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Supplement

Bilateral femoral head reshaping and mosaicplasty in Legg–Calvé–Perthes disease residual deformity

Ángel Palazón-Quevedo[1,†], María Galán-Olleros[1,2,*,†] and Rosa M. Egea-Gámez[1]

[1]Pediatric Orthopaedic and Traumatology Department, Hospital Infantil Universitario Niño Jesús, Av. de Menéndez Pelayo 65, 28009, Madrid, Spain and [2]Orthopaedic Surgery and Traumatology Department, Hospital Clínico San Carlos, Calle Profesor Martín Lagos s/n 28004, Madrid, Spain.
[†]These authors contributed equally to this work.
*Correspondence to: M. Galán-Olleros. E-mail: mgalanolleros@gmail.com
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ABSTRACT

Residual hip deformity secondary to Perthes disease may lead to early symptomatic joint degeneration. The altered anatomy results in biomechanical and biological problems that can be surgically addressed in adolescents or young adults with hip preservation procedures. This case report aims to demonstrate a customized surgical treatment performed on a 15-year-old male who developed painful hips with significant intra- and extra-articular impingement, secondary to bilateral Leg–Calvé–Perthes disease residual deformity. Intra-articular procedures were executed through a safe surgical dislocation of the hip, with a mosaicplasty using osteochondral autografts from the exceeding peripheral ipsilateral femoral head, a femoral head–neck osteochondroplasty and a labrum repair. A relative lengthening of the femoral neck was also carried out with a trochanteric advancement to solve the extra-articular issues. On follow-up, he referred to a substantial improvement in pain and function, being his radiographic studies satisfactory. At 4 and 5 years from surgery, the patient was able to exercise regularly with minimal complaints, with a Harris Hip Score of 85.85% and a Hip Outcome Score of 94.1% for activities of daily life and 86.1% for sports. In patients with hip deformity after healed Perthes disease, treatment strategies that address both the morphological disturbance of coxa magna, plana and breva, as well as the biological concerns arising from osteochondral injuries or labral tears, and mechanical dysfunctions lead to improvements in symptomatology, function and medium-term prognosis. Further procedures to address residual adaptative acetabular dysplasia would favor outcomes of conservative hip surgery in the sequelae of LCPD.

INTRODUCTION

Legg–Calvé–Perthes disease (LCPD) is a pediatric orthopaedic disorder characterized by idiopathic osteonecrosis of the proximal femoral epiphysis [1]. The condition involves several phases from necrosis, fragmentation and reosification, up to a final stage of sequelae leading in some cases to a residual deformity [2]. Once the disease has healed, the future symptoms and disfunction around the hip joint depend on the severity of the residual deformity, the degree of sphericity of the femoral head and the congruence of the joint [3, 4], which highly correlate with prognosis.

Femoral head residual deformities include coxa magna with lateral extrusion, coxa plana and chondral injuries due to the necrotic insult to the femoral epiphysis, and coxa breva and trochanteric overgrowth secondary to damage of the proximal physis. The deformity of the femoral head produces an adaptive dysplasia of the acetabulum, with retroversion, as well as progressive damage to the articular cartilage and labrum that may also influence the long-term prognosis of the disease due to insufficient femoral head coverage [3, 5, 6].

The most appropriate treatment requires the identification of the diverse pathological morphology found through anamnesis, physical examination and imaging tests. To completely restore the local anatomy and biomechanics of the patient's hip, it is essential to assess all the information as a whole and plan a tailored surgical treatment that

addresses each of the main problems. Both intra- and extra-articular problems should be addressed, together with those that occur on the femoral side and any secondarily occurring on the acetabulum [7, 8]. The goal is to achieve a stable and concentric joint with an optimized range of motion. In cases where the joint is seriously damaged, the goal becomes to improve the quality of life and delay the joint-replacement procedure.

CASE DESCRIPTION

A 15-year-old male with a history of bilateral LCPD consulted for pain in both hips. Perthes disease had an onset at 7 and 8 years old in the left and right hip, respectively, which were both treated conservatively at another institution. No other remarkable medical records were reported.

On examination, he had significant intra- and extra-articular impingement-related symptoms, making daily life activities difficult and impairing his sports practice. He exhibited a limited passive hip range of movement bilaterally (right/left) using the neutral-zero method [9]: flexion 80°/70°, extension 0°/0°, abduction 25°/20°, adduction 5°/10°, internal rotation 15°/10° and external rotation 20°/15°. No signs of hip abductor insufficiency were evident on evaluation. No abnormalities in the bony rotational profile were appreciated in the examination of the lower extremities.

His preoperative radiographs are shown in Fig. 1 in which the residual deformity of both proximal femurs can be observed, consisting of coxa magna, plana and breva, with proximal migration of the greater trochanter and a large central osteochondral lesion, as well as associated shallow acetabulum and lateral under coverage and femoral head extrusion as seen in the X-ray (Fig. 1) and CT scan images (Fig. 2). Both hips presented a Stulberg's grade V residual deformity [3].

After explaining to the patient and family the different options to address the femoral and acetabular deformities, the decision was to perform the femoral surgery first, followed by a potential procedure to treat residual symptoms originating from the adaptative dysplastic acetabulum later on. Therefore, the patient underwent staged hip preservation surgery on both hips, with a 1-year interval between procedures. The same procedures were performed on both hips. With the patient placed in lateral decubitus, through a direct lateral approach, a partial thickness osteotomy of the greater trochanter and a Z-shape capsulotomy were performed to allow a safe surgical dislocation of the hip [10]. The femoral head had an ovoid appearance, aside from an osteochondral defect in the central area. This was debrided up to reaching stable cartilage and visualizing well-vascularized subchondral bone. According to the size and morphology of the lesion, three deep cylindrical holes perpendicular to the defect were carved in the injured area, which was then replaced by osteochondral cylindrical autografts from a non-weight bearing excess peripheral area of the ipsilateral femoral head. The plugs were transported using tubular chisels and introduced in the recipient site until the graft was positioned at the same level as the surrounding cartilage. Subsequently, an osteochondroplasty of the proximal femur was performed with a large cheilectomy of the anteroinferior, posteroinferior and lateral aspects of the femoral head using a curved osteotome to obtain a more spherical shape and create a smooth head–neck junction. The acetabular surface remained intact, but the labrum had a longitudinal tear that was repaired via suture anchors. The hip was then reduced and hip stability

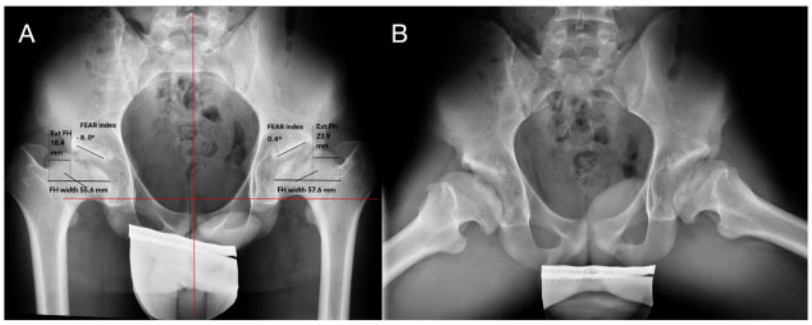

Fig. 1. Pre-operative anteroposterior pelvic radiograph (A) and axial view of both hips (B). Widened, flattened and non-spherical femoral head, high-riding greater trochanter with negative articulo-trochanteric distance, short femoral neck and acetabulum under coverage. The extrusion index defined as the % of the femoral head (FH) width not covered by the acetabulum was 33.1 and 41.9% for the right and left hip, respectively. The Femoro-Epiphyseal Acetabular Roof (FEAR) index measured between the line of the acetabular roof and the central third of the physeal scar of the FH was −8° and 0.4°. The pelvis appears to be anteriorly rotated or anteverted due to the hip flexion contracture of the patient, which resulted in an apparent acetabular retroversion, inferred by the crossover sign and prominent ischial spines.

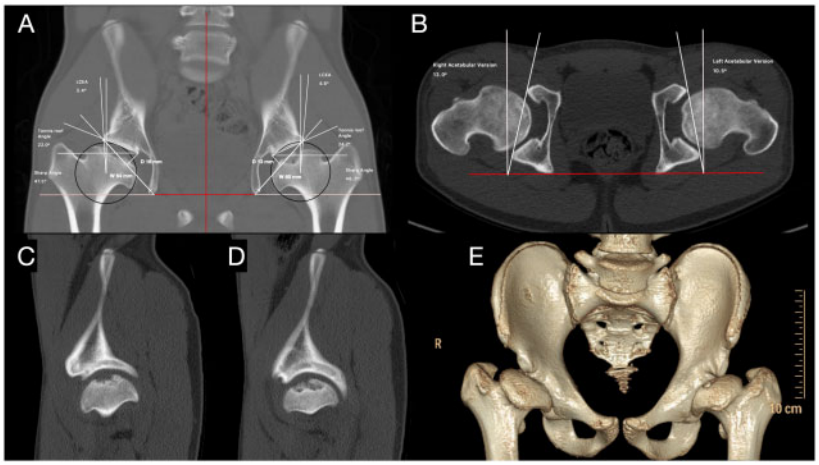

Fig. 2. Preoperative CT scan of the pelvis. Coronal (**A**), axial (**B**), right (**C**) and left (**D**) sagittal sections and three-dimensional reconstruction (**E**). Dysmorphic femoral heads not well covered by the acetabulum, trochanteric overgrowth, normal acetabular anteversion and central osteochondral lesion. Measurements for right/left hip were: Lateral Center-Edge Angle (LCEA): 3.4°/4.6°; Tonnis roof angle: 22°/24.2°; Sharp angle: 47.5°/48.3°; Acetabular depth-width ratio calculated as depth (D)/width (W) × 1000: 250/216.7; Acetabular version: 13°/10.5°.

and mobility without impingement were intraoperatively checked in flexion and internal rotation, external rotation in extension and abduction. A capsulorrhaphy was done and finally, a relative lengthening of the femoral neck through a distal and lateral trochanteric advancement was also executed. This was fixed using two 7.3 mm cannulated partially threaded screws. The wound was closed in layers with one subfascial suction drain. Figure 3 shows intraoperative images.

Post-operatively, the patient was allowed to partially weight-bear with technical aids, and limitations were set on hip flexion above 90° and active abduction for 6 weeks. Following this period, he transitioned to full weight bearing as tolerated and was instructed to gradually execute a complete hip range of motion and strengthening exercises.

On follow-up, he referred to a substantial reduction of pain and improvement of function and range of motion, mainly in flexion and with modest gains in internal and external rotation. The left hip was operated on first, and at the time of the right hip intervention an attempt was made to remove the screws from the left hip, but one of them remained, as shown in the postoperative radiographs in Fig. 4. In this figure, the distalization of the greater trochanter is evident compared to preoperative images, and a more spherical shape of the head of the femur can be appreciated, together with an improvement in the central osteochondral lesion, despite the residual acetabular dysplasia.

At 4 and 5 years from surgery, the patient can exercise regularly with minimal complaints or functional limitations. The most recent radiographs are shown in Fig. 5. The left hip appears to be more congruent and spherical, with almost complete radiological healing of the osteochondral lesion. In the right hip, however, the central osteochondral lesion is still visible, although it has improved and is less extensive and in-depth, probably due to partial failure of the osteochondral grafts. The greater trochanter advancement osteotomy has achieved a positive increase in the articulotrochanteric distance, obtaining a relative lengthening of the femoral neck which correlates with the improvement in the biomechanics of the hip. Currently, his Harris Hip Score is 85.85% and the Hip Outcome Score is 94.1% for activities of daily living and 86.1% for sports. As the patient is satisfied with the results, no additional imaging studies or surgical procedures have been performed at our institution, a pediatric hospital, to date. Still, he is being closely monitored at his adult reference center, as he may benefit from periacetabular reorientation osteotomy surgery [11] to treat the residual adaptative acetabular dysplasia and an additional procedure, such as a head reduction osteotomy [12, 17], to deal with the remaining deformity of the right femoral head and the central chondral lesion. These could be performed as a combined procedure, as previously described [13].

DISCUSSION

Orthopedic treatment of residual deformity in LCPD is not yet completely resolved. Hip deformity leads to biomechanical alterations and joint incongruence, which combined with osteochondral lesions favor the risk of a

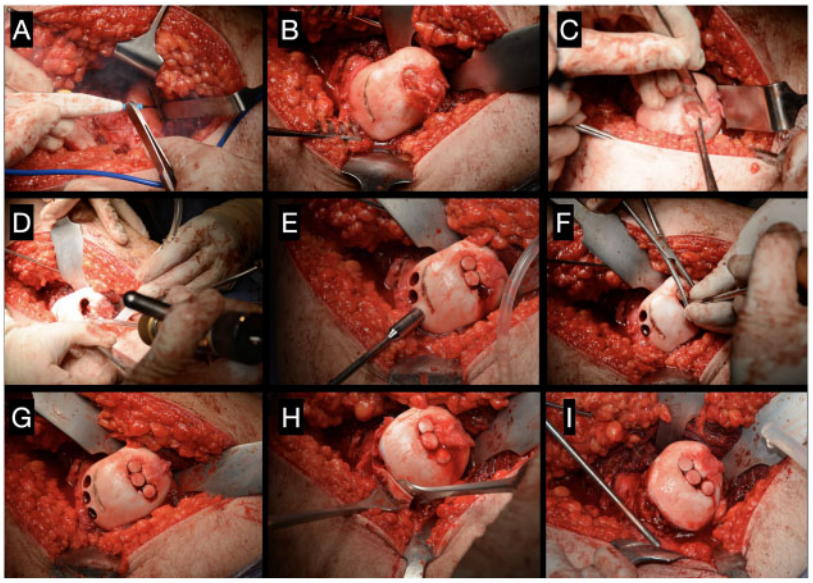

Fig. 3. Surgical technique: (**A**) Delineation of the excess femoral head area. (**B**) Safe surgical dislocation of the hip and identification of the large central osteochondral lesion. (**C**) Removal of devitalized tissue and debridement up to stable cartilage. (**D**) Cylinder design at the recipient site, carved deep and perpendicular to the defect. (**E**) Graft obtention from the donor site with a tubular chisel. (**F**) Transplantation of the graft to the recipient site and introduction until the graft is at the same level as the surrounding cartilage. (**G**) Cylindrical graft transferred to the articular femoral head defect. (**H**) Cheilectomy and reshaping of the femoral head with a curved osteotome until obtaining a uniform femoral head-neck junction with the absence of impingement and a spherical femoral head. (**I**) Definitive result of the mosaicplasty and osteochondroplasty.

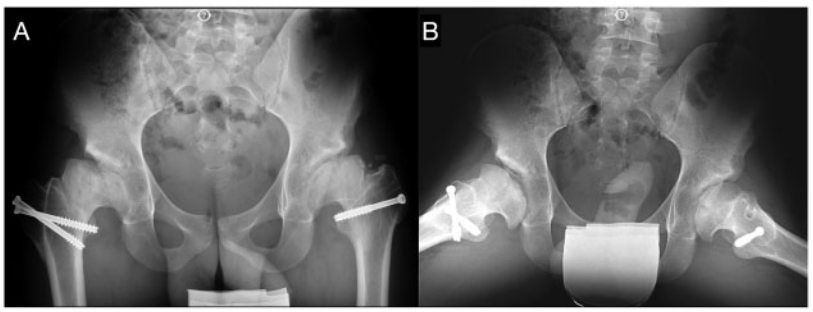

Fig. 4. Anteroposterior (**A**) and axial (**B**) radiographs of both hips after the surgical procedures. Trochanteric osteotomies radiographically healed in a more distal position, femoral heads reshaped to achieve a more spherical morphology and a transitional head–neck junction and the osteochondral autografts appeared to be well incorporated.

rapid progression to early symptomatic coxo-femoral arthritis [3].

Several procedures have been described to approach this complex sequelae. Total hip arthroplasty in young patients carries a greater risk of wear and loosening, leading to high revision rates [14], thus hip preservation techniques are more suitable options. There are no standardized surgical procedures on the hip for residual deformity in LCPD because the pathomorphology is quite varied. Instead, an individualized treatment must be done according to the particular alterations that the patient presents.

Different techniques using a surgical hip dislocation [10] have been published in small sample studies or case reports in recent years [7, 15–19], including femoral head–neck osteochondroplasty, intertrochanteric osteotomy, head reduction osteotomy, relative femoral neck lengthening through trochanteric advancement, labral debridement, labral repair, osteochondral defect debridement and fixation, mosaicplasty, acetabular rim trimming and periacetabular osteotomy. The combination of the surgical procedures here explained and briefly illustrated in the current case aims to optimize, in an individualized fashion,

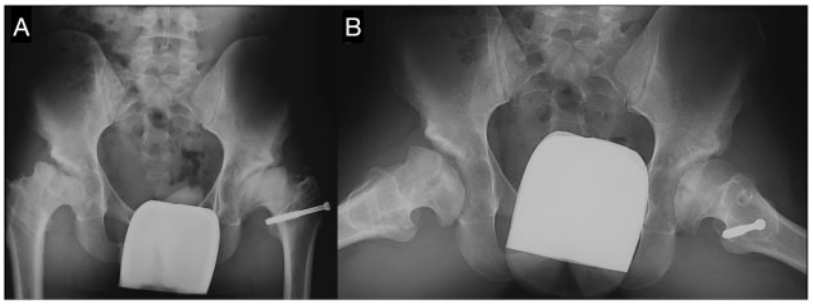

Fig. 5. Anteroposterior pelvic radiograph (**A**) and axial view of both hips (**B**) at the last follow-up at 4 and 5 years post-operatively. The findings are similar to the ones in previous radiographs but with all of the screws already extracted except for the left lower one. Radiological signs of healing of the osteochondral lesion are evident in the left hip, while in the right hip the central osteochondral lesion is still partially visible. Extrusion index has improved, as well as LCEA, however, there is residual adaptative acetabular dysplasia.

both the mechanical and the biological environment simultaneously for joint preservation (Table I).

Mosaicplasty has already been presented as a treatment for osteochondral lesions in different joints with promising results and can also be performed on the hip through a safe surgical dislocation, as previously described [16, 20, 21] and as observed in the current case. This approach facilitates almost circumferential access to the femoral head, allows full acetabular exposure, and permits dynamic assessment of impingement and stability. The basis of the mosaicplasty performed in this patient is the autogenous osteochondral transplant that involves the transfer of bone plugs covered with normal hyaline articular cartilage to the focal osteochondral defects [22], which then heal within the surrounding receptor tissue. Associated morbidity to healthy areas is avoided by using the non-weight bearing exceeding ipsilateral peripheral cartilaginous head before cheilectomy [16, 20, 21].

Excessive growth of the anterolateral and inferior part of the femoral head due to epiphyseal damage occurring early in the course of the disease leads to an intra-articular cam-type femoroacetabular impingement after healing. The impact of the misshapen head creates shear forces on the acetabular cartilage and the chondrolabral junction which predisposes to labral tears and cartilage delamination. Reshaping the femoral head through a femoral head–neck osteochondroplasty aims to achieve a more spherical morphology and a smooth head–neck junction with increased head–neck offset. Dynamic examinations should be used to delineate the excess of femoral head and determine the optimal degree of resection, as well as to check the complete range of motion without impingement once trimmed. Another procedure to treat the coxa magna, femoral head asphericity and central condral lesion is head reduction osteotomy [12, 17], which is proposed as an alternative treatment for the persistent deformity in our patient.

The distal and lateral advancement of the greater trochanter has a double effect. On the one hand, it solves the extraarticular source of impingement between the high-riding trochanter against the ilium and posterolateral acetabular rim. On the other hand, it addresses a biomechanical issue by providing tension to the hip abductor mechanism, achieving a relative femoral neck lengthening and increasing the lever arm, thus reducing the force that must be generated by the hip abductor muscles and reducing their fatigue. This results in a better counterbalance of the body weight during monopodal support and the stance phase of walking, thereby decreasing the reaction forces around the hip joint and reducing the overload and joint damage in the bearing area of the femoral head and acetabular roof, which potentially protects the integrity of the joint.

Residual adaptative acetabular dysplasia could lead to suboptimal clinical and radiological results and early joint degeneration [6, 8]. Despite the lead surgeon's previous experience in performing a combined procedure, the decision in the current case was to proceed with a staged procedure [7]. Thus, the correction of the persistent acetabular structural abnormalities could be pursued at a later time.

CONCLUSIONS

The variable residual deformity in LCPD depends on the changes occurring during the different phases of the disease and can lead to early symptomatic hip degeneration. Moderate to severe deformities often have an unfavorable outcome without treatment. The management of these alterations represents a significant challenge in young patients. Although expectations must be carefully managed in the setting of a severe residual LCPD deformity, surgical treatment should be customized according to the primary problems that arise. The approach here proposed with a safe surgical hip dislocation and cartilage restoration

Table I. Schematic summary of the main problems in the LCPD residual deformity of the featured case, the mechanical and biological implications, the therapeutic procedures performed and the reconstructive objective of each of them.

Primary problem	*Type of alteration*	*Surgical procedure*	*Reconstructive objective*
Osteochondral lesion	Biological, cartilage deterioration	Mosaicplasty	Cartilage articular surface reconstruction
Coxa magna	Overgrowth of the anteroinferior, posteroinferior and lateral aspects of the femoral head	FHNO	Joint congruence Elimination of intra-articular FAI
	Intra-articular FAI (with flexion, adduction, IR)		
Coxa plana	Mechanical, joint incongruence	Femoral head reshaping through FHNO and mosaicplasty	Joint congruence and femoroacetabular gliding
Labrum tear	Mechanical and biological, through under coverage and containment, suction seal and negative pressure	Labral repair	Increases stability
			Uniform distribution of pressures around the joint
			↓ hip joint pressures
Trochanteric overgrowth	Mechanical	Trochanteric advancement	Hip abductor mechanism restoration
	Abductor insufficiency		Elimination of extra articular FAI
	Extra-articular FAI (with abduction, extension, ER)		
Coxa breva	Mechanical, ↓ lever of arm, abductor insufficiency, ↑ hip reaction forces, limp	RFNL through trochanteric distalization	↑ lever of arm
			Hip abductor mechanism restoration
			↓ hip joint overload
Acetabular dysplasia	Mechanical, joint incongruence, under coverage, instability, ↑ hip reaction forces, ↑ abductor muscle force	PAO	↑femoral head-acetabulum contact area, ↓ hip joint overload, stability, ↓abductor muscle force through medial translation of the hip joint center

Abbreviations: LCPD, Leg–Calvé–Perthes disease; FAI, Femoroacetabular impingement; IR, Internal rotation; FHNO, femoral head–neck osteochondroplasty; ER, External rotation; RFNL, Relative femoral neck lengthening; PAO, Periacetabular reorientation osteotomy.

procedures, along with addressing the mechanical disturbances, enables a full spectrum of hip joint preservation reconstructive possibilities. Further procedures to address residual adaptative acetabular dysplasia would favor outcomes of conservative hip surgery in the sequelae of LCPD.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare that are relevant to the content of this article.

STATEMENT OF INFORMED CONSENT

Informed written consent was obtained from the patients before submission. This study has been conducted according to the principles of the Declaration of Helsinki.

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