■ HIP

Concurrent femoral head reduction and periacetabular osteotomies for the treatment of severe femoral head deformities

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Aims

The aims of this study were to review the surgical technique for a combined femoral head reduction osteotomy (FHRO) and periacetabular osteotomy (PAO), and to report the short-term clinical and radiological results of a combined FHRO/PAO for the treatment of selected severe femoral head deformities.

Patients and Methods

Between 2011 and 2016, six female patients were treated with a combined FHRO and PAO. The mean patient age was 13.6 years (12.6 to 15.7). Clinical data, including patient demographics and patient-reported outcome scores, were collected prospectively. Radiologicalally, hip morphology was assessed evaluating the Tönnis angle, the lateral centre to edge angle, the medial offset distance, the extrusion index, and the alpha angle.

Results

The mean follow-up was 3.3 years (2 to 4.6). The modified Harris Hip Score improved by 33.0 points from 53.5 preoperatively to 83.4 postoperatively (p = 0.03). The Western Ontario McMasters University Osteoarthritic Index score improved by 30 points from 62 preoperatively to 90 postoperatively (p = 0.029). All radiological parameters showed significant improvement. There were no long-term disabilities and none of the hips required early conversion to total hip arthroplasty.

Conclusion

FHRO combined with a PAO resulted in clinical and radiological improvement at short-term follow-up, suggesting it may serve as an appropriate salvage treatment option for selected young patients with severe symptomatic hip deformities.

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Complex hip deformities are often the sequelae of childhood disorders such as Legg–Calvé–Perthes disease (LCPD) or severe hip dysplasia. These deformities are often associated with coxa magna, asphericity of the femoral head, central osteonecrosis of the femoral head, coxa breva and vara, and abnormal height of the greater trochanter in relation to the femoral head.[1] In severe cases, the deformed and enlarged femoral head is not contained by the acetabulum, resulting in a 'hinged abduction hip' with impingement between the aspherical head and the acetabulum.[2] The altered joint biomechanics ultimately can result in impaired function, hip pain, and early joint degeneration.[3]

In adolescent and young adult patients with these complex proximal femoral deformities, there exists controversy on the optimal surgical treatment.[4] Attempts to improve containment of the diseased femoral head with a proximal femoral osteotomy can result in redirection of unhealthy cartilage into the acetabulum and result in suboptimal outcomes. Incongruency between the deformed femoral head and the acetabulum could occur, which may accelerate the degenerative process.[4] Ganz et al[5,6] and Leunig and Ganz[7] developed a new technique to address the misshapen aspherical femoral head derived from LCPD disease. It was recognized that the central third of the enlarged femoral head was commonly the most damaged, while the lateral third had the best preservation of the articular cartilage. Therefore, resection of the diseased central portion of femoral head with reduction of lateral more spherical portion to the stable medial segment could create a more spherical femoral head. This procedure was described as a femoral head reduction osteotomy (FHRO).[5,7] In acetabular dysplasia, as the femoral

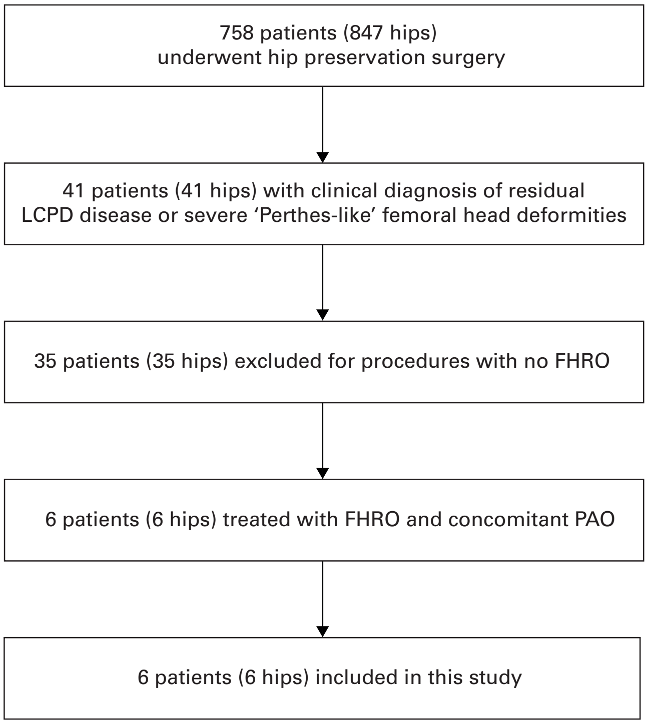

Fig. 1

Patient selection flowchart. LCPD, Legg–Calvé–Perthes disease; FHRO, femoral head reduction osteotomy; PAO, periacetabular osteotomy.

head is commonly aspherical, performing an isolated FHRO might produce or worsen hip instability. Therefore, a concurrent acetabular re-orientation, such as the periacetabular osteotomy (PAO), has been proposed to prevent further instability.[7-9]

To date, the literature on FHRO with or without concurrent PAO is very limited, and the role of this procedure in hip preservation is controversial. Three previous reports have evaluated clinical results of FHRO, yet these previous series have not consistently included a concurrent PAO for stabilization.[7,8,10] The purposes of this study were to review the surgical technique for a combined FHRO/PAO procedure, and to report a case series on the short-term clinical and radiological results following the combined FHRO and PAO.

Patients and Methods

Study design. Following institutional review board approval, a retrospective review of the joint preservation database of one of the senior authors (JCC) was inspected to identify patients who underwent surgical treatment between 2011 and 2016. A total of 847 hip joint preservation procedures were performed during this time period. Of these, 41 patients were treated for major aspherical femoral head deformities and six patients (six hips) underwent a combined FHRO and PAO procedure (Fig. 1). Thus, the current case series represents 5.4% of all hip preservation procedures and 14% of procedures performed for major femoral head deformities. The characteristics of the six patients reported are listed in Tables I and II.[11] There were five right hips and one left hip. None of the patients exhibited advanced endstage arthritis (Tönnis Grade III).[12]

Table I. Patient demographics

Variable	Finding
Hips, n (patients, n)	6 (6)
Males:females, n	0:6
Mean body mass index, kg/cm^2 (range)	22.2 (18 to 26)
Mean age at surgery, yrs (range)	13.6 (12.6 to 15.7)

Surgery was most commonly indicated for young patients (less than 20 years old) with a painful hip secondary to an aspherical and oversized femoral head, central femoral head osteonecrosis, hinged abduction, and/or incongruency with insufficient femoral head containment. Contraindications included patients with severe incongruency, in that central head reduction would not improve congruency and/or sphericity. This assessment was made with plain radiographs, MRI, and CT scans with three dimensional reconstructions. Other contraindications included articular cartilage disease or asphericity at the lateral and medial segments of the femoral head, advanced articular disease, and age over 20 years. A relatively healthy central femoral head is a common contraindication, as these hips are treated with a peripheral head reduction rather than FHRO. A hip MRI was used to assess the morphology and viability of the lateral and medial segments of the femoral head before each procedure. This combined procedure is only indicated as a salvage procedure when there is no other option for predictable joint preservation.

Preoperative planning. The goals of the surgery are to reduce symptoms by improving femoral head sphericity, containment/stability, and joint congruency. Radiological evaluation includes an anteroposterior (AP) pelvic radiograph, Dunn 45° view,[13] false profile,[14] and functional abduction radiograph. Preoperatively, MRI and CT with 3D reconstruction is performed on all patients. MRI is used to confirm and measure necrosis of the central head and to assess the size of any osteochondral lesion, as well as whether the ostechondral fragment is detached. The CT with 3D reconstructions is used to confirm the central necrosis, and to assess the subchondral bone integritiy and femoral head morphology. Templating the FHRO is performed on plain radiographs by hand with tracing paper (Fig. 2).[15,16] The sphericity is subjectively determined by templating the head reduction osteotomy and identifying the most appropriate resection to provide relative head sphericity after reduction of the medial and lateral head fragments. Care needs to be taken so that the resected central femoral segement is not oversized, resulting in a excessively small femoral head and possible joint instability. We have found MRI to be sufficient in assessing intra-articular disease and enabling appropriate patient selection. All intra-articular abnormalities can be accessed and treated with the open procedure.

The preoperative planning process is multifactorial and somewhat subjective, in that patient age, joint health, hip morphology, and femoral head lesion characteristics are all considered in patient selection and preoperative/operative planning. It is important to note that the equipment and technical expertise for various cartilage sparring treatments is available for all cases undergoing possible head reduction. While preoperative planning indicates the most likely intervention, intraoperative

Table II. Age, gender, diagnosis, intra-articular lesions, and surgical procedures performed in each included patient; Beck et al[11] classification was used to quantify cartilage damage

Patient	Age at surgery, yrs	Gender	Primary diagnosis	BMI, kg/m^2	Procedures	Intra-articular pathology	Preoperative to postoperative mHHS	Δ mHHS	Time to follow-up, mths
1	13	Female	LCPD	22.7	Surgical hip dislocation, FHRO-RFNL, ligamentum teres debridement, PAO, and trochanteric advancement	Grade 4 femoral head cartilage lesion, hyperthrophic labrum, Grade 2 malacia at the femoral head/neck	42.9 to 100	57.1	56.19
2	15.7	Female	LCPD	25.83	Surgical hip dislocation, FHRO-RFNL, femoral head/ neck osteochondroplasty, ligamentum teres debridement, PAO, and trochanteric advancement	Grade 4 femoral head cartilage lesion, hyperthrophic labrum, complete tear of the ligamentum teres	60.5 to 70.4	9.9	23.2
3	14	Female	DDH	23.97	Surgical hip disloaction, FHRO, femoral subtrochanteric osteotomy, PAO, Adductor release and trochanteric advancement	Grade 2 acetabular cartilage lesion, grade 2 femoral head cartilage lesion, complete tear of the ligamentum teres	63.8 to 89.1	25.3	23.4
4	12.6	Female	LCPD	18.13	Surgical hip dislocation, FHRO, RFNL, femoral head/ neck osteochondroplasty, ligamentum teres debridement, PAO, and trochanteric advancement	Grade 2 acetabular cartilage lesion, grade 4 femoral head cartilage lesion, hyperthrophic labrum, grade 4 femoral head neck cartilage lesion, complete tear of the ligamentum teres	28.6 to 92.6	63.8	50.89
5	13	Female	LCPD	20.4	Surgical hip dislocation, FHRO, RFNL, femoral head/ neck osteochondroplasty, ligamentum teres debridement, PAO, and trochanteric advancement	Grade 4 acetabular cartilage lesion, grade 4 femoral head cartilage lesion, hyperthrophic labrum	71.5 to 68.2	-3	26
6	13	Female	LCPD	21.8	Surgical hip dislocation, FHRO, RFNL, femoral head/ neck osteochondroplasty, ligamentum teres debridement, PAO and trochanteric advancement	Grade 4 acetabular cartilage lesion, grade 4 femoral head cartilage lesion, hyperthrophic labrum	53.9 to 96.8	43	23

BMI, body mass index; mHHS, modified Harris Hip Score; LCPD, Legg-Calvé-Perthes isease; FHRO, femoral head reduction osteotomy; RFNL, relative femoral neck lengthening; PAO, periacetabular osteotomy

flexibility enables selection of the most appropriate treatment after direct inspection of the femoral head. Potential treatments include chondroplasty and microfracture, osteochondral open reduction and internal fixation with miniature screws, osteochondral grafting (donor tissue from redundant femoral head or ipsilateral knee), or FHRO.

In our practice, FHRO is most commonly considered for hips with a necrotic central head accompanied by a large unhealthy and unstable osteochondral lesion.

Head reduction cases are templated/sketched by hand to assess head sphericity and determine the size and location of the reduction osteotomy. The medial and lateral head segments should have preserved articular cartilage and subchondral bone, and to create relative head sphericity when the reduction is drawn. Articular cartilage and subchondral bone disease in these areas as well as a ‘squared off’ appearance of the lateral head are relative contraindications. The FHRO is planned to remove as much of the central head lesion as possible without compromising the integrity of the stable medial neck and mobile lateral segment. Most commonly, 6 mm to 12 mm of the head is removed with a slight wedge configuration (anterior wider than posterior). In some cases, complete resection of the central lesion is not possible, yet 80% resection is usually accomplished. The osteotomy reduction is planned and usually requires proximal medial translation of the lateral segment to reduce the osteotomy and optimize sphericity. Intraoperatively, the resection is measured by hand, and performed with a standard reciprocating saw (without specialized instrumentation or guides). The exact size and location of the resection may be adjusted intraoperatively after visual assessment of articular cartilage health and stability, and the medial and lateral head morphology. These steps should optimize the resection of unhealthy osteochondral tissue, maintain adequate head size, and enable reduction to create a relatively spherical femoral head. Osteotomy fixation is planned with small fragment 3.5 mm cortical screws placed distal to the true femoral head, free from the terminal branches of the deep branch of the medial femoral circumflex vessels and directed perpendicular to the head osteotomy.

Surgical technique

Femoral head reduction osteotomy. FHRO should be performed first, followed by the PAO. The technique has been reported in detail previously.[7,17] In brief, the patient is positioned laterally and surgical dislocation of the hip is performed anteriorly with use of a flat, oblique trochanteric osteotomy. An extended retinacular soft-tissue flap is developed, and the FHRO

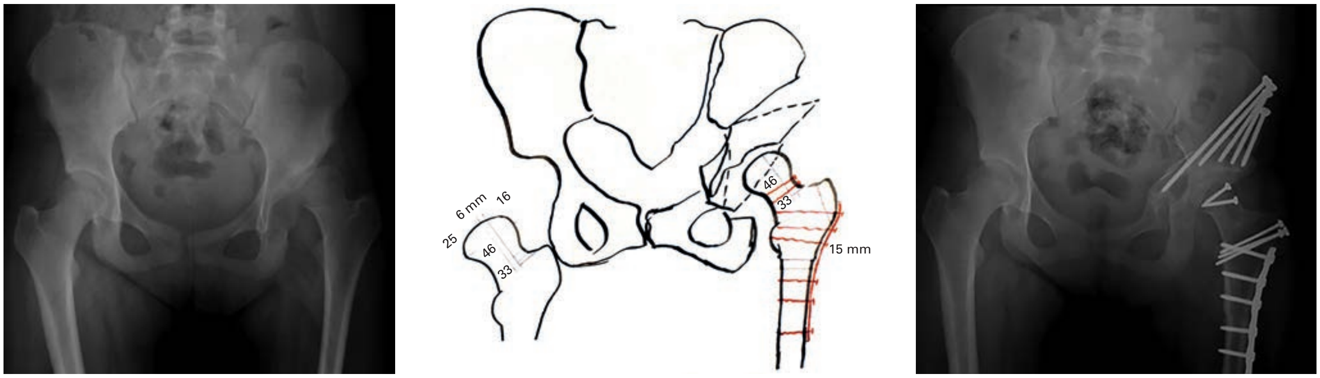

Fig. 2a Fig. 2b Fig. 2c

a) Anteroposterior pelvis radiograph of a 14-year-old female patient. The left hip has severe acetabular dysplasia, subluxation, and an enlarged femoral head. b) Illustration of preoperative templating. The patient underwent a femoral head reduction osteotomy to reduce the size of the large, incongruous femoral head and to enable improved reduction and congruency. She also had a subtrochanteric shortening and derotation osteotomy to address excessive femoral anteversion and to allow reduction. c) The periacetabular osteotomy was performed in the same setting to stabilize the hip. Note the improvement of the extrusion index (white lines) and joint congruity at 23.4 months postoperatively. She reported satisfaction with surgery and a modified Harris Hip Score of 89.1 at last follow-up.[15,16]

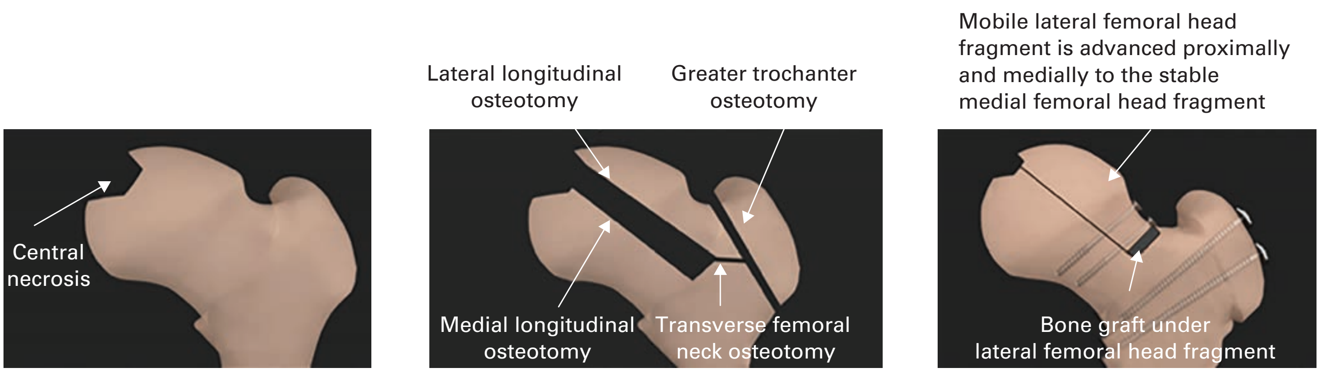

Fig. 3a Fig. 3b Fig. 3c

Illustrations showing femoral head reduction osteotomy as initially described by Leunig and Ganz.[7] a) Aspherical and oversized femoral head, central femoral head necrosis, high trochanter. b) After a flat oblique trochanteric osteotomy is performed, the necrotic centre part of the femoral head is resected by osteotomies performed in the sagittal direction. c) The mobile fragment is then fixed to the stable part of the head with the goal of restoring sphericity to the femoral head. Resulting bone deficiency of the femoral neck is filled with bone from the stable part of the greater trochanter. The trochanteric fragment is refixed in an advanced position. Graphic design courtesy of Udayabhanu Jammalamadaka, PhD.

is performed.[7,17] The greater trochanter is trimmed down to the level of the superior aspect of the femoral neck, referred to as relative femoral neck lengthening (RFNL).[7] The extended retinacular soft-tissue flap is developed through the periosteal flap of the posterior aspect of the proximal femur. This flap contains the relevant branches of the medial circumflex femoral artery (MCFA), which ensures the essential preservation of the vascularity of the femoral head.[18] The determination of the medial and lateral head fragments is performed with femoral head sizing templates and intraoperative visual inspection. The medial longitudinal femoral head osteotomy should leave at least one-third of the femoral neck intact. The central segment can then be resected, while keeping the medial portion of the femoral head in continuity with the neck. The lateral longitudinal femoral head osteotomy should be placed to remove all interval damaged/deformed femoral head; the goal is to reduce the femoral head to a size that is completely contained within the acetabulum. The transverse femoral neck osteotomy that creates the free interval and lateral femoral head fragments should not violate the medial femoral neck. The lateral portion of the femoral head is then reduced to the medial, stable head-neck region, with careful adjustment to limit any articular step-off between the segments. The lateral fragment may need to shift superiorly to optimize joint surface congruity. The osteotomy is fixed with three to four small fragment headless (3.5 mm) screws providing fixation of the mobile lateral head to the stable medial head-neck segment. Gaps at the inferior margin of the lateral head fragment can be filled with bone graft to reduce any remaining step-off between the lateral head and femoral neck. After the FHRO is completed, a dynamic range of movement examination of the hip is performed. All sources of residual intra-articular (peripheral head and head-neck junction) and extra-articular (anterior inferior iliac spine, intertrochanteric ridge, and stable trochanteric bed) impingement are then removed. The mobile trochanteric segment is then reduced and stabilized with screw fixation. Trochanteric advancement is performed with the goal

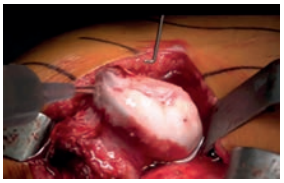

Fig. 4a

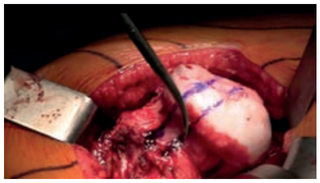

Fig. 4b

Fig. 4c

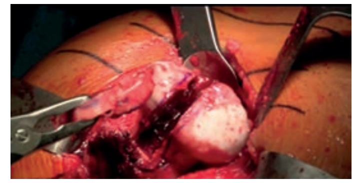

Fig. 4d

a) Intraoperative photographs showing the major aspherical femoral head with a central necrotic fragment. b) Using a marking pen, the area where the osteotomy will be performed is marked. c) Using an oscilating saw, the lateral and medial longitudinal osteotomy are performed. d) The central necrosis is removed.

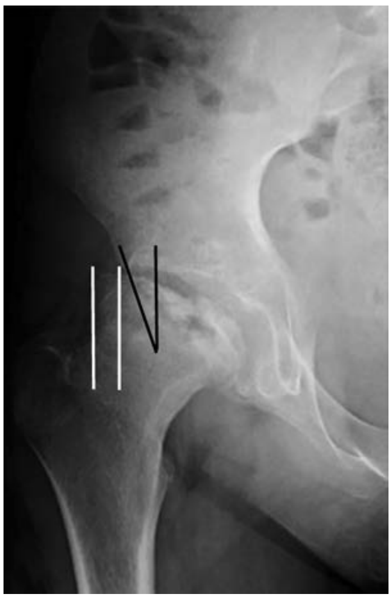

Fig. 5a

Fig. 5b

Radiographs of 12-year-old female with Legg Calvé-Perthes disease of the right hip. a) preoperatively with collapse of the central part of the femoral head, joint incongruity and associated dysplastic retroverted acetabulum; b) Postoperative radiographs follwing femoral head reduction osteotomy with removal of the central necrotic segment, relative femoral neck lengthening and trochanteric advancement. The patient had a concomitant anteverted periacetabular osteotomy to prevent instability through re-orientation of the acetabulum. Note the improvement of the LCE (lateral centre to edge, black lines) and the extrusion index (white lines) on the 22 months follow-up radiograph. At 22 months after surgery the patient had modified Harris Hip Score of 92.4 compared to 28.6 preoperatively.

of placing the superior tip of the mobile trochanter at the same vertical level as the centre of the femoral head (Figs 3 and 4).

Periacetabular osteotomy. A concomitant PAO was performed following the FHRO.[19-21] The deformity correction was analyzed intraoperatively with AP and false profile fluoroscopic images to obtain a lateral centre to edge angle (LCEA) between 20° to 35°,[22] acetabular inclination (AI) between 0° to 15°, and anterior centre to edge angle (ACEA) 18° to 38°.[14,23] Definitive correction was also influenced by the degree of the acetabular deformity, the range of movement of the hip following the correction with the goal of maintaining at least 90° of hip flexion.

Postoperative rehabilitation. Patients remained toe-touch weight-bearing for the first eight weeks. A continuous passive motion machine was prescribed for four weeks for six to eight hours per day. Patients were restricted to 90° of hip flexion for the first four weeks. All patients followed a strict pain and anticoagulation protocol, as previously described.[24-26] Hardware removal is routinely performed 6 to 12 months postoperatively.

Patient-reported outcome measures. Patient-reported outcome measures (PROMs), including the modified Harris Hip Score (mHHS) and Western Ontario and McMaster Osteoarthritis Index (WOMAC), were collected at preoperative and follow-up visits.[27] The difference between preoperative scores and scores at the last follow-up was analyzed. To determine whether patients achieved minimum clinically meaningful important difference (MCID), we used published MCID values in hip procedures of 9 to 12 for WOMAC.[28]

Radiological examination. Hip deformity correction was assessed radiologically (by SD and GP) with standardized standing AP pelvis, false profile, frog leg lateral, and 45° Dunn lateral view radiographs. Morphological characteristics of the acetabulum, as seen on radiographs, were defined with the LCEA (AP), the ACEA (false profile), acetabular index (AI),[29,30] extrusion index,[31] and medial offset distance.[32] Evaluation of femoral head-neck junction abnormalities included the alpha angle described by Nötzli et al[33] in both anterior and lateral

Table III. Patient-reported outcome measures (PROMs) at the last follow-up

Outcome score	Preoperative	Postoperative	Δ improvement	MCID	p-value*
Mean mHHS	53.5 (28.6 to 71.5)	86.5 (68 to 100)	33.0	N/A	0.03
Mean WOMAC, total	62.3 (28.1 to 85.4)	90.3 (80.2 to 95.8)	30.0	9 to 12	0.003

*Student's *t*-test

MCID, minimal clinically importance difference; mHHS, modified Harris Hip score; N/A: non applicable; WOMAC, Western Ontario and McMaster Osteoarthritis Index

Table IV. Western Ontario and McMaster Osteoarthritis Index (WOMAC) subscores

	Preoperative	Postoperative	Δ improvement	p-value*
WOMAC Pain	60.0	89.1	33.0	< 0.001
WOMAC Stiffness	47.9	70.8	22.9	< 0.001
WOMAC Physical Function	64.7	92.8	28.8	< 0.001

*Student's *t*-test

WOMAC, Western Ontario and McMaster Osteoarthritis Index

Table V. Preoperative and postoperative radiological status of all patients

Radiological measurement	Preoperative	Postoperative	Mean correction	p-value*
Tönnis angle, °	20.1 (11 to 39)	2.5 (1 to 5)	17.6	0.03
LCEA, °	2.5 (-20 to 22)	30.6 (18 to 40)	28.1	0.03
ACEA, °	18.2 (0 to 31)	35.2 (30 to 40)	17.0	0.07
Medial offset, mm	16.8 (14 to 23)	5.6 (3 to 8)	11.2	0.01
Extrusion index, %	*45.3* (*20* to *64*)	*13.6* (*0* to *28*)	31.7	0.008
α angle, Dunn view, °	68.5 (47 to 97)	40.2 (32 to 45)	28.3	0.04
α angle, Frog lateral view, °	65.7 (31 to 99)	32.7 (25 to 38)	33.0	0.05

*Student's *t*-test

LCEA, lateral centre to edge angle; ACEA, anterior centre to edge angle

view.[13,33,34] Stulberg[3] classification was used to define sequelae of head deformity.

Complications and survival rate. The complication scheme of Dindo et al,[35] as modified by Sink et al[36,37] for the surgical hip dislocation, was applied. We only reported on grade III (requiring invasive treatment) and grade IV (life-threatening or with the potential of permanent disfunction) complications. Failure was defined as the need for conversion to total hip arthroplasty (THA) or not reaching a clinical meaningful improvement (i.e. MCID).

Statistical analysis. The preoperative and postoperative PROMs and radiological results were analyzed using the Student's *t*-test for continuous data. All analyses were undertaken using (SPSS) software (IBM Corp., Armonk, New York). Statistical significance was defined as $p < 0.05$.

Results

Patient-reported outcome measures. The mean follow-up was 3.3 years (2 to 4.6). At final follow-up, all but one patient experienced significant improvements from their preoperative state. The mean mHHS improved from baseline to final follow-up by 33 points ($p = 0.03$).(Table III) The mean WOMAC score also improved by 30 points ($p = 0.029$) (Table IV). WOMAC subscores also showed significant improvement. MCID was achieved in five of the six patients. The one patient (number 5) who did not improve continued with pain and was unable to resume sports.

Radiological results. Comparison of the preoperative and postoperative radiological parameters demonstrated significant improvements in most of the parameters examined (Table V). All patients were a grade IV according to Stulberg classification.

Complications and survival rate. At the most recent follow-up, none of the six hips failed, were converted to THA, or required additional osteotomies. One patient was still complaining of pain with sports participation (football) and the PROMs worsened at the time of final follow-up (Patient 5). There was only one patient with a major complication; Patient 3 suffered from a postoperative wound infection requiring irrigation and debridement. This did not result in any long-term sequela.

Discussion

We have found in our small series that FHRO with a combined PAO as a salvage procedure significantly improved patient-reported outcomes and radiological parameters in the majority of patients with severe femoral head deformities secondary to sequelae of LCPD or severe acetabular dysplasia. All patients healed the FHRO and there were no early failures. Although patients significantly improve their symptoms, the clinical results show modest improvements. It is important to counsel these patients and their families to set realistic expectations for the surgical outcome. In addition, it is sensible to encourage the patient to pursue occupations that will not depend upon manual labour as hip degeneration is likely to progress over time. The indications for FHRO are rare and specific. In our series, during a five-year period, only six of 41 patients with major deformities of the femoral head were identified as suitable for this procedure. We routinely combine a PAO with the FHRO, as previous reports have emphasized the risk of femoral head subluxation after the FHRO and the potential need for a subsequent surgery to correct residual instability.[7,10]

This report documents acceptable clinical outcomes when combining FHRO and PAO for the treatment of severe aspherical femoral head deformities. Most of these deformities have been treated in the past with isolated surgical dislocation with relative femoral neck lengthening (RFNL) with or without the addition of a PAO.[38] However, in severe femoral head deformity with hinged abduction and/or central head necrosis, the RFNL may not provide adequate reduction of the femoral head to its native socket. In these circumstances FHRO offers a potential salvage procedure.[1,7,8] In our practice, FHRO is reserved for carefully selected young patients (< 20 years old) with persistent hip symptoms associated with an osteonecrotic central femoral head and/or a large incongruous head not amenable to peripheral head reduction. Importantly, the lateral and medial femoral head segments should have reasonably healthy articular cartilage and create a relatively spherical head when reduced.

As demonstrated by the preoperative modified HHS and WOMAC scores, the patients in our study had severe limitations in their daily activities in terms of pain and function. At this short-term follow-up, although significant improvements in pain and function of the hips were seen with improvements of the mHSS and the WOMAC score, some of the hips remained symptomatic with functional limitations. Still, MCID was achieved in five of the six patients (83%), suggesting this procedure provides improvement clinically important to the patients.

Paley[10] has reported on clinical results following FHRO for aspherical head deformities in 20 patients with a mean follow-up of 2.7 years. In contrast to our study, PAO was performed in only five of the 20 hips. Unfortunately, instability after isolated FHRO was reported in five of his patients secondary to lateral subluxation. He presented three failures, one avascular necrosis and two with persistent pain and progressive joint degeneration requiring THA. Siebenrock et al[8] reported on 11 patients that underwent FHRO and concomitant RFNL, with a minimum of three years follow-up. Five of the 11 patients required additional concomitant acetabular containment, including two triple osteotomies, two PAO, and one Colonna[39] surgery for residual instability following the FHRO.[8] Similar to our study, although radiological improvement was evident, clinically these patients still had some pain in activities of daily living. In our series, the PAO was performed at the time of the FHRO to help prevent the need for further surgery while also improving the stability of the hip in all patients.This approach has avoided any patient requiring supplementary stabilization.

Performing two extensive procedures together resulted in only one wound infection, which resolved following irrigation and debridement. In the series by Siebenrock et al,[8] one patient developed heterotopic ossification requiring resection. None of the patients in our series developed avascular necrosis (AVN) or required conversion to THA. Similarly, Siebenrock et al[8] reported no cases of AVN or hips requiring conversion to THA.

Other options commonly used to treat adults with sequelae of Perthes disease includes a proximal valgus-producing osteotomy concomitantly with the PAO, to optimize hip congruency, range of movement, abductor function, and limb length. Clohisy et al[9] reported on the outcomes in 20 patients (24 hips) treated for symptomtatic acetabular dysplasia associated with major aspherical femoral head deformities. All hips underwent a PAO. A concomitant proximal femoral valgus osteotomy was performed in 13 hips. At a mean of 4.5 years, there was substantial improvement in clinical hip function and a high rate of satisfaction. However, this surgical technique does not address the oversized femoral head with associated central femoral head necrosis.[40,41]

We acknowledge the limitations of our study. First, we only report on six patients. Although this cohort was small, the only other study to date that examined a similar subset of patients included 11 patients.[8] In the series by Siebenrock et al,[8] only two of the 11 patients had an initial PAO and one additional patient required a subsequent PAO to help with femoral head containment. In addition, two patients had a concomitant triple osteotomy at the time of the FHRO, and three patients had subsequent triple osteotomies to help with containment following their initial index procedure. Second, we recognize the technically demanding nature of this surgical intervention and are not intending to promote this procedure. We believe it should only be performed by specialized hip surgeons.

In conclusion, FHRO combined with a PAO resulted in clinical and radiological improvement at short-term follow-up, suggesting an appropriate salvage treatment for patients with a large incongruous femoral head and central head necrosis. Additionally, no patients in this series had postoperative osteonecrosis, all osteotomies healed, and none required additional reconstructive or arthroplasty surgery. These data demonstrate the feasibility and safety of the procedure for carefully selected hips in which there is no alternative, predictable joint preservation option.

Take home message

- Femoral head reduction osteotomy (FHRO) has a rare but distinct indication for the treatment of severe femoral head deformities.
- FHRO with a combined periacetabular osteotomy (PAO) can be considered a salvage procedure in young patients (< 20 years old) with a symptomatic hip secondary to an aspherical, oversized femoral head with advanced central head degeneration/osteonecrosis.

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