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Revision of Outcomes and Complications Following Open Reduction, and Zigzag Osteotomy Combined with Fibular Allograft for Developmental Dysplasia of the Hip in Children

Nguyen Ngoc Hung

Vietnam National Hospital for Pediatrics, Hanoi, Vietnam
Email: ngocyenhung@gmail.com

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Abstract

Background: Reports of the efficacy of open reduction and Zigzag Osteotomy combined Fibular Allograft (ZOFA) for developmental dysplasia of the hip. The purposes of this study were to evaluate the long-term outcomes and complications after surgery. Methods: We performed a retrospective match-controlled study in which 158 patients had 181 hips with developmental dysplasia of the hip. Radiographs were found of acetabular index, height of dislocation, Tönnis grade, abduction angle in the spica cast, and Severin grade. At final follow-up, deformity of femoral head or neck or acetabulum was evaluated according to the Severin. Avascular necrosis was rated according to Kalamchi. Clinical evaluation was made according to modified McKay criteria. Results: Between 2009 and 2012, 133 girls (84.2%) and 25 boys (15.8%) with developmental dysplasia of the hip underwent open reduction and ZOFA; 135 (85.4%) were unilateral, and 23 (14.6%) were bilateral. Patients were divided into 2 groups: group 1 included 54 patients (62 hips) aged 12 months - ≤18 months and group 2 included 84 patients (119 hips), aged >18 months - ≤36 months. According to Tönnis system: type 3 appeared in 127 hips (70.2%), and Type 4 in 54 hip (29.8%). The anterior approach was used to expose inner table of the ilium and ZOFA in all cases. Acetabular index was improved; preoperation was 42.95˚, and latest follow-up 17.26˚. The Kirschner Wires (KW) were not used to fix the fibular allograft at the pelvic osteotomy site. All of the fibular allografts were completely incorporated in mean time of 14 weeks (range, 12 weeks - 17 weeks) post-surgery. Clinical evaluation according to modified McKay criteria: satisfactory result (excellent and good) was achieved in 141 hips (77.9%). Avascular Necrosis (AVN) happened in 61 hips (33.7%), redislocation in 18 hips (9.9%), coxa vara in 4 hips (2.2%), trendelenburg gait in 4 hips (2.2%), and supracondylar femoral fractures in 2 hips (1.1%). Conclusions: On the basis of this

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study, ZOFA was strength and graft was not resorption, graft problems; without medial displacement of the distal fragment. Acetabular index was improved, without KW problem. Surgical technique with ZOFA did not expose outer table of the illium, limiting abductor muscle injury with negative trendelenburg gait; on the other hand, the blood loss from this procedure is acceptable. Some complications have been seen in this study: AVN, redislocation, coxa magna, coxa vara, trendelenburg gait, and distal femoral fracture.

Keywords

DDH, Redislocation, Revision Surgery, Hip Dysplasia, Bone Allograft, Salter's Osteotomy, Avascular Necrosis

1. Introduction

The management of developmental dysplasia of the hip aims at early diagnosis and treatment. It is claimed that adequate acetabular remodelling is possible only during the first 18 months of life. After this, satisfactory development cannot always be assured by non-operative treatment following closed reduction [1]. Many methods of management have been described, but all have complications and result in a proportion of hips which develop imperfectly [2].

Innominate osteotomy was originally designed for children with delayed presentation of developmental hip dysplasia and those in whom earlier treatment had failed to produce remodelling [3]. Reorientation of the acetabulum makes the reduced hip more stable, increases the load-bearing area of the acetabulum in the weight-bearing position, and does not alter its shape or volume. Many surgical procedures have been described for the management of these late-presenting cases [4]. Salter [5], 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 [5], as an acetabuloplasty that changes the acetabular configuration and its inclination.

Since its first description by Hey Groves and Ombrédanne [6] [7] femoral shortening osteotomy has become increasingly popular as an adjunct in the open treatment of Developmental Dislocation of the Hip (DDH). Femoral shortening effectively lengthens the muscles surrounding the hip, thereby reducing the force required to achieve concentric reduction [8]. The use of femoral shortening has been shown to decrease the complications associated with open reduction, particularly redislocation and Avascular Necrosis (AVN) [9]. Developmental dysplasia of hip is a common condition presenting to a pediatric orthopedic surgeon. Early management is of utmost importance to achieve normal development of hip and prevent residual acetabular dysplasia. In infants below 6 months of age, Pavlik harness is the gold standard of treatment. Once the child achieves walking age, treatment becomes more extensive. In the management of age group 18 - 24 months, a majority of surgeons agree on open reduction and hip spica and a supplementary procedure like a proximal femoral osteotomy is usually not necessary in this age group [10].

In the older child the reduction of hip is difficult because of adaptive shortening of the extraarticular soft tissues, acetabular dysplasia, capsular constriction, increased femoral anteversion, fibrofatty tissue in the acetabulum, hypertrophied ligamentum teres, and fixed inversion of limbus. If left untreated, these dysplastic changes lead to osteoarthritis in early adulthood [11]. Complications that can accompany surgical treatment of Developmental Dysplasia of the Hip (DDH) include subluxation-redislocation, KW migration, implant loss, AVN of the femoral head, lower limb discrepancy, infection, joint stiffness, malunion or nonunion of the osteotomy line, graft problems, lateralization defects of the femoral head, and sciatic nerve damage.

The purpose of this study was to review the clinical and radiological outcome, and to assess the incidence of complications following open reduction and ZOFA.

2. Material and Methods

After obtaining approval from our institutional review board, we queried the surgical database at our center to identify all patients who had undergone an open reduction for the treatment of DDH with ZOFA [12]. Patients with teratologic dislocations, neuromuscular or connective tissue disorders, and those patients with a history of a previous open hip procedure at another institution were excluded from the study. Patients with Tonnis grades I and II were excluded from this study. Only patients presenting with grades III and IV were included in study. This study was retrospective evaluating results and complications following ZOFA. This study group was composed of patients with a diagnosis of DDH who were operated on between 2009 and 2012. The operations were performed by a single surgeon (Author) and the evaluation by two independent orthopaedic surgeons, who were not members of the department.

Informed consent was obtained from all participants. The study had the approval of the Ethical Review Committee of our Institute and was carried out in accordance with the tenets of the Declaration of Helsinki.

Between 2009 and 2012, 133 girls (84.2%) and 25 boys (15.2%) with DDH underwent open reduction and ZOFA [12]; 135 (85.4%) were unilateral, and 23 (14.6%) were bilateral. Patients were divided into 2 groups: group 1 included 54 patients (62 hips) aged from 12 months - ≤18 months and group 2 included 84 patients (119 hips), aged from >18 months - ≤36 months. There were 118 (74.7%) of the patients were girls and 40 (27.3%) were boys. None had preoperative skin or skeletal traction, nor derotational varus or valgus osteotomies. The patient was performed at a mean age of 21.5 months (12 to 36) and the mean age at final follow-up was 69.7 months (58 to 105) and the mean time follow-up was 32.6 months (24 to 76).

Dislocations of the hip were graded using the Tönnis system [13].

Grade	Criteria
1	Capital femoral epiphysis medial to Perkins line
2	Capital femoral epiphysis lateral to Perkins line but below the level of the superior acetabular rim
3	Capital femoral epiphysis at the level of the superior acetabular rim
4	Capital femoral epiphysis above the level of the superior acetabular rim

2.1. The Acetabular Index Angle

The acetabular index was measured as the main variable to evaluate the correction of the acetabular dysplasia and the subsequent maintenance thereof. The term acetabular index was introced by Kleinberg and Lieberman of New York in 1936 to mane a radiograohic sign [14]. "The angle formed between the roof or iliac portion of the acetabulum and a horizontal line passing through the triradiate cartilages".

The AI was measured pre-operatively, immediate post-operatively and at 3 months, 6 months, 1 year, 2 years, and latest follow-up.

2.2. Femoral Neck Anteversion Angle

The angle of torsion is called anteversion, anterotation, or anterior twist; similarly, if it points backward (posterior to the transcondylar plane), it is called retroversion, retrotorsion, or posterior twist [15].

There are many imaging methods described and used for measuring femoral anteversion, we agree Ruby's opinion favor the use of the Ryder-Crane technique [16].

Biplanar method (Ryder-Crane) [16]: With this technique, all roentgenograms are made with the patient supine. The X-ray tube is positioned directly over the hip. One roentgenogram is made with the limb in neutral position (extended) and a second with the hips and knees flexed to 90 degrees and with the thighs abducted to 30 degrees, the position being maintained by a specially constructed box. Lines representing the axis of the neck and the shaft of the femur are drawn of the first roentgenogram. This is the apparent angle of torsion. The true torsion is determined by reference to a standard table of angles de rived from trigonometric considerations.

2.3. Femoral Shaft-Neck Angle

Using the AP view of the hip, angle formed by axis of femoral shaft and line drawn along axis of femoral neck passing through center of head of femur.

2.4. Acetabular Anteversion Angle

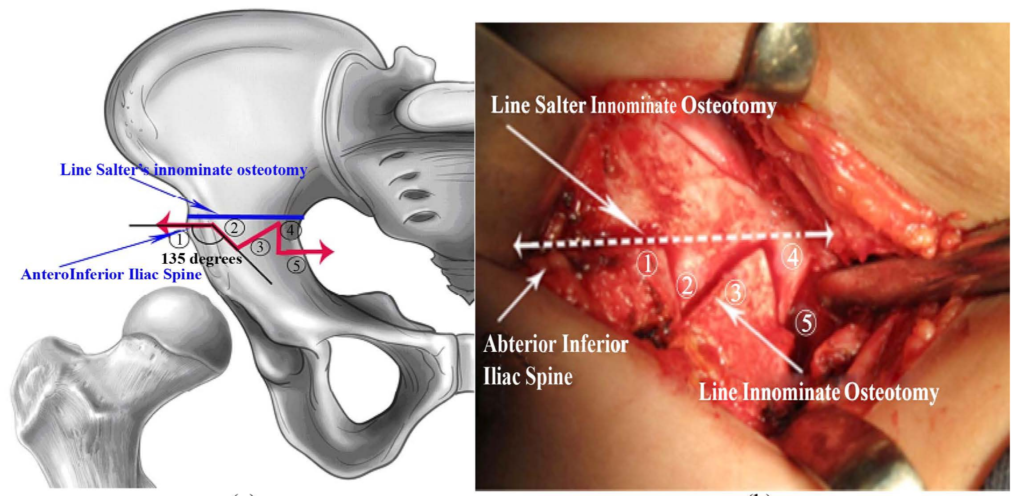
AAV was analyzed in the axial sections placed parallel to the pelvic obliquity showing both the triradiate cartilages. AAV was expressed as the angle between a line perpendicular to the trans-triradiate line and a line drawn across the margins of the acetabulum, from its posterior to anterior edge [17] 30 to 40 degrees is the normal range for the McKibbin instability index [18].

We elected not to use the central-edge angle of Weiberg (CE angle), as the femoral heads in the majority of hips were partially ossified.

2.5. Surgical Technique

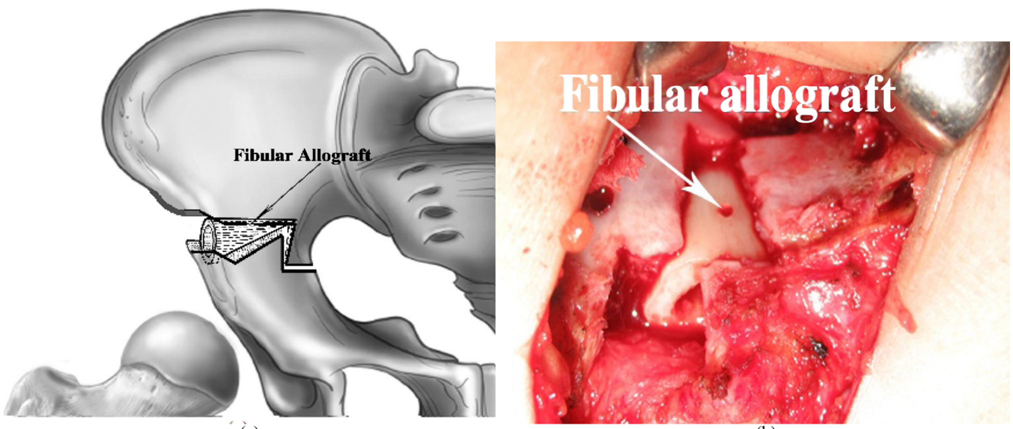
No traction was applied to the hip before the operation. The patients are operated on in the supine position with a sandbag under the ipsilateral hip. An anterolateral approach is used. The bikini (modified ilioinguinal) anterior approach was used in all the studied cases [12], while the femoral osteotomy was performed through a separate direct lateral approach and incision to the proximal femur in indicated cases. The straight head of the rectus femoris is elevated from the anterior inferior iliac spine and the reflected head transected. The iliopsoas tendon is divided at the pelvic brim. When open reduction is necessary, a “T”-shaped capsulotomy is performed with the stem of the T horizontal rather than in line with the neck. Care is taken to extend the capsulotomy as medial as possible. The ligamentum teres and the transverse acetabular ligament are excised.

Secondary to the zigzag of the osteotomy, line ostotomy is opened by using towel clips on both sides [12] (cf. **Figure 1(a)** & **Figure 1(b)**). A fibular allograft with sides approximately 12 - 15 mm × 20 - 25 mm long, and is placed into the osteotomy perpendicular to the weight-bearing axis (cf. **Figure 2(a)** & **Figure 2(b)**). The stability is tested in the mediolateral direction and by a push-pull test, pushing the ipsilateral hip upwards.



(a) (b)

Figure 1. (a) Outlining the iliac osteotomy; (b) Line osteotomy of the ilium.



(a) (b)

Figure 2. (a) (b) Fibular allograft is placed between the two iliac fragments.

Before capsulorraphy, to maintain concentric reduction, the hip was applied in position with hip in 30 degrees of flexion, 50 degrees of abduction, and 20 degrees of internal rotation. The Kirschner wires was passed through the greater trochanter and into the ilium above the capsule after capsulorrhaphy and was retained seven days.

2.6. Femoral Shortening

Femoral shortening should be performed 10 - 12 weeks after ZOFA, pre-operation with high dislocation and femoral neck-shaft angle more 150 degrees.

Through a separate lateral approach, the proximal end of the femur was exposed subperiosteally and a transverse osteotomy was made in the subtrochanteric region [12]. The two femoral fragments were allowed to overlap, and reduction was obtained quite easily. A segment of femur that was 1 to 1.5 centimeters long, sufficient to relieve the muscular tension across the hip joint, was then removed. If, at the time of the trial reduction of the hip, internal rotation of the femur seemed to contribute to stability of the joint, derotation was achieved by externally rotating the distal femoral fragment in relation to the proximal fragment before applying the plate. We believe that it is important to avoid excessive derotation of the femur, especially if an acetabular procedure is anticipated, as posterior instability may result. The osteotomy is then fixed rigidly with a pediatric blade-plate or a 3.5 dynamic-compression plate.

2.7. Postoperative Care

The double spica cast was applied immediately after surgery, hip in 30 degrees of flexion, 50 degrees of abduction, and 20 degrees of internal rotation.

Three months after surgery, the entire cast is removed, and Patients is gradually weaned haft spica cast it only at night and nap time until acetabular development is normal. The haft spica cast is usually worn for an average of 12 to 24 months after surgery. Weight bearing was not allowed until radiographic evidence of healing of the osteotomy site was obtained.

In bilateral cases, the other hip was operated upon after 3 months from the first side, and then the hip spica cast was applied for immobilization of both hips.

The allograft was considered to have been stable if the correction of the dysplastic acetabulum was maintained during the 2-year post-operative period and non extrusion of the graft had occurred from the osteotomy site. Fibular allograft incorporation into the ilium was considered to have taken place if complete union at the osteotomy site had occurred and confluence of the graft to the ilium was evident on the X-rays.

2.8. Evaluating Result

The patients were scheduled to return to the outpatient clinic at three months intervals during the first day postoperatively and at 3 months, 6 months, 1 year, and 2 years after surgery and then at yearly intervals. The patients were evaluated clinically during each visit as to the range of motion of the affected hip, the quality of gait, Trendelenburg test, and the presence of any pain. Radiographs of each hip were made to assess the quality of reduction, the acetabular index, and the presence or absence of avascular necrosis. Each patient's preoperative radiographs were evaluated to determine the affected hip's acetabular index and station.

Limb length discrepancy can be measured by a physician during a physical examination and through X-rays. Usually, the physician measures the level of the hips when the child is standing barefoot. A series of measured wooden blocks may be placed under the short leg until the hips are level. If the physician believes a more precise measurement is needed, he or she may use X-rays. In growing children, a physician may repeat the physical examination and X-rays every six months to a year to see if the limb length discrepancy has increased or remained unchanged.

Assessment of AVN of the femoral head was performed according to Kalamchi and MacEwen's classification [19]: Grade 1: Changes affecting the ossific nucleus; Grade 2: Lateral physeal damage; Grade 3: Central physeal damage; Grade 4: Total damage to the head and physis.

Details of radiological according to the Severin [20] was used for the radiologic assessment of postoperative results: Gade 1: Normal; Grade 2: Moderate deformity of femoral head or neck or acetabulum; Grade 3: Dysplastic no subluxed; Grade 4: Subluxed; Grade 5: Head articulating with secondary acetabulum in upper of the original acetabulum; Grade 6: Dislocated; Grade 7: Arthritic.

Barrett's modification of McKay's criteria [21] was used for the clinical assessment of postoperative results: Excelent result: Stable, painless hip, no limp, negative Trendelenburg sign, full range of motion. Good result: Stable, painless hip, slight limp, slight degree in range of motion. Fair result: Stable, painless hip, limp, positive Trendelenburg sign, and limited range of motion, or a combination of these. Poor result: Unstable or painful hip, or both; positive Trendelenburg sign.

2.9. Method of Statistical Analysis

Statistical analysis was done using the statistical program for social sciences (SPSS)-version 9.0. T-test was used to analyze the relations between the obtained results and the different variables. Five percent level of significance was chosen.

3. Result

Between 2009 and 2012, 133 girls (84.2%) and 25 boys (15.2%) with DDH underwent open reduction and ZOFA [12]; 135 (85.4%) were unilateral, and 23 (14.6%) were bilateral. Patients were divided into 2 groups: group 1 included 54 patients (62 hips) aged from 12 months - ≤18 months and group 2 included 84 patients (119 hips), aged from >18 months - ≤36 months. There were 118 (74.7%) of the patients were girls and 40 (27.3%) were boys.

None had preoperative skin or skeletal traction, nor derotational varus or valgus osteotomies or shortening procedures for initially operation in 139 hips, and second operation with femoral osteotomy in 42 hips.

Tönnis system Type 3 in 127 hips (70.2%), and Type 4 in 54 hip (29.8%).

The anterior approach was used to expose inner table of the ilium and Zigzag osteotomy combined with fibular allograft with fibular allografting in all cases.

The KW did not use to fix the fibular allograft at the pelvic osteotomy site.

All of the fibulat allografts were completely incorporated mean 14 weeks (range, 12 weeks - 17 weeks) postsurgery (cf. Figures 3(a)-(c)). Without graft was related infections.

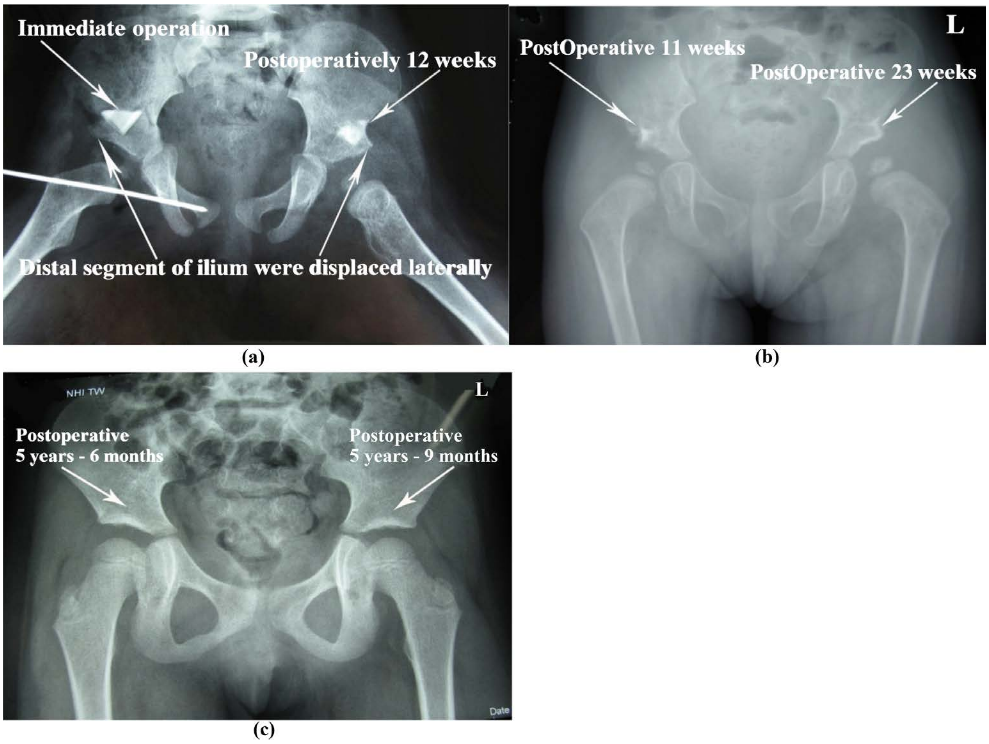


Figure 3. Potoerativly, (a) Left hip, postoperatively 12 weeks; right hip, imeediate operation; (b) Left hip, postoperatively 23 weeks; right hip, postoperatively 11 weeks; (c) Left hip, postoperatively 5 years - 9 months; right hip, postoperatively 5 years - 6 months.

The average operative time was 95 min (range 80 - 105 min). Radiographs were made preoperatively, and immediately postoperatively.

The blood loss from this procedure is acceptable. Post-operative blood transfusion was no required.

The preoperative Acetabular Indices, mean was 42.957˚, ranged from 36.17˚ to 51.56˚ (SD = 4.4046). Compared AI Preoperation and AI Immediate postoperation with P *valuate* is 0.0000001; AI Immediate postoperation and AI Postoperative 3 months with P *valuate* is 0.0000001; AI Postoperative 3 months and AI Postoperative 6 months with P *valuate* is 0.0000001; AI Postoperative 6 months and AI Postoperative 12 months with P *valuate* is 0.0000001; AI Postoperative 12 months and AI Postoperative 24 months with P *valuate* is 0.0000001; AI Postoperative 24 months and AI latest follow-up with P *valuate* is 0.202263.

In **Table 1**: Femoral Neck angle: Average 27.726˚ (SD = 12.153), Shaft—Neck angle: Average 149.649˚ (SD = 5.815), Acetabular Anteversion: Average: 21.233˚ (SD = 5.264).

In **Table 2**: Adductor tenotomy: 132 (94.9%); Poas tendon: 124 (89.2%); Ligamentum teres: 129 (82.86%); Transverse acetabular ligament: 129 (82.2%); Pulvinar: 132 (94.4%); Capsulorraphy: 139 (100.0%); Kirschner: 139 (100.0%).

Open reduction and ZOFA performed initially operation and Femoral shortening osteotomy performed after initally operation 3 months.

In **Table 3**: Adductor tenotomy: 37 (88.1%), Psoas tendon: 35 (83.3%), Ligamentum teres present: 38 (90.5%), Puvinar present: 39 (92.9%), Transverse ligament present: 37 (81.1%), Capsulorrhaphy: 42 (100.0%), Kirschner wire: 42 (100.0%), Femoral shortening: 42 (100.0%).

Table 1. Comparision of acetabular index preoperative and lastest fellow-up.

Acetabular index	Preope*. AI	Immediate postope. AI*	Postope*. AI 3 months	Postope. AI 6 months	Postope. AI 12 months	Postope. AI 24 months	AI latest follow-up
Mean	42.95˚	24.56˚	22.91˚	21.70˚	20.54˚	19.45˚	17.26˚
SD	4.404	2.5452	2.0702	2.280	1.798	1.7308	1.6033
Range	36.17˚ - 51.56˚	18.92˚ - 30.52˚	18.36˚ - 28.10˚	16.64˚ - 26.35˚	15.26˚ - 25.38˚	16.14˚ - 23.43˚	14.08˚ - 19.35˚

*Preope.: Preoperative. *Postope.: Postoperative. *AI: Acetabular Index.

Table 2. Details of primery treatment and later operations in 139 hips with congenital dislocation requiring repeat open reduction with ZOFA without femoral shortening osteotomy.

Age	No patient		No hip	Side		Primery operation						
	Unilateral (%)	Bilateral (%)		R (%)	L (%)	AT (%)	PS (%)	LT (%)	PV (%)	TL (%)	CR (%)	KW (%)
Group 1	36 (85.7)	6 (14.3)	48	12 (25.0)	36 (75.0)	46 (95.8)	46 (95.8)	45 (93.8)	44 (91,7)	47 (97.9)	48 (100.0)	48 (100.0)
Group 2	67 (84.8)	12 (15.2)	91	20	71	86 (94.5)	78 (85.7)	84 (92.3)	88 (96.7)	82 (90.1)	91 (100.0)	91 (100.0)
	103 (85.1)	18 (14.9)	139	32	107	132 (94.9)	124 (89.2)	129 (82.8)	132 (94.9)	129 (82.2)	139 (100.0)	139 (100.0)

AT: Adductor tenotomy; LT: Ligamentum teres present; PS: Psoas tendon; PV: Puvinar present; TL: Transverse ligament present; CR: Capsulorrhaphy; KW: Kirschner wire was passed through the greater trochanter and into the ilium.

Table 3. Second operation with femoral shortening after initally operation 3 months.

Age	No. patient		No. hip	Side		Primery operation							
	Unila. (%)	Bila. (%)		R (%)	L (%)	AT (%)	PS (%)	LT (%)	PV (%)	TL (%)	CR (%)	KW (%)	FS (%)
Group 1	10	2	14	5	9	11	10	12	13	12	14	14	14
Group 2	22	3	28	6	22	26	25	26	26	25	28	28	28
	32 (86.5)	5 (13.5)	42	11 (26.2)	31 (73.8)	37 (88.1)	35 (83.3)	38 (90.5)	39 (92.9)	37 (88.1)	42 (100.0)	42 (100.0)	42 (100.0)

Unila.: Unilateral; Bila.: Bilateral; R: Right; LO: Left; AT: Adductor tenotomy; LT: Ligamentum teres present; PS: Psoas tendon; PV: Puvinar present; TL: Transverse ligament present; CR: Capsulorrhaphy; KW: Kirschner wire was passed through the greater trochanter and into the ilium ; FS: Femoral shortening.

In **Table 4**: Deformity of femoral head or neck or acetabulum according to Severin with Grade 1: 127 (70.2%), Grade 2: 36 (19.9%), Grade 4: 16 (8.8%), Grade 6: 2 (1.1%); in Primery Operation 47 hips (32.4%), Femoral Shortening 7 hips (16.7%).

Compared according to classification of Severin, deformity of femoral, head or neck or acetabulum in Grade 1 of Primery Operation group hips (66.2%) more than Femoral Shortening group 35 hips (83.3%) (P *valuate* is 0.033308).

In **Table 5**: AVN Classification according to the Kalamchi with Grade I: 5 (8.3%), Grade II: 42 (70%), Grade III: 13 (21.7%). In this study with AVN: 61 (33.1%). AVN in Primery Operation group 45 hips (32.4%), AVN in Femoral Shortening group 16 hips (38.1%).

Compared AVN according to Kalamchi of Primery Operation group 45 hips (32.4%) AVN and Femoral Shortening group 16 hips (38.1%) AVN, did not differ significantly between the two groups (P *valuate* is 0.491842).

In **Table 6**: Deficiency of leg length 1 cm: 168 (92.8%), Deficiency 2 cm: 12 (6.6%), Deficiency 3 cm: 1 (0.5%). Deficiency of leg length in 12 (6.6%). Total: 12 hips (6.6%) and mean 1.5 cm (1 - 3 cm). Deficiency of leg length in Primery Operation group 8 hips (5.8%), Femoral Shortening group 4 hips (9.5%).

Compared Deficiency of normal leg length of Primery Operation group 131 hips (92.2%) and Femoral Shortening group 38 hips (90.5%) did not differ significantly between the two groups (P *valuate* is 0.0990146).

In **Table 7**: Clinical evaluation according to modified McKay criteria**:** Excellent 113 (62.4%), Good 28 (15.5%), Fair 22 (12.2%), Poor: 18 (9.9%). Satisfy Results (Excellent and Good) in Primery Operation group 105 hips (75.5%) and Femoral Shortening group 36 hips (85.7%).

Compared Clinical evaluation according to modified McKay criteria of Satisfy Results in Primery Operation group 105 hips (75.5%) and Femoral Shortening group 36 hips (85.7%), did not differ significantly between the two groups (P *valuate* is 0.163714).

Complications:

1) Redislocation: 18 hips (9.9%)

Table 4. Deformity of femoral head or neck or acetabulum according to Severin [20].

	Number hip	Classification according to Severin						
		1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)	7 (%)
Primery operation	139	92 (66.2)	31 (22.3)		14 (10.1)		2 (1.4)	
Femoral shortening	42	35 (83.3)	5 (11.9)		2 (4.8)			
	181	127 (70.2)	36 (19.9)		16 (8.8)		2 (1.1)	

Table 5. Avascular necrosis according to Kalamchi [19].

	No. hip AVN	Classification according to Kalamchi			
		I	II	III	IV
Primery operation (n = 139)	45 (32.4%)	4	31	10	0
Femoral shortening (n = 42)	16 (38.1%)	1	12	3	
	61 (33.7%)	5 (8.3%)	42 (70.0%)	13 (21.7%)	

Table 6. Deficiency of leg length.

	Number hip	Deficiency of leg length (cm)				
		Normal (%)	1 (%)	2 (%)	3 (%)	4 (%)
Primery operation	139	131 (92.2)	6	1	1	
Femoral shortening	42	38 (90.5)	1	3		
	181	169 (93.4)	7 (3.9)	4 (2.2)	1 (0.5)	

Table 7. Clinical evaluation according to modified McKay criteria [21].

	Number hip	Modified McKay criteria for clinical evaluation			
		Excellent (%)	Good (%)	Fair (%)	Poor (%)
Primery operation	139	84 (60.4)	21 (15.1)	18 (12.9)	16 (11.6)
Femoral shortening	42	29 (69.1)	7 (16.6)	4 (9.5)	2 (4.8)
	181	113 (62.4)	28 (15.5)	22 (12.2)	18 (9.9)

2) Avascular necrosis: 61 hips (33.7%)
3) Coxa magna: 4 hips (2.2%)
4) Coxa vara: 4 hips (2.2%)
5) Infection: O
6) Fracture: 2 hips (1.1%)
7) Trendelenburg gait: 4 hips (2.2%)
8) Sciatic nerve damage: O

We performed ZOFA, did not use KW to fix the fibular allograft at the pelvic osteotomy site, so don't have some complications such as: KW migration, KW luxation/breakage, implant loss, graft problems, medial displacement of the distal fragment.

4. Discussion

4.1. Zigzag Osteotomy Combined Fibular Allograft

Bone grafts are widely used in paediatric orthopaedic surgery. Autogenous bone grafts remain the "gold standard" in reconstructive surgery because of their osteoinductive, osteoconductive, and non-immunogenic properties. The iliac crest is the most common donor site because of easy access and procurement, and availability of large quantities of both cortical and cancellous bone.

Trevor DLJ and Fixen JA. 1975 [22] performing cetabuloplasty in the treatment of Congenital Dislocation of the hip with use of bone bank rib grafts. Kessler *et al*. 2001 [23] use of allografts in Pemberton osteotomies with patellar allograft wedges, which allows good correction of acetabular dysplasia with immediate graft stability. Grudziak and Ward. 2001 [5] with the height of the graft can be increased by utilizing freeze-dried fibular allograft cut into trapezoidal sections in Dega osteotomy. Wade 2010 [24], used iliac crest allograft interposition for pericapsular acetabuloplasty in developmental dislocation of the hip. In this study, we used single fibular allograft only.

Radiological evaluation demonstrated that ZOFA produced similar results to the original osteotomy [12]. The acetabular index was restored to within normal limits in the immediate post-operative period and continued to improve thereafter. Bohm and Brzuske [25] reported a mean of 11.9˚ of correction with a Salter osteotomy. Ito *et al*. [26] reported a mean 16.4˚ improvement in the acetabular index. The mean correction of 17.26˚ in this series was comparable to those reported in the literature. Rab [27] estimated that the Salter innominate osteotomy provides about 15 degrees of lateral coverage and 25 degrees of anterior coverage, although many clinicians believe that more lateral coverage can be obtained. In this study was comparable to those reported in the literature. In the literature, the rate of graft displacement ranges between 0% and 17% [21]. In ZOFA, the rate of graft displacement was 0%. This postoperative result of graft may be the result of the care taken to verify the stability of the graft with this technique. An initial increased acetabular index reflects the absence of normally located femoral epiphysis and its stimulus in the acetabulum [10]. This may indicate that this complication is a real failure of the previous closed and open reduction, instead of a redislocation, when some acetabular improvement must appear in acetabular index values. In this study, the mean correction of 17.26˚ (range, 14.08˚ - 19.35˚) (see **Table 1**), we demonstrated that acetabular index was continued to improve.

However, there remain some associated problems. One is the need for internal fixation to control the graft and the distal fragment. Complications of fixation include pin breakage, joint penetration, and pin migration with or without secondary graft displacement [28]. In some children, the iliac crest may be very thin and the pins used for internal fixation may damage the graft itself. A second operation to remove the pins is necessary. In this retrospective study, we present a ZOFA which is relatively stable and does not require internal fixation (see **Table 2**).

The authors have, over the years, not been satisfied that iliac crest autograft as the interposition material for the osteotomy is structurally sound and sufficiently stable. Problems such as graft extrusion, rotation and absorption, leading to loss of acetabular correction, were often noted in cases previously treated at the our National Hospital for Pediatrics, without those complications in this study.

The fibular allograft is contoured to conform to the configuration of the osteotomy site. This like triangular configuration of the contoured allograft and the substantial surface area there of due to its width contributes to the stability of the graft, which is further augmented by the inherent recoil plasticity of the acetabulum roof. There are two bar osseous and two slots in proximal and distal segment of the ilium, this stability is evident intra-operatively by the graft not being able to be translated or rotated or sliped. This exceptional graft stability eliminates the need for routine internal fixation of the osteotomy. Graft extrusion or displacement was not encountered in our series.

The original SIO describes both tables of the ilium to be exposed, which increases the amount of intra-operative bleeding [25]. Our technique did not expose outer table of the ilium, the blood loss from this procedure is acceptable. Post-operative blood transfusion was no required.

4.2. Femoral Osteotomy

Femoral shortening as an aid to treatment of longstanding dislocation of the hip was first described by Ombrédanne in 1923 [7], interest in this therapeutic modality has been evident in several recent reports, all of which demonstrated that femoral shortening is useful in facilitating the reduction of a congenitally dislocated hip in children, and that it leads to better results as compared with traction [29] (see **Table 3**).

The next stage in the treatment was to correct excessive femoral anteversion since they believed that reduction could be stabilised by this manoeuvre. The belief that a rotation osteotomy conferred stability is based on the assumption that a deeply placed and correctly centred femoral head stimulates normal growth of the dysplastic acetabulum. Indeed, Harris *et al*. [30] suggested that, following congruent reduction, 95% of acetabula would develop normally in children up to four years old. In essence, our present long-term review tests that belief. The high proportion of hips that, at follow-up, proved to have dysplastic acetabula or to be subluxated once again must call into question this assumption. Pre-existing flattening of the posterior part of the femoral head, which articulates with the side wall of the pelvis, contributes to oval malformation of the head. With rotation and abduction, the thickened anterior cartilage is placed medially in the acetabulum, and it is not uncommon to see a second ossific nucleus appear in this area. Furthermore, because of the femoral head asymmetry, rotation may not allow the instant centre to be placed centrally in the acetabulum. This failure to centralise the femoral head predisposes to persistent and indeed progressive anterolateral subluxation. Deformity of femoral head or neck or acetabulum according to Severin with Grade 1: 127 (70.2%), Grade 2: 36 (19.9%), Grade 4: 16 (8.8%), Grade 6: 2 (1.1%) (see **Table 4**). Compared according to classification of Severin, deformity of femoral, head or neck or acetabulum in Primery Operation group were more than Femoral Shortening group (P *valuate* is 0.0330). This problem saw Femoral osteotomy was not affective ratio of Deformity of femoral head or neck or acetabulum.

Klisic and Jancovic [31] reported good results with femoral shortening in a series of patients older than 5 years of age, whereas Galpin *et al*. [8] performed femoral shortening osteotomies in all children over 2 years of age. Wenger *et al*. [9] have even advocated femoral shortening in certain children younger than 2 years of age. In this study, we performing femoral shortening osteotomy in children younger than 2 years of age (see **Table 5**) and Compared AVN according to Kalamchi of Primery Operation group and Femoral Shortening group did not differ significantly between the two groups (P *valuate* is 0.6869).

Massie and Howorth [32], as well as Durham [33], recommended that a femur with an anteversion of more than +45 degrees should be corrected by osteotomy; Sankar *et al*. in 2011 [34] derotation of the femur is planned if there is more than 50 degrees of femoral anteversion. while Warndorf [35] only did a correctional osteotomy if it was +60 degrees or over, and Badgley in 1943 [36] with femoral anteversion in excess of 60 degrees as determined at the time of open reduction is considered an indication for derotational osteotomy. This was done either before or after reduction. Hibbs, in 1915 [37], also advocated the osteotomy, often times before reduction; however, Farrell, von Lackum, and Smith, in 1926 [38], from Hibbs Clinic, wrote that ordinarily osteotomy should not be done until after the hip had been reduced. Others, such as Lorenz [39], Bradford [40], Soutter [41], and Compere and Schnute [42], were of the opinion that an osteotomy is not necessary for a good result and that the anteversion will usually correct itself. Lorenz, in 1905 [39], went so far as to say that operative correction of the anteversion may lead to a posterior subluxation. Bradford, in 1923 [40] wrote that, if the reduction has been complete and stable, locomotion and joint function becomes normal despite the femoral twist which tends to correct itself after reduction. Soutter and Lovett, in 1924 [41], stated that, in their experience, cases of congenital dislocation with extreme torsion have improved markedly after two or three years of weight-bearing. Fairbank, in 1930 [42], stated that, if the hip is reduced before the fourth year, it is very rare to have to do a rotation osteotomy in order to correct the anteversion. We advocated those authors's opinion so did not derotation osteotomy of the femur to correct the anteversion.

We performed femoral osteotomy after 12 weeks initial operation when femoral neck-shaft angle more 150˚ and high Dislocation with grade IV of Tönnis classification only (see **Table 3**). We agree with Kumar *et al.*'s [43] opinion that the femoral shortening might prolong the operating time, increase blood loss, or increase the incidence of heterotopic bone formation.

4.3. Unilateral and Bilateral Developmental Dysplasia of the Hips

Ryan *et al*. [44] reported that patients with bilateral dysplasia and an older age tended to have a poor radiographic outcome. Kershaw *et al.* studied a group of thirty two patients who underwent revision surgery after an unsuccessful initial open reduction for dysplasia and reported that 63% of these patients initially had bilateral involvement [45]. However, the outcome of treatment in patients with bilateral dysplasia has not been fully addressed. Most authors have evaluated patients with unilateral and bilateral dysplasia together, with the resulting cohort including only a small number of patients with bilateral involvement [8].

In a recent study, Ting-Ming Wang *et al.* [46] compared the outcomes of surgical treatment in unilateral and bilateral DDH in the children of walking age. The authors finally concluded that the clinical outcomes of bilateral DDH were worse than unilateral ones, primarily because of asymmetrical results. Age and Tönnis grade played an important role in the risk of AVN occurrence. The radiographic outcome according to the Severin classification did not differ significantly between the two groups.

4.4. Skin or Bone Traction

Haidar *et al*. used skin traction for 2 weeks before simultaneous open reduction and Salter osteotomy [47]. Only 3 of 37 hips had femoral head deformity from osteonecrosis and 4 hips had temporary mottling of the femoral epiphysis (19%). Gulman *et al*., who did not use preoperative traction, reported osteonecrosis in 33 of 52 hips (63%) treated with one-stage open reduction and Salter's osteotomy [48]. Comparison with previous reports indicates that preoperative traction may be useful in reducing the rate of osteonecrosis. Further comparative study is required to prove the effectiveness of pre-operative traction in preventing osteonecrosis.

Shih and Shih [49] found no difference in outcome in patients treated with or without traction. In the present study, complications were fewer in patients who underwent open reduction and femoral shortening without preoperative traction. We did not use preoperative limb traction on all of our patients.

4.5. The abduction in the Spica Cast

The abduction in the spica cast was significantly higher in the control patients (mean 50.8 degrees) compared with those who failed open reduction (mean 38.8 degrees). Increased abduction in the spica cast is likely effective for 2 reasons. First, abduction can prevent redislocation during the casting period by directing forces more perpendicular to the mouth of the acetabulum, and second, increased abduction may improve acetabular remodeling during the period of immobilization so that the acetabulum is a better shape upon cast removal. Salter and others have warned against immobilization in excessive abduction as this increases the risk of osteonecrosis [50], but to our knowledge, the correlation between abduction and osteonecrosis has only been shown in flexed hips after closed reduction, not the relatively extended position after open reduction. Salter, himself, preferred a spica cast with the hip placed in slight flexion, approximately 45 degrees of abduction, and mild internal rotation to maintain a concentric reduction. Our all patient postoperative the double spica cast was applied immediately after surgery, hip in 30 degrees of flexion, 50 degrees of abduction, and 20 degrees of internal rotation.

4.6. Avasculae Necrosis Femoral Head

Avascular necrosis, also called osteonecrosis, bone infarction, aseptic necrosis, and ischemic bone necrosis, is cellular death (necrosis) of bone components due to interruption of the blood supply. Without blood, the bone tissue dies and the bone collapses. If AVN involves the bones of a joint, it often leads to destruction of the joint articular surfaces.

4.7. Factors Associated with AVN

Osteonecrosis is a major complication following surgery for DDH, hindering the subsequent development of the hip. The occurrence of early signs of osteonecrosis served as the independent variable. Factors that may be associated with the occurrence of osteonecrosis included the age of the patient at the time of operation, gender. Unfortunately, AVN of the femoral head and damage to the physis following treatment of congenital dislocation of the hip is a serious complication and prevents satisfactory long-term results [18]. The reported incidence of AVN has ranged from zero to 73 per cent [18]. The actual incidence of AVN is difficult, if not impossible, to evaluate because of the various methods of treatment for congenital dislocation of the hip. Also, the criteria for determining the presence of AVN differ significantly with each series. The most feared complication of treatment for developmental hip dysplasia is AVN. The diagnosis can be difficult, and a series of radiographs is required over a considerable time.

In earlier stages, it is defined as epiphisytis. Later, vascular damage progresses in femoral proximal areas and in the acetabulum. Kalamchi and MacEwen classified these vascular changes. Kalamchi reported the frequency of AVN as between 0% and 73%. [19]. Barrett reported the frequency of AVN as 6% [21]. Hajdar reported AVN as 8.1% [47]. In the etiology of AVN, there are two factors: blockage of the extracapsular vessels by immobilization and mechanical pressure. In this study, AVN Classification according to the Kalamchi with Grade I: 5 (8.3%), Grade II: 42 (70%), Grade III: 13 (21.7%); with AVN: 60 (33.1%) (see **Table 5**). Compared AVN according to Kalamchi of Primery Operation group and Femoral Shortening did not differ significantly between the two groups (P *valuate* is 0.6869).

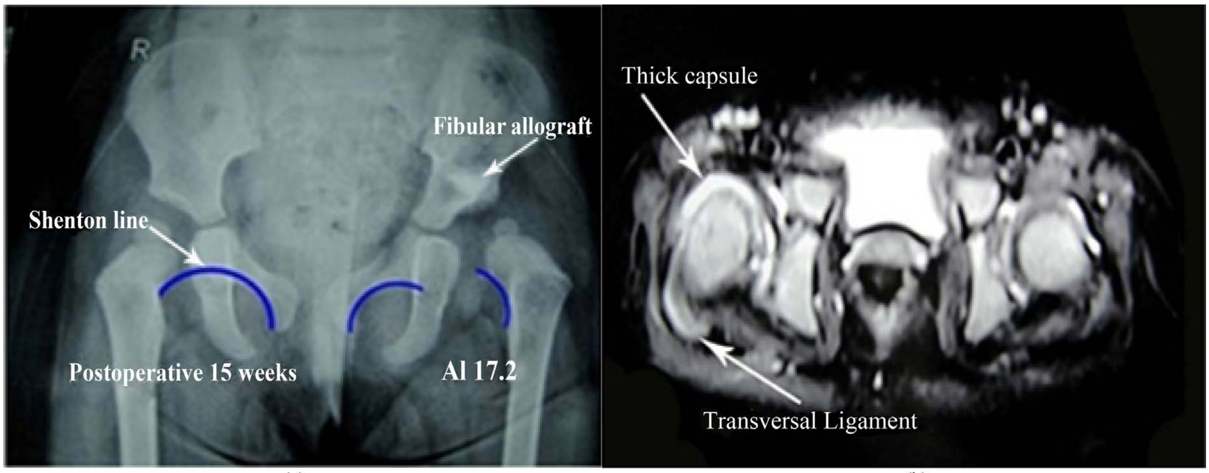
4.8. Redislocation of the Hip

Putti [51] distinguished subluxation from dislocation on the basis of the relationship between the articular surfaces of the femoral head and the acetabulum. He noted that the femoral head in subluxation was abnormally positioned in the socket, whereas in dislocation the head lay completely out of the acetabulum. Although the articular surfaces were in contact, the femoral head was not congruently or concentrically located in the acetabulum.

In the current study two patients (4.5%) had resubluxation of the hip. Rudolf *et al.* [52] reported 3 of 54 hips with redislocation, Grill [53] reported 12 of 50 hips with redislocation and resubluxation. Ruszkowski and Pucher [54] reported one of 33 hips in 26 children with redislocation. Both Tachdjian [55] and Fixsen [56] suggest that the reasons for failure to maintain a reduced hip are a poorly executed osteotomy, a lax capsulorrhaphy and exessive femoral anteversion. A correct technique of capsulorrhaphy helps to prevent posterior displacement in the early postoperative period while the hip is remodelling. In this study, had 18 hips in 158 children with redislocation (cf. **Figure 4(a)** & **Figure 4(b)**). We suggest that technical failure is usually the cause for re-dislocation with all had an intact anteromedial capsule, there was an inverted transverse ligament, tight psoas tendon, eversion of the limbus, and densing anterior capsule. We perform with all hips was cleared of scar tissue; adductor tenotomy; hips required release of the psoas tendon, eversion of the limbus; release of the transverse ligament was required. The hips required femoral shortening (average of 1.5 cm), should be performed in hips from ten and twelve weeks after repeat open reduction.

4.9. Lower Limb Discrepancy

Lower limb discrepancy is both a cosmetic and functional problem. Fifty-six of 63 hips with SIO had lower limb lengthening, the mean of which was 0.47 cm. This can be caused by the greater vertical translation with SIO. No other intervention was performed in patients having a discrepancy of less than 1.5 cm [57]. In this study, limb length discrepancy was also found in 12 hips (6.6%) 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. Deficiency of leg length 1 cm: 168 (92.8%), Deficiency 2 cm: 12 (6.6%), Deficiency 3 cm: 1 (0.5%), and mean 1.5 cm (1 - 3 cm) (see **Table 6**). Compared Deficiency of leg length of Primery Operation group and Femoral Shortening group did not differ significantly between the two groups (P *valuate* is 0.6869).



(a) (b)

Figure 4. Postoperatively 15 weeks, left hip with subluxation. (a) Roentgenography shown acetabular index with normal limits; broken shenton line; (b) MRI shown thick capsule and hypertrophic transverse ligamentum.

4.10. Coxa Magna

Sakamaki.1979 [58] reported enlargement of the femoral head is frequently observed in roentgenographs during the treatment of congenital dislocation of the hip. By measuring the longitudinal and cross-sectional lengths of both the femoral heads and necks, they felt that "coxa magna" should be defined as the condition with enlargement of all of these parameters. The incidence of coxa magnawas 47% after open reduction, but only 5% after closed reduction. In most cases, coxa magna was roentgenographically evident approximately 10 months after open reduction. Gamble *et al*. 1985 [59] studied coxa magna after operative treatment of congenital dislocation of the hip. Coxa magna was defined as a femoral head with a horizontal diameter at least 15% greater than the symmetrical position on the opposite side. Coxa magna developed in 16 hips (33%). The mean increase was 20.9% (range 15% - 30%). Three factors correlated with coxa magna: femoral osteotomy (100%), open reduction (75%), and operation at a younger age (mean 15.6 vs. 35.8 months). Imatani *et al.* 1995 [60] studied coxa magna after open reduction DDH in 47 hips of 47 patients were radiographically examined for at least 10 years, and another 20 hips in 20 patients were examined arthrographically at an early stage after open reduction. The incidence of coxa magna, which was defined as a femoral head with a size ≥20% greater than the opposite side at follow-up, was 34.0%, and that seemed to be one of factors that worsened the long-term results. One of the most important causes of coxa magna is to over widen the acetabular capacity by excising the limbus; another cause is the surgical invasion and synovitis of the hip joint after operation. There were 4 hips with Coxa magna in this study, after initially operation mean 18 months.

4.11. Supracondylar Femoral Fractures

Two patients (1.1%) had complications in this study during removal of the cast three month after the operation, This fracture was treated by above knee plaster cast, The final clinical outcome in this patients was fair.

Supracondylar and intertrochanteric femoral fractures are observed rarely after reduction and during rehabilitation. The long immobilization times aggravate osteoporosis and increase fracture risk. Ege [61] reported the frequency of supracondylar femoral fractures as 1.6% - 7.8%; Crellin [62] reported 7.6%; Hajdar [47] reported 5.4%.

4.12. Trendelenburg Gait

Trendelenburg gait pattern (or gluteus medius lurch) is an abnormalgait (as with walking) caused by weakness of the abductor muscles of the lower limb, gluteus medius and gluteus minimus. Kershaw *et al*. 1993 [45] reported 21 of 33 hips (63.6%), Sayed *et al*. 2012 [28] reported 7 of 109 hips (6.4%), Basant. 2012 [63] repored 3 of 35 (8.6%) with Trendelenburg gait in the final clinical outcome group and are still under follow-up. Our surgical technique with ZOFA did not expose outer table of the illium, abductor muscle injury is limited, so negative Trendelenburg gait, only 4 hips (2.2%) with Trendelenburg gait in this study.

Overall, in this study with Clinical evaluation according to modified McKay criteria: Excellent 113 (62.4%), Good 28 (15.5%), Fair 22 (12.2%), Poor: 18 (9.9%). Satisfy Results (Excellent and Good): 141 (77.9%) (see **Table 7**). Compared Clinical evaluation according to modified McKay criteria of Primery Operation and Femoral Shortening, did not differ significantly between the two groups (P *valuate* is 0.6869).

5. Conclusions

1) The surgical technique of open reduction, and zigzag osteotomy combined with fibular allograft for developmental dysplasia of the hip proved to be safe and effective. Acetabular index was improved from 42.95˚ preoperatively to 17.26˚ at latest follow-up. Satisfactory result (excellent and good) was achieved in 141 hips (77.9%). We did not use KW to fix the fibular allograft at the pelvic osteotomy site. Surgical technique with ZOFA limited abductor muscle injury with negative trendelenburg gait; post-operative blood transfusion was not required.

2) Complications in this study were included: AVN in 61 hips (33.7%), redislocation in 18 hips (9.9%), coxa vara in 4 hips (2.2%), trendelenburg gait in 4 hips (2.2%), and distal femoral fracture in 2 hips (1.1%).

6. Limitations

Limitations of this study included the following: 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.

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