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ORIGINAL CLINICAL ARTICLE

# The effect of Dega acetabuloplasty and Salter innominate osteotomy on acetabular remodeling monitored by the acetabular index in walking DDH patients between 2 and 6 years of age: short- to middle-term follow-up

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**Abstract**

*Introduction* The surgical management of neglected developmental dysplasia of the hip (DDH) in walking children has always been a challenge to orthopedic surgeons. The aim of this study was to evaluate the short- to middle-term clinical and radiographic results of the management of DDH.

*Patients and methods* Patients less than 6 years old using two of the most commonly used osteotomies, namely, Salter innominate osteotomy and the Dega acetabuloplasty. Special attention was paid to acetabular remodeling after concentric reduction, which was monitored by the acetabular index, that, in turn, was measured preoperatively, immediately postoperatively, every 6 months, and at the final follow-up examination.

*Results* The final overall clinical end results were favorable (excellent or good) in 93 hips (85.3 %). There was a marked improvement of the acetabular coverage during the follow-up period, which proved the good remodeling potential of the acetabulum for this particular age group after concentric reduction was achieved and maintained.

*Conclusion* Both osteotomy types were found to be adequate for the management of neglected walking DDH patients under the age of 6 years.

**Keywords** DDH · Dislocation · Reduction · Open · Pelvic osteotomy · Femoral shortening · Salter · Dega

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## Introduction

Developmental dysplasia of the hip (DDH) is a wide spectrum of anomalies that ranges from mild acetabular dysplasia to high-riding dislocations. Dislocated hip joint in a child who has began to walk is even more difficult to treat because of adaptive shortening of the extra-articular soft tissues, acetabular dysplasia, capsular constriction, increased femoral anteversion, and fixed inversion of the limbus. Many surgical procedures have been described for the management of these late-presenting cases [1]. Salter [2], back in 1961, described one of the most commonly used osteotomies. We also found a growing interest in the iliac osteotomy described by Dega in Poland in 1969 [3], as an acetabuloplasty that changes the acetabular configuration and its inclination. This study was designed to evaluate acetabular remodeling after the use of both osteotomies in walking DDH patients with high dislocation grades (Tonnis grades III and IV), under the age of 6 years.

## Patients and methods

Between October 2000 and December 2009, DDH was diagnosed and treated in 425 hips at our referral, academically supervised center. The degree of severity ranged between acetabular dysplasia, hip subluxation, and frank dislocation. Patients with Tonnis grades I and II were excluded from this study. Only patients presenting with grades III and IV were included in this study. The total number of hips included in this study was 109 hips. There were 87 DDH patients. Unilateral DDH was found in 65 patients, while 22 patients had bilateral DDH (Fig. 1). Criteria for inclusion of the patients in this study included the following: only neglected patients presenting after the

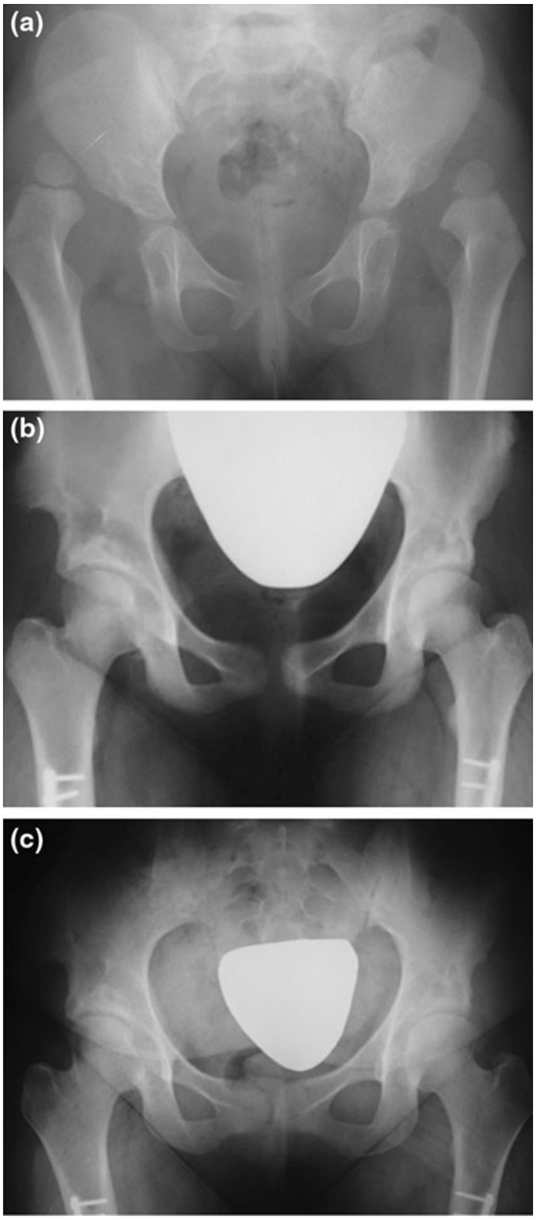


**Fig. 1** **a** Female patient 4 years of age with bilateral high-riding dislocations (Tonnis grade IV). Plain X-ray anteroposterior (AP) view. **b** Plain X-ray AP view 4 years after surgery, showing good acetabular remodeling and containment of the head of the femur bilaterally. **c** Plain X-ray AP view 10 years postoperatively, with excellent clinical and radiographic results

walking age; they should not have any history of previous surgical management; only patients subjected to the index surgery were included; a minimal period of postoperative follow-up of 2 years was a must for inclusion; and patients with teratologic dislocations were excluded from this study. There were 71 females and 16 males. The age of the patients at presentation ranged between 20 and 71 months, with a mean age of 55 months. For statistical reasons and better interpretation of the results, the patients were subdivided into two age subgroups; whereas the A subgroup included patients younger than 4 years of age (47 patients, with 53 hips), the B subgroup included patients aged 4 years or older (40 patients with 56 hips) (Table 1).

In unilateral cases, the left hip was affected in 41 patients, while the right hip was affected in only 24 cases, and there were 22 bilateral cases. All patients underwent a thorough clinical examination, including measuring the range of motion, limping, limb length discrepancy (LLD), and radiographic examination including conventional X-rays in the two classic views and computed tomography (CT) scanning. Dega or Salter osteotomies were used based on the surgeons' preferences.

Sixty-one hips were operated upon using Salter osteotomy (35 in subgroup A and 26 in subgroup B), while 48 hips were treated using the Dega osteotomy (18 in subgroup A and 30 in subgroup B) (Table 2).

General anaesthesia was induced using a face mask with halothane, and 100% oxygen, an intravenous access was secured, and a laryngeal mask airway (LMA) of appropriate size was placed. Then a caudal block was performed using a 23 gauge short-bevel needle under aseptic conditions. After negative aspiration for blood or cerebrospinal fluid, Bupivacaine 0.5 ml/kg plus Tramadol 1mg/kg was injected and the anaesthesia was maintained with spontaneous ventilation till the end of surgery.

All the patients underwent a single-stage, adductor tenotomy (AT), open reduction (OR), capsulorrhaphy (Cap.), as well as one of the studied pelvic osteotomies. This was considered as the index surgery. Subtrochanteric femoral shortening osteotomy (Fem) was performed in only 86 hips (78.8 %), of which only 11 varus derotations were done. Adding a varus component was done only when the true neck-shaft angle was more than 135°, while derotation was indicated when the anteversion of the proximal femur was more than 50°. The amount of femoral shortening ranged from 10 to 38 mm, with an average of 22 mm. This was performed when indicated at the same surgical setting, but was considered as an adjuvant surgery (Table 2).

The bikini (modified ilioinguinal) anterior approach was used in all the studied cases, while the femoral osteotomy was performed through a separate direct lateral approach and incision to the proximal femur in indicated cases. Salter osteotomy was performed in 61 hips, the same way that Salter described in his original article [2], and all the surgical details and guidelines were followed. Dega osteotomy was performed in 48 hips as an incomplete transiliac osteotomy [3]. No internal fixation was performed to fix the graft in situ, while in cases of femoral shortening, the femur was fixed by a small dynamic compression plate (DCP).

Postoperatively, in cases subjected to Salter osteotomy and cases of Dega osteotomy and concomitant femoral

**Table 1** Classification of the patients according to age at first presentation and type of osteotomy performed

| Age subgroup (years) | Salter osteotomy | | Dega osteotomy | | Total no. of hips | |
|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % |
| 18–48 (A) | 35 | 32.1 | 18 | 16.6 | 53 | 48.6 |
| ≥48–72 (B) | 26 | 23.8 | 30 | 27.5 | 56 | 51.4 |
| Total | 61 | 55.9 | 48 | 44.1 | 109 | 100 |

**Table 2** The index surgery for each age subgroup

| Patient subgroup | Salter | | Salter + Fem | | Dega | | Dega + Fem | |
|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % |
| A | 24 | 22.0 | 11 | 10.1 | 12 | 11.0 | 6 | 5.5 |
| B | – | | 26 | 23.8 | 1 | 0.9 | 29 | 26.7 |
| Total | 24 | 22.0 | 37 | 33.9 | 13 | 11.9 | 35 | 32.2 |

shortening, a spica cast with hips in 10–15° of flexion, about 20–30° of abduction, and neutral rotation was applied. In bilateral cases, the second operation was performed 6 weeks after the first surgery. If Salter osteotomy was performed in the first hip, the pins used to stabilize the graft were removed at that time.

Radiographs were taken preoperatively, immediately postoperatively, after 6 weeks, after removal of the spica cast, and at 6-month intervals in ordinary cases, or as indicated in complicated cases. A single-cut CT scan was performed within 1 week after the surgery to check the adequacy of reduction in doubtful cases.

The clinical criteria for assessment of the results at the final follow-up visit were based on Barrett's modification of McKay's criteria, as shown in Tables 3 and 4, [4].

The radiographs were tested using the following parameters; the Tonnis [2] grading system for dislocation variants, the acetabular index (AI) [5], the Sharp angle [6], the center-edge angle (CE) of Wiberg [7], the migration percentage described by Reimers [8], and the grade of avascular necrosis (AVN) of the femoral head according to the Bucholz–Ogden classification, the severity of the degenerative changes of the hip according to Tonnis [2], and the radiographic results according to the Severin classification [9]. According to the Severin classification, class 1 was established as excellent, class 2 good, class 3 fair, class 4 bad, and classes 5 and 6 as very bad (Table 5), [10].

Differences between the groups were compared using a two-tailed Student's $t$-test for normally distributed values. For the comparison of categorical variables, a Chi-squared test was performed; otherwise, the Wilcoxon signed-rank test was used to compare variables.

The symmetry of the distribution was determined by measuring the value by which the data was skewed. The results are presented as the mean and range. A two-tailed $p$-value $\leq 0.05$ was considered to be statistically significant. All the analyses were performed using SPSS version 11.0 software (SPSS Inc., Chicago, IL, USA).

**Table 3** Criteria for clinical evaluation (Barrett's modification of McKay's criteria)

| Rating | Criteria |
|---|---|
| Excellent | Stable, painless hip; no limp, Trendelenburg sign negative, full range of motion |
| Good | Stable, painless hip; slight limp, slight decrease in range of motion |
| Fair | Stable, painless hip; limp, positive Trendelenburg sign, limited range of motion, or a combination of these |
| Poor | Unstable or painful hip or both; positive Trendelenburg sign |

**Table 4** The final clinical outcome in the two different age subgroups with each type of osteotomy

| Clinical end results | Salter osteotomy | | Dega osteotomy | | Total no. of hips | |
|---|---|---|---|---|---|---|
| | A | B | A | B | No. | % |
| Excellent | 22 | 10 | 5 | 19 | 56 | 51.4 |
| Good | 11 | 12 | 5 | 9 | 37 | 33.9 |
| Fair | 1 | 3 | 6 | 2 | 12 | 11.0 |
| Poor | 1 | 1 | 2 | – | 4 | 3.7 |

**Table 5** The final radiographic outcomes in relation to the age groups of different osteotomy types

| Severin classification | | Salter osteotomy | | Dega osteotomy | |
|---|---|---|---|---|---|
| | | A | B | A | B |
| Ia | Excellent | 9 | 7 | 2 | 8 |
| Ib | | 10 | 6 | 4 | 15 |
| IIa | Good | 8 | 8 | 3 | 2 |
| IIb | | 6 | 3 | 1 | 4 |
| III | Fair | 1 | – | 3 | 1 |
| IVa | Bad | 1 | 2 | 2 | – |
| IVb | | – | – | 2 | – |
| V | Very bad | – | – | – | – |
| VI | | – | – | 1 | – |

## Results

The postoperative follow-up period ranged from 24 month to 10 years, with a mean of 62 months. Examination of the

**Table 6** The mean values of the acetabular index (AI) preoperatively, immediately postoperatively, and at the final follow-up examination

| Mean AI | Salter osteotomy | | Dega osteotomy | |
|---|---|---|---|---|
| | A | B | A | B |
| Preoperatively | 41.56 | 38.77 | 39.87 | 43.54 |
| Immediate postoperatively | 20.42 | 21.95 | 26.32 | 19.82 |
| Final follow-up | 15.25 | 16.19 | 19.91 | 14.01 |

patients at the final follow-up revealed overall favorable (excellent and good) clinical results in 93 patients (85.3 %), while the clinically unfavorable clinical results (fair and poor) were observed in 16 patients (14.7 %). At the final follow-up examination, 39 hips were skeletally mature (35.7 % of the studied hips). The detailed final clinical results with special consideration for the age subgroups are shown in Table 4. It was found that the subgroup A patients treated with Salter osteotomy showed more favorable clinical results compared to the same age subgroup of patients treated using the Dega osteotomy, and this was statistically significant ($p < 0.05$).

Most of the patients showing unfavorable final clinical outcome belonged to the A subgroup of patients treated with the Dega osteotomy. This group alone showed unfavorable results in 8 hips (50 % of the total unfavorable results). This was also found to be of high significance statistically ($p < 0.05$). The final clinical end results were also found to be statistically correlated to the preoperative dislocation grade (almost all of the unfavorable results took place in Tonnis grade IV cases) in both groups of pelvic osteotomies.

The final radiological examination was performed at the final follow-up visit, and the X-rays were assessed according to the Severin classification (Table 5). In patients younger than 5 years old, at the final follow-up visit, the ossific nucleus-edge angle was used instead of the lateral CE angle of Wiberg [11]. Again, it was found that most of the hips showing unfavorable final radiographic outcomes (8 out of 13 hips classed as fair, bad, and/or very bad) belonged to the A subgroup of patients treated using the Dega osteotomy, and this was statistically significant. Correlation between the final radiographic and clinical outcome was also statistically significant ($p < 0.05$).

It was also found that the overall favorable radiological outcomes (excellent or good) in the Dega group of patients was higher than in the Salter group. All of the patients of the B subgroup treated with Dega osteotomy except one (29 out of 30) had favorable final radiographic outcomes, regardless of the preoperative dislocation grade, and this was statistically significant ($p < 0.05$).

The AI was measured in all the studied groups, and the results are shown in Table 6.

There was a significant statistical difference between the mean preoperative and postoperative AI values, as well as a significant statistical difference between the mean immediately postoperative values and the mean AI values at the final follow-up measurement, in all the studied subgroups ($p < 0.05$).

The AI in patients treated with the Dega acetabuloplasty had a preoperative mean value of 39.87 and 43.54 in the A and B age subgroups, respectively. This was changed immediately postoperatively to 26.32 and 19.82, respectively. The average degree of correction was 20 and 25 in the A and B subgroups, respectively, while the maximum degree of correction of each subgroup was 35 and 45, respectively. Better correction of the AI values was found both immediately postoperatively and at the final follow-up examination in patients of the B subgroup.

On the other hand, with Salter osteotomy, the mean preoperative AI values were 41.56 and 38.77 in the A and B subgroups, respectively. Immediate AI mean values were 20.41 and 21.95 after the osteotomy. The average degree of AI correction after Salter osteotomy was 18° and 19° in the A and B subgroups, respectively. No statistically significant reduction of the AI values was found between both of the age subgroups treated with Salter osteotomy. The maximum degree of correction recorded in the A and B subgroups was 25 and 28, respectively. This showed evidence of a statistically significant difference in favor of the Dega osteotomy ($p < 0.05$).

## Complications

There were minor as well as major complications recorded in this series, as follows; superficial wound infection took place in three cases in this study, and was managed properly, which did not alter the final outcome. Injury of the superficial lateral cutaneous nerve of the thigh occurred in eight cases, which did not leave any permanent complaint in the studied patients at the final follow-up visit and required no further intervention. There were three cases of postoperative posttraumatic supracondylar fractures of the femur after removal of the spica casts, which were treated conservatively, and did not affect the final outcome.

Pain was recorded and followed carefully during the follow-up period in six hips. In three of those patients, it became incapacitating to a degree that interfered with the patient's daily life activities. Those three hips needed and underwent further surgical interference (one revision of open reduction, one Chiari, and one valgus subtrochanteric osteotomy), and were considered as failure. Two were of the Salter group, one in each age subgroup, and one was in Dega subgroup A; in that case, a failed reduction (re-dislocation) was found and open reduction was performed and the result was considered as failure. None of the patients older than 4 years of age (B subgroup) treated with Dega osteotomy required a second operation during the follow-up period. None of the patients treated with Dega osteotomy needed an operation to remove the osteosynthesis material, as in cases treated with Salter osteotomy.

Residual acetabular dysplasia and/or persistent subluxation were found in only two cases in the Salter group, and this was not recorded in the Dega group of patients. Trendelenburg sign was positive in seven patients during the final follow-up examination. These patients were in the fair final clinical outcome group and are still under follow-up.

AVN was detected in nine cases during the follow-up period. It was noted that one of those patients had had preoperative signs of AVN. They were classified according to the Bucholz–Ogden classification into 3, 2, 2, and 2, for types I, II, III, and IV, respectively. There was no statistically significant incidence of AVN between the different types of osteotomies used. However, there was a statistically significant correlation between the younger age group of patients (A) and the incidence of AVN.

Limb length discrepancy was also found in five cases in this study, which was less than 3 cm in all the recorded cases, and needed no further surgical intervention till the final follow-up visit.

It was also noted that more than one of the above-mentioned complications took place in one hip.

## Discussion

It has been estimated that degenerative joint disease of the hip is secondary to subluxation or dysplasia of the acetabulum in 20 to 50 % of the affected hips, and that 50 % of the patients with osteoarthrosis associated with acetabular dysplasia had the first reconstructive hip procedure before the age of 60 years, whereas less than 5 % had the first procedure after the age of 70 years [12].

The younger the patient at the time of diagnosis and proper management, the better the final clinical outcome would be. The age group in this study was selected based on the importance of early reduction for the development of a normal hip joint, and because of the good growth and remodeling potential of the acetabulum in infancy and early childhood. Several reasons were proposed to explain the difficulty of the comparison of the results of different studies performed for DDH patients at different centers [13].

This study was designed to compare two of the most commonly used osteotomies for the management of DDH in walking patients, namely, Salter innominate osteotomy and the Dega acetabuloplasty. Special attention was paid to the acetabular remodeling and was monitored using the AI.

The decrease of the AI mean values were 21.14, 16.82, 13.55, and 23.72, for the Salter A, Salter B, Dega A, and Dega B subgroups, respectively. Based on these results, the least favorable results were recorded in the Dega A subgroup. On the other hand, the greatest reduction in the mean AI was when Dega was performed in children aged 4 years or older. Despite the improvement of the mean AI in both groups treated with Salter osteotomy not being statistically significant, a better result was recorded in favor of the younger age group.

This supports the fact that the younger the patient, the better the surgical outcome would be anticipated. Patients treated with Dega osteotomy before the age of 4 years had the worst clinical and radiographic outcomes in this study, and this might be attributed to the small size of the thin ilium at that age, which made the osteotomy more technically demanding. The degree of correction and inclination of the outer table of the ilium after the osteotomy was also restricted, as indexed by the postoperative AI values. Progressive improvement of the AI values was noted and measured in all the studied groups, as long as concentric reduction of the femoral head was maintained after reduction during the follow-up period.

In this study, to limit the variables and provide more reliable results clinically and statistically, only the DDH patients with frank dislocations (Tonnis grades 3 or 4 only) were included. Moreover, the index surgery was performed at a single stage and was not staged. Preoperative traction was not performed for any of the studied cases. The AI measures in this study were found to be comparable to published studies in the literature. López-Carreño et al. [14] reported an average reduction of 11° and 18° with Salter and Dega osteotomies, respectively, just after the operation. Barrett et al. [15] reported an average of 16° of improvement with Salter osteotomy after an average of 7 years of follow-up of four different groups. Ozgur et al. [16] reported an average of 17° of improvement with Dega osteotomy. Ruszkowski and Pucher [17] reported an average of 25° of improvement of the AI values after Dega osteotomy with a mean follow-up of 9.4 years. Grudziak and Ward [18] also reported an average of 21° of reduction with Dega osteotomy.

It was also noted that immediate examination of the postoperative films revealed that, in unilateral DDH cases, the AI was greater on the treated dislocated side, than on the normal side in all the patients. While, during the first year of follow-up after surgery, there was a marked improvement of the AI in all the treated patients, in all the uncomplicated cases, with good or excellent clinical results, there was no statistical difference at the end of the follow-up period between the AI on the normal and the operated sides in unilateral cases in all the studied groups. This might be explained by the improved coverage of the femoral head in the weight-bearing surface of the acetabulum, which, in turn, acts as a stimulus for acetabular growth and development. This might explain the marked improvement of the AI after reduction till the time of the last follow-up radiography in this study. This also confirms that the good remodeling potential of the acetabulum before the age of 6 years persists [14–19].

Patients treated clinically using Salter and Dega osteotomies showed overall favorable results of 90.16 and 79.16 %, respectively. Nevertheless, the final clinical outcome of the Dega acetabuloplasty performed in the B subgroup of patients alone was 93.3 %. These results were comparable to the results reported by López-Carreño et al. [14], who reported statistically significantly better clinical results in favor of Dega osteotomy. Barrett et al. [15] reported 75 % good or excellent clinical results with Salter osteotomy. Ruszkowski and Pucher [17], on the other hand, reported 89 % favorable results with Dega osteotomy, while Grudziak and Ward [18] reported satisfactory final clinical results for all patients who underwent Dega osteotomy.

The variation in the clinical outcomes between the two main groups in this study could be attributed to the learning curve of the surgeons participating in this study, as the Dega acetabuloplasty was more recently implemented at our center. Plus, the Dega osteotomy is a more technically demanding procedure, and should be performed under good fluoroscopic guidance. It was also apparent that the unfavorable results obtained with the Dega A subgroup significantly lowered the overall final results of the Dega group of patients in this study. On the other hand, there was no statistically significant difference between the two studied subgroups treated with Salter osteotomy.

On the contrary, the only two cases having residual acetabular dysplasia and/or persistent subluxation were of the Salter group. This might be explained by the fact that Salter osteotomy is of special value only in cases with anterolateral deficiencies of the acetabulum. The versatility and tailoring of the osteotomy to address the type of the deficiency present in the acetabulum is a major advantage of the Dega acetabuloplasty over the Salter osteotomy. Again, we have to remember that this type of osteotomy was originally designed for patients with cerebral palsy, who have greater lateral and posterior deficiencies [20].

It was also noted that the cases with unfavorable results were cases with early complications and this supports the idea that good postoperative results have the tendency to persist and poor results have the tendency to get worse.

In this study, it was clear that there is a significant difference in the average decrease of the AI in hips treated with the Dega osteotomy compared to the Salter group of patients. This might be due to the fact that the Dega osteotomy uses the triradiate cartilage flexibility as the hinge point, which offers a greater degree of correction compared to the limited flexibility obtained from the pubic symphysis, which is the hinge in case of Salter osteotomy [20].

In conclusion, the Dega osteotomy was a stable incomplete osteotomy that did not require osteosynthesis, and, subsequently, there was no need for osteosynthesis removal. The hinge with the Dega osteotomy was at the triradiate cartilage and its elasticity is a must when considering this type of osteotomy. It provided better acetabular coverage in all types of acetabular deficiencies; anterior, lateral, posterior, and global. Higher degrees of correction (up to 39–45° in both age subgroups) could be attained using this type of acetabuloplasty, provided that the triradiate cartilage was open and elastic. Fluoroscopic guidance is a must with this type of osteotomy. We conclude that, if the reduction of the AI value needed to be equal to or more than 25°, Dega osteotomy is more favorable and is found to be more beneficial than the Salter osteotomy, even in cases with anterior or anterolateral deficiencies. We also noted better final clinical and radiographic results reported with Dega osteotomy when performed in children older than 4 years of age, and many complications with this procedure could be found if used in younger children.

Acetabular remodeling in the studied age group was evident, and the acetabulum at this age showed a great remodeling potential when the head was concentrically reduced and maintained in position.

Limitations of this study included the following. This was a retrospective study, with a relatively short follow-up period. Not all the included patients were followed till skeletal maturity, which is of critical importance, as the clinical, as well as radiographic results tend to vary with time. Nevertheless, this study shows that Salter innominate osteotomy and Dega acetabuloplasty are both adequate techniques for the management of neglected DDH cases in children below 6 years of age.

**Conflict of interest** None.

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