A Systemic Review of Dega versus Salter Osteotomy in the Management of Developmental Dysplasia of the Hip

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The Egyptian Orthopedic Journal; 2021 supplement (2), December, 56: 125-134

Abstract

Background
One of the usual and effective methods for the treatment is osteotomy of the pelvic bone, namely, Salter osteotomy. Dega osteotomy is one of the most commonly used osteotomies in the management of DDH.
Objective: This systematic review compares and summarizes the collected data of Dega and salter osteotomy in the management of developmental dysplasia of the hip.
Patients & Methods
Literature search for all published articles that evaluated Dega or Salter osteotomy in the management of developmental dysplasia of the hip between January 2000 till February 2021 using PubMed, Scopus, Web of Science, and Cochrane Library. Clinical trials whether randomized or nonrandomized prospective and retrospective comparative cohort studies, case-control, nested case-control studies, or case series with more than 10 patients are included.
Results
Both approaches are reliable, result in restoring normal development of the hip in most patients. In terms of several functional and radiological outcomes including acetabular index, center-edge angle, Severin's classification, and McKay scored. However, there is a tendency in reporting a higher rate of avascular necrosis of the femoral head in Salter osteotomy.
Conclusion
Both Dega and salter osteotomy are reliable in the management of DDH but with a higher rate of avascular necrosis of the femoral head in Salter osteotomy.
Abbreviations: DDH; developmental dysplasia of the hip

Keywords
developmental dysplasia of the hip, Salter osteotomy, Dega salter osteotomy, acetabular index, center-edge angle.

Introduction

One of the usual and effective methods for the treatment is osteotomy of the pelvic bone, namely, Salter osteotomy which was initially described in 1961 [1]. In this technique, the pelvic bone undergoes osteotomy above the acetabulum, and the distal segment is shifted outwards, forwards, and downwards for appropriate construction of the acetabular roof.

Shifting the distal segment downwards, which is the most displacement in this surgery, opens the osteotomy site anterolaterally which is filled with the triangular bone graft removed from the pelvic bone [1]. Shifting the distal segment downwards causes a decrease in the acetabular volume cavity and an increase in the pressure on the femoral head, leading to an increase in the risk of chondrolysis and avascular necrosis (AVN) of the femoral head.

Furthermore, there is a possible displacement of the inserted graft in the gap between the distal and proximal segments, leading to the displacement of the distal segment upwards and inwards and decrease in or destroying the primary coverage of the femoral head [2],[3].

Dega osteotomy is one of the most commonly used osteotomies in the management of DDH. The first transiliac osteotomy was performed and registered by Wiktor Dega in 1958 in Poznan Hospital in Poland. Dega's initial osteotomy was first mentioned briefly in a 1964 German publication [4], but it was not until 1969, in a Polish publication, that he first referred to this initial osteotomy as a supra-acetabular semicircular osteotomy [5].

The iliac osteotomy described by **Dega in 1969** [5] in Poland is an acetabuloplasty that changes the acetabular configuration and its inclination.

This allows an adequate acetabular coverage for anterior, lateral, and mainly posterior deficiencies [4]. In the 1964 German publication, **Dega** [4] did not provide a detailed description of the osteotomy, but he did emphasize that the medial iliac cortex was not to be cut, to prevent the acetabular fragment from displacing medially in a ‘manner consistent with a Chiari osteotomy.

The osteotomy was described as a semicircular cut through the lateral wall of the ilium directed toward but not through the medial cortex of the ilium. It established a basis for the subsequent development of what Dega termed a transiliac osteotomy [6].

Patients and Methods

we prepared this systematic review with a careful following of the Cochrane Handbook for Systematic Reviews of Interventions. We also adhered to The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines during the design of our study.

Literature search

We conducted a literature search between January 2000 till February 2021 using PubMed, Scopus, Web of Science, and Cochrane Library. We performed a search for all published articles that evaluated Dega or Salter osteotomy in the management of developmental dysplasia of the hip.

We searched article title, abstract, keywords using the following keywords: "Dega", "Dega osteotomy", "Dega transiliac", "Dega acetabular", "Salter", "Salter osteotomy", "developmental dysplasia of the hip", acetabuloplasty. "acetabulum plasty", "dysplasia", "hip dysplasia" and "acetabuloplasty".

We used “OR” and “AND” operators during the Literature search as following: (Dega OR "Dega osteotomy" OR "Dega transiliac" OR "Dega acetabular" OR Salter OR "Salter osteotomy") AND ("developmental dysplasia of the hip" OR acetabuloplasty OR "acetabulum plasty" OR dysplasia OR "hip dysplasia" OR acetabuloplasty).

The "related articles" function was used to expand the search from each relevant study identified. Bibliographies of retrieved papers were further screened for any additional eligible studies. We searched for articles that were included in previous related systematic reviews. The identified citations were retrieved using the Endnote X8 software package (Thompson Reuter, USA).

Eligibility criteria

We included studies that met the following inclusion criteria:

I) **Population**: patients with developmental hip dysplasia.

II) **Intervention**: Dega osteotomy

III) **Comparator**: Salter osteotomy

IV) **Outcome parameters**: safety and efficacy outcomes.

V) **Study design**: clinical trials whether randomized or nonrandomized prospective and retrospective comparative cohort studies, case-control, nested case-control studies, or case series with more than 10 patients.

We excluded animal studies, reviews, book chapters, thesis, editorial letters, and papers with the overlapped dataset. Eligibility screening was conducted in a two step-wise manner (title/abstract screening and full-text screening). Each step was done by two reviewers independently according to the predetermined criteria.

Data extraction

Data were extracted by two independent authors and revised by another two independent authors. We extracted the characteristics of each study as following: first author, Number of hips, Number of patients, gender, and mean age at surgery, mean follow-up, Tönnis grade before surgery, and interventions. Additionally, we extracted functional, radiological outcomes and incidence of complications.

Results

Result of literature search

We obtained 243 articles from PubMed, 329 articles from Scopus, 5 articles from Cochrane library, and 258 from the web of science. 269 duplicated articles were removed using the Endnote X8 program (Thompson Reuter, USA), 566 articles manually underwent titles and abstracts screening and 99 articled underwent full-text review as shown (Figure 1). 25 studies finally met our inclusion criteria.

Characteristics of included studies

We identified 25 studies that evaluated Dega or Salter osteotomy in the management of developmental dysplasia of the hip with a total of 1243 hips. The mean age of patients across the studies ranged between 16 and 80 months with exception of Lyu et al. [7], authors included patients with 10.9 years old. There was male predominance in the included cases. Mean follow-up across the studies ranged between 70 to 519 months. The rest of included studies' characteristics are summarized in Table 1.

Table 1: Characteristics of included studies

Author	Number of hips (N° of patients)		Male Female	Mean age at surgery in months (range)		Mean follow-up in months (range)		Tönnis grade before surgery			Surgical technique
								I	II	III & IV	
Lin et al. [13]	53	(53)	NA	16	(12;18)	70	(61;98)	NA	NA	NA	Salter
Ito et al. [11]	35	(33)	25: 8	55	(30;96)	198	(120; 288)	NA	NA	NA	Salter
Ruszkowski and Pucker [18]	33	(33)	NA	18.5	(13;24)	114.9	(55;177.6)	10	1	4	Dega
Baki et al. [20]	15	(15)	NA	20	(13;30)	115	(48;168)	0	0	15	Salter
Macnicol and Bertol [18]	148	(132)	117: 15	33	(18;72)	NA	(60;300)	NA	NA	NA	Salter
Tezeren et al[16]	28	(21)	21:3	65	(39;96)	75.6	(31;108)	NA	NA	NA	Salter
Thomas et al. [21]	51	(51)	61: 15	33.6	(18;56.4)	519.6	(480;576)	NA	NA	NA	Salter
Rocha et al.[22]	18	(14)	14: 0	n. r	(24;96)	56	(26;132)	NA	NA	NA	Salter
Morin et al.[15]	27	(23)	21: 2	31	(20;57)	444	(372; 528)	NA	NA	27	Salter
El-Sayed et al. [23]	109	NA	NA	n. r	(18;72)	62	(24;120)	0	0	109	Salter 44%, Dega 56%
Bhuyan [24]	30	(25)	17: 8	46.8	(18;96)	49.2	(24;91.2)	NA	NA	NA	Salter
Gholve et al. [14]	26	(26)	n. r	31.8	(17;48,6)	116.4	(60;202.8)	0	0	33	Salter 18%, Dega 61%
Ahmed et al[25]	26	(20)	15:5	14.7	(12;18)	46.7	(36;70)	0	3	23	Salter
Kaneko et al.[26]	46	(46)	43: 3	69.6	(60;84)	123.6	(84;240)	NA	NA	NA	Salter
Rampal et al.[27]	16	(15)	14: 1	87.4	(12;72)	94.2	(60;156)	NA	NA	NA	Dega
Neto et al.[28]	42	(21)	19: 2	27	(12;54)	69.6	(24;156)	NA	NA	NA	Salter
El-Sayed et al. [12]	58	(48)	32: 16	48.8	(25;90)	199	(158; 302)	3	23	32	Dega
Chang et al. ([29])	63	(63)	58: 5	22	(18;33)	128		0	35	28	Salter
Ming-Hua et al.[19]	191	(162)	134: 28	43.2	(18;72)	135.6	(60;202.8)	7	32	152	Dega
Bayhan et al. [8]	25	(20)	17: 3	35.6	(17;100)	59.9	(31,108)	2	6	17	Salter
Baghdadi et al. [30]	85	(70)	57: 13	34.1	(18;64)	70.2	(25C118)	NA	NA	NA	Salter
Badrinath et al. [17]	45	NA	NA	6 years	2.8	4.5	years	NA	NA	NA	Dega
Gurger et al. [10]	32	(24)	0:24	43.22	28.4	50		0	32	0	Salter
Alassaf [9]	41	NA	NA	20	(19–31)	40	(30:54)	NA	NA	NA	Dega
Lyu et al. [7]	NA	(22)	NA	10.9 years	(9.1–14.8)	25.7	(14:48).	0	0	22	Dega

NA: Not reported

Outcomes

Acetabular index (AI)

Eleven studies reported data for Salter osteotomy compared to six studies reported data for Dega osteotomy about AI. Operative correction with Salter osteotomy resulted in a decrease in AI; the maximum decrease was reported by Bayhan et al. [8] (19.4) while the maximum decrease using Dega osteotomy was Alassaf [9](42.9). At the final follow-up, the maximum decrease was 28.6 [8] in Salter osteotomy compared to 42.8 [9] in Dega osteotomy, Table 2.

Center-edge angle (CEA)

Twelve studies reported data for Salter osteotomy compared to six studies reported data for Dega osteotomy about CEA. At the final follow-up, the angle was highest in [10] that used Salter osteotomy compared to 43.4 in Lyu et al. [7] that used Dega osteotomy, Table 3.

Sharp angle

Three studies reported data for Salter osteotomy compared to two studies reported data for Dega osteotomy about Sharp angle. At the final follow-up, the maximum improvement reported for two osteotomies were comparable to each other; 40.5 for Salter osteotomy [11] versus 40 for Dega osteotomy [12] Table 4.

Severin's Classification

Thirteen studies reported data for Salter osteotomy compared to six studies reported data for Dega osteotomy about Severin's Classification with two studies compared directly Salter osteotomy to Dega osteotomy. Best results for Severin's Classification (grade1) for Salter osteotomy was reported by [13](100%), Gholve et al. [14](100%), Morin et al.[15]) (85%) and Tezeren et al.[16](71%) while the best outcome for Dega osteotomy was reported by Gholve et al. [14]) (90%), Badrinath et al. [17](87%) and Ruszkowski and Pucker [18] (72%). In the two studies that compared Salter and Dega osteotomy directly, both techniques had comparable results however better outcomes were reported in Salter osteotomy, Table 5, Figure 2, 3.

McKay score

Eleven studies reported data for Salter osteotomy compared to seven studies reported data for Dega osteotomy about McKay score with two studies compared directly Salter osteotomy to Dega osteotomy. Best results for McKay score (excellent) for Salter osteotomy was reported by Lin et al. [13](85%), Gholve et al. [14](88%), Bayhan et al. [8](88%), and Macnicol and Bertol [18](70%) while the best outcome for Dega osteotomy was reported by Gholve et al. [14](100%), and Ming-Hua et al. [19] (77%). In the two studies that compared Salter and Dega osteotomy directly, both techniques had comparable results however better outcomes were reported in Dega osteotomy, Table 6, Figure 4, 5.

Incidence of Avascular necrosis of femoral head (AVN)

Eleven studies reported data for Salter osteotomy compared to five studies reported data for Dega osteotomy about AVN with one study reported the outcomes of both Salter and Dega osteotomy. Best results for AVN for Salter osteotomy was reported by Ito et al. [11](0%) and Baki et al. [20](0%) while the best outcome for Dega osteotomy was reported by Ruszkowski and Pucker [18] (3%) and Alassaf [9] (10%), Table 7.

Table 2: Acetabular index (AI)

Author	Surgical technique	Acetabular index **(AI)**				
		Pre	Post	Final follow-up	Op effect (posttop AI - preop AI)	Final effect (Final follow-up - preop AI)
Lin et al. [13]	Salter	36 ± 5	23 ± 5	13 ± 4	13	23
Ito et al. [11]	Salter	34.5 (22 –40)	18.1 (8 –33)		16.4	
Baki et al. [20]	Salter	33.4 (20 –48)		10.7 (5 –24)		22.7
Thomas et al. [21]	Salter	40 (0 –61)				
Bhuyan [24]	Salter	42±5	21±2		21	
Ahmed et al. [25]	Salter	35.4 (24 – 48)	19 (6–30)		15.4	
Neto et al. ([28])	Salter	Right:36.9 ±5.6 Left:39± 6.5		Right: 19.6 ±7.3 Left:16.9 ±5.0		Right:17.3 Left:22.1
Gurger et al. [10]	Salter	35.5 (34–38)		18.0 (17–19)		17.5
Chang et al. [29]	Salter	35.4 (23.0)		12.6 (13.6		22.8
Bayhan et al. [8]	Salter	40.6 ±7	21.2 ±6	12 ± 8	19.4	28.6
Baghdadi et al. [30])	Salter	39.31 (32-49)	21.28 (12-29)		17.9	
El-Sayed et al. [12]	Dega	39 (32–60)	18 (9–29)		21	
Ming-Hua et al. [19]	Dega	38.0° (28–45°)		20.8 (15–25)		17.2
Alassaf [9]	Dega	40 (35–44)	25 (20–31)	21 (16–27)	14.31	19
Lyu et al. [7]	Dega	43.4 ± 6.9	0.5 ± 2.2	0.6° ± 2.4	42.9	42.8
Badrinath et al. [17]	Dega	27.6 (7.5)		12.1 (5.9)		15.5
Rampal et al. [27]	Dega	30 (25 –45)	21.5 (5 –30)	15 (3 to 24)	8.5	15

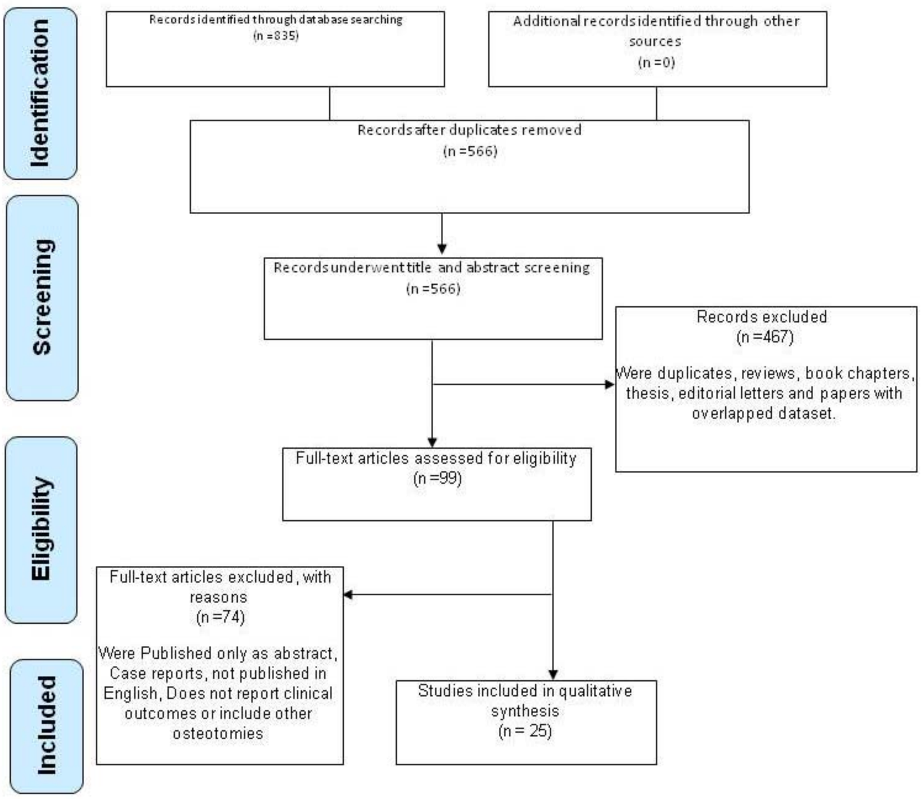

Figure 1: PRISMA flow diagram showing the process of studies selection

Table 3: Center-edge angle (CEA)

Author	Surgical technique	Center-edge angle (CEA)		
		Pre	Post	Follow up
Lin et al. [13]	Salter		35 ± 10	
Ito et al. [11]	Salter	-0.5 (range, - 15 –10),		25.3 (5 –45)
Baki et al. [20]	Salter			34.2 (20 – 44)
Tezeren et al. [16]	Salter			37 (15– 53)
Thomas et al. [21]	Salter	32 (20 – 34)		
Bhuyan [24]	Salter		23.5 (21–26)	
Ahmed et al. [25]	Salter		26 (±7)	
Neto et al. ([28])	Salter		Right: 18.1 ±11.7 Left:19.7 ±12.3	
Chang et al. [29])	Salter			29.4 (25.3)
Bayhan et al. [8]	Salter		30 ±9	
Baghdadi et al. [30]	Salter			24.59 (6-47)
Gurger et al. [10]	Salter	8.0 (0–13)		39.0 (35–44)
Rampal et al. [27]	Dega	10 (−30 –30)	22 (10 –38)	24 (12 –45)
El-Sayed et al. [12]	Dega		26 (9 –33)	34 (15 – 46)
Ming-Hua et al. [19]	Dega	–10.7 (–47–17°)		29.4 (21–40)
Alassaf [9]	Dega			23 (19–30)
Lyu et al. [7]	Dega	−24.3° ± 17.1	43.4 ± 7.6	43.4 ± 7.6
Badrinath et al. [17]	Dega			30.2° (8.2)

Table 4: Sharp angle

Author	Surgical technique	Sharp angle		
		Pre	Post	Follow up
Ito et al. [11]	Salter			40.5 (29 –54)
Tezeren et al. [16]	Salter	41° (32–50)		19 (10 – 45)
Ahmed et al. [25]	Salter	130 (115 – 156)	130 (115 – 156)	
Ming-Hua et al.[19]	Dega	59.9 (46–82)		39.2 (31– 46)
El-Sayed et al. [12]	Dega	52 (30–61)	39 (28–50)	40 (30–51)

Table 5: Severin’s Classification

Author	Surgical technique	Severin’s Classification			
		I	II	III	IV
Lin et al. [13]	Salter	53 (100%)			
Ito et al. [11]	Salter	15 (42%)	11 (31%)	6 (17%)	3 (8%)
Macnicol and Bertol [18]	Salter	67 (45%)	54 (36%)	19 (12%)	8 (5%)
Tezeren et al. [16]	Salter	20 (71%)	7 (25%)	00 (0%)	1 (3%)
Rocha et al. [22]	Salter	6 (33%)	10 (55%)	0 (0%)	2 (11%)
Morin et al.[15]	Salter	23 (85%)	3 (11%)	1 (3%)	0 (0%)
Bhuyan [24]	Salter	15 (60%)	5 (20%)	4 (16%)	1 (4%)
Ahmed et al. [25]	Salter	10 (38%)	10 (38%)	4 (15%)	2 (7%)
Bayhan et al. [8]	Salter	10 (40%)	13 (52%)	1 (4%)	1 (4%)
Baghdadi et al. [30]	Salter	64 (77%)	7 (8%)	9 (10%)	3 (3%)
Chang et al. [29])	Salter	38 (60%)	16 (25%)	9 (14%)	
Gholve et al. [14]	Salter 18%, Dega 61%	Salter:6 (100%) Dega:18 (90%)	Salter: 0 (0%) Dega:1 (5%)	Salter: 0 (0%) Dega: 1 (5%)	Salter: 0 (0%) Dega: 0 (0%)
El-Sayed et al. [12]	Salter 44%, Dega 56%	Salter:32 (52%) Dega:29 (60%)	Salter: 25(40%) Dega: 10 (20%)	Salter: 1(1.6%) Dega: 4 (8%)	Salter: 3(4.9%) Dega: 5 (10%)
Lyu et al. [7]	Dega	4 (18.2%)	18 (81.8%)		
Badrinath et al. [17]	Dega	39 (87%)	6 (13%)	0 (0%)	0 (0%)
Ruszkowski and Pucker [18]	Dega	14 (72%)	12%	4 18%	3 (9%)
Rampal et al. ([27]	Dega	11 (68.5%)	4(25%)		1(6.5%)

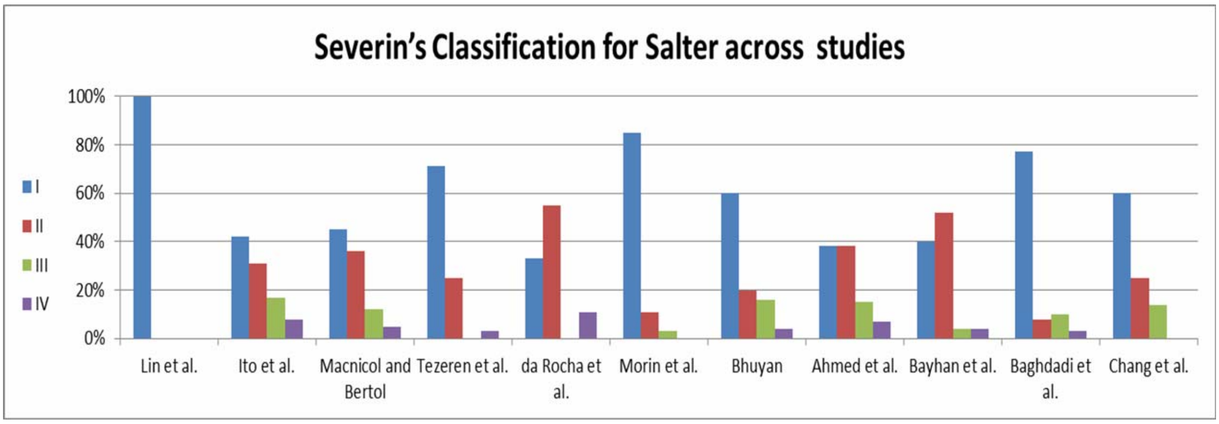

Figure 2: Severin's Classification for Salter across studies.

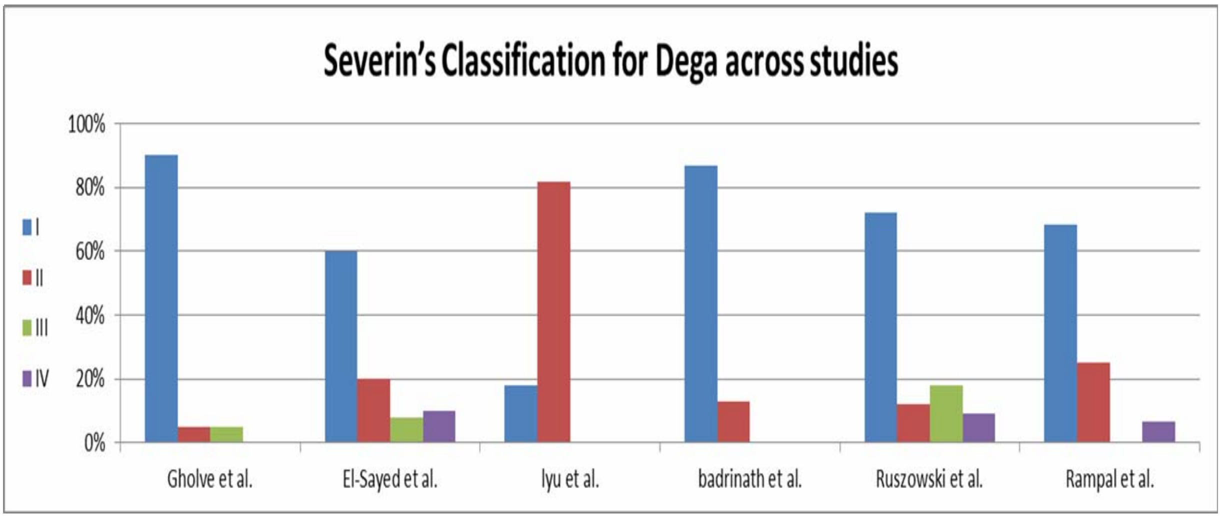

Figure 3: Severin's Classification for Dega across studies.

Table 6: McKay score

Author	Surgical technique	McKay score			
		E, excellent	G, Good,	F, Fair	Poor
Lin et al. ([13]	Salter	45 (85%)	8(15%)	0(0%)	0(0%)
Ito et al. [11]	Salter	15 (42%)	11 (31%)	6 (17%)	3(8%)
Macnicol and Bertol ([18]	Salter	105 (70%)	0(0%)	37 (25%)	6 (4%)
Tezeren et al. [16]	Salter	6 (21%)	12 (42%)	7 (25%)	3 (17%)
Bhuyan [24]	Salter	11 (44%)	11 (44%)	3 (12%)	0(0%)
Bayhan et al. [8]	Salter	22 (88%)	NA	NA	NA
Baghdadi et al. [30]	Salter	23 (27%)	47 (55%)	11 (12%)	4 (4%)
Gurger et al. [10]	Salter	0(0%)	0 (0%)	0(0%)	0(0%)
Ahmed et al. [25]	Salter	6 (23%)	15 (57%)	5 (19%)	0(0%)
Gholve et al. [14]	Salter 18%, Dega 61%	Salter: 22 (88%) Dega:5 (100%)	Salter: 1 (4%) Dega: 0(0%)	Salter: 1 (4%) Dega: 0(0%)	Salter:1(4%) Dega: 0(0%)
El-Sayed et al. [12]	Salter 44%, Dega 56%	Salter: 22 (43%) Dega:24 (50%)	Salter: 23 (45%) Dega:14 (29%)	Salter: 4 (7%) Dega:8 (16%)	Salter:2 (3%) Dega:2 (4%)
Ruszkowski and Pucker [18]	Dega	13 (39%)	16 (48%)	4 (12%)	0(0%)
El-Sayed et al. [12]	Dega	19 (32.8%)	25 (43.1%)	4 (6.9%)	10 (17.2%)
Ming-Hua et al. [19]	Dega	147 (77%)	30 (15.7%)	13 (6.8%)	1 (0.5%)
Lyu et al. [7]	Dega	3 (13.6%)	7 (31.8%)	12 (54.5%)	0(0%)
Badrinath et al. [17]	Dega	24 (53%)	8 (18%)	2 (4%)	7 (16%)

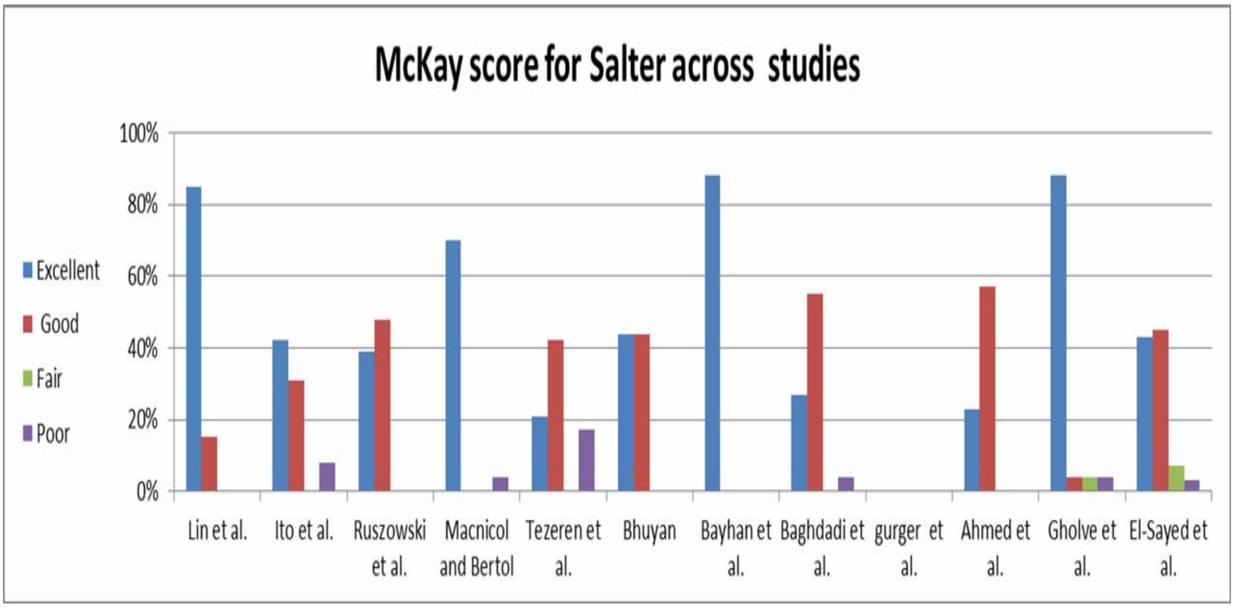

Figure 4: McKay score for Salter across studies.

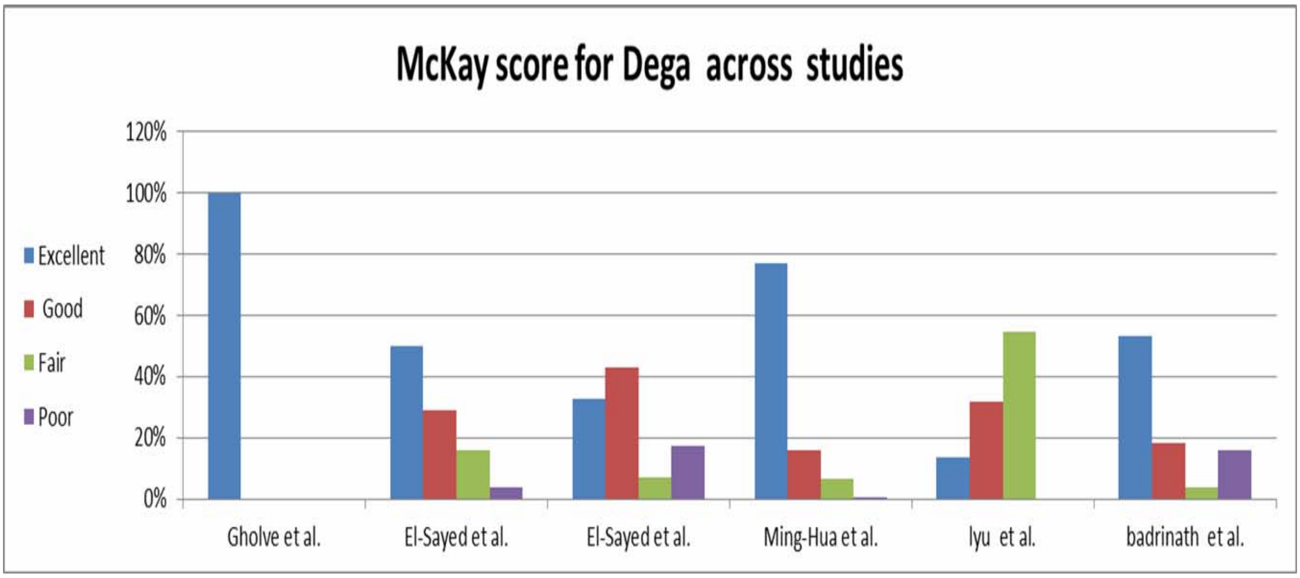

Figure 5: McKay score for Dega across studies.

Table 7: Incidence of Avascular necrosis of femoral head (AVN)

Author	Surgical technique	AVN n(%)
Lin et al. [13]	Salter	5 hips (9%)
Ito et al. [11]	Salter	No AVN
Baki et al. [20]	Salter	No AVN
Tezeren et al. [16]	Salter	5 hips (28%)
Rocha et al. [22]	Salter	5 hips (27%)
Morin et al. [15]	Salter	2 hips (7%)
Ahmed et al. [25]	Salter	6 hips (26%)
Neto et al. ([28])	Salter	15 hips (62%)
Bayhan et al. [8]	Salter	4 hips (25%)
Baghdadi et al. [30]	Salter	13 hips (15%)
El-Sayed et al. [12]	Salter 44%, Dega 56%	9 hips (8%)
Alassaf [9]	Dega	4 hips (10%)
Badrinath et al. [17]	Dega	6 hips (13%)
Ruszkowski and Pucker [18]	Dega	2 hip (3%)
El-Sayed et al. [12]	Dega	8 hips (13.7 %)

Discussion

Developmental dysplasia of the hip (DDH) represents a spectrum of pathology involving the acetabulum and occasionally the proximal femur with implications over a lifetime. The transition in terminology from "congenital hip dislocation" to "developmental dysplasia of the hip" reflects an evolution in the understanding of the symbiotic development of the femoroacetabular joint [31].

The etiology of DDH is multifactorial. Risk factors for DDH are breech positioning in utero, female sex, being firstborn, and positive family history [32]. Alone with prolonged abnormal positioning whether prenatal positioning including metatarsus adductus and torticollis or postnatal such as swaddling is associated with higher rates of DDH [33].

During infancy, the plasticity of the hip allows for a variety of non-surgical treatment modalities to reposition the femoral head as a template for acetabular development [34]. Throughout childhood, osteotomies of the pelvis and proximal femur have been developed to encourage normal morphology at skeletal maturity; however, many cases of dysplasia remain unrecognized, or residual dysplastic features persist despite treatment and present to the clinician after triradiate cartilage closure [35].

Acetabular dysplasia, the acetabulum is shallow and/or vertically oriented which leads to inadequate coverage to contain the femoral head in a reduced position with the possibility of acceleration of arthritis due to abnormal edge contact loading [36]. In patients who have failed initial treatment and have persistent acetabular dysplasia, pelvic osteotomies may be indicated to resume a more normal development of the acetabulum. The goal in the treatment of DDH is to achieve and maintain a concentric reduction of the femoral head in the acetabulum to allow for continued normal development of the hip [37]

Two of the commonest techniques used in pelvic osteotomies are Salter and Dega osteotomy. Salter osteotomy addresses the anterolateral deficiency of the acetabulum in children with DDH and a pelvic osteotomy is done to displace the acetabulum in an anterolateral direction [38]. While Dega osteotomy is an incomplete osteotomy that modifies the shape of the acetabulum by hinging it into the triradiate cartilage to obtain the best possible femoral head-acetabulum relationship [12].

Till now there is no clear evidence the support the superiority of certain osteotomy over the other. Hence, we conducted the current study to evaluate the data in the literature regarding both osteotomies.

One of the main factors that direct the line of treatment is the patient's age. Usually, surgeries like osteotomies are reserved for older children as the acetabulum has been shown to remodel throughout childhood up to age 5 years allowing for continued development in the presence of a well-located hip [(63)]. Consequently, there is an opinion to perform the osteotomy at 3 to 5 years of age for residual acetabular dysplasia. However, the exact appropriate age is still controversial

Salter [1], in his early report, recommended using his technique only in children between 18 months and 6 years, and later on, he proposed it could be performed also on young adults [39]. As we stated before, there is no agreement regarding the optimum age for surgery for the correction of residual dysplasia. Experience showed best results are obtained when performing the osteotomy before the closure of the triradiate cartilage, provided by as favorable outcomes when the acetabulum still maintains its remodeling ability that is mainly dependent on the flexibility of the triradiate cartilage [40, 41]. This is even more important for Dega osteotomy which hinges on the triradiate cartilage [14].

In the current study, we included a wide range of age groups between 1.5 years and 10.9 years. Dega group had a higher upper limit of age than the Salter group. In the Dega group, the age of the patients ranged between 18.5 months and 10.9 years. In the Salter group, the age of the patients ranged between 16 months and 69.6 months.

In the Dega group, Lyu et al. [7] reported the highest age limit (10.9 years) while Ruszkowski and Pucker [18] reported the lowest age limit (18.5 months). We found that Ruszkowski and Pucker [18] had better results in Severin's Classification (18.2% were grade I and 81.8% were grade II in Lyu et al. [7] vs. 72% were grade I and 12% were grade II in Ruszkowski and Pucker [18] and McKay score (13.6% were excellent and 31.8 % were good in Lyu et al. [7] vs. 39% were excellent and 48 % were good in Ruszkowski and Pucker [18].

In the Salter group, Kaneko et al. [26]reported the highest age limit (69.6 months) while Lin et al. [13] reported the lowest age limit (16 months). We found that Lin et al. [13] had better results (100% were grade in Severin's Classification and 85% were excellent in McKay score) compared to Kaneko et al. [26] that reported a success rate of 87% in the radiological outcomes with some patients to have the insufficient cover of the femoral head at maturity, despite having undergone reconstructive osteotomy for persistent dysplasia.

These findings are consistent with most if studies that suggest the younger the patient at the time of diagnosis and proper management, the better the final clinical outcome would be, on the contrary, Gholve and his colleagues [14] who performed both osteotomies in their study reported that age of the patients didn't have a direct influence on the outcome or the need for secondary procedures. The authors explained that older children were more likely to be treated with a combined procedure when compared with children less than 18 months old.

Our analysis found an overall favorable clinical and radiological outcome for Salter in many outcomes; acetabular index (AI), center-edge angle (CEA), Severin's classification, and McKay scored. In AI, the decrease ranged between 17.3 and 28.6. In CEA, the angle ranged between 24.5 and 39, In Severin's classification; patients had grade1 ranged between 33% and 100%. In McKay score, patients had excellent scores ranged between 27% and 85%.

We also noticed that Dega osteotomy had a similarly favorable outcome. In AI, the decrease ranged between 17.3 and 42.8. In CEA, the angle ranged between 24 and 43.4. In Severin's classification; patients had grade1 ranged between 18.2% and 90%. In McKay score, patients had excellent scores ranged between 13.6% and 100%.

Avascular necrosis of the femoral head (AVN) is the most feared complication in DDH treatment. The rate of AVN occurrence after DDH treatment varies between 3 % and 62% in the literature with higher incidence reported in the Salter group. In the Dega group, the incidence of AVN was 3% in Ruszkowski and Pucker [18], 10% in Alassaf [9], 13% in Badrinath et al. [17], and 13.7% [12]. While in the Salter group, studies weren't consistent regarding the incidence of AVN with some reported a relatively low incidence as in the Dega group; 7% in Morin et al. [15] and 9% in Lin et al. [13] and others reported much higher incidence; 62% in Neto et al. [28] and 28% in Tezeren et al. [16]. Despite that two studies reported then there was no incidence of AVN in Salter osteotomy [11, 20]

The reasons for this wide variation may be explained by the different schemes for classification/identification of AVN, possible different AVN rates for different age groups, and the different surgical approaches in open reduction.

Our review is consistent with and previously conducted meta-analysis by Merckaert and his colleagues [41]. Despite the Dega, the group had a statistically significant result over the Salter group after pooling data across the studies. The authors highlighted that these results are not reliable to conclude as studies were heterogeneous in many aspects including the type of patients and techniques used in each study and concluded that there is no clear recommendation towards one of these techniques.

We couldn't identify studies that compared directly between both surgical methods to evaluate if one approach is superior to the other. Further investigations are required to evaluate the long-term outcome of both methods on a homogenous population. Also, future studies should focus on identifying clear indications for each technique. Till now the approach of surgical correction should be selectively according to the patient's conditions and the surgeon's preference.

Conclusion

We found that both approaches are reliable, result in restoring normal development of the hip in most patients. In terms of several functional and radiological outcomes including acetabular index, center-edge angle, Severin's classification, and McKay scored. However, there is a tendency in reporting a higher rate of avascular necrosis of the femoral head in Salter osteotomy.

Referance

1. Salter, R.B. Innominate osteotomy in the treatment of congenital dislocation and subluxation of the hip. The Journal of Bone and Joint Surgery. British volume,1961. 43(3): p. 518-539.
2. Gür, E. and Sarlak, O. The complications of Salter innominate osteotomy in the treatment of congenital dislocation of hip. Acta orthopaedica belgica,1990. 56(1 Pt B): p. 257-261.
3. De Pellegrin, M. and Moharamzadeh, D. Developmental dysplasia of the hip in twins: the importance of mechanical factors in the etiology of DDH. Journal of Pediatric Orthopaedics,2010. 30(8): p. 774-778.
4. Dega, W. Difficulties in the surgical reposition of the obsolete congenital subluxation of the hip joint in children. Beitr Orthop Traumatol,1964. 11: p. 642-647.
5. Dega, W. Selection of surgical methods in the treatment of congenital dislocation of the hip in children. Chirurgia narzadow ruchu i ortopedia polska,1969. 34(3): p. 357-366.
6. Dega, W. Transiliac osteotomy in the treatment of congenital hip dysplasia. Chirurgia narzadow ruchu i ortopedia polska,1974. 39(5): p. 601-613.
7. Lyu, X., Fu, G., Feng, C., Yang, J., Wang, Y., and Zhu, Z. Clinical and radiological outcomes of combined acetabuloplasty with acetabular redirectional osteotomy and femoral shortening for children older than 9 years of age with developmental dysplasia of the hip: a retrospective case series. Journal of Pediatric Orthopaedics B,2020. 29(5): p. 417-423.
8. Bayhan, I.A., Beng, K., Yildirim, T., Akpinar, E., Ozcan, C., and Yagmurlu, F. Comparison of Salter osteotomy and Tonnis lateral acetabuloplasty with simultaneous open reduction for the treatment of developmental dysplasia of the hip: midterm results. Journal of Pediatric Orthopaedics B,2016. 25(6): p. 493-498.
9. Alassaf, N. Correction of the acetabular index is more crucial than the type of acetabuloplasty in developmental dysplasia. European Journal of Orthopaedic Surgery & Traumatology,2020. 30(4): p. 665-670.
10. Gurger, M., Demir, S., Yilmaz, M., and Once, G. Salter osteotomy without open reduction in the Tönnis type II developmental hip

dysplasia: A retrospective clinical study. Journal of Orthopaedic Surgery,2019. 27(1): p. 2309499019835572.

11. Ito, H., Ooura, H., Kobayashi, M., and Matsuno, T. Middle-term results of Salter innominate osteotomy. Clinical Orthopaedics and Related Research®,2001. 387: p. 156-164.
12. El-Sayed, M.M., Hegazy, M., Abdelatif, N.M., ElGebeily, M.A., ElSobky, T., and Nader, S. Dega osteotomy for the management of developmental dysplasia of the hip in children aged 2–8 years: results of 58 consecutive osteotomies after 13–25 years of follow-up. Journal of children's orthopaedics,2015. 9(3): p. 191-198.
13. Lin, C.-J., Lin, Y.-T., and Lai, K.-A. Intraoperative instability for developmental dysplasia of the hip in children 12 to 18 months of age as a guide to Salter osteotomy. Journal of Pediatric Orthopaedics,2000. 20(5): p. 575-578.
14. Gholve, P.A., Flynn, J.M., Garner, M.R., Millis, M.B., and Kim, Y.-J. Predictors for secondary procedures in walking DDH. Journal of Pediatric Orthopaedics,2012. 32(3): p. 282-289.
15. Morin, C., Bisogno, J., Kulkarni, S., and Morel, G. Treatment of late-presenting developmental dislocation of the hip by progressive orthopaedic reduction and innominate osteotomy. Our results with more than 30 years of follow up. Journal of children's orthopaedics,2011. 5(4): p. 251-260.
16. Tezeren, G., Tukenmez, M., Bulut, O., Cekin, T., and Percin, S. One-stage combined surgery with or without preoperative traction for developmental dislocation of the hip in older children. Journal of Orthopaedic Surgery,2006. 14(3): p. 259-264.
17. Badrinath, R., Bomar, J., Wenger, D., Mubarak, S., and Upasani, V. Comparing the Pemberton osteotomy and modified San Diego acetabuloplasty in developmental dysplasia of the hip. Journal of children's orthopaedics,2019. 13(2): p. 172-179.
18. Ruszkowski, K. and Pucher, A. Simultaneous open reduction and Dega transiliac osteotomy for developmental dislocation of the hip in children under 24 months of age. Journal of pediatric Orthopaedics,2005. 25(5): p. 695-701.
19. Ming-Hua, D., Rui-Jiang, X., and Wen-Chao, L. The high osteotomy cut of Dega procedure for developmental dysplasia of the hip in children under 6 years of age. Der Orthopäde,2016. 45(12): p. 1050-1057.
20. Baki, C., Sener, M., Aydin, H., Yildiz, M., and Saruhan, S. Single-stage open reduction through a medial approach and innominate osteotomy in developmental dysplasia of the hip. The Journal of bone and joint surgery. British volume,2005. 87(3): p. 380-383.
21. Thomas, S.R., Wedge, J.H., and Salter, R.B. Outcome at forty-five years after open reduction and innominate osteotomy for late-presenting developmental dislocation of the hip. JBJS,2007. 89(11): p. 2341-2350.
22. Rocha, V.L.d., Marques, G.L., Silva, L.J.d., Bernardes, T.A.d.M., and Moraes, F.B.d. Clinical and radiographic medium-term evaluation on patients with developmental dysplasia of the hip, who were submitted to open reduction, capsuloplasty and Salter osteotomy , . Revista brasileira de ortopedia,2014. 49: p. 51-55.
23. El-Sayed, M., Ahmed, T., Fathy, S., and Zyton, H. 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. Journal of children's orthopaedics,2012. 6(6): p. 471-477.
24. Bhuyan, B.K. Outcome of one-stage treatment of developmental dysplasia of hip in older children. Indian journal of orthopaedics,2012. 46(5): p. 548-555.
25. Ahmed, E., Mohamed, A.-h., and Wael, H. Tratamento cirúrgico de displasia de desenvolvimento do quadril de apresentação tardia depois da idade da marcha. Acta ortopedica brasileira,2013. 21: p. 276-280.
26. Kaneko, H., Kitoh, H., Mishima, K., Matsushita, M., Kadono, I., Ishiguro, N., and Hattori, T. Factors associated with an unfavourable outcome after Salter innominate osteotomy in patients with unilateral developmental dysplasia of the hip: Does occult dysplasia of the contralateral hip affect the outcome? The bone & joint journal,2014. 96(10): p. 1419-1423.
27. Rampal, V., Klein, C., Arellano, E., Boubakeur, Y., Seringe, R., Glorion, C., and Wicart, P. Outcomes of modified Dega acetabuloplasty in acetabular dysplasia related to developmental dislocation of the hip. Orthopaedics & Traumatology: Surgery & Research,2014. 100(2): p. 207-211.
28. Kotzias, A., Ferraz, A., Foresti, F.B., and Hoffmann, R.B. Bilateral developmental dysplasia of the hip treated with open reduction and Salter osteotomy: analysis on the radiographic results . Revista brasileira de ortopedia,2014. 49: p. 350-358.
29. Chang, C.-H., Yang, W.-E., Kao, H.-K., Lee, W.-C., Shih, C.-H., and Kuo, K.N. Prognostic radiographic factors in developmental dysplasia of the hip following Salter osteotomy. Journal of Pediatric Orthopaedics B,2015. 24(1): p. 31-34.
30. Baghdadi, T., Bagheri, N., Khabiri, S.S., and Kalantar, H. The outcome of salter innominate osteotomy for developmental hip dysplasia before and after 3 years old. Archives of Bone and Joint Surgery,2018. 6(4): p. 318.
31. Kenanidis, E., Gkekas, N.K., Karasmani, A., Anagnostis, P., Christofilopoulos, P., and Tsiridis, E. Genetic predisposition to developmental dysplasia of the hip. The Journal of arthroplasty,2020. 35(1): p. 291-300. e1.
32. Ortiz-Neira, C.L., Paolucci, E.O., and Donnon, T. A meta-analysis of common risk factors associated with the diagnosis of developmental dysplasia of the hip in newborns. European journal of radiology,2012. 81(3): p. e344-e351.
33. Roof, A.C., Jinguji, T.M., and White, K.K. Musculoskeletal screening: developmental dysplasia of the hip. Pediatric annals,2013. 42(11): p. e238-e244.
34. Frank, J.S., Gambacorta, P.L., and Eisner, E.A. Hip pathology in the adolescent athlete. JAAOS-Journal of the American Academy of Orthopaedic Surgeons,2013. 21(11): p. 665-674.
35. Wyles, C.C., Heidenreich, M.J., Jeng, J., Larson, D.R., Trousdale, R.T., and Sierra, R.J. The John Charnley Award: redefining the natural history of osteoarthritis in patients with hip dysplasia and impingement. Clinical Orthopaedics and Related Research®,2017. 475(2): p. 336-350.
36. Bittersohl, B., Hosalkar, H.S., and Wenger, D.R. Surgical treatment of hip dysplasia in children and adolescents. Orthopedic Clinics,2012. 43(3): p. 301-315.
37. Kraeutler, M.J., Garabekyan, T., Pascual-Garrido, C., and Mei-Dan, O. Hip instability: a review of hip dysplasia and other contributing factors. Muscles, ligaments and tendons journal,2016. 6(3): p. 343.
38. Salter, R.B., Hansson, G., and THOMPsoN, G.H. Innominate osteotomy in the management of residual congenital subluxation of the hip in young adults. Clinical orthopaedics and related research,1984. (182): p. 53-68.
39. Wang, C.-W., Wu, K.-W., Wang, T.-M., Huang, S.-C., and Kuo, K.N. Comparison of acetabular anterior coverage after Salter osteotomy and Pemberton acetabuloplasty: a long-term followup. Clinical Orthopaedics and Related Research®,2014. 472(3): p. 1001-1009.
40. Gala, L., Clohisy, J.C., and Beaulé, P.E. Hip dysplasia in the young adult. JBJS,2016. 98(1): p. 63-73.
41. Lalonde, F.D., Frick, S.L., and Wenger, D.R. Surgical correction of residual hip dysplasia in two pediatric age-groups. JBJS,2002. 84(7): p. 1148-1156.