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Hip dysplasia in adolescence: osteotomy in childhood improves the results of periacetabular osteotomy in adolescents and young adults

A PROSPECTIVE STUDY

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Aims

Developmental dysplasia of the hip (DDH) describes a pathological relationship between the femoral head and acetabulum. Periacetabular osteotomy (PAO) may be used to treat this condition. The aim of this study was to evaluate the results of PAO in adolescents and adults with persistent DDH.

Methods

Patients were divided into four groups: A, adolescents who had not undergone surgery for DDH in childhood (25 hips); B, adolescents who had undergone surgery for DDH in childhood (20 hips); C, adults with DDH who had not undergone previous surgery (80 hips); and D, a control group of patients with healthy hips (70 hips). The radiological evaluation of digital anteroposterior views of hips included the Wiberg angle (centre-edge angle (CEA)), femoral head cover (FHC), medialization, distalization, and the ilioischial angle. Clinical assessment involved the Harris Hip Score (HHS) and gluteal muscle performance assessment.

Results

Significant improvements in radiological parameters were achieved in all measurements in all groups ($p < 0.05$). The greatest improvement was in CEA (mean of 19° (17.2° to 22.3°) in Group B), medialization (mean of 3 mm (0.9 to 5.2) in Group C), distalization (mean of 6 mm (3.5 to 8.2) in Group B), FHC (mean of 17% (12.7% to 21.2%) in Group B), and ilioischial angle (mean of 5° (2.3° to 8.1°) in Group B). There were significant improvements in the mean HHS and gluteal muscle performance scores postoperatively in all three groups.

Conclusion

The greatest correction of radiological parameters and clinical outcomes was found in patients who had undergone hip surgery in childhood. Although the surgical treatment of DDH in childhood makes subsequent hip surgery more difficult due to scarring, adhesions, and altered anatomy, it requires less correction of the deformity and has a beneficial effect on the outcome of PAO in adolescence and early adulthood.

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Introduction

Developmental dysplasia of the hip (DDH) is characterized by a pathological relationship between the elements of the joint. Adolescent and adult patients with this condition develop symptoms either because of ineffective initial treatment or late diagnosis (when diagnosed in children aged > six months). These patients may become symptomatic in the third decade of life; however, most are in their 40s.

The unstable hip may displace laterally (lateralization) or cephalically (proximalization).[1-3] Subluxation occurs with varying degrees of contact between the femoral head and the dysplastic acetabulum. The Bernese periacetabular osteotomy (PAO), as described by Ganz et al,[4–8] may

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Table I. Demographic data of the patients.

Characteristic	Group A	Group B	Group C	Group D
Mean age, yrs (range)	16 (14 to 18)	15 (13 to 17)	29 (18 to 50)	34 (19 to 60)
Sex, n				
Female	21	16	72	58
Male	4	4	8	12
Patients. n	25	20	80	70
Operation side, n				
Left	14	12	42	35
Right	9	8	38	35
Tönnis grade, n				
0	25	18	70	70
1	0	2	10	0
Previous operation, n				
Dega	0	18	0	0
Salter	0	5	0	0
Pemberton	0	2	0	0
Mean follow-up, after PAO mths (range)	10 (9 to 12)	11 (9 to 12)	12 (9 to 15)	N/A
Complication, % (n patients)				
Minor	3 (1)	2 (1)	5 (4)	0
Major	0	0	2 (2)	0

N/A, not applicable; PAO, periacetabular osteotomy.

be used to 'preserve' the hip. It can be used in these patients who have been previously treated conservatively or not treated at all for DDH, and for those who have undergone surgical treatment of the hip in childhood. PAO is also an effective treatment for acetabular retroversion of the hip.[9] The procedure involves an ostetomy of the pubis, ischium, and ilium to change the configuration of the acetabulum, and achieve stability of the dysplastic hip. The main objective is to stop or slow down the development of secondary osteoarthritis (OA), which might result in the need for total hip arthroplasty (THA). This is especially true for the treatment of persistent dysplasia adolescents.[5,10-12] Radiological parameters routinely used to describe the reorientation of the acetabulum in PAO, such as Wiberg's angle (centre-edge angle (CEA))[13] and femoral head cover (FHC),[14] are in our opinion not sufficient. We suggest the use of three further parameters in order to assess the required correction of the acetabular orientation completely: medialization, distalization, and the ilioischial angle. Medialization involves displacement of the acetabular fragment towards the midline and corrects one of the components of the dysplastic hip, lateralization in the horizontal plane. The value of this parameter should decrease after the operation. Distalization involves the distal displacement of the acetabular fragment and the femoral head following it. This corrects the second component of the dysplastic hip, proximalization in the vertical plane. The value of this parameter should also decrease after the operation. The parameter of reorientation is the ilioischial angle. The iliac and ischial osteotomies meet at the greater sciatic notch, which is where the reorientation of the acetabular fragment takes place. The ilioischial angle reflects the orientation of the acetabulum during PAO, and its value should also decrease after the operation.

The aim of this study was to evaluate the outcomes of the treatment of DDH with PAO in adolescents and young adults, and to assess the differences between patients who have undergone surgery in childhood, those who have not, and healthy hips.

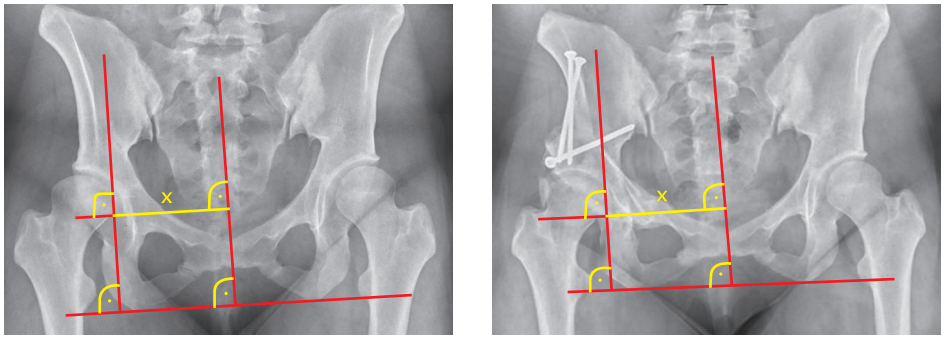
Methods

This prospective study included patients with persistent DDH who underwent surgery between 2013 and 2018, using our technique for PAO. The mean follow-up was 13 months (9 to 15). Inclusion criteria included: adolescents and young adults with symptomatic persistent DDH, and either no evidence of OA or a low grade of OA (Tönnis grade 0 to 1).[15]

The inclusion criteria for the control group included patients without any disease involving the hip, pelvis, lumbar spine, and lower limbs.

The patients were divided into four groups (Table I): Group A, adolescents who had not undergone surgery for DDH in childhood (25 hips); Group B, adolescents who had undergone surgery including techniques as the Dega,[16] Salter,[17] or Pemberton osteotomy,[18] open or closed reduction of the hip, and femoral osteotomy (20 hips); Group C, adults who had not undergone previous surgery for DDH (80 hips); and Group D, adults with healthy hips, as a control group (70 hips).

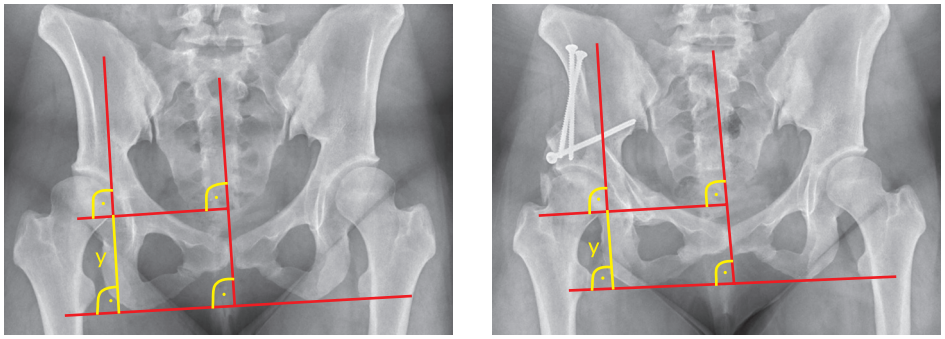
Radiological evaluation was undertaken on standard digital anteroposterior (AP) radiographs of the hips preoperatively, and at the last visit. The severity of OA of the hip was assessed using the Tönnis classification preoperatively. Radiological evaluation included the Wiberg angle (CEA), medialization, distalization, FHC, and the ilioischial angle. Medialization was recorded as the distance between the midline of the body and the most medial aspect of the femoral head (Figure 1). Distalization was recorded as the distance between lines connecting the greater ischial tuberosity and the lower aspect of the femoral head (Figure 2). The ilioischial angle was recorded as the angle between the ilioischial line running tangentially to the greater sciatic notch and the lateral aspect of the obturator foramen, and a line connecting the greater ischial tuberosity on AP radiographs (Figure 3). Clinical assessment was undertaken using the Harris Hip Score,[19] and the performance of the gluteal muscles



a b

Fig. 1

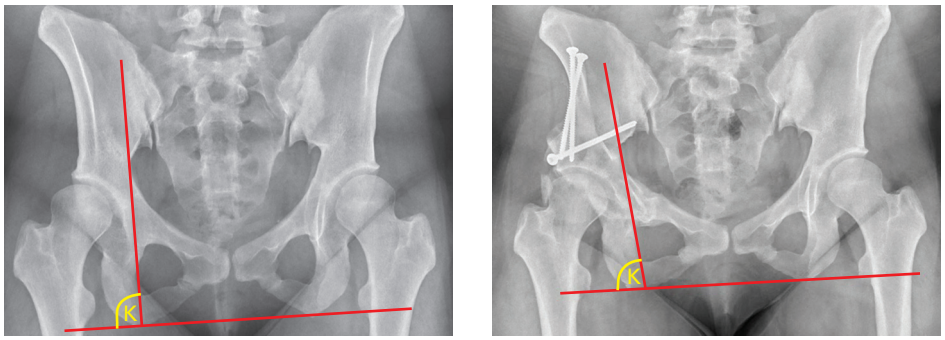
Medialization of the hip a) pre- and b) postoperatively, showing the line connecting the midline of the body and the medial aspect of the femoral head (x).



a b

Fig. 2

Distalization of the hip a) pre- and b) postoperatively, showing the line connecting the baseline and the lowest aspect of the femoral head (y).



a b

Fig. 3

The ilioischial angle a) pre- and b) postoperatively showing the angle between the ilioischial line and the line connecting the greater ischial tuberosity (k).

using the Hip Lag Sign (HLS) test,[20] with radiological evaluation, just prior to surgery by the admitting physician (KK), and approximately 12 months postoperatively by a physician from our department.

The study had institutional review board approval (number: 83/PB/2015). Informed consent was obtained from all the patients (or, if aged under of 16 years, from their parents/guardians).

Table II. The pre- and postoperative radiological measurements of the hips, divided into their respective groups.

Variable	Group A				Group B				Group C				Group D
	Preop	Postop	Diff	p-value*	Preop	Postop	Diff	p-value*	Preop	Postop	Diff	p-value*	Control
Mean CEA, °	5	22	17	0.002	6	25	19	0.002	4	22	18	0.001	29
Mean medialization, mm	81	80	-1	0.037	79	78	-1	0.042	84	81	-3	0.026	78
Mean distalization, mm	50	48	-2	0.021	56	50	-6	0.014	58	54	-4	0.018	47
Mean FHC, %	56	72	16	0.005	58	75	17	0.005	53	71	16	0.006	77
Mean ilioischial angle, °	88	84	-4	0.015	85	80	-5	0.016	86	83	-3	0.022	78

*Paired *t*-test.
CEA, centre-edge angle; Diff, difference; FHC, femoral head cover.

Table III. Clinical evaluation using Harris Hip Score scale and Hip Lag Sign test.

Measure	Group A				Group B				Group C				Group D
	Preop	Postop	Diff	p-value*	Preop	Postop	Diff	p-value*	Preop	Postop	Diff	p-value*	Control
Mean HHS, points	58	84	26	0.003	60	88	28	0.002	58	82	24	0.005	100
Mean HLS, % positive test	40	3	37	0.004	44	5	39	0.005	55	5	50	0.002	0

*Paired *t*-test.
Diff, difference; HHS, Harris Hip Score; HLS, Hip Lag Sign.

Statistical analysis. Using CareStream Solution software (CareStream Health, USA), the accuracy of measurement was 0.5° for angles and 0.5 mm for distances. The main measurements were recorded by one research worker (KK, an orthopaedic surgeon). The normal distribution was assessed using the Shapiro-Wilk test. For normally distributed parameters, we used paired *t*-test, and for parameters with an abnormal distribution, we used the Wilcoxon signed-rank test. Significance was set at $p < 0.05$. Analysis of the data included descriptive statistics and was performed in Stata v. 11.0 (StataCorp, USA) and Excel (Microsoft, USA). The intra- and interobserver reproducibility and reliability of the parameters were analyzed on ten randomly selected patients. Three research workers with different levels of experience were selected to perform the control radiological measurements: investigator I (substantial experience; a medical student), investigator II (extensive experience; an orthopaedic surgeon), and investigator III (moderate experience; a resident in orthopaedics), achieving comparable and reproducible results.

Results

There was a significant improvement in all pre- and postoperative radiological and clinical measurements. Groups A, B, C, and D were not compared statistically between each other due to the different sizes of the groups. Only the differences of the results were analyzed. Correction of the orientation of the hip following PAO is associated with increases in CEA, FHC, and decreases in medialization, distalization, and the ilioischial angle. The greatest improvements were seen for the CEA in Group B, by a mean of 19° (17.2° to 22.3°), medialization in Group C by a mean of 3 mm (0.9 to 5.2), distalization in Group B by a mean of 6 mm (3.5 to 8.2), FHC in Group B by a mean of 17% (12.7% to 21.2%), and ilioischial angle, also in Group B, by a mean of 5° (2.3° to 8.1°). We also compared the differences in radiological measurements of the dysplastic hips after PAO with those of the healthy hips (Group D). The smallest differences were for the CEA in Group B of 4°, medialization in Group B of 0 mm, distalization in Group A of 1 mm, FHC in Group B of 2%, and the ilioischial angle, also in Group B of 2°. The radiological results are shown in Table II.

Significant improvement in the HHS was seen in all groups, with the greatest being in Group B with a mean of 28 points (55 to 83). There was also significant improvement in the HLS score in all groups, with the greatest being in Group C with a mean of 50% (39% to 63%). The clinical results are shown in Table III.

Postoperative complications were classified as minor (haematoma, skin conflict (discomfort over the screws in thin patients), scarring, and neurapraxia of the anterolateral cutaneous nerve of the thigh) and major (femoral nerve damage, vascular damage, uncontrolled intra-articular fracture or damage to the posterior column of the acetabulum, and periarticular ossification) and are shown in Table I.

The greatest radiological and clinical improvements were seen in adolescents who had been previously treated surgically for DDH (Group B).

Discussion

This study is the first to compare the radiological and clinical results, including gluteal muscle function, after PAO in adolescent patients who had previously undergone surgery in childhood, adults with DDH who had not previously undergone surgery, and patients with healthy hips. The comparison included adolescents and adults with DDH and closed triradiate cartilage. Skeletal maturity of the pelvis is required before a PAO can be perfomed. Thus, we assumed that these patients had mature pelvic bones and the two age groups could be compared. It is essential to improve the congruence of the hips at a young

age before the development of degenerative changes in order to ensure their longest possible survival. Conservative management of DDH in this age group is usually not sufficient, and allows the rapid development of OA and the need for THA. The development of degenerative changes may be delayed by PAO, especially in adolescents, and has good mid- and long-term outcomes.[5,10,11] Medialization and distalization of the hip are important for repositioning the femoral head, bringing it closer to the ischium. This position offers favourable conditions for improving the dynamic stabilization of the hip and lengthens the lever arm of the gluteal muscles. [3,5,10,21] Delp and Maloney[22] described the effects that medialization and distalization of the centre of the hip have on the strength of the abductor muscles. They demonstrated the importance of lowering the centre of the hip on the force and lever arm of the abductors. Czubak[23] reported a mean correction of the Wiberg angle of 29° (12° to 55°) in adolescent dysplastic hips after PAO. Complications included urinary tract infections, ectopic bone formation, and early postoperative soft-tissue infection. There was no evidence of haemorrhage or vascular complications, or of injury to either the sciatic or femoral nerves.

Millis and McClincy[11] emphasized the importance of the appropriate indications for PAO. They confirmed that the function and longevity of at-risk hips is greatly improved after PAO. It can also help symptomatic pre-arthritic young patients who have congruous acetabular dysplasia. Swarup et al[12] demonstrated that, for adolescent patients with long-standing anterior or medial hip pain and instability on physical examination, and DDH on radiological imaging, PAO is the treatment of choice after nonoperative treatment options have been exhausted. They also noted that mechanical signs of incongruency of the femoral head can be treated concurrently with open or arthroscopic procedures, and that PAO has been shown to be a reliable form of treatment for symptomatic adolescent DDH, with significant improvement in radiological and patient-reported outcome measures (PROMs). De La Rocha et al[24] showed that, at one year after surgery in adolescents with DDH (29 hips in 26 patients), the Ganz PAO provided similar radiological, gait, and functional results when previous pelvic surgery has been performed to those in whom it has not been performed. The strength of abduction and flexion tended to be lower in the patients who had undergone previous surgery. PAO may be more technically demanding in this group of patients, but excellent correction of the deformity and good clinical results have been shown at early follow-up. Zhu et al[25] measured the radiological cover of the femoral head in a group of 41 dysplastic adult hips. The mean age of the patients was 39 years and the mean follow-up was 60 months. They noted that the mean improvement in medialization (the distance between the medial edge of the femoral head and the ilioischial line (Kohler's line) was 6.5 mm (from 15.4 mm preoperatively to 8.9 mm postoperatively). They also extended the study by measuring the CEA, whose mean was 6.4° preoperatively and 29.1° postoperatively. The cover of the femoral head improved by a mean of 22.7°. Clinical assessment was undertaken using the HHS score. They reported a mean improvement of 24.7 points (from 63.7 preoperatively to 88.4 postoperatively). We did not find publications in the literature which have reported measurements of distalization of dysplastic hips after PAO. In a meta-analysis, Ahmad et al[26] reported survival of the hip after PAO at the following timepoints: 96% (five years), 91% (ten years), 85% (15 years), and 67% (20 years).

Persistent DDH is a treatable condition, but only if it is diagnosed early and properly treated. In adolescence, PAO is a dedicated procedure. However, there are more complications in patients who have undergone previous surgery to the hip in childhood. Following PAO, patients usually have less pain and improved mobility. Some studies have shown that hips treated with PAO have a reduced incidence of OA after 18 to 20 years of follow-up, compared with hips which are treated conservatively.[27] In a prospective study, Terjesen and Horn[28] assessed the value of gentle closed reduction of the hip according to the age of the patient. A total of 49 children (52 hips) with a mean age of 13.3 months (3 to 33) were treated for late DDH. Traction and gentle closed reduction under general anaesthesia were initially attempted. No concomitant pelvic osteotomy was performed. Gentle closed reduction can be used in children up to three years of age, but is probably less effective in those aged > 18 months. Simultaneous pelvic osteotomy in early childhood is not always necessary.

According to the literature, the rate of major complications following PAO ranges from 0.6% to 5.3%, while the rate of minor complications is up to 30%. However, thromboembolic complications, lack of union, and necrosis of the pelvic acetabular component are rare.[29,30]

The study has limitations, including the very short follow-up, the different sizes of the groups of patients who were compared and the lack of data about the specialized postoperative rehabilitation. Radiological evaluation only included routine AP radiographs of the hips. Measurement based on CT scans would be more accurate, but with a much higher dose of radiation for a young patient. We recognize that although THA may ultimately be required, by improving the anatomy of the hip during adolescence and early adulthood, one can make the most of the function during these important years.

We also acknowledge that further research in this area is required to clarify the findings. Additional observations and long-term analyses are needed to improve our understand of the impact of previous operations on the final correction after PAO. Although these findings offer an insight into acetabular orientation after PAO based on a digital AP radiograph, we think that medialization and distalization improve the 3D shape, position, and orientation of the acetabulum. We believe that not only the head cover, but also complete reorientation of the acetabulum, has an important impact on the long-term clinical outcomes.

In conclusion, greater correction of radiological parameters and clinical outcome were obtained in patients who had previously undergone surgery in childhood. Although the surgical treatment of DDH in childhood can make surgery in adolescence more complicated due to scars, adhesions, and altered anatomy of the hip, it needs a lesser correction of the deformity during further surgery. This observation allows us to conclude that the surgical treatment of DDH in childhood may have a beneficial effect on the final outcome of patients undergoing PAO in adolescence and early adulthood. The radiological parameters after PAO, performed in

adolescents who underwent surgery for DDH in childhood, resembled those of healthy hips more closely.

Take home message

- The surgical treatment of developmental dysplasia of the hip in childhood may have a beneficial effect on the final outcome of patients undergoing periacetabular osteotomy in adolescence and early adulthood.
- Greater correction of radiological parameters and clinical outcome were obtained in patients who had previously undergone surgery in childhood.

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