Research Article

Treatment of Slipped Capital Femoral Epiphysis with a Modified Dunn Procedure

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Abstract
Background: Moderate to severe slipped capital femoral epiphysis leads to premature osteoarthritis resulting from femoroacetabular impingement. Modified dunn procedure restore the normal anatomy, complete correction of the slip angle, and minimize the probability of cam-type FAI with preservation of physeal blood supply. **Patients, Methods**: A prospective study was conducted on 15 patients with moderate and severs SCFE were treated with modified dunn procedure during the period from March 2017 to February 2020 , 12 males (80%) and 3 females (20%) with mean age was 15.2 years at the date of surgery The Right hip was affected in 9 patients (60%) and the left hip in 6 patients (40%). 10 cases were stable, while 5 cases were unstable. The mean follow up period was 15.1 month. **Results:** *Postoperatively*, the harris hip score (HHS) ranged from 60 to 100 with mean value 93.7 (SD was 13), WOMAC score ranged from 0 to 20 with mean value 3.7 (SD was 5.5) and the Heyman and Herndon score was excellent-good in 13 cases (86.7%),and poor in two cases (13.3%). *Radiologically*, all parameters showed significant improvement with the mean slip angle corrected from 53.9^0 (SD 11.7) preoperatively to 5.1^0 (SD 5.7) postoperatively, the mean alpha angle corrected from 100^0 (SD 14.1) preoperatively to 51.9 (SD 5.3) postoperatively. AVN and implant removal occurred in only two cases (13.3%). **Conclusion**: Capital realignment through the modified dunn procedure is an effective and safe treatment option for moderate and severe SCFE in patients with open physes as it allows anatomical restoration of hip anatomy thus preventing FAI with its sequalae and and provide good short-term outcome with low complication rate.

Keywords: Modified Dunn procedure, Slipped capital femoral epiphysis, Avascular necrosis in SCFE.

Introduction
Slipped Capital Femoral Epiphysis (SCFE), a misnomer represents gradually acquired mal-alignment of the proximal femoral metaphysis, through the physis, in relation to the epiphysis, which remains in the acetabulum held by the ligamentum teres[(1)]. In most patients, the deformity is three-dimensional with the distal fragment in varus in the coronal plane, extension in the sagittal plane and external rotation in the axial plane[(2)].This mal-alignment may result in major deformity of the proximal femur and abnormal hip mechanics leading to femeroacetabular impingment, articular cartel-age damage and premature osteoarthritis[(3)]. The treatment of SCFE is evolving. Several surgical procedures have been used to stabilize and produce closure of the epiphyseal plate, and no single method has gained universal acceptance[(4)]

Historically long-term outcomes after in situ pinning, a lower surgical risk procedure, were successful for mild and moderate SCFE[(5)]. It has been advocated by authors who believe in the remodeling potential of the deformed hip with some restoration of the disturbed anatomic axes[(6)]. But,this remodeling potential remains controversial as the head-neck offset will remain abnormal with potential impingement of the femoral neck with the acetabular cartilage especially with the recent recognition that even small slips may produce cam deformity, cartilage damage and premature osteoarthritis[(7)].

The modified dunn subcapital realignment procedure using a surgical hip dislocation approach described by Ganz[(8)] has been reported to provide restoration of the femoral head-neck anatomy, a higher rate of good and excellent Heyman and Herndon clinical

outcome, and a similar occurrence of complications when compared with in situ pinning with low rates of osteonecrosis [9-12]

The purpose of our study is to determine whether capital realignment through the modified dunn procedure will be feasible and repeatable to restore hip anatomy and function and provide good short-term out-come while avoiding osteonecrosis in moderate and severe SCFE.

Patients and Methods

This prospective study was conducted on SCFE patients presented to the outpatient clinic at Minia University Hospital and treated with modified dunn procedure during the period from March 2017 to February 2020. Out of 52 patients with SCFE treated at our institution during this period, only 15 patients fulfill our inclusion criteria and were treated by modified dunn procedure. Inclusion criteria includes patients with moderate or severe SCFE who agreeing to actively participate in a strict rehabilitation protocol and follow-up program.

Patients who have previous hip surgery, established AVN of the affected epiphysis, and other congenital or acquired hip deformity were excluded from the study. The age of patients ranged between 13 to 17 years with mean age was 15.2 (SD was 1.1) years at the date of surgery. Twelve patients were males (80%) and three were females (20%). The right hip was affected in 9 patients (60%) and the left hip in 6 patients (40%). The duration of symptoms before the operation ranged from 1 week to 30 weeks with mean was 13.7 weeks (SD was 11.1).

The study was authorized by the local Ethical Committee and details of the patient condition, operative details, prognosis, complication, the follow up, and their role post-operatively was discussed in details and proper performed consents were obtained from all patients and their parents.

- ***Pre operative assessment:***

Each patient in this study was subjected for history taking, general and local exami-nation, radiographic evaluation and preope-rative clinical outcome scores using Harris Hip Score[13] and WOMAC score[14].

Hip ROM and preoperative clinical outcome scores were not recorded in unstable cases as it was painful in these cases. Radiographic evaluation were carried out with antero-posterior pelvis x-ray of both hips and frog-leg lateral views in most cases. Cross-table lateral views were done only when the slip is unstable or the frog-leg lateral position is painful
. These views were used to measure the slip angle with the southwick method ,and alpha angle and to evaluate presence of femoral head AVN.

- ***Surgical technique:***

All the patients were treated with modified dunn procedure using the safe surgical hip dislocation technique described by Ganz[8]. The patient was positioned in a full lateral position, a digastric trochanteric osteotomy was perfo-rmed, and Z-shaped capsulotomy was done. In cases of an unstable SCFE, the femoral head was temporarily fixed with 2 mm-Kirschner wires before dislocation followed by surgical hip dislocation**. Figure (1)**

The periosteum of the neck, including the retinaculum, was gradually released from the femoral neck. **(Figure 2A)**. The epiphysis was gently mobilized posteriorly from the femoral neck using chisels, the femoral neck then contoured by resecting the postero-medial callus using curved osteotome.The remaining physis of the femoral head was curreted out with use of asmall curette.

The femoral head was then reduced manually on the metaphyseal stump without tension on the retinaculum and provisionally fixed with anterograde Kirschner wire starting at the fovea of the femoral head, **(Figures 2B, C)**. Definitive fixation was done using two or more 3.0mm K-wires or by using one or two cancellous (6.5 mm) screws or shanz screws . Epiphyseal perfusion after the capital realignment is checked routinely using a 1.2 mm-drill hole with observation of subsequent bleeding**. (Figure 2D)**.The periosteal flaps and capsule were reattached loosely with tension-free sutures. The greater trochanter is reatta-ched with two cancellous screws with advan-cement, if needed.

- ***Post operative care:*** In the second post-operative day wound dressing was done, and drain was removed in all patients.

Passive hip ROM was encouraged immediately after surgery, then after three weeks all active motion except abduction was allowed. Active abduction was allowed once radiological union of the trochanter was confirmed; generally after six weeks. Non wt-bearing ambulation for at least 2 month and toe-touch weight bearing with crutches will be allowed at 6 weeks post-operative. Full weight bearing allowed when healing of the trochanteric osteotomy and femoral neck could be seen.

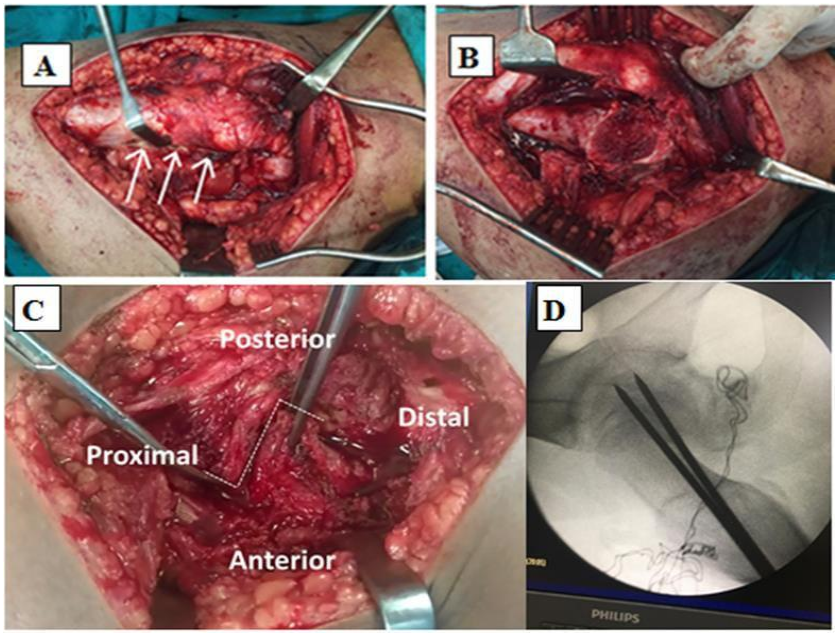

Figure (1) A) Incision is made from the posterosuperior edge of the greater trochanter (White arrows) in patient (No. 1). B) Mobilization of the trochanteric fragment anteriorly after digastric osteotomy in patient (No.) C) Fashioning of the Z-shaped capsulotomy (dotted line). D) fluoroscopic image showing temporarily pinned epiphysis with 2 K- wire befor dislocation in patient (No 5)

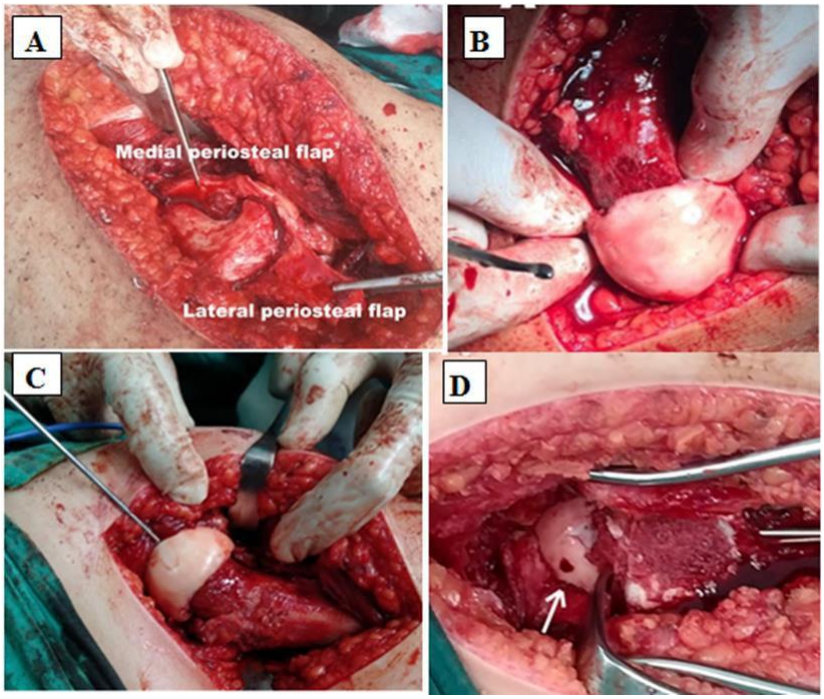

Figure (2) A) Development of periosteal flap. The periosteum is elevated both medially and laterally in patient (No. 2) B) Reduction of the femoral head over the neck in patient(No. 1) C) Provisional fixation by K wire starting at fovea of femoral head in patient (No. 14) D) Bleeding test of the head after definitive fixation A) in patient (No 14.)

Statistical analysis

Parametric and non parametric quantitative data were expressed as means±SD (standard deviation), while qualitative data expressed as frequency and percentage. The differences between pre and post-operative parametric quantitative data were analyzed by paired sample T test. A statistical significance was set at $p < 0.05$.

Results

The Follow up period was ranged from 6 months to 30 month with mean 15.1 month(SD was 8). Preoperatively, according to Fahey classifications[15] 8 hips (53.3%) were chronic , and 6 hips (40%) were acute on top of chronic and only one hip (6.7%) was acute. According to Loder classification[16] 10 cases (66.7%) were stable, while 5 cases (33.3%) were unstable.

Preoperative slip angle ranged from 34^0 to 68^0 with mean 53.9^0 (SD was 11.7), This study involves 6 cases with moderate slip (slip angle ranged $30\text{-}50^0$), and 9 cases with severe slip (slip angle more than 50^0) . Preoperative alpha angle ranged from 75^0 to 130^0 degree with mean 100^0 degree (SD was 14.1)

Regarding bleeding test of the head, before dislocation 13 heads (86.7%) had positive bleeding while 2 heads (13.3%) had negative bleeding. After provisional fixation 12 heads (80%) had positive bleeding while 3 heads (20%) had negative bleeding, two of them was negative bleeding before dislocation .In these three cases with negative bleeding, additional neck shortening was done to remove tension on posterior retinaculum vessels but they also did not bleed, and fixation was done hoping for reperfusion .

Regarding intraoperative epiphyseal stability, we used the method proposed by Slongo et al.,[11] for assessing physeal stability. In our study, all clinically unstable cases (5 patients) (33.3%) had intraoperative gross instability, however, in the clinically stable cases, two (13.3%) out of ten patients (53.3%) had partial intraoperative instability. We did not revealed any case with obvious chondrolabral injury among all 15 patients.

- ***Postoperative assessment***

Postoperative ROM was assessed for all patients at 3 and 6 month postoperatively. The mean postoperative flexion was 108.7^{O} (SD was 20.7),the mean flexion with internal rotation was 36.7^{0} (SD as 9.9), and the mean flexion with external rotation was 45 degree (SD was 7.8)

Postoperative clinical outcome scores were assessed for all patients at final follow up visit after full union of osteotomy side and regaining of functional activities. **Figures (3)**. The mean HHS value 93.7 (SD was 13). In stable cases (10 patients), HHS showed significant improvement in comparison to the preoperative scores with mean improvement was (26.1), (P-value 0.001) was considered statistically significant. The mean WOMAC score was 3.7 (SD was 5.5). In stable cases (10 patients), WOMAC score showed significant improvement in comparison to the preoperative scores with mean improvement was (80.4) ,(P-value 0.005) was considered statistically significant. Regarding Heymann and Herndon outcome classification system[17] 8 patients (53.3%) were excellent, 5 patients (33.3%) were good, 2 patients (13.3%) was poor. **(Table 1)**

Limb length discrepancy was corrected in 13 patients (86.7%). In the other 2 cases who still having LLD (13.3%),they developed AVN. It postoperative LLD ranged from 0-2 cm with mean was 0.2 cm (SD was 0.6). LLD showed significant improvement in comparison to the preoperative values with mean correction was (1.6 cm). (P-value 0.004) was considered statistically significant.

Postoperative slip angle ranged from 0^{0} to 20^{0} with mean of 5.1^{0}, (SD was 5.7). In comparison with pre operative slip angle, the near normal slip angle was restored with mean correction of 48.8^{0} (P-value 0.005) was considered statistically significant. Postoperative alpha angle ranged from 45^{0} to 60^{0} with mean of 51.9^{0} (SD was 5.3).In comparison with preoperative alpha angle we restored near normal alpha angle with mean correction of 48.1^{0} (P- value < 0.0001) considered statistically significant **(Table 1)**.

Regarding post operative complications, 2 cases of AVN were recorded (13.3%), 13 cases (86.7%) did not require implant removal, only in the 2 patients (13.3%) who developed AVN, implant removal was done due to protruded implants. No patients developed deep infection, DVT, nerve injuries, implant failure, chondrolysis or non-union. **(Table 1)**

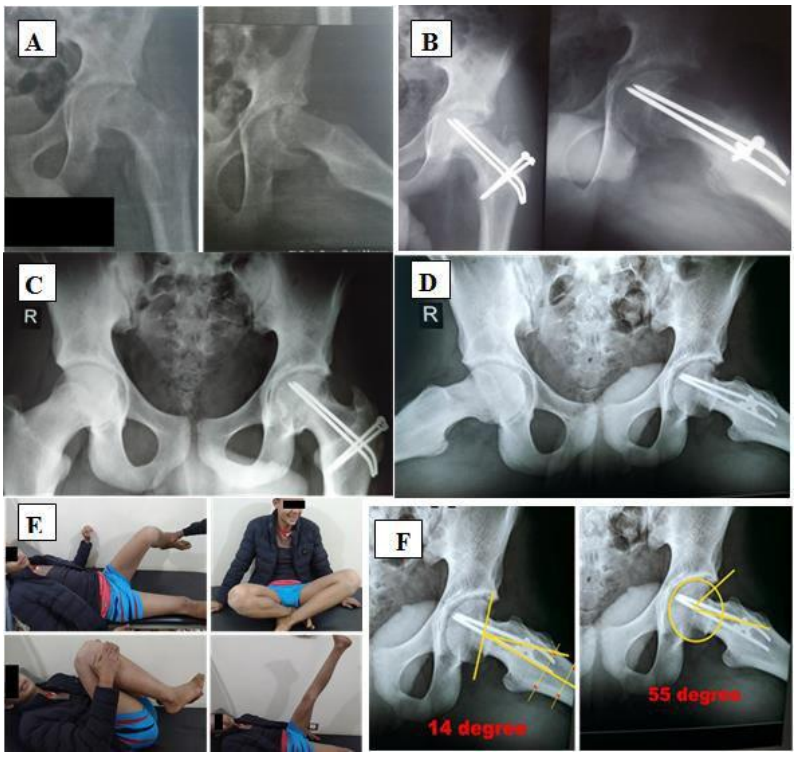

Figure (3) Male 16 ys , with lt-sided severe acute on top of chronic SCFE treated by modified Dunn procedure; (A) preoperative AP & frog lateral views (B) 3 month postoperative radiographs (C,D) 30 months-postoperative AP and frog lateral X-ray showing complete union of trochanteric osteotomy and physis with no evidence of AVN (E) Good postoperative ROM. (F) Post-operative Southwick and Alpha angles.

Discussion

Any child with an SCFE and open physis needs treatment; without stabilization, progression is inevitable, so once a slipped capital femoral epiphysis has been diagnosed, treatment is indicated to prevent progression of the slip[18]

In-situ pinning is the traditional and most commonly used treatment for SCFE, with generally good results and relatively low rate of AVN[9,19] However, there is recent evidence that the persistent metaphyseal deformity, in even a mild SCFE, leads to FAI, with a subsequent ace tabular chondro labral damage and early hip osteoarthritis[11]. Therefore, the goal of optimal treatment of moderate and severe SCFE is to arrest slip progression and to restore normal or near normal morphology of the head-neck junction. A modified Dunn procedure has been introduced to achieve these optimal goals.[9-11, 19]

In our study, we present the outcome of 15 patients of only moderate and severe degree SCFE which requires anatomical reduction by using the modified dunn osteotomy to optimise the long-term outcome.

Table (1): postoperative data

Case No.	LLD (cm)	Flexion , IR	Flexion , ER	Flexion	Heyman Score	HHS	WOMAC	Complication	Slip angle	Alpha angle
1	0	45	45	130	Excellent	100	0	NO	2	55
2	2	20	40	70	Poor	64	12	AVN	20	60
3	1	10	20	60	Poor	60	20	AVN	5	45
4	0	45	50	100	Excellent	96	2	NO	0	58
5	0	45	45	130	Excellent	100	0	NO	0	55
6	0	45	45	120	Excellent	98	2	NO	0	60
7	0	35	50	120	Good	100	4	NO	8	45
8	0	40	50	110	Excellent	100	4	NO	5	48
9	0	35	50	100	Good	96	3	NO	1	50
10	0	35	40	110	Good	98	0	NO	2	45
11	0	40	45	120	Excellent	100	1	NO	7	55
12	0	35	45	100	Good	99	4	NO	12	48
13	0	35	50	110	Good	96	3	NO	0	50
14	0	45	50	130	Excellent	100	0	NO	3	55
15	0	40	50	120	Excellent	98	0	NO	11	50

Comparing our patients characterstics to those in other studies, we involve equal number of patients as Novais et al.,[9] but lower than other studies. Our study involve the lowest follow period (mean 14.9 m) in comparison to other studies, Passaplan et al.,[20] involve the highest long term follow up period (4.2- 20.8 years) with mean 9.4 years. Table (2)

Regarding degree of slippage ,our study included 6 hips were classified as moderate, and 9 hips were classified as severe. In Ziebarth et al.,[19] study, 23 patients were classified as moderate and 12 patients were severe, in Slongo et al.,[11] study 6 patients were classified as mild, 8 were moderate, and 9 patients were severe. In Novais et al.,[9] study, 15 patients (100%) were severe. In Abdelazeem, A. H., et al.,[21], 10 were moderate, and 22 patients were severe. Othman et al.,[22], 9 were moderate, and 11 patients were severe, Elmarghany et al.,[23], 2 were mild, 10 were moderate, and 20 patients were severe . In Passaplan et al.,[20], 8 were mild, 8 were moderate, and 2 patients were severe.

Regarding intraoperative epiphyseal stability, In our study all clinically unstable cases (5 patients) (33.3%) had intraoperative gross instability. However, in the clinically stable cases, two (13.3%) out of ten patients (53.3%) had partial intraoperative instability. These findings were comparable to that of Zeibarth et al.,[19], Slongo et al.,[11] and Othman et al.,[22] .

In Zeibarth et al.,[19] eleven clinically unstable SCFE had physes that were grossly unstable (five) or physes that were easily separated from the metaphyses (five). However, even in the clinically stable SCFE, 13 of 26 hips had physes that were either grossly unstable (four) or easily separated (nine). In Slongo et al.,[11] 8 hips were designated as unstable,10 hips were stable ,3 hips were partially unstable and 2 hips no information was available about the intra-operative stability of the epiphysis. In Othman et al.,[22] all clinically-unstable SCFE (7 hips) had intraoperative instability (5 hips grossly unstable and 2 hips partially-unstable). However, even in the clinically stable SCFE, five out of 13 hips had partial intraoperative instability.

Regarding bleeding of the femoral head after reduction, in our study 12 heads (80%) had positive bleeding while 3 heads (20%) had negative bleeding ,two of them was negative

bleeding befor dislocation. These results were comparable to that of Zeibarth etal.,[19], Slongo et al.,[11] Abdelazeem, A. H., et al.,[21] and Elmarghany et al.,[23]

In our study, the postoperative ROM was restored to near normal. Postoperative flexion ranged from 60 to 130 degree with mean 108.6 degree, postoperative flexion with IR ranged from 10 to 45 degree with mean 36.7 degree ,Flexion with ER ranged from 20 to 50 degree with mean 45 degree. This coincided with many other studies. Table (2)

Table (2): Patients' characteristics, Postoperative ROM, clinical scores in different studies

		Zeibarth et al ., 2009	Slongo et al., 2010	Novais et al.., 2015	Abdelazeem,A. H., et al., 2016	M. Elmarghany et al., J 2017	Othman etal 2018	Masquijo, et al., 2019	Passaplan et al., 2020	Current study
Hips NO.		40 (40pts)	23 (23pts)	15 (15pts)	32 (31pts)	32 (30pts)	20 (20pts)	21 (20pts)	18 (17pts)	15 (15pts)
Follow up (months)		42	23-62 mean 24	12- 60 mean 28.8	12-40 mean 24.1	6-36 mean 17.3	12-36 mean 19.9	12-84 mean 40.4	4.2-20.8 mean 9.4 y	6-30 mean 14.9
	Range	96-100	82-100	=	65-100	66-100	=	40-100	52-100	60-100
	Mean	99.6	99	=	96.3	96.16	86.2	76.3	88.7	93.6
WOMAC	Range	=	=	=	=	$0\text{-}12^0$	=	=	=	0- 20
	Mean	Pain (2.1) Function (3)	=	=	=	3.3^0	=	=	=	3.46
Heymann and Herndon (good and excellent results)		=	=	9/15	=	30/32	15/20	=	=	13/15
Flexion	Range	$80\text{-}120^0$	$20\text{-}130^0$	=	$30\text{-}130^0$	$50\text{-}130^0$	$50\text{-}120^0$	$80\text{-}120^0$	=	$60\text{-}130^0$
	Mean	104^0	107^0	=	104^0	111.9^0	105.5^0	97^0	=	108.6^0
Flexion,IR	Range	$5\text{-}45^0$	$10\text{-}60^0$	=	$10\text{-}50^0$	$10\text{-}45^0$	$15\text{-}45^0$	$5 - 45^0$	=	$10\text{-}45^0$
	Mean	29^0	37.8^0	=	40^0	41.6^0	36^0	23^0	=	37^0
Flexion, ER	Range	$20\text{-}60^0$	$10\text{-}60^0$	=	$15\text{-}60^0$	$15\text{-}50^0$	$15\text{-}50^0$	$20\text{-}60^0$	=	$20\text{-}50^0$
	Mean	43^0	45^0	=	45^0	45.6^0	42.4^0	38^0	=	45^0

The postoperative clinical outcome was evaluated by use of three clinical scores and it demonstrated improved functional hip scores to a satisfactory degree. The HHS in our series ranged from 66 to 100 with mean of 93.7. Our mean HHS was higher than that of the series of Othman et al.,[22], Masquijo, et al.,[24] and Passaplan et al.,[20] but lower than that of other studies, which may be attributed to involvement of more chronic slips, with some persistent postoperative pain and limited ROM which may improve on the long-term. Excellent and good results according to the Heyman and Herndon

score in our study was higher than that in Novais et al.,[9] and Othman et al.,[22] studies , but lower than that in Elmarghany et al.,[23] J study. **Table (2)**

Radiographic assessment in our study showed improvement of all radiographic parameters, indicating normal or near-normal femoral head-neck anatomy, with significant correction of the slip angle and alpha angle, without excessive femoral neck shortening . In this study the pre

operative slip angle ranged from 34 to 68 degrees with mean 53.9. Postoperative slip angle ranged from 0^0 to 20^0 with mean of 5.1^0,with mean correction (48.8^0).

Table (3): Pre and post operative slip angle and alpha angle in different studies

		Zeibarth etal 2009	Slongo etal 2010	Novais et al.,., 2015	Abdelazeem, A. H., et al., 2016	M. Elmarghany et al., J 2017	Persinger et al.,., 2018	Othman etal 2018	Masquijo, et al., 2019	Passaplan et al.,., 2020	Current study
Mean Preop. Slip angle		**45.6^0**	**47.6^0**	**65^0**	**56^0**	**52.5^0**	=	**61^0**	**59.1^0**	**42.1^0**	**53.9^0**
Postop Slip angle	**Mean**	**8.6^0**	**4.6^0**	**16^0**	**12.2^0**	**5.6^0**	**2.5^0**	**10^0**	**5.4^0**	**4.1^0**	**5.1^0**
	Mean correction	**37^0**	**43^0**	=	**43.42**	**46.85^0**	=	**51^o**	**53.7^0**	**38^0**	**48.8^0**
Mean Preop. Alpha angle		=	=	**111^0**	**100^0**	**97.85^0**	=	**90.2^0**	=	**92.3^0**	**100^0**
Postop Alpha angle	**Mean**	**40.6^0**	**38^0**	**44^0**	**46.9^0**	**51.15^0**	**47.4^0**	**49.1^0**	**40.8^0**	**37.9^0**	**51.9^0**
	Mean correction	=	=	=	**53**	**46.7^0**	=	**42.1**	=	**54.4^0**	**48.1^0**

In comparison our results to other studies, it reveals that our mean correction of slip angle is only lower than Masquijo, et al., 2019 and Othman et al., 2018 but it is slightly higher than other studies due to inclusion of more severe cases. In our study, postoperative alpha angle was restored to normal, the pre operative alpha angle ranged from 75 to 130 degrees with mean 100^0. Postoperative alpha angle ranged from 45^0 to 60^0 with mean of 51.9^0, with mean correction (48.1^0). These results were comparable to that of many other studies **Table(3)**

Regarding the incidence of postoperative AVN, in our study two cases (13%) developed post operative AVN. Zeibarth et al.,[19] didn't record any case of AVN. Slongo et al.,[11], Novais et al.,[9], and Abdelazeem, A. H., et al.,[21]. recorded one case of AVN. Persinger et al.,[10], recorded two cases of AVN (6%) at an average 19 weeks postoperative. Masquijo, et al.,[24], recorded 10 cases with AVN (50%), six patients had complete osteonecrosis with severe involvement and 4 partial femoral head necrosis with minimal deformity. In Passaplan et al.,[20], two hips (11.1%) presented with AVN with concomitant OA grade 2 and 3. The incidence of AVN in our study is lower than Masquijo, et al., 2019 but higher than other studies, which is attributed to low number of patients involved in the study. We didn't record any case with infection, implant failure, Chondrolysis, FAI or heterotopic ossification.

Implant failure did not occur in our study. This coincided with the findings of Elmarghany et al.,[23], Abdelazeem, A. H., et al.,[21]. and Othman et al.,[22] but did not coincide with the findings of many other authors, who reported implant failure in their studies. In Ziebarth et al.,[19]. study they recorded three cases of implant failure which necessitated revision of surgery, Slongo et al.,[11] study recorded one case of implant protrusion that needed revision of fixation. Novais et al.,[9]. recorded two cases of implant failure which necessitate revision of surgery. Persinger et al.,[10] 2018, recorded only one case of hardware failure. Passaplan et al.,[20] 2020, recorded one case of implant fatigue failure and intra-articular protrusion of the K-wires surgery that required revision at three months after the index procedure .

In our study the need for reoperation was low in

comparison to other series. Only 2 patients needed reoperation, both who developed post-operative AVN needed another surgery to remove the protruded k-wires. Most of reoperations in other studies were due to revision of failed fixation and H.O excision which didn't occur in our study

Elmarghany et al.,[23] reported 3 patients needed reoperation; one of the three who developed postoperative AVN needed another surgery to remove the protruded screws and arthrodiastasis, one with late deep infection needed debridement and screw removal and, one of bad reduction needed revision with adjustment of the reduction In othman et al.,[22], two cases (10%) required reoperation; for excision of a bony spurs at the femoral head-neck junction that led to FAI in one patient and removal of screws in another case with AVN Masquijo et al.,[24], Ten hips required additional surgery: Hardware removal (6 hips), hardware removal, and epiphyseal drilling (2 hips), valgus osteotomy (1 hip), total hip replacement (1 hip).

- **The limitations of our study include;** First, a relatively small number of patients involved and . Second, the short-term follow up which didnot allow us to detect all potential complications associated with moderate and severe SCFE in the long term, including degenerative osteoarthritis. Third, randomization of the study and lack of control or comparison group. Finally, our technique for assessment of head vascularity by peripheral K-wire drilling which is rough method and lacks both sensitivity and specificity rather than the use of laser Doppler which can be a good reliable test for predicting the development of postoperative AVN.
- **The strength points** in our study includes, firstly is using 3 different clinical scores to assess postoperative clinical outcome and this helps us to compare our results with the results of other published studies. Secondly , our mean correction of slip angle postoperatively is larger than other studies due to inclusion of more severe cases.

In conclusion, capital realignment through the modified dun procedure is an effective and safe treatment option for moderate and severe SCFE in patients with open physes as it allows anatomical restoration of hip anatomy thus preventing FAI with its squeal and provide good short-term outcome with low complication rate and it also allows inspection of intra-articular pathology which can managed at the same operation. It is a technically demanding procedure and needs along learning curve before using it in the clinical practice.

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