DOI: https://doi.org/10.17816/PTORS64500

How to prevent graft resorption or breakage in shelf acetabuloplasty for Perthes disease with hinge abduction – A modified Staheli technique successful in 31 hips in midterm results

© Nariman Abol Oyoun, Mohamed Khaled, Hesham Elbaseet, Abdel Khalek Ibrahim

Assiut University Hospital, Assiut, Egypt

BACKGROUND: Shelf acetabuloplasty covers the hip and allows remodeling in hips with Legg-Calvé-Perthes disease and hinge abduction. Graft resorption or breakage is a bad complication that necessitate another surgical procedure.

AIM: Our report evaluates a modified Staheli technique for graft resorption or breakage.

MATERIALS AND METHODS: Case series study of 31 hips (29 patients) with mean age at operation was 8.1 (range 6-14 years). Duration of complaint ranged between one year and up to three years with the mean duration 1.52 ± 0.76 years. The different parameters evaluating the hip as: Tönnis angle, Sharp angle, center-edge angle, and acetabular coverage percentage were measured. For unilateral cases only, medial joint space ratio and epiphyseal height ratio were evaluated.

RESULTS: The mean postoperative follow-up was 47.8 ± 9.8 months. All studied joints had Catterall type IV, Salter-Thompson classification type B. Seven joints were in Fragmentation stage whereas 24 joints were in re-ossification stage. Based on Lateral Pillar classification; only two joints were classified as B/C and 29 joints were classified as C. Final follow up internal rotation, abduction, center-edge angle, and acetabular coverage percentage were found to be significantly higher. In contrast, Tönnis angle and Sharp's angle were significantly decreased. For unilateral cases, it was found that medial joint space ratio and epiphyseal height ratio were significantly decreased. None of the hips had resorbed or broken graft till final follow up.

CONCLUSIONS: This modified Staheli technique prevent graft resorption or breakage. Shelf provides a good acetabular coverage for the deformed aspherical head with Legg-Calvé-Perthes disease and hinge abduction to improve hip clinical and radiological outcome.

Keywords: Perthes disease; shelf acetabuloplasty; hinge abduction; Legg-Calvé-Perthes disease.

To cite this article:
Abol Oyoun N, Khaled M, Elbaseet H, Ibrahim A. How to prevent graft resorption or breakage in shelf acetabuloplasty for Perthes disease with hinge abduction – A modified Staheli technique successful in 31 hips in midterm results. *Pediatric Traumatology, Orthopaedics and Reconstructive Surgery.* 2021;9(3):287–296. DOI: https://doi.org/10.17816/PTORS64500

Received: 02.04.2021 **Accepted:** 12.07.2021 **Published:** 30.09.2021

УДК 616.718.41-018.3-002.4-053.2-089.87
DOI: https://doi.org/10.17816/PTORS64500

Предотвращение резорбции или поломки трансплантата при ацетабулопластике в сочетании с корригирующей shelf-остеотомией при болезни Пертеса с феноменом hinge-abduction: 31 случай успешного применения усовершенствованной техники Staheli в среднесрочной перспективе

© Nariman Abol Oyoun, Mohamed Khaled, Hesham Elbaseet, Abdel Khalek Ibrahim

Assiut University Hospital, Асьют, Египет

Обоснование. Ацетабулопластика с shelf-остеотомией обеспечивает хорошее покрытие головки бедра и позволяет производить ее ремоделирование при болезни Легга – Кальве – Пертеса с феноменом hinge-abduction (шарнирного отведения). Резорбция или поломка трансплантата — серьезное осложнение, требующее повторной хирургической операции.

Цель — оценить усовершенствованную технику Staheli, применяемую для предотвращения резорбции или поломки трансплантата.

Материалы и методы. Исследование серии случаев (31 тазобедренный сустав, 29 пациентов), средний возраст на момент операции составил 8,1 года (6–14 лет), продолжительность заболевания варьировала от 1 года до 3 лет (в среднем 1,52 ± 0,76 года). Состояние головки бедренной кости оценивали с помощью различных показателей: углы Tönnis, Sharp, Wiberg (центрально-краевой угол, CEA), величину ацетабулярного покрытия. При односторонней болезни Легга – Кальве – Пертеса определяли коэффициенты ширины суставной щели в медиальном отделе и высоты эпифиза.

Результаты. Средний период послеоперационного наблюдения составил 47,8 ± 9,8 мес. В соответствии с классификацией Catterall все исследуемые суставы относили к IV типу, согласно классификации Salter – Thompson — к типу B. Из них 7 суставов находились на стадии фрагментации, 24 сустава — на стадии реоссификации. По классификации Lateral pillar только 2 сустава имели степень некроза B/C, 29 суставов — степень C. По окончании периода наблюдения отмечали значительно более высокие показатели внутренней ротации и отведения бедра, CEA и ацетабулярного покрытия, тогда как углы Tönnis и Sharp стали менее выраженными. Обнаружено также значительное уменьшение коэффициентов ширины суставной щели медиального отдела и высоты эпифиза при односторонней болезни Легга – Кальве – Пертеса. До окончания периода наблюдения ни в одном из тазобедренных суставов не было обнаружено признаков резорбции или поломки трансплантата.

Заключение. Усовершенствованная техника Staheli предотвращает резорбцию или поломку трансплантата. Shelf-процедуры обеспечивают хорошее ацетабулярное покрытие деформированной головки бедренной кости асферической формы при болезни Легга – Кальве – Пертеса с феноменом hinge-abduction, что способствует улучшению результатов клинического и рентгенологического обследования.

Ключевые слова: болезнь Пертеса; ацетабулопластика в сочетании с shelf-остеотомией; феномен hinge-abduction; болезнь Легга – Кальве – Пертеса.

Как цитировать:
Abol Oyoun N., Khaled M., Elbaseet H., Ibrahim A. Предотвращение резорбции или поломки трансплантата при ацетабулопластике в сочетании с корригирующей shelf-остеотомией при болезни Пертеса с феноменом hinge-abduction: 31 случай успешного применения усовершенствованной техники Staheli в среднесрочной перспективе // Ортопедия, травматология и восстановительная хирургия детского возраста. 2021. Т. 9. № 3. С. 287–296. DOI: https://doi.org/10.17816/PTORS64500

Рукопись получена: 02.04.2021 **Рукопись одобрена:** 12.07.2021 **Опубликована:** 30.09.2021

BACKGROUND

Shelf acetabuloplasty covers the femoral head and allow remodeling in hips with Legg-Calvé-Perthes disease (LCPD) and hinge abduction. The exact etiology of Perthes is unknown till now. Disruption of the blood supply of the capital femoral epiphysis (head) results in osteonecrosis and chondronecrosis of femoral epiphysis and ossific nucleus ceases to grow. Resorption of the necrotic bone and replacement by new bone happens at the end. Weakness of mechanical properties of the femoral head during resorptive phase may result in *coxa plana* deformity, while during re-ossification phase overgrowth may end by *coxa magna* deformity. Until reaching skeletal maturity, variable degrees of roundness take place by remodeling [1].

Deformed hip (by flattening, lateral displacement, and/or enlargement of the femoral head) in severe Perthes disease, cannot gain normal motion. This leads to pivoting of the femoral head on superolateral edge of the acetabulum and incongruity resulting in hinge abduction as described by Catteral. Redirection of the acetabulum around flattened or enlarged head cannot contain it, so another technique is needed to stabilize and contain the head. If stresses upon the epiphysis is changed, this could cause dynamic change in the structure and sphericity of it ,especially when it is still doughy and a good chance of remodeling is still present [2].

Shelf acetabuloplasty promotes the coverage of the femoral head through direct increase in the acetabulum size by iliac graft implanted into the lateral rim. Proper technique is needed to have a well united shelf to the ilium without breakage or resorption [3]. Nowadays, assessment of hip containment loss and hinge abduction is preferably confirmed by Hip arthrography [4].

This study aimed to evaluate a modified Staheli technique for graft resorption or breakage.

MATERIALS AND METHODS

Research design. Case series study was prospectively performed between 2013 and 2020 on 31 hips (29 patients) using a modified Staheli technique to do shelf acetabuloplasty to hips with LCPD with hinge abduction. This technique was evaluated for graft resorption or breakage. Clinical & radiological outcomes were also assessed.

Conformity criteria. Included patients were between 6 up to 14 years. Patients with Perthes disease and hinge abduction. Fragmentation stage or re-ossification stage.

Lateral Pillar classification type B/C or type C.

Patients without hinge abduction based on clinical exam and arthrogram under general anesthesia, epiphyseal dysplasia and coagulopathy were excluded.

Research facilities. Assiut University Hospital, Assiut, Egypt.

Research duration. The study was prospectively performed between 2013 and 2020 on 31 hips (29 patients). Follow up of 31hips (29 patients as two of them were bilateral) ranged from 38 to 78.6 months with mean follow up 47.8 months ± 9.8. Clinical & radiological outcomes were assessed preoperatively and at final follow up.

Medical procedure description

Clinical evaluation

Age, sex, bilaterality and age of the onset of symptoms. Abduction and Internal rotation ranges were evaluated preoperatively and in the last follow up using a Goniometer.

Radiological evaluation

By x-ray both hips and upper thighs (anteroposterior (AP), lateral frog position and abduction views). Waldenström Staging [5] and classifications by: Lateral Pillar (Herring) classification [6], Catterall classification [7] and Salter-Thompson [8] classification were done and confirmed by all investigators. The different parameters evaluating the hip as: Tönnis angle [9], Sharp angle [10], center-edge angle (CEA) [11], and acetabular coverage percentage [12] were measured. For unilateral cases only, medial joint space ratio [13] and epiphyseal height ratio [14] were evaluated. Head at risk signs were also evaluated as: lateral subluxation and calcification, diffuse metaphyseal reaction, horizontal growth plate and gage sign [15].

Hip Arthrogram under general anesthesia

Using sub-adductor approach, Urograffin dye (diluted with a 50:50 mix of sterile saline) is used for hip arthrography. If is there is a hinge abduction (presence of a bump at the superolateral margin of femoral head that prevent rotation around axis at the center of the head and causes medial joint space widening more than 4 mm and hinging at this bump instead, shelf acetabuloplasty will be done (Figure 1). If not, varisation of proximal femur will be done and exclude this case [16].

Modified Staheli technique for Shelf acetabuloplasty

A bikini straight incision is made 2 to 3 cm below and paralleling the iliac crest. A standard iliofemoral approach is then developed to expose the hip joint. The tendon of the reflected head of rectus femoris (RHRF) is divided anteriorly and displaced posteriorly. If the capsule is abnormally thick (greater than 6–7 mm), as determined by palpation or by measurement through small capsular incision, it should be thinned. This is done by "filleting" the capsule to proper thickness with a scalpel. If the greater trochanter is prominent, the limb is adducted to help directing the slot upwards to put the graft in direct contact with the

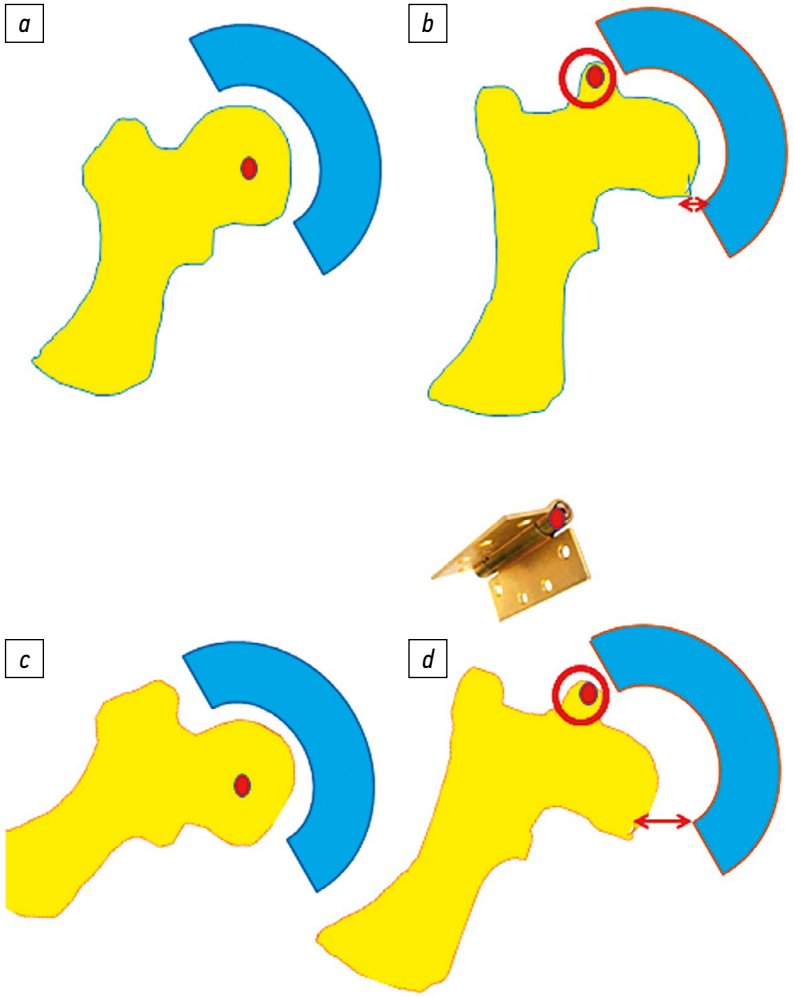

Fig. 1. Hinge Abduction Illustration: *a* — normal hip in neutral position; *b* — deformed hip with superiolateral bump in neutral position; *c* — normal hip in abduction rotates around axis in the centre of the head; *d* — deformed hip hinges around axis at the superiolateral margin during abduction with medial joint space widening

head capsule and preventing high position which makes it vulnerable to breakage. After the exact acetabular edge is identified, a bone trough is made just above the subchondral bone of the acetabulum.

RHRF's proximal attachment to ilium should be cautiously preserved intra-operatively. As it provides both vascular and mechanical support to the graft till union. IF it was accidently detached, the shelf will be at risk.

We made a modification for Staheli technique (Done by the same surgeon in all cases) by using a single trapezoid shaped graft of cortical and cancellous bone is harvested from the lateral surface of the ilium and placed in the bone trough, extending out over the capsule (length 3.5 cm, height 4 mm and depth 1 cm). Instead of multiple strips in 2 layers perpendicular to each other as original Staheli technique [1]. The shelf is fashioned to cover the head and not to protrude laterally beyond its lateral border to prevent impingement to the greater trochanter. More cancellous bone fragments is put at the corner between the graft and iliac bone. No metal is used as the graft is press-fit into the ilium. No Bone Morphogenic Protein (BMP) nor other synthetic substitutes are added.

The RHRF is sutured back anteriorly to maintain the new shelf in place. Then non-weight bearing hip spica cast for 6 weeks. After cast removal, immediate weight bearing is allowed as much as tolerated. See case example in Figure 2. If trochanteric overgrowth happened or shelf is too long to cause impingement trochanteric distal transfer or Apophysiodesis could be considered.

Research findings

The main research outcome. The efficacy of this Modified Staheli technique to prevent graft resorption or breakage till final follow up.

Additional research outcomes. Improvement of clinical (internal rotation and abduction ranges of motion) & Radiological outcomes.

Statistical analysis

The samples size was not calculated previously. Data was collected and analyzed those using SPSS (Statistical Package for the Social Science, version 20, IBM, and

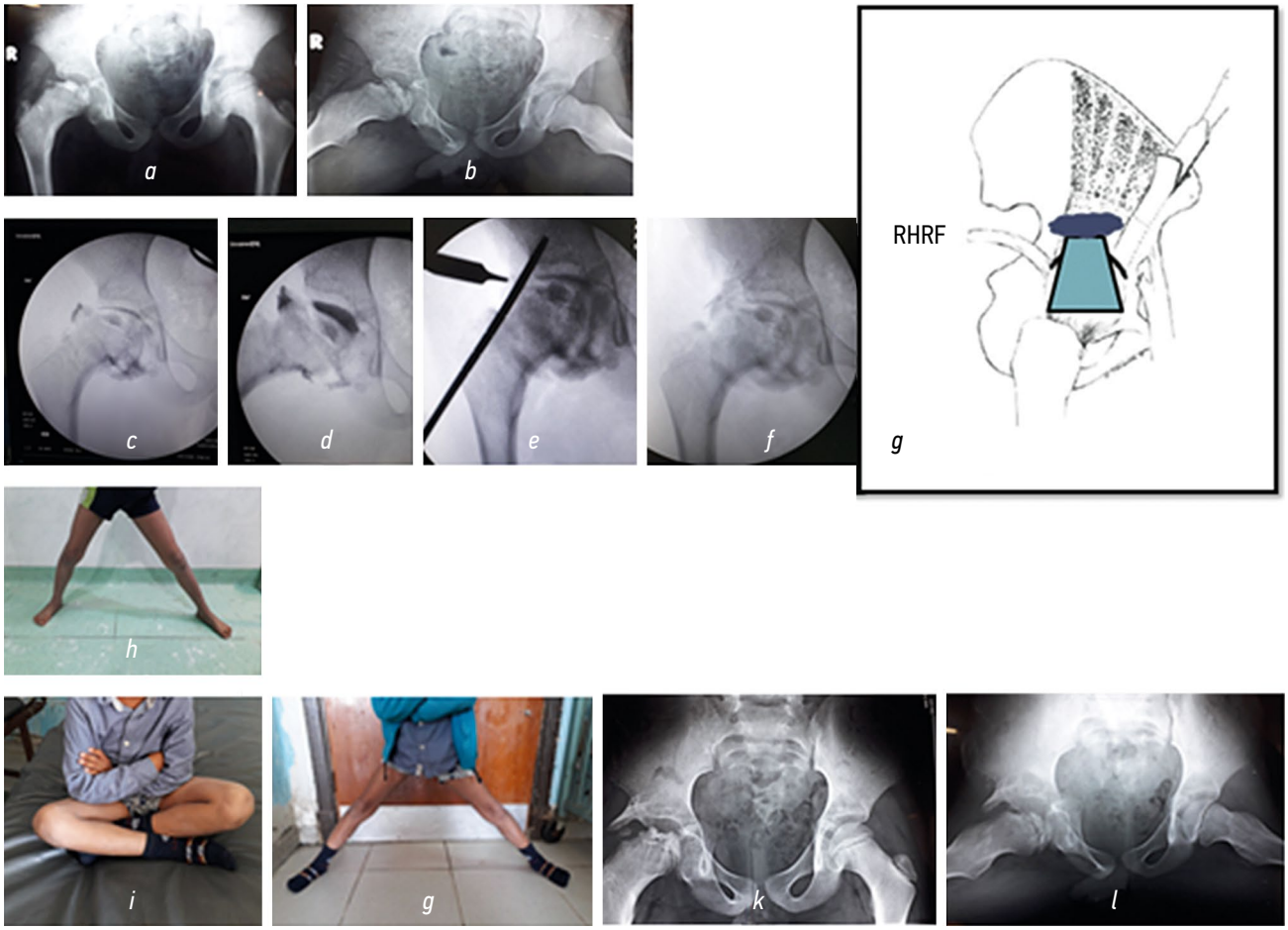

Fig. 2. Ten years old male with Legg-Calvé-Perthes disease right hip. Pre-operative x rays: *a* — anterio-posterior pelvis; *b* — lateral frog position. Intraoperative hip arthrogram showing hinge abduction; *c* — neutral; *d* — in abduction; *e* — direction of slot of shelf; *f* — after Shelf placement; *g* — diagram shows Trapezoidal shaped shelf with cancellous fragments at the edge of iliac bone; *h* — preoperative abduction. After 3 years follow up: *i* and *j* — postoperative range of motion; *k* — anterio-posterior pelvis; *l* — lateral frog position. RHRF — reflected head of Rectus Femoris

Armonk, New York). Continuous data were expressed in the form of mean ± SD or (range) while nominal data was expressed in form of frequency (percentage). Preoperative and postoperative different parameters of hip joint and acetabulum evaluation were compared with Paired *t*-test. Level of confidence was kept at 95% and hence, *p* value was considered significant if <0.05.

RESULTS

Research sample (participants/respondents)

The study included 6 females and 25 males with age group ranged from 6 to 14 years (Mean age at operation was 8.1). Based on preoperative radiological evaluation; all studied joints had Catterall classification IV, Salter-Thompson classification (B) and hinge abduction confirmed by hip arthrogram.

Primary findings

All hips did not show graft resorption or breakage till final follow up.

Additional findings

It was noticed that range of internal rotation (24 vs. 30°, $p < 0.001$) and abduction (34 vs. 46°, $p < 0.001$) were significantly increased postoperatively at final follow up. Radiological parameters are shown in table 1 and 2. Mean operative time in the current study was 53 minutes with range between 45 and 90 minutes. Adductor tenotomy was performed in 8 joints while Iliopsoas tenotomy was

Table 1. Radiological evaluation among enrolled hip joints

Stages of the disease	Affected hip joints (*n* = 31)
Waldenström staging	
Fragmentation	7 (22.5%)
Re-ossification	24 (77.4%)
Lateral Pillar classification	
B/C	2 (6.4%)
C	29 (93.5%)

Note. Data expressed as frequency (percentage); *n* — number.

Table 2. Pre and final follow up acetabular parameters among enrolled joints

Parameters	Preoperative data	Final follow up data	*p* value
Center-edge angle (°)	22.78 ± 9.71	52.95 ± 10.89	<0.001
Acetabular coverage percentage	75.43 ± 17.64	117.40 ± 17.95	<0.001
Tönnis angle (°)	26 ± 5.12	18.08 ± 4.81	<0.001
Sharp angle (°)	45.56 ± 3.83	31.52 ± 5.20	<0.001

Table 3. Medial joint ration and epiphyseal height ratio in unilateral affected joint

Parameters	Preoperative data	Final follow up data	*p* value
Medial joint space ratio	1.68 ± 0.78	1.34 ± 0.59	<0.001
Epiphyseal height ratio	0.44 ± 0.20	0.50 ± 0.21	<0.001

Note. Data expressed as mean (SD). *P* value was significant if <0.05.

performed in only one joint due to presence of hip flexion deformity. See Table 1–3.

Undesirable phenomena

Seven hips showed trochanteric overgrowth and impingement and were planned for another procedure (trochanteric Apophysiodesis or distal transfer according to remaining growth potential)

DISCUSSION

Harrison and Menon stated that "if the head is covered well within the acetabular cup, then like jelly poured into a mold the head should be the same shape as the cup when it is allowed to come out after reconstitution" [17].

Authors considered the following indication for shelf acetabuloplasty: Age between 6 up to 14 years (before skeletal maturity), patients with Perthes disease and hinge abduction (aspherical hip) and Fragmentation stage or re-ossification stage (early stages with chance of remodeling). Lateral Pillar classification type B/C or type C (sever affection of the femoral physis).

Mean age in our study was 9.23 ± 2.75 years with a range between 6 and 14 years similar to many other authors [3, 18–21]. Freeman et al. 2008 started doing shelf since the age of 4.6 years old depending on the severity of the disease [22].

Shelf acetabuloplasty when done in early stages of disease (fragmentation (10 joints) or re-ossification (13 joints) in our study) have better outcome due to presence of more remodeling ability. Freeman et al. 2008 did shelf in initial (4 joints), fragmentation(17 joints) and healing (6 joints) stages [22]. Also, Pecquery et al. 2010 did shelf in fragmentation (19 joints) and healing (2 joints) stages [23].

Shelf acetabuloplasty represents a good option for Lateral pillar more than type B who do not have a good chance for remodeling with other measures which was applied in many studies [3, 18–21]. Our series had more sever hips compared to these studies as all joints were type C except for 2 joints B/C type.

Hip arthrography is most often used in the assessment of loss of hip coverage and hinge abduction of the hip, inwhich the femoral head "hinges" out of the acetabulum when the hip is abducted. It can differentiate whether the head is still spherical enough to do femoral varus osteotomy or shelf acetabuloplasty is needed if hinge abduction present [4].

Kotnis et al. 2008 reported that, following arthrography of the hip in 19 patients with LCPD, the treatment plan was modified in 6 (32%). The authors recommended routine use of arthrography for treatment planning [16].

In order to have an effective shelf just above the head, thinning of joint capsule and adducting the limb during making slot of shelf in the iliac bone helps to put the shelf in a close to the head and avoid high position which makes it vulnerable to breakage or resorption which happened in one case with Bursali et al. 2004 [19] and 6 cases with Grzegorzewsk et al. 2013 [3]. Also keeping proximal attachment of reflected head of rectus femoris (RHRF) to the ilium is crucial to avoid resorption.

Li et al. 2016 [20] added Bone Morphogenic Protein (BMP) and A spica cast was worn for 8 weeks and protective weight bearing in a cast was continued for 8 additional weeks. We find this unnecessary if the shelf site and RHRF integrity were properly managed and casting for 6 weeks is enough. They also performed Adductor and Iliospaos tenotomy for all cases. In our series, Adductor tenotomy was done in only 8 patients and iliospaos tenotomy was performed in only one patient with hip flexion deformity as muscle shortening was not a constant feature in all cases.

Coverage of the head by shelf acetabuloplasty leads to improvement of internal rotation and abduction [18, 23, 24]. In our study ,it was noticed that internal rotation (preoperative 23.91 ± 11.17 vs. postoperative 29.76 ± 12.09°, $p < 0.001$) and abduction (preoperative 34.13 ± 9.01 vs.

Table 4. Comparison between shelf acetabuloplasty studies

Name of the investigator	Number of hips	Average age, years	Gender		Lateral pillar classification		Waldenström staging		Catterall classification		Length of follow-up, months
Chang et al. (2011) [1]	21	9.4 ± 2.0	M	18	Group B	13	–		–		67 ± 15.6
			F	3	Group C	8					
Freeman et al. (2008) [2]	27	8.3	M	21	Group B	12	Initial	4	III	16	62
							Fragmentation	17			
			F	6	Group C	15	Healing	6	IV	11	
Bursali et al. (2004) [3]	19 (1 patients bilateral)	9.19	M	13	Group B	7					31.68
			F	15	Group C	12					
Li et al. (2016) [4]	51	9.2	M	40	Group B	12	–		II	11	132.35
					Group B/C	24			III	15	
			F	11	Group C	15			IV	25	
Wright et al. (2013) [5]	24	9.8	M	21	Group B	18	–		–		40
			F	3	Group C	6					
Grzegorzewsk et al. (2013) [6]	23 (3 patients bilateral)	9.3	M	17	Group B	10			II	2	69.9
					Group B/C	7			III	15	
			F	3	Group C	6			IV	6	
Pecquery et al. (2010) [7]	21	7.16	M	19	Group B	13	Fragmentation	19	II	3	51
									III	7	
					Group B/C	4			IV	11	
			F	2	Group C	4	Re-ossification	2			
This study	23 (2 patients bilateral)	9.23	M	16	Group B/C	2	Fragmentation	10	IV	23	21.2

DOI: https://doi.org/10.17816/PTORS64500

postoperative 46.08 ± 10.87°, $p < 0.001$) were significantly increased postoperatively.

Significant improvement of acetabular coverage (measured by increase in center-edge angle (CEA) & acetabular coverage percentage and decrease in Tönnis angle and Sharp angle) is achieved by shelf acetabulplasty [3, 18, 20, 21] matching our study results.

Medial joint space ratio and epiphyseal height ratio were found to be significantly decreased after head remodeling following shelf procedure [18, 20–22]. We measured these parameters for unilateral cases only and were significantly decreased. See Table 4.

Seven hips in our report showed trochanteric overgrowth and impingement and were planned for another procedure (trochanteric Apophysiodesis or distal transfer according to remaining growth potential)later on.

Summary of the primary research results

All hips did not show graft resorption or breakage till final follow up. No metal was needed to fix the graft. Only hip spica was applied for 6 weeks.

Discussion of the primary research results

This Modified Staheli technique for Shelf acetabuloplasty allows good mechanical support for the shelf without need of fixing metal, BMP or extended cast immobilization. It provides good coverage for extruded physis and allows remodeling to improve clinical outcome.

Research limitations

Lack of follow up till skeletal maturity.

CONCLUSION

This modified Staheli technique prevent graft resorption or breakage. Shelf provides a good acetabular coverage for the deformed aspherical head with LCPD and hinge abduction to improve hip clinical and radiological outcome in midterm results.

ADDITIONAL INFORMATION

Funding. The study had no external funding.

Conflict of interests. Authors declare no explicit and potential conflicts of interests associated with the publication of this article.

Ethical considerations. The study was approved by local ethical committee. Assiut Medical School Ethical Review Board Approval Number (in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki): 17200142. Clinical Trial Registration: NCT03321422.

Approval from Parents or guardians of the patients was taken for publication their data.

Author contributions. *Nariman Abol Oyoun* — performed conception and design, analysis and interpretation of data and acquisition of data. *Mohamed Khaled* — performed drafting of the submitted protocol and critical revision of the submitted protocol for important intellectual content. *Hesham Mohamed Elbaseet* — performed statistical analysis and manuscript preparation. *Abdel Khalek Hafez Ibrahim* — performed manuscript preparation and supervision.

All authors made a significant contribution to the research and preparation of the article, read and approved the final version before its publication.

REFERENCES

1. Staheli LT. Slotted acetabular augmentation. *J Pediatr Orthop*. 1981;1(3):321–327.

2. Catterall A. Adolescent hip pain after Perthes' disease. *Clin Orthop Relat Res*. 1986;209(65–69).

3. Grzegorzewski A, Synder M, Kmiec K, et al. Shelf acetabuloplasty in the treatment of severe Legg-Calvé-Perthes disease: good outcomes at midterm follow-up. *Biomed Res Int*. 2013;2013(859483).

4. Shore BJ, Miller PE, Zaltz I, et al. Determining hinge abduction in Legg-Calvé-Perthes disease: Can we reliably make the diagnosis? *J Pediatr Orthop*. 2019;39(2):E95–E101.

5. Waldenstrom HJ. On coxa plana. Osteochondritis deformans coxae juvenilis. Leggs disease, maladie de Calvé, Perthes krankheit. *AMA Am J Dis Child*. 1923;55:577–590.

6. Herring JA, Neustadt JB, Williams JJ, et al. The lateral pillar classification of Legg-Calvé-Perthes disease. *J Pediatr Orthop*. 1992;12(2):143–150.

7. Catterall A. The natural history of Perthes' disease. *J Bone Joint Surg Br*. 1971;53(1):37–53.

8. Salter RB, Thompson GH. Legg-Calvé-Perthes disease. The prognostic significance of the subchondral fracture and a two-group classification of the femoral head involvement. *J Bone Joint Surg Am*. 1984;66(4):479–489.

9. Tönnis D, Brunken D. Differentiation of normal and pathological acetabular roof angle in the diagnosis of hip dysplasia. Evaluation of 2294 acetabular roof angles of hip joints in children. *Arch Orthop Unfallchir*. 1968;64(3):197–228. (In German)

10. Cooperman DR, Wallensten R, Stulberg SD. Acetabular dysplasia in the adult. Clinical orthopaedics and related research. *Clin Orthop Relat Res* 1983(175):79–85.

11. Fredensborg N. The CE angle of normal hips. *Acta Orthopaedica Scandinavica*. 1976;47(4):403–405.

12. Heyman CH, Herdon CH. Legg-Perthes disease: a method for the measurement of the roentgenographic result. *J Bone Joint Surg Am*. 1950;32(4):767–778.

13. Eyring EJ, Bjornson DR, Peterson CA. Early diagnostic and prognostic signs in Legg-Calvé-Perthes disease. *Am J Roentgenol Radium Ther Nucl Med*. 1965;9:382–387.

14. Willett K, Hudson I, Catterall AJ. Lateral shelf acetabuloplasty: an operation for older children with Perthes' disease. *J Pediatr Orthop*. 1992;12(5):563–568.

15. Kim HK, Herring JA. Pathophysiology, classifications, and natural history of Perthes disease. *Orthop Clin North Am*. 2011;42(3):285–295.

16. Kotnis R, Spiteri V, Little C, et al. Hip arthrography in the assessment of children with developmental dysplasia of the hip and Perthes' disease. *J Pediatr Orthop B*. 2008;17(3):114–119. DOI: 10.1097/BPB.0b013e3280103684

17. Harrison MH, Menon MP. Legg-Calvé-Perthes disease: the value of roentgenographic measurement in clinical practice with special

reference to the Broomstick plaster method. *J Bone Joint Surg Am.* 1966;48(7):1301–1318.
18. Chang J-H, Kuo KN, Huang S-C. Outcomes in advanced Legg-Calvé-Perthes disease treated with the Staheli procedure. *J Surg Res.* 2011;168(2):237–242. DOI: 10.1016/j.jss.2009.09.056
19. Bursal A, Erkula G. Lateral shelf acetabuloplasty in the treatment of Legg–Calvé–Perthes disease. *J Pediatr Orthop B.* 2004;13(3):150–152. DOI: 10.1097/00009957-200405000-00002
20. Li W-C, Xu R-J. Lateral shelf acetabuloplasty for severe Legg–Calvé–Perthes disease in patients older than 8 years: A mean eleven-year follow-up. *Medicine (Baltimore).* 2016;95(45):e5272. DOI: 10.1097/MD.0000000000005272
21. Wright DM, Perry DC, Bruce CE. Shelf acetabuloplasty for Perthes disease in patients older than eight years of age: an observational cohort study. *J Pediatr Orthop B.* 2013;22(2):96–100. DOI: 10.1097/BPB.0b013e32835b5726
22. Freeman RT, Wainwright AM, Theologis TN, Benson MK. The outcome of patients with hinge abduction in severe Perthes disease treated by shelf acetabuloplasty. *J Pediatr Orthop.* 2008;28(6):619–625. DOI: 10.1097/BPO.0b013e3181804be0
23. Pecquery R, Laville J-M, Salmeron FJO. Legg-Calvé-Perthes disease treatment by augmentation acetabuloplasty. *Orthop Traumatol Surg Res.* 2010;962:166–174. DOI: 10.1016/j.rcot.2010.02.007
24. Grzegorzewski A, Synder M, Kmieć K, et al. Shelf acetabuloplasty in the treatment of severe Legg-Calvé-Perthes disease: good outcomes at midterm follow-up. *Biomed Res Int.* 2013;2013:859483. DOI: 10.1155/2013/859483

СПИСОК ЛИТЕРАТУРЫ

1. Staheli L.T. Slotted acetabular augmentation // J. Pediatr. Orthop. 1981. Vol. 1. No. 3. P. 321–327.
2. Catterall A. Adolescent hip pain after Perthes' disease // Clin. Orthop. Relat. Res. 1986. Vol. 209. P. 65–69.
3. Grzegorzewski A., Synder M., Kmiec K., et al. Shelf acetabuloplasty in the treatment of severe Legg-Calvé-Perthes disease: good outcomes at midterm follow-up // Biomed. Res. Int. 2013. Vol. 2013. P. 859483.
4. Shore B.J., Miller P.E., Zaltz I., et al. Determining hinge abduction in Legg-Calvé-Perthes disease: Can we reliably make the diagnosis? // J. Pediatr. Orthop. 2019. Vol. 39. No. 2. P. E95–E101.
5. Waldenstrom H.J. On coxa plana. Osteochondritis deformans coxae juvenilis. Leggs disease, maladie de Calvé, Perthes krankheit // AMA Am. J. Dis. Child. 1923. Vol. 55. P. 577–590.
6. Herring J.A., Neustadt J.B., Williams J.J., et al. The lateral pillar classification of Legg-Calvé-Perthes disease // J Pediatr. Orthop. 1992. Vol. 12. No. 2. P. 143–150.
7. Catterall A. The natural history of Perthes' disease // J. Bone Joint Surg. Br. 1971. Vol. 53. No. 1. P. 37–53.
8. Salter R.B., Thompson G.H. Legg-Calvé-Perthes disease. The prognostic significance of the subchondral fracture and a two-group classification of the femoral head involvement // J. Bone Joint Surg. Am. 1984. Vol. 66. No. 4. P. 479–489.
9. Tönnis D., Brunken D. Differentiation of normal and pathological acetabular roof angle in the diagnosis of hip dysplasia. Evaluation of 2294 acetabular roof angles of hip joints in children // Arch. Orthop. Unfallchir. 1968. Vol. 64. No. 3. P. 197–228. (In German)
10. Cooperman D.R., Wallensten R., Stulberg S.D. Acetabular dysplasia in the adult. Clinical orthopaedics and related research // Clin. Orthop. Relat. Res 1983. Vol. 175. P. 79–85.
11. Fredensborg N. The CE angle of normal hips // Acta Orthopaedica Scandinavica. 1976. Vol. 47. No. 4. P. 403–405.
12. Heyman C.H., Herdon C.H. Legg-Perthes disease: a method for the measurement of the roentgenographic result // J. Bone Joint Surg. Am. 1950. Vol. 32. No. 4. P. 767–778.
13. Eyring E.J., Bjornson D.R., Peterson C.A. Early diagnostic and prognostic signs in Legg-Calvé-Perthes disease // Am. J. Roentgenol. Radium. Ther. Nucl. Med. 1965. Vol. 93. P. 382–387.
14. Willett K., Hudson I., Catterall A.J. Lateral shelf acetabuloplasty: an operation for older children with Perthes' disease // J. Pediatr. Orthop. 1992. Vol. 12. No. 5. P. 563–568.
15. Kim H.K., Herring J.A. Pathophysiology, classifications, and natural history of Perthes disease // Orthop. Clin. North. Am. 2011. Vol. 42. No. 3. P. 285–295.
16. Kotnis R., Spiteri V., Little C., et al. Hip arthrography in the assessment of children with developmental dysplasia of the hip and Perthes' disease // J. Pediatr. Orthop. B. 2008. Vol. 17. No. 3. P. 114–119. DOI: 10.1097/BPB.0b013e3280103684
17. Harrison M.H., Menon M.P. Legg-Calvé-Perthes disease: the value of roentgenographic measurement in clinical practice with special reference to the Broomstick plaster method // J. Bone Joint Surg. Am. 1966. Vol. 48. No. 7. P. 1301–1318.
18. Chang J.-H., Kuo K.N., Huang S.-C. Outcomes in advanced Legg-Calvé-Perthes disease treated with the Staheli procedure // J. Surg. Res. 2011. Vol. 168. No. 2. P. 237–242. DOI: 10.1016/j.jss.2009.09.056
19. Bursal A., Erkula G. Lateral shelf acetabuloplasty in the treatment of Legg–Calvé–Perthes disease // J. Pediatr. Orthop. B. 2004. Vol. 13. No. 3. P. 150–152. DOI: 10.1097/00009957-200405000-00002
20. Li W.-C., Xu R.-J. Lateral shelf acetabuloplasty for severe Legg–Calvé–Perthes disease in patients older than 8 years: A mean eleven-year follow-up // Medicine (Baltimore). 2016. Vol. 95. No. 45. P. e5272. DOI: 10.1097/MD.0000000000005272
21. Wright D.M., Perry D.C., Bruce C.E. Shelf acetabuloplasty for Perthes disease in patients older than eight years of age: an observational cohort study // J. Pediatr. Orthop. B. 2013. Vol. 22. No. 2. P. 96–100. DOI: 10.1097/BPB.0b013e32835b5726
22. Freeman R.T., Wainwright A.M., Theologis T.N., Benson M.K. The outcome of patients with hinge abduction in severe Perthes disease treated by shelf acetabuloplasty // J. Pediatr. Orthop. 2008. Vol. 28. No. 6. P. 619–625. DOI: 10.1097/BPO.0b013e3181804be0
23. Pecquery R., Laville J.-M., Salmeron F.J.O. Legg-Calvé-Perthes disease treatment by augmentation acetabuloplasty // Orthop. Traumatol. Surg. Res. 2010. Vol. 96. No. 2. P. 166–174. DOI: 10.1016/j.rcot.2010.02.007
24. Grzegorzewski A., Synder M., Kmieć K., et al. Shelf acetabuloplasty in the treatment of severe Legg-Calvé-Perthes disease: good outcomes at midterm follow-up // Biomed. Res. Int. 2013. Vol. 2013. P. 859483. DOI: 10.1155/2013/859483

AUTHOR INFORMATION

Nariman Abol Oyoun, MD;
ORCID: https://orcid.org/0000-0003-1847-8056;
e-mail: n.aboloyoun@aun.edu.eg, aboloyoun@yahoo.com

Mohamed Khaled, MD;
ORCID: https://orcid.org/0000-0002-6235-2090;
e-mail: mohamed.khaled@aun.edu.eg,
Mohamedkhaledortho@gmail.com

***Hesham Mohamed Elbaseet**, MD;
address: Orthopedic and Traumatology Department,
Assiut University Hospital, Assiut, Egypt;
ORCID: https://orcid.org/0000-0001-5362-2362;
e-mail: drhesham20@aun.edu.eg, drhesham20@yahoo.com

Abdel Khalek Hafez Ibrahim, MD, Professor;
ORCID: https://orcid.org/0000-0002-1283-2512;
e-mail: abdelkhalekhafezortho@med.aun.edu.eg,
AbdelKhalekHafezortho@yahoo.com

ОБ АВТОРАХ

Nariman Abol Oyoun, доктор медицины;
ORCID: https://orcid.org/0000-0003-1847-8056;
e-mail: n.aboloyoun@aun.edu.eg, aboloyoun@yahoo.com

Mohamed Khaled, доктор медицины;
ORCID: https://orcid.org/0000-0002-6235-2090;
e-mail: mohamed.khaled@aun.edu.eg,
Mohamedkhaledortho@gmail.com

***Hesham Mohamed Elbaseet**, доктор медицины;
адрес: Orthopedic and Traumatology Department,
Assiut University Hospital, Assiut, Egypt;
ORCID: https://orcid.org/0000-0001-5362-2362;
e-mail: drhesham20@aun.edu.eg, drhesham20@yahoo.com

Abdel Khalek Hafez Ibrahim, д-р мед. наук, профессор;
ORCID: https://orcid.org/0000-0002-1283-2512;
e-mail: abdelkhalekhafezortho@med.aun.edu.eg,
AbdelKhalekHafezortho@yahoo.com