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Research Article

Predictive Factors for Requiring Salter Osteotomy in DDH

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Abstract

Purpose: Developmental dysplasia of the hip (DDH) is a wide spectrum condition, ranging from stable acetabular dysplasia to irreducible dislocation, with a variety of different treatment approaches. We aim to find any correlation between some of the most in use pre-operative values and requiring a concomitant salter osteotomy (SO).

Methods: In our retrospective cohort study, all defined DDH over 12 months old, assessed between the years of 2017 and 2021 in our orthopedic hospital and categorized under two groups: open reduction, and salter group. Retrospectively, we compared age, gender, pre-operative acetabular index (AI) and medial gap (MG) between two groups.

Results: There was no relationship between SO requirement and patient's gender (p=0.186). There was a higher chance of requiring SO in bilateral cases without any significance (p=0.11). Also, the difference between the two groups, in MG terms, was not significant (p=0.91). With an AI over 30°, salter osteotomy requirement would increase 2.5-fold and 4.8-fold, with each year (age) and degree (AI) increase, respectively. And if we include age over 3.5 years in the matter, SO requirement would increase by 15.7-fold and 5.8-fold with each year and degree increase, respectively.

Conclusions: OR with wide safe zone would be a safe treatment method. According to our analysis, pelvic osteotomy would be done more often when age or pre-operative AI increases, but exact determination of osteotomy requirement pre-operatively, is considered highly difficult.

***Keywords:** Developmental Hip Dysplasia, Hip Dysplasia, Hip Dislocation, Open Reduction, Pelvic Osteotomy*

Introduction

Developmental dysplasia of the hip (DDH) has a wide spectrum of conditions ranging from stable acetabular dysplasia to irreducible dislocations [1]. Pathological changes of the hip are usually reversible in newborn cases, but corrections face more resistance in late childhood [2].

Among surgical interventions in DDH treatment, there is no straightforward choice that can both, reduce the risk of further complications, and result in good clinical and radiological outcomes [3]. Open Reduction (OR), capsulorrhaphy, femoral shortening and pelvic osteotomies, are reported to have successful results [4].

Single stage surgeries are preferred in late diagnosed DDH, but even with a precise choice of treatment approach, many unpredictable problems may arise in older cases [5]. OR alone or concomitant with pelvic and/or femoral osteotomy is recommended in cases over 18 months [6, 7]. Failure of the concentric reduction is mainly due to the failed acetabular remodeling, following surgical technique errors, and inadequate soft tissue release [8].

In recent studies, appropriate factors to consider in deciding whether to perform a salter osteotomy (SO), have been controversial among orthopedic surgeons, like; whether to decide based on the patient's age at operation time or based on the hip's stability in the operating room. [9] We aim to find the pre-operative factors that predict the requirement of a concomitant pelvic osteotomy.

Materials and Method

This retrospective cohort study assessed the cases of definite DDH diagnosis, admitted to our referral orthopedics hospital from 2017 to 2021. Our research has been approved by the IRB of our institution.

We collected demographic and radiographic data of the cases for two years. We excluded all cases meeting the following criteria: closed reduction, OR with a medial approach -all cases were under 12 months and an anterolateral approach was of no use in that age interval-, a history of septic arthritis, incomplete follow-up and associated femoral shortening osteotomy.

We operated with an anterolateral approach to the hip joint, removed the soft tissue standing in the way of a favorable reduction, like transverse ligament, ligamentum teres and fat at the base of the acetabulum. In patients who did not achieve reduction with a proper (wide) safe zone in abduction and flexion (at least 30° from maximum abduction or flexion), we performed a concomitant SO. So the decision whether to do a SO was made based on the safe zone in the operating room; and the hips with a proper safe zone (at least 30°), were managed with OR alone.

We categorized our patients under two groups: cases that had a hip reduction with a proper safe zone, under OR group and cases that needed a concomitant SO to achieve a favorable reduction, under SO group.

A pediatric orthopedic surgeon evaluated all preoperative radiographic parameters on our "picture archiving and communication system" (PACS) and measured their acetabular index (AI) and medial gap (MG) with an intra-observer value of 85%. Retrospectively; we compared these data; age, gender, bilaterality plus radiologic criteria; AI, MG in the two groups.

In data analysis, mean and standard deviation were used to describe quantitative variables. In addition, number and percentage were used for categorical variables. Fischer's test was used to investigate the relationship between two qualitative variables. Regarding the difference in the mean of quantitative variables in the strata, we used the independent t-test instead of the non-parametric Mann-Whitney test, because data distribution was normal and variances were equal. All analyzes were performed in SPSS software at a significant level of 5% by our statistics specialist.

Results

We examined a total number of 120 hips (105 cases), diagnosed with DDH at our referral orthopedics hospital between 2017 and 2021. Figure 1 illustrates the number of excluded cases alongside the exclusion reasons. Ultimately, 76 hips (63 cases) were considered eligible for our study and were grouped into either the OR group or the SO group. Additional details regarding the characteristics of these hips are presented in Table 1.

14 hips (12 cases) were male and 62 hips (51 cases) were female (80.9% of patients). Also, 37 of the hips (31 cases) in OR group were female and 20 of cases (25 of 28 hips) requiring SO were also female (77.5%, 86.9%, respectively); but there was no statistical relationship between SO requirement and gender (p=0.186).

Out of 49 unilateral involvements, 24 involved left side only, 25 involved right side only. and 14 cases were bilateral (27 hips). As shown in Table 2, SO requirement was higher in bilateral cases, compared to unilateral cases. However, it was not statistically significant (p=0.11).

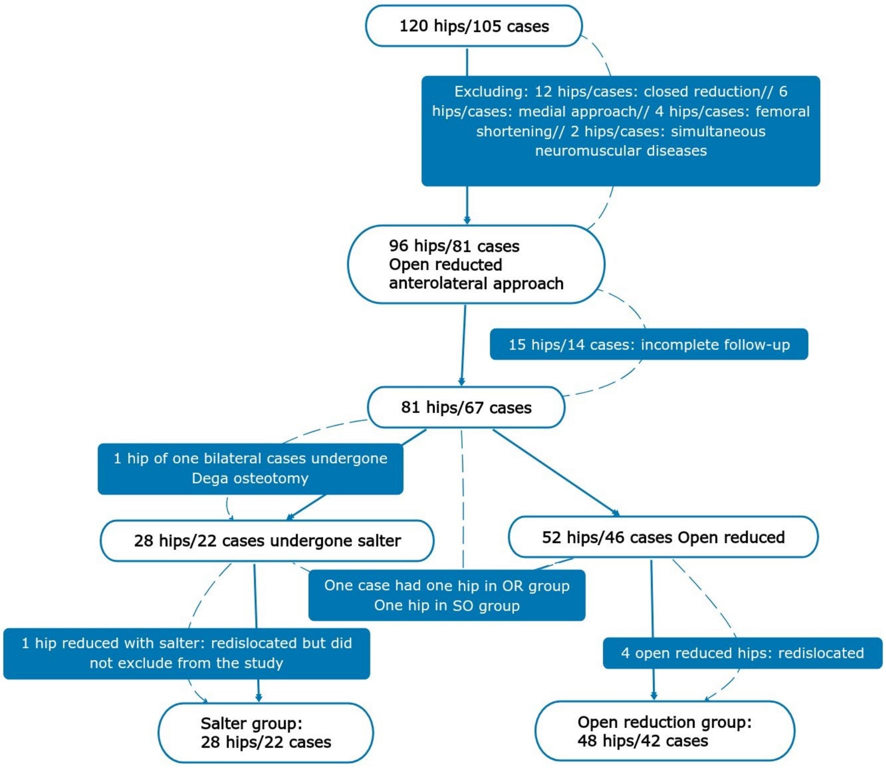

Figure 1. *How many cases excluded the study and why.*

Table 1– Cases specifics in each group [percentage is based on hips].

		SO group	OR group	total
gender	Female	86.9%	77.5%	80.9%
	Male	13.1%	22.5%	19.1%
laterality	unilateral	50%	73.5%	64.4%
	bilateral	50%	26.5%	35.6%
Pre-op AI	over 30°	89.3%	70.8%	77.6%
[degree]	Under 30°	10.7%	29.2%	22.4%
Age	Over 3.5	50%	10.4%	25%
[years]	2y-3.5	43%	31.2%	35.5%
	Under 2	7%	58.4%	39.5%

Table 2– Side involvement in each group.

	SO group	OR group	Total
Right [hips]	17	22	39
Left [hips]	11	26	37
Bilateral [hips]	8 cases (14 hips)*,**	7 cases (13 hips)**	27
Right unilateral [hips]	10	15	25
Left unilateral [hips]	4	20	24

*: one of cases: one side salter osteotomy and another side Dega osteotomy

**: one of cases one side salter osteotomy and another side open reduction only

Two of our bilateral cases had different situations (both female), as both sides were not in the same group; the first had one of her hips reduced with OR alone (OR group), and another hip with concomitant SO (SO group). The second case; had one hip reduced with concomitant SO (SO group) and another hip with Dega osteotomy that the second hip was excluded.

52 of these hips were reduced with OR alone, out of which 4 hips re-dislocated and excluded the study. Finally we had 48 hips of successful OR without pelvic osteotomy (42 cases), categorized under OR group, plus 28 salter hips (22 cases), under SO group.

MG in the SO group was 19.6 millimeters (mm) and in the OR group it was 19.7 mm, but difference between the two groups was not statistically significant (p=0.91). **Table 3** provides a description of AI and MG distribution among the cases. In addition, as age increased, the number of cases decreased in both groups; however, this quantity decrease was dramatic in the OR group.

Finally, in our data review we came across an incidental finding; we did not perform SO in cases under 1.5 years old, spontaneously.

Table 3- MG (medial gap) and AI (acetabular index) distribution in each group.

	SO group			**OR group**		
	AI pre-op [degree]	MG [millimeter]	Hips	AI pre-op [degree]	MG [millimeter]	Hips
All cases	38.5°	19.6	28	34°	20.7	48
1.5 year≥	38.5°	19.6	28	34.1°	20.5	40
2 year	38.2°	19.5	26	34.6°	21.6	20
3.5 year	38.7°	21	14	38.8°	22.6	5

Multiple Logistic regression (Table 4) showed; SO increased 2.7-fold by each year increase in age and 10% by each degree increase of AI in all our cases. When we involved AI over 30° in the assessment, SO requirement would increase 2.5-fold and 4.8-fold, with each year increase in age and each degree increase in AI, respectively.

If we also include age distribution in our assessment; in cases with an age above two years and an AI over 30°; the necessity of SO would increase by 9.9-fold and 4.9-fold by each year increase in age and each degree increases in AI, respectively. In age above 3.5 years and AI over 30°; SO requirement would increase by 15.7-fold and 5.8-fold with each year increase in age and each degree increase in AI, respectively.

Table 4- Multiple logistic regression/ age and AI (acetabular index) effect on osteotomy requirement.

Models	Multiple Logistic regression			Prediction (ROC Curve)		
	Explanatory variable	OR (CI %95)	p-value	AUC(CI %95)	Std.Error	p-value
Model 1	Age	2.74 (1.40- 3.68)	0.001	0.86 (0.77- 0.94)	0.044	<0.001
	Degree	1.10 (1.01- 1.19)	0.027			
	Individual	2.83 (0.87- 8.33)	0.085			
	Side	1.85 (0.56- 6.04)	0.306			
Model 2	Age	2.53 (1.52- 4.14)	< 0.001	0.85 (0.76- 0.93)	0.043	<0.001
	Degree(cat)#	4.89 (0.97- 24.67)	0.052			
	Individual	3.08 (.95- 10.06)	0.062			
	Side	1.67 (0.52- 5.34)	0.390			
Model 3	Age(cat)&	15.74 (3.62- 54.37)	<0.001	0.83 (0.75- 0.92)	0.045	<0.001
	Degree(cat)#	5.84 (1.08- 27.64)	0.041			
	Individual	2.80 (0.85- 9.25)	0.091			
	Side	1.99 (0.62- 6.44)	0.248			
Model 4	Age(cat)*	9.95 (3.11- 31.92)	<0.001	0.84 (0.75- 0.93)	0.045	<0.001
	Degree(cat)#	4.92 (1.0- 24.25)	0.050			
	Individual	2.49 (0.75- 8.28)	0.138			
	Side	1.57 (0.50- 4.97)	0.441			

#Degree>30

&Age≥3.5

*Age>2

Discussion

There are important factors for joint development in DDH patients, the most important one is concentric reduction of femoral head [10] in the acetabulum by a closed or open procedure, and sometimes, pelvic or femoral osteotomy needs to be done to stabilize the reduction, so choosing the optimal method in DDH treatment is challenging.

In this retrospective cohort study, we assessed our two groups (SO and OR) by analyzing preoperative factors retrospectively, including; age, gender, AI, and MG. Our aim was to compare these two groups to identify any significant associations of these factors and pelvic osteotomy requirement.

Age is an important factor affecting the reduction method. In different studies, DDH has been treated in a wide age range from 10 months to 11.4 years. [11-14] Between 6 to 18 months, CR is the treatment choice and OR is only performed in unsuccessful CRs. Pelvic osteotomy is generally used in over 24 months cases. Primary approach to DDH remains controversial between 18 to 24 months. [9] Majority of DDH cases are females, approximately 75%-82% of all DDH cases in recent studies [8, 14, 16]. Moreover, Gurger et al. found all their cases to be female [15]. In our study, we also observed a predominance of females, accountable for 80.9% of all DDH cases and 77.1% of the OR group. However, our data analysis did not indicate any significant correlation between SO requirement and gender (p=0.186), thus gender was not a valuable predictor factor for pelvic osteotomy requirement.

MG is a factor for evaluating lateral migration of femoral head in DDH. MG in the SO group was 19.6 mm and in the OR group, 19.7 mm but with a (p=0.91) we showed no relationship between SO requirement and MG.

While several studies have found left-side involvement to be more common in DDH patients (52-66%), others have reported a higher incidence on the right side [15]. However, regardless of which side is affected, treatment outcomes do not appear to be significantly influenced by the side involved. This finding is consistent with our own study as well as previous research [8, 11, 16]. In our study, we observed 24 cases of left-side involvement, 25 cases of right-side involvement, and 14 cases of bilateral involvement (27 hips in total). We found that there was a slightly higher likelihood of requiring SO in cases of bilateral involvement, but this difference did not reach statistical significance (p=0.11).

While regardless of hip's acceptable reduction [17], proper acetabular remodeling was observed more frequently after OR with capsulorrhaphy than after CR, some authors believed that stability of reduction depends on removal of soft tissue obstacles and proper correction of the bony configuration with or without osteotomy, and that capsulorrhaphy did not play an important role in the reduction stability, [18] and soft tissue procedure alone is associated with a high failure rate [19].

In our study, we made the decision whether to do an osteotomy, regardless of the age and based on post-reduction stability of the joint–proper safe zone-, as did Zadeh et al. [20]. We performed capsulorrhaphy for all hips in both groups, as we believed that capsulorrhaphy alongside the main procedure helps to maintain the stability of the reduction.

Also in our study, we came across an incidental finding when observing the study retrospectively; although, we did not take the patient's age under consideration whether to add a concomitant SO, we haven't had performed SO in cases under 1.5 years old, spontaneously. And Mostly, a case of an older age had a higher tendency towards requiring osteotomy to create a better baseline AI for further acetabular remodeling.

Higher AI and dysplasia are elements of DDH, the mean pre-operative AI was 36°-42° in multiple studies [11, 15]. Pelvic osteotomy such as SO induced higher AI decrease, and significant radiological improvements, compared to OR. [15, 21] pelvic osteotomy usually induces an AI decrease of 11°- 22.5° Post-operatively [12, 15, 22, 23, 11, 14], regardless of age. Although, after SO, AI decreased 18.8° and 16.6° in under and over 3 years old cases respectively, so it was more improved in younger patients, but it was not statistically significant. [23]

AVN may have been caused by a relative increased pressure, primarily due to the new position of the femoral head in the acetabulum. [24] Some factors can further increase AVN risk, such as difficult reduction or excessive internal rotation and abduction. As well as failed preoperative conservative treatment, [20] and the older ages [8, 16]. Risk of AVN was 1% to 48% [25] after reduction in DDH, which was increased with OR plus SO [24, 26] in some studies. While others report no significant difference in AVN rate between the two groups; [3,11] Even, Akman did not report any AVN occurrence in CR plus SO [2]. In addition, Ozkan believed that AVN in SO relates more to surgical technique than age at the operation [16] but we did not compare our two groups on this subject.

Re-dislocation rate was variable in different studies. In our study, it was 3.5% (1 of 28 hips) and 7.5% (4 of 53 hips) in SO and OR group respectively; without significant difference as in Tahririan's study [27]. In same category of studies; Yilar [11] reported a re-dislocation rate of 28.6% and 3.7%, and Kothari [3] a rate of 56% and 11% in open reduction and pelvic osteotomy group respectively; and additional surgery would be needed in 22.4% of OR cases. [28]

Although age had no effect on re-dislocation mean rate and it was 6.8% and 4.8% in 18-30 months and 31-48 months intervals, respectively [16]. Some authors concluded that the best results in pelvic osteotomy can be obtained from 2.5 or 5 years to 8 years of age, [14] while radiologic results were more acceptable under the age of 2 years (94%) compared to over the age of 4 (71%) or between the age 2 to 4 (80%), [20] and patients between 1.5 and 2 years had better functional hip scores after surgery. [14]

Some factors increase the risk of re-dislocation such as large femoral head, shallow acetabulum, excessive femoral ante-version or inadequate pelvic osteotomy.[26] Residual dysplasia after closed reduction is more than OR plus pelvic osteotomy (27% vs 11% of cases) and higher preoperative AI (above 40°) had 50% risk of residual dysplasia. [9] Also, 86% of patients with AI over 26° have worse results after age of five. [29]

In our study, the number of cases in both groups decreased by aging, but this decrease was significant in OR group, which can emphasize the idea that age increase, comes with an increase in pelvic osteotomy requirement for a stable reduction. Our study showed a SO chance increase by 2.7-fold with each year increase in age and 10% increase with each degree AI increase. When we involve AI over 30° in the assessment, SO requirement would increase by 2.5-fold and 4.8-fold, with each year increase in age and each degree increase in AI respectively. However, we cannot define a cut off point for pre-operative AI or age.

Age and pre-operative AI have synergistic effects on necessity of pelvic osteotomy; in cases with an age above two years old and AI above 30°, each year increase in age and each degree in AI would increase the necessity of SO by 9.9-fold and 4.9-fold, respectively. In age above 3.5 years and AI above 30°, SO would increase by 15.7-fold and 5.8-fold with each year increase in age and each degree increase in AI, respectively. Also satisfactory results can be achieved in AI below 24°.[12]

Limitations

Age and AI have an important and synergistic role in increasing necessity of pelvic osteotomy, so a bigger sample size and wider age distribution could help the analysis to come to a more convenient conclusion on their co-relation with pelvic osteotomy.

Conclusion

OR with wide safe zone is a safe method in DDH treatment. We prefer to treat DDH as soon as possible, because reduction in newborns is associated with better results compared to interventions in late childhood, requiring SO concomitant with the initial OR. According to our analysis, pelvic osteotomy would be done more often when age or pre-operative AI increases but determining cut off point for them pre-operatively was not possible in our study. Probably, other factors enroll in successful hip reduction that we were not able to assess.

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Authors' contributions

Arash maleki conceived and designed the study, conducted research, provided research materials, and collected and organized data and co-wrote the final draft. Amirhosein sabetian analyzed and interpreted data and provided logistic support. Ghazal valinejad collected, organized data, and wrote the initial and final draft of the article. All authors have critically reviewed and approved the final draft and are responsible for the manuscript’s content and similarity index.

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