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Modified Salter versus Dega Osteotomy for the Treatment of Developmental Dysplasia of the Hip after Walking Age

Conflict of interest: nothing to declare.
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Abstract

Introduction. It is unknown whether a Modified salter osteotomy is superior than a Dega osteotomy in the treatment of hip developmental dysplasia after walking age.
Purpose. To examine the clinical and radiological outcomes of an untreated developmentally dislocated hip treated by open reduction with or without a femoral osteotomy and either a Modified salter or a Dega pelvic osteotomy in walking-age patients.
Materials and methods. This prospective study involved a consecutive series of cases treated by a single surgeon at one institution between October 2010 and January 2015. Inclusion criteria were cases of untreated developmental dislocation of the hip in children presenting after walking age. Patients were randomized into two groups, namely Modified salter or Dega pelvic osteotomy, and further divided into two subgroups (Subgroup A patients less than 4 years) and (Subgroup B those >4 years).
Results. The study found no significant clinical and radiological differences between subgroup A of Dega and Modified salter osteotomy, favorable clinical result was found in 83.3% of Dega subgroup A and 92.7% for Modified salter with the same age subgroup, also the favorable radiological result was found in 91.6%, 87.9% for Dega subgroup A and Modified salter subgroup A respectively. Significant clinical and radiological differences were found between subgroup B of Dega and Modified salter osteotomy. Favorable clinical result was found in 93.1% of Dega subgroup B and 54.6% for Modified salter with same age subgroup, while favorable radiological result was found in 93.2%, 54.5%, for Dega subgroup B and Modified salter subgroup B respectively.
Conclusion. For patients more than 4 years old, Dega osteotomy is more favorable and associated with fewer complications than Modified salter osteotomy, while in patients less than 4 years both types of osteotomy can be used safely.
Keywords: modified Salter, Dega osteotomy, developmental dysplasia , derotation, avascular necros

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Сравнительный анализ модифицированной остеотомии Солтера и остеотомии Дега в лечении врожденной дисплазии тазобедренного сустава у детей, достигших возраста ходьбы

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Резюме

Введение. До настоящего времени не установлено, является ли модифицированная остеотомия по Солтеру более эффективной, чем остеотомия по Дега, в лечении врожденной дисплазии тазобедренного сустава в возрасте ходьбы.
Цель. Изучить клинические и рентгенологические результаты первичного лечения врожденного вывиха бедра методом открытого вправления в сочетании с подвздошной остеотомией таза или без нее с проведением модифицированной остеотомии таза по Солтеру или остеотомии таза по Дега у пациентов в возрасте ходьбы.
Материалы и методы. В данном перспективном исследовании проведен анализ последовательной серии операционных вмешательств, выполненных одним хирургом в одном медицинском учреждении в период с октября 2010 года по январь 2015 года. Критерием включения было первичное обращение по поводу врожденного вывиха бедра у детей, достигших возраста ходьбы. Пациенты были случайным образом распределены на две группы: в группу модифицированной остеотомии таза по Солтеру или в группу остеотомии таза по Дега. Далее пациентов каждой из групп разделили на две подгруппы: подгруппа А – пациенты до 4 лет и подгруппа В – пациенты старше 4 лет.
Результаты. Исследование не выявило существенных клинических и рентгенологических различий между подгруппами А групп с остеотомией по Дега и с модифицированной остеотомией по Солтеру; благоприятный клинический исход был отмечен в 83,3% случаев в подгруппе А группы с остеотомией по Дега и в 92,7% случаев в такой же возрастной подгруппе группы с модифицированной остеотомией по Солтеру. Также были отмечены благоприятные результаты рентгенологических исследований у 91,6% и 87,9% испытуемых подгруппы А группы с остеотомией по Дега и подгруппы А группы с модифицированной остеотомией по Солтеру соответственно. Достоверные различия в клинических и рентгенологических показателях были выявлены между подгруппами В группы с остеотомией по Дега и группы с модифицированной

остеотомией по Солтеру. Благоприятный клинический исход достигнут в 93,1% случаев в подгруппе B группы с остеотомией по Дега и в 54,6% случаев в подгруппе B группы с модифицированной остеотомией по Солтеру, в то время как благоприятные рентгенологические результаты отмечены в 93,2% и 54,5% случаев в подгруппе B группы с остеотомией по Дега и в подгруппе B группы с модифицированной остеотомией по Солтеру соответственно.

Заключение. При лечении пациентов старше 4 лет предпочтительнее проводить остеотомию по Дега, которая сопровождается меньшим количеством осложнений, чем модифицированная остеотомия по Солтеру, в то время как у пациентов младше 4 лет можно безопасно использовать оба вида остеотомии.

Ключевые слова: модифицированная остеотомия по Солтеру, остеотомия по Дега, врожденная дисплазия, коррекция вращательной деформации, аваскулярный некроз

■ INTRODUCTION

The sequel of developmental dysplasia of the hip (DDH) are a common cause of osteoarthritis of the hip and may create challenges when performing total hip arthroplasty [1]. Surgical treatment of a developmentally dislocated hip presenting after walking age involves an open reduction and capsulorrhaphy, usually an osteotomy of the proximal femur for shortening and derotation, and often a pelvic osteotomy. Many authors have suggested that the results following a pelvic osteotomy are best when the procedure is performed before 4–5 years of age as the acetabular remodeling is greatest during is early years [2–4]. While some surgeons favor using Modified salter's redirectional osteotomy [5], others utilize a volume-reducing pelvic osteotomy such as the Pemberton or Dega to address acetabular dysplasia at the time of open relocation of the hip [6].

■ PURPOSE OF THE STUDY

To compare clinical and radiographic results in patients of walking age with a developmentally dislocated hip treated by open reduction and capsulorrhaphy, femoral shortening osteotomy with or without derotation and varus, and either a Modified salter or a Dega pelvic osteotomy.

■ MATERIALS AND METHODS

We reviewed clinical and radiographic data on a consecutive series of cases treated by a single surgeon at one institution between October 2010 and January 2015. Patients were included if they had an untreated developmentally dislocated hip(s) and presented after walking age. Patients were excluded if they had previous surgical management, a teratologic dislocation, or any neurologic condition, syndrome, or connective tissue disorder.

The surgical technique involved a percutaneous adductor tenotomy, open surgical relocation and capsulorrhaphy, a femoral shortening osteotomy with or without derotation and/or varus, and a pelvic osteotomy. The indication for a femoral derotation was anteversion greater than 60°, and for varus was a neck-shaft angle greater than 145°. The amount of femoral shortening ranged from 10 to 35 mm, with an average of

Table 1
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 2
Bucholz – Ogden classification system of avascular necrosis of the proximal femur

Type	Description
I	Irregular ossification of the femoral head with no abnormalities of ossification of the metaphysis is the hallmark of type I AVN
II	Lateral metaphysis shows evidence of injury; femoral head grows into valgus deformity following premature lateral epiphyseal closure; relative overgrowth of greater trochanter
III	Entire metaphysis affected; femoral neck extremely short, with marked trochanteric overgrowth
IV	Lucent defect along medial metaphysis indicates growth disturbance of medial growth plate, which causes femoral head to grow into varus deformity; relative overgrowth of greater trochanter

Table 3
Severin criteria for evaluation of radiographic results

Type	Rating	Criteria
Type I	Excellent	Normal hips
Type II	Good	Concentric reduction of the joint with deformity of the femoral neck, head, or acetabulum
Type III	Fair	Dysplastic hips without subluxation
Type IV	Bad	Subluxation
Type V	Very bad	The head articulating with a secondary acetabulum in the upper part of the original acetabulum
Type VI		Redislocation

20 mm, the femoral osteotomy was fixed by a 2.7 dynamic compression plate (DCP) with 5 or 6 holes. The Modified salter osteotomy was performed using a standard technique (Add reference).

In addition to these procedures, patients were randomly divided into those who received a Modified salter (Group 1) versus a Dega (Group 2) osteotomy. For the purposes of our analysis, the patients were further divided based on age ≤4 years (1A, 2A) versus >4 years (1B, 2B), yielding four study groups. Demographic information was collected preoperatively, and radiographs and clinical records were reviewed throughout the postoperative course. The clinical outcomes were assessed by a modification of McKay's criteria (Table 1) [7]. The radiograph assessment was based on the acetabular index (AI) [8], the Bucholz – Ogden classification (Table 2) [9], and the Severin classification [10] (Table 3).

The volume-reducing pelvic osteotomy consists of an incomplete semicircular transiliac osteotomy, in which the osteotomy started about 1.5 cm above the superior

acetabular ridge and is directed obliquely from the lateral superior to medial and inferior aspect to exit through the inner cortex just above the horizontal limb of the triradiate cartilage, leaving the posterior one-third of the inner cortex intact (approximately 1 to 1.5 cm in front of the sciatic notch). Tricortical autologous iliac crest graft was used in all pelvic osteotomies. Patients were immobilized in a one-and-a-half spica cast with hip in 10–15° flexion, 15–25° abduction, and neutral rotation for six weeks then trimmed to bilateral above knee cast for additional four weeks. In bilateral cases, contralateral hip surgery was performed 2 months after the first surgery, if Modified salter osteotomy was performed in the first hip, the pins used for fixation of the graft were removed at that time. Radiographs were taken preoperatively, immediate postoperatively, after 2 weeks, after 6 weeks, after removal of the spica cast, at 6-month intervals, and at the final visit.

Differences between the groups were compared using the Chi-squared test for the comparison of categorical variables, while for normally distributed values a two-tailed Student's t-test was used. A two-tailed p-value of 0.05 was regarded to be statistically significant. The analyses were performed using SPSS version 17.0 software.

■ RESULTS

The average age was 2.8 years at the time of surgery (18 months to 6 years), and the average follow-up was (4–50) months. Varus derotational osteotomies were performed in 24 patients (30 hips). There were no significant differences in the percentage of favorable results between the Dega (83.3%) and Modified salter (92.7%) osteotomies in the younger cohort of patients (1A, 2A) ($p>0.05$), patients treated by the Dega had a greater percentage of favorable results, 93.1% versus 54.6% for the Modified salter group, in the older cohort ($P<0.05$). For those patients treated with Dega osteotomy, no statistical difference was observed between subgroups A (83.3% favorable) and B (93.1% favorable) ($P>0.05$), while there was a significant difference between subgroup A (92.1% favorable) and B (54.6% favorable) for those who underwent Modified salter osteotomy ($P<0.05$) (Table 4).

There were statistically significant differences ($P<0.05$) between subgroup B for those patients treated with Dega osteotomy (favorable 93.2%) and subgroup B of those treated

Table 4
Classification of the patients at first presentation according to the age and type of osteotomy performed

Age subgroup (Months)	Dega osteotomy	Modified salter osteotomy	Total no. of hips
18–48 (A)	36 (55.39%)	41 (65.08%)	77 (60.16%)
48–72 (B)	29 (44.61%)	22 (34.92%)	51 (39.84%)
Total	65 (100%)	63 (100%)	128 (100%)

Table 5
Final clinical outcome in the two different age subgroups with each type of osteotomy

Clinical end results	Dega osteotomy		Modified salter osteotomy	
	A	B	A	B
Excellent	9 (25%)	12 (41.4%)	13 (31.7%)	6 (27.3%)
Good	21 (58.3%)	15 (51.7%)	25 (61%)	6 (27.3%)
Fair	4 (11.1%)	2 (6.9%)	2 (4.9%)	3 (13.6%)
Poor	2 (5.6%)	0 (0.0%)	1 (2.4%)	7 (31.8%)
Total	36 (100%)	29 (100%)	41 (100%)	22 (100%)

with Modified salter osteotomy (favorable 54.5%), while no significant difference (P>0.05) was noted between subgroup A for patients treated with Dega osteotomy (favorable 91.6%) and subgroup A of those treated with Modified salter osteotomy (favorable 87.9%) (Table 5).

For those patients treated with Dega osteotomy, there was no significant radiological difference (P>0.05) between both subgroup A (favorable 91.6%) and subgroup B (favorable 93.2%), while a significant difference (P<0.05) was found between subgroup A (favorable 87.9%) and subgroup B (favorable 54.5%) for those treated with Modified salter osteotomy (Table 6).

Three repeated Acetabular index measurements were performed in all the studied groups during the preoperative, immediate postoperative, and final visit, and the results are shown in Table 7. Significant statistical difference in the mean of acetabular degree correction was found both in the immediate postoperative period (P<0.05) and at the

Table 6
Final radiographic outcome in the two different age subgroups with each type of osteotomy

Severin classification		Dega osteotomy		Modified salter osteotomy	
		A	B	A	B
Type I	Excellent	7 (19.4%)	8 (27.6%)	9 (22%)	5 (22.7%)
Type II	Good	26 (72.2%)	19 (65.5%)	27 (65.9%)	7 (31.8%)
Type III	Fair	1 (2.8%)	1 (3.4%)	2 (4.9%)	3 (13.6%)
Type IV	Bad	1 (2.8%)	1 (3.4%)	2 (4.9%)	3 (13.6%)
Type V	Very bad	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (9.1%)
Type VI		1 (2.8%)	0 (0.0%)	1 (2.4%)	2 (9.1%)

Table 7
The Acetabular index (AI) mean values for both groups of osteotomies

Mean Acetabular index	Dega osteotomy		Modified salter osteotomy	
	A	B	A	B
Preoperatively	38.5	45.2	37.8	42.4
Immediate postoperatively	23.6	19.2	25.2	30.8
Final follow-up	16.8	14.8	18.2	27.04

Table 8
Complications

Complications		Dega osteotomy		Modified salter osteotomy	
		A (n=36)	B (n=29)	A (n=41)	B (n=22)
AVN according to Bucholz – Ogden classification	Grade 1	–	–	–	–
	Grade 2	6 (17%)	5 (17%)	4 (10%)	5 (23%)
	Grade 3	2 (6%)	1 (3%)	3 (7%)	5 (23%)
	Grade 4	1 (3%)	–	–	2 (9%)
Limitation of hip joint movement		6 (17%)	2 (7%)	3 (7%)	10 (45%)
Subluxation		1 (3%)	1 (3%)	2 (5%)	3 (14%)
Redislocation		1 (3%)	–	1 (2%)	4 (18%)
Superficial wound infection		1 (3%)	–	3 (7%)	–
Distal femoral fracture		3 (8%)	–	1 (2%)	–

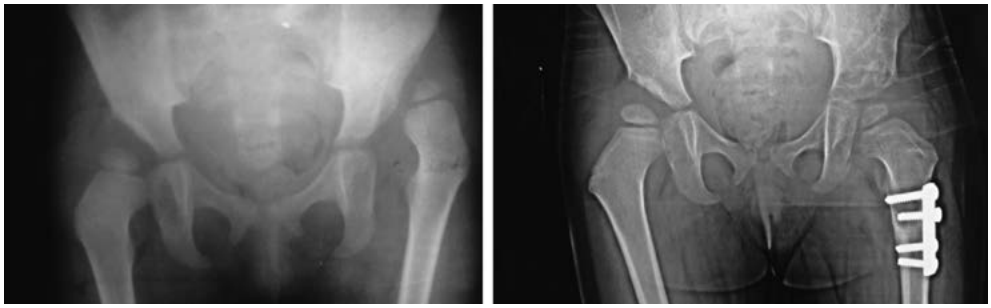
final follow-up visit (P<0.05) when comparing subgroup, A of patients treated with Dega osteotomy and those of the same age group treated with Modified salter osteotomy, and this was in favor of Dega osteotomy. When comparing subgroup B of patients treated with Dega osteotomy and subgroup B of patients treated with Modified salter osteotomy regarding the mean of acetabular degree correction significant statistical difference was observed both in the immediate postoperative period (P<0.05) and at the final follow-up visit (P<0.05) which was also in favor of Dega osteotomy.

Complications are listed in Table 8 and included stiffness (21), avascular necrosis (9), a subluxation (7), redislocation (6), superficial wound infection (4), and distal femur fracture (4).

Complications included limitation in range of motion Regarding subgroup (A) of patients treated with Dega osteotomy limitation of hip joint movement was observed in six patients. Avascular necrosis occurred in nine hips according to the Bucholz – Ogden classification (six were grade II, two were grade III, and one grade IV), and all patients were managed conservatively. Subluxation occurred in one patient and redislocation also occurred in one patient and was considered a failure. Superficial wound infection was observed in one patient and was managed with oral antibiotics and dressing. The distal femoral fracture was observed in three patients after changing the spica to the above knee.

Subgroup (B) of patients treated with Dega osteotomy limitation of the hip joint movement was observed in two patients. Avascular necrosis occurred in six hips (five were grade II, one grade III) and all patients were managed conservatively. Subluxation was noted in one patient only.

Subgroup (A) of patients treated with Modified salter osteotomy limitation of the hip joint movement was observed in three patients. Avascular necrosis occurred in seven patients (four were grade II, three were grade III) and all patients were managed conservatively. Subluxation occurred in two patients and re-dislocation was observed in one patient and was considered a failure. Superficial wound infection was observed in three patients and was managed with oral antibiotics and dressing. A distal femoral fracture happened in one patient after changing the spica to the above knee.



A **B**

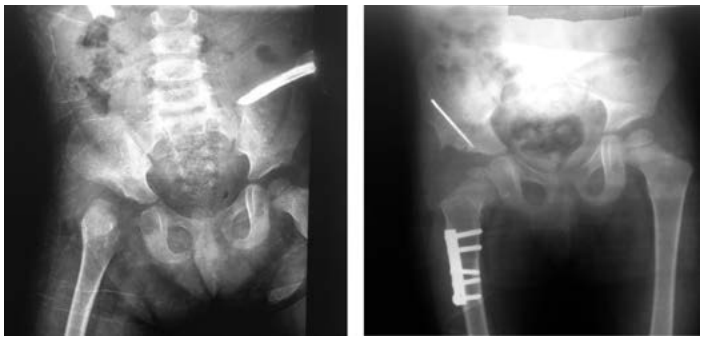
Fig. 1. (A) Preoperative radiograph of 2.5 years old girl with left side DDH. (B) Same patient after 1 year follow-up of Dega osteotomy and femoral shorting

A B

Fig. 2. (A) Preoperative radiograph of 2 years old boy with right side DDH. (B) Same patient after 16 months follow-up of Dega osteotomy and femoral shorting

A B

Fig. 3. (A) Preoperative radiograph of 2 years and eight months old girl with bilateral DDH. (B) Same patient after 20 months follow-up of Bilateral Modified salter osteotomy and femoral shorting



A B

Fig. 4. (A) Preoperative radiograph of 22 months old girl with right side DDH. (B) Same patient after 15 months follow-up of Modified salter osteotomy and femoral shorting

Subgroup (B) of patients treated with Modified salter osteotomy limitation of the hip joint movement was observed in ten patients (three patients improve with physiotherapy and seven patients show no improvement). Avascular necrosis occurred in twelve

patients (five were grade II, five were grade III, and two were grade IV) and all patients were managed conservatively. Subluxation occurred in three patients and redislocation happened in four patients and was considered a failure.

■ DISCUSSION

In the dysplastic hip, point loading occurs at the edge of the steep and shallow acetabulum, pelvic osteotomies reduce this load by increasing the contact area, relaxing the capsule and muscles about the hip, improving the moment arm of the hip, and normalizing the forces of weight bearing [11].

In this study, we divided the patients according to age into two subgroups A and B in each type of pelvic osteotomy (for better interpretation of the results) and we chose the age of 4 years as a cut-off age between the two subgroups because the tendency of acetabular remodeling is markedly decreased after the age of 4 years [12].

The acetabular index was used to assess femoral head coverage and follow-up of acetabular remodeling [13]. For those patients who underwent Dega osteotomy the mean degree of acetabular index descent at the final follow-up visit was 22°, 30° degree for A, B subgroup respectively, these results are similar to those mentioned by Grudziak and Ward (21°) [14], also Karlen and Skaggs et al., reported a (24°) degree of descent in 26 hips at the final follow-up visit [15], while for those patients who underwent Modified salter osteotomy the mean degree of acetabular index descent at the final follow-up visit was 20°, 15° degree for A, B subgroup respectively, and these results are similar to that mentioned by Sun et al. who reported an average of 20° of descent of AI postoperatively [16], while Bohm and Brzuske reported 21° of AI descent at the last follow-up in a period of 30 years follow up [17].

Patients who underwent Dega osteotomy reported 83.3%, 93.1% favorable clinical and 91.6%, and 93.2% favorable radiological results for subgroups A, B respectively. Similarly, Ruszkowski and Pucher documented favorable clinical outcomes in 89% and favorable radiographic outcomes in 72% [18], while Grudziak and Ward reported good outcomes in most of their patients [14].

In our study, subgroup A of patients with Dega osteotomy had 16.7% unfavorable clinical outcomes (six cases of limitation of hip movement) which might be due to early osteonecrosis of the femoral head and some technical difficulties of the osteotomy procedure.

In subgroup A of patients treated with Modified salter osteotomy, 92.7% favorable clinical and 87.9% favorable radiological results were documented, comparable results were obtained by Chia-Hsieh Chang et al. who reported good clinical and radiographic results in 89% and 92% of their patients, respectively [19]. However, in Modified salter subgroup B favorable clinical and radiological results were 54.6%, and 54.5% respectively, we explain these results by the following reasons: first, limited acetabular coverage offered by Modified salter osteotomy because of the limited flexibility of its hinge mechanism which is the pubic symphysis [11], second, decrease acetabular remodeling after 4 years old as mentioned previously, third, in our study all patients had frank dislocation which might negatively affect the results of Modified salter osteotomy by increasing the incidence of avascular necrosis of the femoral head [17]. Modified Salter R.B. and Dubos J.P. also documented less favorable results in Modified Salter osteotomy for those more than 4 years old [20].

In other studies which compare both types of osteotomy, Lopez-Carreno et al. [21] reported significant differences in favor of Dega osteotomy in clinical results and degree of AI descent, but radiological results according to Severin's classification were not significant, while in our results in subgroup B of Dega and Modified salter osteotomy significant differences were found in clinical results, degree of AI descent and radiological results, also in subgroup A of Dega and Modified salter osteotomy no significant difference was noted in clinical results and radiological results, however, a significant difference was only noted in the degree of AI descent, this explains by the fact that Lopez-Carreno et al. not classified his patients according to the age and he took into account the varieties of DDH: luxation of the hip, subluxation, and acetabular dysplasia, while we included only frank dislocation.

Another prospective study by Ahmed Essam Kandil et al. [22] which was done for patients with a mean age of 2.3±0.5 years revealed no significant differences both in clinical and radiological results and this was similar to our result in subgroups A.

Another study by Mohamed El-Sayed et al. [23] who involved patients from 2–6 years and divided the patients into those below 4 years and those above 4 years, showed that in those above 4 years old favorable results in Dega osteotomy were higher than that of Modified salter osteotomy and this was similar to our results, while in those under 4 years he reported better clinical and radiological results in Modified salter osteotomy and he stated that Dega osteotomy performed in those below 4 years old had the worst clinical and radiological results among all other subgroups in his study and explained this by technical difficulties and the recent introduction of Dega osteotomy to their center.

Avascular necrosis of the proximal femur which is a devastating complication occurred in 26.5% of our patients, Thomas et al, reported 37% of AVN [24], Brougham et al. [25] reported 47%, while Zionts L.E. et al, reported 6% of ANV in their study [26]. Marcin Domzalski et al. [27] explained this wide variation might be due to classification systems and the strictness with which the criteria are interpreted and the period of follow-up of the study which may show an increased incidence of AVN as follow-up increases and therefore the diagnosis of growth disturbance of proximal femur in a period less than 10 years is considered a preliminary, also he noted like many authors, Sibinsk et al. [28] Chia-Hsieh Chang et al. [19] that those patients with increasing age, high grade of dislocation, Without pre-op. traction or without femoral shaft shortening had an increased incidence of AVN, we also believed this and did femoral shorting routinely in our patients.

In patients who underwent Modified salter osteotomy we noted an increased incidence of AVN in those more than 4 years old, while in the Dega osteotomy group we not seen any difference between both subgroups, this might be due to increasing ANV in those below 4 years because of technical difficulties in Dega osteotomy in young children.

In the Dega osteotomy group, we encountered two cases of subluxation and one case of dislocation, while in the Modified salter osteotomy group subluxation was noted in five patients and dislocation occurred in five patients, we might explain this by the fact that Modified salter osteotomy is suitable only in those with anterolateral deficiencies of the acetabulum [29, 30]. In contrast, Dega osteotomy can give anterior, lateral, and posterior coverage and that is why Dega osteotomy was designed originally for patients with cerebral palsy, who have greater lateral and posterior acetabular coverage deficiencies [11].

■ CONCLUSION

We concluded that Dega osteotomy is valuable in the treatment of DDH after walking age, especially for those with shallow acetabulum since it gives anterior, lateral and posterior coverage and a greater degree of acetabular index correction. Hinge sites of Dega osteotomy can involve to varying degrees, the sciatic notch, the posterior portion of the inner pelvic cortex, and the horizontal limb of the triradiate cartilage, while Modified salter osteotomy only redirects the acetabulum and only provide anterolateral coverage. Also, Dega osteotomy is considered stable and not requires osteosynthesis so there is no additional risk for osteosynthesis removal, while Modified salter osteotomy is unstable and requires pins fixation and had an additional risk for osteosynthesis removal. Despite all of this, Modified salter osteotomy is also considered a good option in those less than 4 years who require only 10°–15° of AI correction and it has the advantage in that it can be performed without fluoroscopy and no technical difficulties as Dega osteotomy.

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