técnicamente demandante, pero logra resultados predecibles en pacientes con integridad del cartílago articular y deformidades corregibles. La artroscopia antes de la osteotomía permite evaluar las condiciones del cartílago, diagnosticar y tratar lesiones intrarticulares asociadas a con esta enfermedad y decidir si es necesaria la corrección del déficit de cobertura.
Palabras clave: Displasia; cadera; artrosis; labrum; osteotomía; Ganz.
Nivel de Evidencia: IV

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INTRODUCTION

Anatomical alterations of the hip lead to the development of irreversible joint damage.[1,2] Currently, developmental dysplasia of the hip (DDH) and femoroacetabular impingement are considered the most common conditions leading to osteoarthritis of the hip in young adults.[3]

The Bernese periacetabular osteotomy (PAO), described by Ganz, is the treatment of choice for DDH with or without acetabular retroversion, since it seeks to correct the poor coverage or acetabular incongruity and, therefore, the instability that characterizes this disease.[4] The correction process is characterized by restoring coverage to the femoral head, and correcting the anteversion and retroversion of the acetabulum, according to each patient.

Adolescent or young adult patients with symptomatic DDH with correctable deformity and preserved range of motion are eligible for PAO.[5] In general, it is recommended for patients between 10 and 40 years of age with closed triradiate cartilage due to the joint characteristics, closest to osteoarthritis. For symptomatic patients >40 years of age who have a dysplastic hip, the indications for a joint sparing procedure are controversial.[6-9]

Contraindications to PAO include advanced osteoarthritis (Tönnis 2 or 3), with joint subluxation that can alter joint congruence. On the other hand, patients with severe restrictions in the range of motion are also poor candidates for this procedure.[10,11]

The objective of this study is to describe the surgical technique, highlight the indications, and report the initial results of a series of 44 patients who underwent PAO to treat DDH in our Center. Second, we seek to analyze the short-term clinical and radiographic outcomes of osteotomy combined with hip arthroscopy in the same surgical stage.

MATERIALS AND METHODS

After obtaining approval from the institution's Ethics Committee, we retrospectively evaluated 44 DDH patients who had undergone between 2011 and 2020. In 22 cases, a hip arthroscopy had been performed due to a labral lesion without a CAM lesion in the femoral neck, continuing with a PAO in the same surgical stage (group A). In the remaining 22 cases, PAO had been performed in isolation (group B), since they did not have a labral lesion or CAM lesion visible in previous studies.

The information was collected from the institution's electronic medical records, which have been digitized since 2004. The median age of the patients was 30 years (interquartile range [IQR] 23-38), 31 years (IQR 26-42) for group A and 30 years (IQR 23-35) for group B ($p = 0.30$). Fifteen patients in group A and 20 in group B were women ($p = 0.06$). The median follow-up was 28 months (IQR 12-40), 34 months (IQR 21-45) for group A and 15 months (IQR 11-30) for group B ($p = 0.03$). There were no losses to follow up (Table 1).

The preoperative radiographic evaluation included an anteroposterior pelvic incidence that allowed classifying the patients and determining the acetabular angles, and a profile of the affected side with measurement of the alpha angle. All cases corresponded to grade I of the Crowe classification,[12] because they had proximal displacement <10% and subluxation of the femoral head <50%. The median preoperative acetabular index (AI) was 19° (IQR 16-20) for group A and 17° (IQR 15-18) for group B ($p = 0.14$). The preoperative median lateral center-edge angle (LCEA) was 16° (IQR 8-19) for group A and 19 ° (IQR 10-20) for the other group ($p = 0.19$). Only in seven and six patients in groups A and B, respectively, was a true acetabular retroversion observed, defined by the presence of two of the following radiographic signs: crossover sign, posterior wall sign, and ischial spine sign ($p = 0.74$) (Figure 1). In both groups, joint involvement was evaluated using the Tönnis classification.[13] Joint deterioration was similar in both groups and in no case was it higher than grade 2 ($p = 0.91$) (Table 1).

The clinical-functional evaluation was carried out before and after surgery with the modified Harris Hip Score (mHHS), the score of the University of California at Los Angeles (UCLA), and the visual analog scale (VAS) for pain. The median preoperative mHHS was 61 (IQR 58-64) for group A and 61 (IQR 57-61) for group B ($p = 0.39$). The median preoperative UCLA score was 7 (IQR 6-8) for the first group and 6 (IQR 6-8) for the second ($p = 0.42$). The median preoperative VAS score was 8 (IQR 7-9) in group A and 8 (IQR 7-8) in group B ($p = 0.37$) (Table 1).

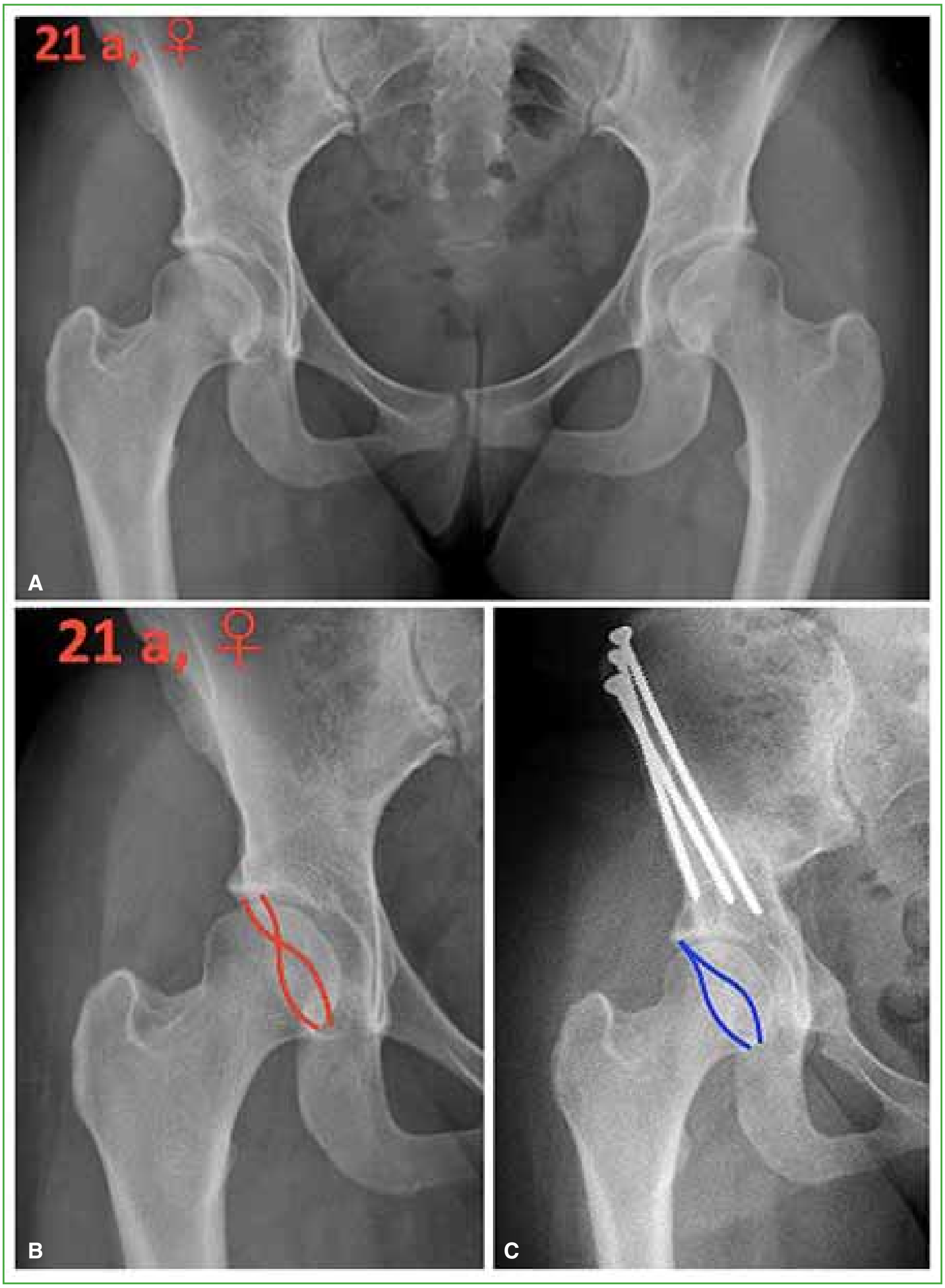

Figure 1. **A.** Anteroposterior radiograph of the preoperative hip of a 21-year-old patient with symptomatic developmental dysplasia of the right hip. **B.** Preoperative image showing the crossover sign in both acetabulum walls. **C.** Postoperative image showing the osteosynthesis of the Bernese periacetabular osteotomy; note the uncrossing of the anterior and posterior walls of the acetabulum.

Table 1. Demographic characteristics of the series.

Variable	Series (n = 44)	Group A (n = 22)	Group B (n = 22)	p
Median age, years	30 (IQR 23-38)	31 (IQR 26-42)	30 (IQR 23-35)	0.30
Sex, female/male	35/9	15/7	20/2	0.06
ASA classification, n (%)				
1	24 (55%)	11 (50%)	13 (59%)	
2	20 (45%)	11 (50%)	9 (41%)	0.44
Tönnis classification, n (%)				
0	19 (43%)	9 (41%)	10 (45%)	
1	18 (41%)	9 (41%)	9 (41%)	
2	7 (16%)	4 (18)	3 (14%)	
3	-	-	-	0.91
Acetabular retroversion, n (%)				
Yes	13 (30%)	7 (32%)	6 (27%)	
No	31 (70%)	15 (68%)	16 (73%)	0.74
Preoperative LCEA (°)	17 (IQR 9-20)	16 (IQR 8-19)	19 (IQR 10-20)	0.19
Preoperative AI (°)	18 (IQR 15-20)	19 (IQR16-20)	17 (IQR 15-18)	0.14
Preoperative UCLA	7 (IQR 6-8)	7 (IQR 6-8)	6 (IQR 6-8)	0.42
Preoperative mHHS	61 (IQR 57-64)	61 (IQR 58-64)	61 (IQR 57-61)	0.39
Preoperative VAS	8 (IQR 7-8)	8 (IQR 7-9)	8 (IQR 7-8)	0.37
Surgical time (min)	141 (IQR 129-175)	148 (IQR 139-190)	130 (IQR 113-151)	0.004
Follow-up (months)	28 (IQR 12-40)	34 (IQR 21-45)	15 (IQR 11-30)	0.03

IQR = interquartile range, ASA = American Society of Anesthesiologists, LCEA = lateral center-edge angle, AI = acetabular index, UCLA = University of California Los Angeles, mHHS = modified Harris Hip Score, VAS = visual analog scale.

All surgeries were performed by the same surgeon, specialized in hip pathology, following the principles described for both surgical techniques.[14,15] The senior surgeon carried out a fellowship in joint preservation surgery in a high-volume center with an increasing level of responsibility for six months. None of the patients had undergone surgery before. The classification of the American Society of Anesthesiologists (ASA)[16] was used to categorize the preoperative physiological state: 11 patients in group A and 13 in group B were ASA I (p = 0.44). Group A patients underwent the arthroscopic procedure on a traction table under hypotensive epidural anesthesia in the first surgical stage. After the change to a radiolucent table and the placement of new sterile drapes, a Smith-Petersen approach was performed in all patients to continue with the PAO. In group A, the arthroscopic labral repair was performed with 3.2 mm biodegradable anchors (Arthrex®). The number of anchors used depended on those necessary to obtain labral stability in each specific case, without having a prior protocol. The capsulotomy was not repaired at the end of the arthroscopic procedure in any patient. After obtaining the desired acetabular correction with the PAO, the fragment was fixed with 4.5 mm cortical screws in both groups (DePuy-Synthes®) (Figure 2). No labral repair was performed on patients in group B. The median surgical time of the series was 141 min (IQR 129-175), 148 min (IQR 139-190) for group A and 130 min (IQR 113-151) for group B (p = 0.004).

Figure 2. Intraoperative clinical image. The placement of a 3.2 mm anchor can be observed in the arthroscopic procedure during the first surgical stage.

Low-molecular-weight heparin (40 mg/day) was administered subcutaneously as antithrombotic prophylaxis for four weeks to patients in both groups.[17] Routine prophylactic treatment for heterotopic calcifications was not indicated. After surgery, the operated lower limb was placed in a neutral position. Due to the preservation of the continuity of the pelvic ring, early ambulation with assistance was authorized. A partial load of 15 kg of weight was indicated on the operated side during the first eight weeks, performing hip mobility exercises with flexion limited to 90°, neutral internal rotation, 30° of external rotation and 30° of abduction for 3 -6 weeks. Continuous active and passive movements were monitored by the Kinesiology Service from the first day after surgery to prevent capsular adhesions. Gradual increase in weight-bearing was allowed when signs of bone consolidation were observed at the eight-week postoperative radiographic control. The patients then continued with physical therapy for the next 2-3 months to improve their range of motion and muscle strength. The clinical and radiographic follow-up was performed at 15 and 45 days, and 3, 6, and 12 months after surgery and then annually, with anteroposterior, alar and obturator oblique, and lateral hip radiographs on the affected side. The PAO was considered consolidated when bone bridges were observed in two of the radiographic incidences.[18] Complications were recorded and all cases that required additional surgical treatment due to infection of the surgical site were considered infectious failures. Non-infectious failure comprised all cases that required revision surgery, regardless of the cause.

Statistical analysis

Continuous variables are expressed as median and IQR or as average and standard deviation (SD), depending on whether they have an abnormal distribution or not, respectively. Categorical variables are expressed as frequencies and percentages. Continuous variables were compared using Student's t-test when they had a normal distribution and Mann-Whitney U-test when they did not. The chi-square and Fisher's exact tests were used to compare categorical variables. The demographic variables and radiographic findings of both groups were compared to analyze the evolution of the clinical outcomes. A multivariate logistic regression analysis was performed to assess whether the additional arthroscopic procedure was associated with an improvement in postoperative clinical-functional outcomes. A p value <0.05 was considered statistically significant. The STATA 13™ program (Stata Corp., College Station, Texas, USA) was used for statistical analysis.

RESULTS

Radiographic analysis

There were no cases of progression of joint degeneration in either of the two groups. Regarding postoperative angular measurements, the median AI improved by a value of 11º (IQR 9-13) and the LCEA by a value of 16º (IQR 14-18) in the entire series ($p < 0.001$). However, there was not a statistically significant difference in postoperative measurement between both groups (Table 2).

Table 2. Postoperative outcomes and complications by group.

Variable	Series (n = 44)	Group A (n = 22)	Group B (n = 22)	p
Postoperative LCEA (°)	32 (IQR 27-35)	32 (IQR 26-35)	32 (IQR 30-35)	0.53
Postoperative AI (°)	6 (IQR 4-9)	7 (IQR 6-11)	5 (IQR 4-8)	0.12
Postoperative LCEA improvement (°)	16 (IQR, 14-18)	16 (IQR 14-22)	16 (IQR 13-16)	0.47
Postoperative AI improvement (°)	11 (IQR 9-13)	9 (IQR 8-12)	11 (IQR 10-13)	0.28
Postoperative UCLA	8 (IQR 7-8)	7 (IQR 6-8)	8 (IQR 7-8)	0.33
Postoperative mHHS	87 (IQR 87-91)	87 (IQR 87-91)	87 (IQR 87-87)	0.15
Postoperative VAS	1 (IQR 0-1)	0 (IQR 0-2)	1 (IQR 0-1)	0.84
Postoperative UCLA improvement	1 (IQR 0-2)	1 (IQR 0-1)	1 (IQR 0-2)	0.18
Postoperative mHHS improvement	26 (IQR 26-30)	27 (IQR 25-29)	26 (IQR 26-30)	0.84
Postoperative VAS improvement	7 (IQR, 6-8)	7 (IQR, 5-8)	7 (IQR, 6-7)	0.50
Complications Posterior wall fracture FCN compression Superficial infection	5 (11%) 1 2 2	2 (9%) 1 1 	3 (14%) 1 2	 0.64
Overall postoperative outcomes of the series.				
Variable	**Series (n = 44)**	**p**		
Postoperative LCEA improvement (°)	16 (IQR 14-18)	<0.001		
Postoperative AI improvement (°)	11 (IQR 9-13)	<0.001		
Postoperative UCLA improvement	1 (IQR 0-2)	<0.001		
Postoperative mHHS improvement	26 (IQR 26-30)	<0.001		
Postoperative VAS improvement	7 (IQR 6-8)	<0.001		

IQR = interquartile range, LCEA = lateral center-edge angle, AI = acetabular index, UCLA = University of California Los Angeles, mHHS = modified Harris Hip Score, VAS = visual analog scale, FCN = femoral cutaneous nerve.

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Functional assessment

The median postoperative mHHS was 87 (IQR 87-91) for group A and 87 (IQR 87-87) for group B (p = 0.15). The median postoperative UCLA score was 7 (IQR 6-8) for the first group and 8 (IQR 7-8) for the second (p = 0.33). According to the postoperative VAS, the patients in group A had a median pain score of 0 (IQR 0-2) and those in group B, a median of 1 (IQR 0-1) (p = 0.84). Only one patient in group A developed a complex regional pain syndrome and maintained a value equal to that of the preoperative period (score 7). In the general analysis of the series, the postoperative improvement of the mHHS and UCLA scores was 26 (IQR 26-30) and 1 (IQR 0-2), respectively, (p <0.001). Preoperative pain improved 7 points on average (IQR 6-8) in the VAS (p <0.001). There were no significant differences in the measurement of postoperative improvement between both groups (Table 2).

Complications

No major neurovascular complications were recorded in any group. There were two complications in group A: one patient suffered an incomplete fracture without displacement of the posterior wall of the acetabulum during surgery that did not influence subsequent rehabilitation, and another had meralgia paresthetica due to the involvement of the femoral cutaneous nerve, which improved markedly after 90 days and no further intervention was required. In group B, there was also a sensory compromise of the femoral cutaneous nerve that resolved with conservative treatment, as in the patient in group A. Finally, two patients suffered a superficial infection of the surgical wound, which was cured with oral antibiotics for 14 days [group A (1) vs. group B (1), p = 0.64] (Table 2).

Linear regression analysis

The univariate linear regression analysis did not find a statistically significant association between any of the variables of the clinical-functional evaluation with respect to the performance of the arthroscopic procedure (Table 3).

Table 3. Univariate linear regression model with the arthroscopic procedure as a dependent variable.

Variable	Univariate analysis	
	B - coefficient (95% CI)	p
Postoperative UCLA improvement	-0.06 (-0.15-0.02)	0.14
Postoperative mHHS improvement	-0.01 (-0.03-0.03)	0.84
Postoperative VAS improvement	0.01 (-0.07-0.08)	0.83

UCLA = University of California Los Angeles, mHHS = modified Harris Hip Score, VAS = visual analog scale.

DISCUSSION

Ganz osteotomy is widely recognized as the most anatomical of the periacetabular redirection osteotomies; however, it is the most complex procedure, but it has achieved reproducible success in the short term.

It is essential to be strict in each step of the surgery. For this, every gesture made during the procedure must be controlled under a fluoroscope. One must be very careful when executing the first osteotomy, since a very low cut makes it difficult to position the fragments correctly, and if it is too high, the joint can be damaged, one of the most feared complications (Figure 3). The third cut is, in our opinion, the most important, because it runs between the posterior column on the medial side and the joint on the lateral side. Any variation in this cut can lead to joint violation and damage to the posterior column, thus compromising the stability of the pelvis itself. The cut in the iliac bone is another important point to consider. It is essential to respect the distance from the cut to the superior surface of the acetabulum, since osteotomies performed very close to it can damage the gluteal and obturator arteries, generating acetabular necrosis.[19]

Figure 3. Intraoperative image with intensifier. The ischial osteotomy is observed medially (**A**) and laterally (**B**).

Intrasurgical control of the final position of acetabulum correction is necessary and essential. Before starting the surgery, it is mandatory to carry out a radiographic control of the position of the pelvis on the operating table, respecting the parameters described by Tannast.[20] Once the acetabular correction has been performed, an anteroposterior hip radiograph should be taken to assess the correct acetabular position. In this view, the coverage of the femoral head is evaluated by measuring the LCEA and AI angles, the position of the anterior and posterior walls of the acetabulum, the distance between the femoral head and the fundus of the acetabulum, Shenton's line, and pelvic teardrop.

In 22 patients, hip arthroscopy was performed before PAO in the same surgical procedure. This procedure is beneficial for two reasons. First, it allows the surgeon to identify the intra-articular pathology. Labrum tears, chondral flaps, and chondromalacia can be seen directly. This is an important prognostic value for patients undergoing PAO and, in some circumstances, may lead the surgeon to make the decision not to proceed with an osteotomy immediately after the arthroscopic procedure. In all patients, a labrum injury was found and repaired with anchors. The number of anchors used depended on those that were necessary in each specific case to obtain labral stability, without having a previous protocol.

Regarding postoperative angular measurements, the median AI improved by a value of 11º (IQR 9-15) and the LCEA by a value of 18º (IQR 15-24) in the entire series ($p < 0.001$). However, there was not a statistically significant difference in postoperative measurement between both groups (Table 2). The average postoperative LCEA was 32° in the series (27° - 35°): group A, 32° (26° - 35°) and group B, 32 (30°-35°). The postoperative AI was 6° (4° -9°): group A 7° (6° -11°) and group B 5° (4° -8°). These measurements were maintained over time, without changes in the postoperative controls.

There is a well-known learning curve period for PAO, which is believed to include approximately the first 20 osteotomies and during which major surgical complications are not uncommon. According to our initial experience, the complication rate in the first 44 cases operated on at our institution was 11%.

No patient in our series needed conversion to total hip replacement. Although the follow-up is short, some series show poor outcomes in patients >40 years of age after surgery, such as a lower preoperative Merle d'Aubigné and Postel score, a positive preoperative anterior impingement test, preoperative limping, and an increased preoperative osteoarthritis score according to the Tönnis classification.[21-23] In the literature, it is strongly suggested that young patients with dysplastic hips and minimal or mild joint changes are the ideal candidates for this operation. In patients with moderate or severe joint changes, PAO becomes less predictable and the conversion rate to a total hip replacement is high.[24-26]

Our study has several limitations. First, there is selection bias due to its retrospective nature. Second, the data inherent to the range of mobility were recorded by different authors without a reliability test between the measurers, so there is a risk of measurement error and evaluation bias. On the other hand, we decided to use the mHHS as a clinical outcome based on its validity and reliability, but it does not assess function during sports and recreational activities or quality of life related to the hip. However, our study compares a group of patients who underwent PAO alone versus a group who underwent hip arthroscopy before osteotomy, and a close relationship could be observed in the sequentially combined treatment. Furthermore, our study shows strong data in the short-term follow-up related to functional outcomes and complications in a high-volume surgical center with trained surgeons. As a strength of the study, we emphasize that all patients were operated on by the same surgeon.

CONCLUSIONS

The first results in this initial group of patients treated with PAO at our institution show a reliable radiographic correction of the deformity and an improvement in function, with an acceptable complication rate. We believe that performing a hip arthroscopy before PAO in the same surgical stage is a valid option to assess joint status without increasing the morbidity of the procedure. Nevertheless, we have not been able to demonstrate a statistically significant association between any of the variables of the clinical-functional evaluation with respect to the performance of the arthroscopic procedure.

Conflict of interest: The authors have no conflicts of interest to declare.

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