The Egyptian Orthopaedic Journal

Vol. 60, No. 3, 2025
ISSN: 1110-1148 (print)
ISSN: 2090-9926 (online)
DOI: 10.21608/EOJ.2025.449743

ORIGINAL ARTICLE

Modified Trans-Deltoid Approach for Internal Fixation of Proximal Humeral Fracture

Mohamed K. El-Mesery, Mohamed S. Saeid, Muhammad A. Quolquela, El-Sayed M. El-Forse
Department of Orthopedic Surgery, Faculty of Medicine, Tanta University, Tanta, Egypt.

Correspondence to *Mohamed K. El-Mesery, MBBCh, Department of Orthopedic Surgery, Faculty of Medicine, Tanta University, Tanta, Gharbiya, Egypt.*
E-mail: dr.mohamed.khairy2020@gmail.com

Background This study evaluates outcomes of internal fixation of proximal humeral fracture using modified trans-deltoid procedure, focusing on functional results and complications. The conventional delto-pectoral procedure can be challenging for significantly displaced fractures, especially the greater tuberosity, and frequently necessitates a thorough dissection of soft tissues. In contrast, Trans-deltoid approach offers easier access but carries a possibility of axillary nerve injury.

Patients and Methods A total of 23 patients participated in this prospective trial, both sexes, Neer's type 2, 3, and 4. Depending on the fracture architecture, either a 'two-window' less invasive incision or a longer incision was made using a modified trans-deltoid technique. Utilizing the Constant–Murley shoulder score, functional results were analyzed.

Results Neer's classification categorized fractures as type 2(43.5%), type 3(39.1%), and type 4(17.4%). The mean Constant–Murley score for shoulder function at the last follow-up was 83.7 points, with 4.3% poor, 17.4% moderate, 21.7% good, and 56.5% excellent outcomes. No cases of postoperative axillary nerve palsy were reported.

Conclusions The modified trans-deltoid approach is a practical and simple method for fixing proximal humeral fractures. It offers an early range of movement, little soft tissue damage, short operative time, better surgical exposure, and adequate accessibility for reduction and implant insertion.

Keywords Deltoid splitting approach, Proximal humerus fracture, Trans-deltoid approach.
Received: 07 December 2024, **Accepted:** 04 February 2025

INTRODUCTION

A 4–6% of adult fractures are proximal humeral fractures with a 1:2 male to female ratio [1,2]. Older people often have a history of low-energy trauma, whereas young individuals typically sustain proximal humerus fractures as a consequence of high-energy trauma [3].

The deltopectoral (DP) and trans-deltoid (deltoid splitting) methods are frequently utilized to treat proximal humeral fractures. Nearly all orthopedic specialists are aware with the delto-pectoral method, that involves accessing the inter-nervous plane between the deltoid and pectoralis major muscles. However, for certain fractures, particularly those where there is greater tuberosity displacement, achieving reduction using that method can be challenging. Additionally, Soft tissues need to be dissected and retracted during plate placement to the lateral surface of proximal humerus [3–7]. The delto-pectoral approach enhances the loss of blood supply to bone fragments and raises the chance of damage to the blood vessels supplying the humeral head, leading to avascular necrosis [3,5,6]. Therefore, accessing from the lateral aspect using the trans-deltoid approach would be much more suitable in some instances [3].

There have been worries about using the trans-deltoid method because of the possibility of harming the axillary nerve, which passes around the humeral surgical neck and via deltoid muscle. Therefore, an additional skipped incision may be required to protect the axillary nerve from harm [8].

Proximal humeral fractures are reduced and fixed using a minimally invasive plate osteosynthesis procedure in a modified anterolateral trans-deltoid method. Because the anterior branch of the axillary nerve limits the incision length, a second incision may be required for distal screw placement [6].

At the lateral trans-deltoid approach, the middle 1/3 of the deltoid was identified and splitted among its fibres. While at the modified trans-deltoid approach, Once the fibrous raphe between the deltoid's anterior and middle heads was located, it was split along its fibres. Alternatively, an extended trans-deltoid technique for direct axillary nerve visualization has been shown to have positive clinical results [6].

The anterior branch of the axillary nerve is reliably positioned and rarely exhibits anatomical changes. Extending the standard trans-deltoid incision by 2cm offers excellent exposure of the axillary nerve bundle, which includes the axillary nerve and its associated vascular structures. Isolating and mobilizing this bundle can significantly enhance fracture site visibility and strengthen plate fixation by allowing the addition of extra screws [6].

This study aims to assess the outcomes of internal fixation in the treatment of proximal humerus fractures via the modified trans-deltoid approach, focusing on the functional outcomes and associated complications.

PATIENTS AND METHODS

Between April 2022 and 2023, this study was carried out and included 23 patients who received treatment for proximal humerus fractures via modified trans-deltoid approach at the author's university hospital. Every patient provided written informed consent, and the study was approved by the local research ethics committee of the related medical school.

Inclusion criteria

(a) All patients with closed displaced proximal humeral fractures of two, three, or four parts.

(b) The time of trauma was less than 14 days.

Exclusion criteria

(a) Minimal displacement proximal humerus fracture.

(b) Head split fractures (comminuted humeral head fractures).

(c) Pathological fractures.

(d) Associated Injuries to blood vessels or nerves.

(e) Patients with muscle diseases such as myopathy.

(f) Neurovascular affection or diseases.

A comprehensive history and clinical examination were performed on each patient. radiological examination (three views: axillary lateral, scapular Y, and AP scapular (true AP) views) of shoulder joint. And computed tomography scan with three dimensional imaging was done for almost all patients, laboratory investigations (complete blood count, prothrombin time and international normalized ratio test, renal and hepatic function tests, and random blood glucose. Electromyography was used pre and postoperative to diagnose axillary nerve dysfunction.

Operative technique

General anesthesia was used for all patients, often combined with a scalene block for postoperative pain control. A broad-spectrum third generation cephalosporin antibiotic was given preoperatively within an hour in all cases.

The patient was placed semi-sitting (beach chair) position. For all of them, we should ensure a radiolucent area under the shoulder allowing for intraoperative fluoroscopic AP, external rotation, and internal rotation views. A modified trans-deltoid approach was used, the surgical incision is made from a point between the anterior 1/3 and the posterior 2/3 of the lateral outer edge of the acromion, marking 5cm below the lateral border of the acromion is made as a landmark which helps for easier identification of axillary nerve intraoperatively. After making an incision through the skin and subcutaneous tissues while ensuring proper hemostasis, the fascia covering the deltoid muscle becomes visible.

The fascia is dissected, and the anterior raphe of the deltoid muscle is identified as a white raphe between the anterior and middle fibers. After splitting of the raphe without cutting through any muscle fibers, identification of the axillary nerve at 5–7cm from the lateral margin of the acromion, The nerve is found inside the muscle and sometimes it is more than one branch (leach of nerves) close to each other. The nerve is carefully released anteriorly and posteriorly to free it, followed by gentle elevation, the subdeltoid bursa is identified and the fracture is reached.

The fracture is identified and reduced either by direct or indirect reduction by putting a conventional screw in the oval plate hole after applicating the plate under the nerve (Figure 1).

In Neer Type 3 and Type 4 fractures, securing the greater and/or lesser tuberosity can be effectively achieved by placing nonabsorbable stay sutures (traction sutures) in the rotator cuff tendons (subscapularis, supraspinatus, and infraspinatus) at the junction where the tendon meets the tuberosity. This technique improved control over the fractured fragments. After placing the sutures, the fragments were carefully reduced into their proper

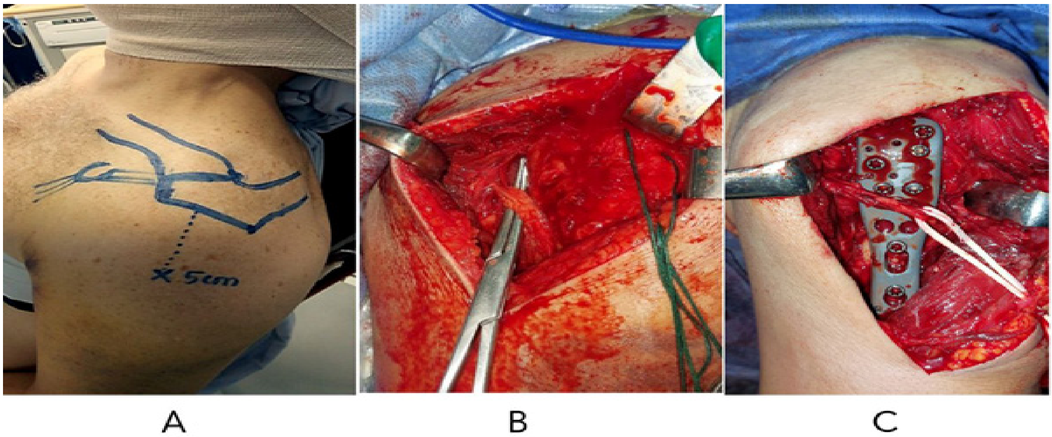

Figure 1: (A): The modified trans-deltoid approach for proximal humerus fractures, Surface marking of bony landmarks; (B): Exposure of proximal humerus and axillary nerve; (C): Intraoperative identification of the axillary nerve and PHILOS plate slid beneath.

anatomical alignment through manipulation and gentle traction on the stay sutures. Once the head screws were secured, the sutures were threaded through the holes in the plate to ensure they were not compromised by the advancing screws. Additionally, K-wires can be used to provide temporary stabilization of the fracture fragments.

It is necessary to pay attention to the correct alignment of the proximal humerus in all planes. especially, the medial 'calcar' region needs to be securely aligned, and any varus malposition should be corrected.

Minor impaction may be acceptable in older patients, as it can enhance stability.

After completing the fixation, the AP view, Internal rotation, and external rotation views are taken under fluoroscopy to ensure fracture reduction and the absence of any screw penetration (Figure 2).

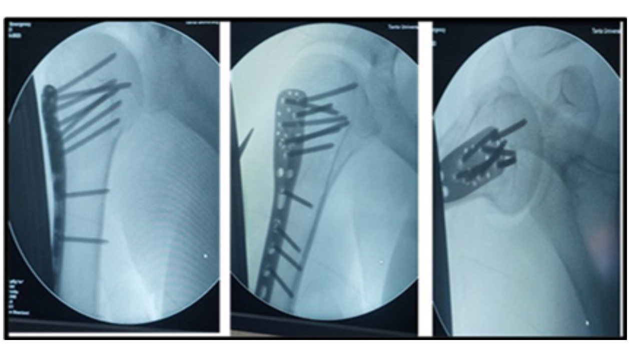

Figure 2: Reduction of proximal humerus fractures aided with Intraoperative Fluoroscopy.

The wound was closed with a suction drain in place and was removed within 24–48h. Intravenous antibiotics were administered for the first three days, utilizing a combination of two types to cover both gram-positive and gram-negative bacteria. After this period, we transitioned to a broad-spectrum oral antibiotic until the skin stitches were removed. Analgesics were provided as necessary.

Postoperative evaluations included a neurological examination and assessment of distal pulses. The patients were positioned in an arm sling immediately following the procedure and were allowed to begin passive exercises as soon as the third or fourth postoperative day if pain was tolerated.

Post-operative follow-up

Visits for follow-up were planned after 1 week, 2 weeks, 1 month, and then monthly for a minimum of 1 year.

Clinical, radiographic, and neurological results were assessed, and outcome measures were applied at the final follow-up visit after 12 months. Exercises may be initiated on the first days postoperatively. Reactive tissues typically require 4–6 weeks of protection from excessive stress. Painful or forceful stretching should be avoided, as it often triggers pain and reflexive muscle guarding which are common responses to trauma or surgery. Passive exercises are intended to maintain or gradually improve the range of movement within relatively pain-free or restricted ranges.

A 6–8 weeks following surgical intervention, assisted elevation using a pulley system is performed, beginning in a supine position and gradually transitioning to an upright position. Isometric strengthening exercises are also incorporated. Additionally, stretches are conducted to enhance forward elevation, extension, abduction, and both external and internal rotation of the affected extremity. Patients are encouraged to gradually incorporate the affected limb into daily activities to build strength and endurance.

Evaluation of outcome

The results were assessed using the Constant–Murley shoulder score. The period of follow-up ranged from 6 to 12 months with 9 months on average.

Statistical analysis

Statistical analysis was done by SPSS, v26 (IBM Inc., Chicago, Illinois, USA). Quantitative variables were presented as mean and SD and compared between the three groups utilizing the analysis of variance (F) test with post-hoc test (Tukey). Quantitative nonparametric data were presented as the median and interquartile range. Qualitative variables were presented as frequency and percentage and were analyzed utilizing the χ^2 test. Effect sizes were reported along with 95% confidence intervals (CIs). A two-tailed *P* value less than 0.05 was considered statistically significant.

RESULTS

A total of 23 patients were involved in that research, 10(43.5%) men and 13(56.5%) women, with an average age of 39.87 years (95% CI: 35.4–44.3), (range: 20–70 years old). The highest fracture rate was found in patients aged 30–50 years (43.5%). 10 cases were smokers.

In terms of the mechanism of injury, eight (34.8%) patients suffered high-energy injuries due to road traffic accidents, while 13(565%) patients experienced isolated low-energy trauma from falls, either on stairs or on the ground. Additionally, two (8.7%) patients were injured due to electric shocks. Right-side fractures occurred in eight (34.8%) patients, while left side fractures occurred in 15(65.2%) patients.

Pre-existing comorbidities were present in seven patients: three individuals were both diabetics and hypertensives, one was hypertensive only, one was diabetic only, and two had a seizure disorder. Neer's system was used to classify the fractures: 10(43.5%) cases were identified as type 2 fractures, nine (39.1%) cases as type 3 fractures, and four (17.4%) cases as type 4 fractures (Table 1).

The mean period from trauma to operation was 2.43±1.44 days, with a range of 1–7 days. An average length of 5.7cm (with a range of 5.4–7.5cm) was found between the axillary nerve and the lateral margine of the acromion. The average surgery duration was 87.4±21.4 min (95% CI: 78.5–96.3). Postoperatively, one (4.3%) patient who was diabetic developed a superficial infection, and another patient experienced shoulder stiffness 1 month after the operation (4.3%). This stiffness improved with both active and passive physiotherapy exercises. Notably, none of the patients had deltoid muscle dysfunction or axillary nerve palsy.

Overall, 20(86.96%) patients achieved good anatomical reduction, while three (13.04%) patients had poor reduction (Table 2).

Table 1: Preoperative data of the patients:

	Total= 23
Mean age	39.87 years
Sex, *n* (%)	
Males	10(43.5)
Females	13(56.5)
Smoking	10(43.5)
Characters of fracture, *n* (%)	
Mode of trauma	
Falling	13(56.5)
RTA	8(34.8)
Electric shock	2(8.7)
Side of fracture	
Right side	8(34.8)
Left Side	15(65.2)
Neer's classification, *n* (%)	
Type 2	10(43.5)
Type 3	9(39.1)
Type 4	4(17.4)
Associated medical conditions, *n* (%)	
Diabetes	4(17.4)
Hypertension	4(17.4)
Seizures	2(8.7)

Table 2: Lag time, duration of surgery, union, and complications of the studied patients:

	***N*= 23**
Lag time before operation (days)	2.43±1.44
Duration of surgery (min)	87.39±21.37
Time for union (weeks)	8.61±2.21
Postoperative complications, *n* (%)	
Infection	1(4.3)
Shoulder stiffness	1(4.3)
Malreduction	3(13.04)
Neurological complications	0

Radiological results

Head Shaft Angle (HSA)

The mean value of the head shaft angle (HSA) of the humerus±SD was 129.7±9.31^0 (95% CI: 125.7–133.7^0), ranging from 100 to 139.8^0. Seven (30.4%) patients had HSA of less than or equal to 125^0, while 16 (69.6%) patients had HSA greater than 125^0. The HSA was measured and classified using the Paavolainen criteria as a measurement of reduction.

The Humeral Head Height (HHH)

The mean value of humeral head height (HHH) in this study±SD was 5.74±2.67mm. Six (26.1%) patients with HHH less than 5mm, while 17(73.9%) patients with HHH greater than or equal to 5mm.

All patients achieved union within 6–12 weeks postoperatively, the mean time of union±SD was 8.61±2.21 weeks (95% CI: 7.6–9.6).

At the last follow-up, the average Constant–Murley score for shoulder function was 83.7 points (95% CI: 80.3–87.1). It was poor in one (4.3%) patient, moderate in four (17.4%) patients, good in five (21.7%) patients, and excellent in 13(56.5%) patients (Table 3).

Table 3: Constant score of the studied patients 12 months postoperatively:

Constant–Murley score		***N*= 23**
Poor		1(4.3)
Moderate		4(17.4)
Good		5(21.7)
Excellent		13(56.5)
Different parameters of Constant score		
Modality	Maximum score	Mean observed score
Pain	15	12.17
Daily living activities	20	17.74
Range of movement	40	33.65
Power	25	20.17
Total score	100	83.73

The Constant score was significantly lower in older patients (mean difference –16.2 points, 95% CI: –29.7– –2.7, P= 0.044) and in patients with Type 4 fractures (mean difference –21.5 points, 95% CI: –34.2 to –8.8, P= 0.008) compared with younger patients and those with Type 2 fractures, respectively (Figure 3). No significant differences in outcomes were observed based on sex (P= 0.378) or side of fracture (P= 0.532) or mechanism of injury (P= 0.787) (Table 4).

Case presentation

A male patient, aged 38, arrived with right proximal humerus fracture (Neer Type 3) sustained after falling while riding. He had no pre-existing medical conditions or associated injuries. The fracture was treated using the modified trans-deltoid approach. During the procedure, axillary nerve identification was made, Using a PHILOS plate, open reduction and internal fixation were carried out.

Postoperatively, after 4 weeks of being immobilized in an arm sling, that patient was allowed to begin passive exercises from the third day after surgery, following an improvement in pain. Both preoperative and postoperative electromyography results were normal. After ten weeks, radiological confirmation of union was observed. The patient started physiotherapy 6 weeks after the surgery and achieved full muscle power by the 6-month mark. There was no restriction on range of movement, and his Constant shoulder score was excellent (99 points) (Figure 4,5).

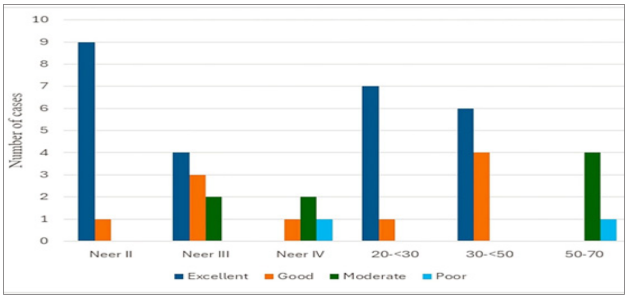

Figure 3: The bar chart illustrates the relationship between Constant–Murley score, patient age groups, and Neer's fracture classification. Outcomes are color-coded: Excellent (blue), Good (orange), Moderate (green), and Poor (light blue), with bar height representing case numbers. The data show that older patients (50–70 years) and complex fractures (Neer IV) have lower scores and poorer outcomes, while younger patients (20–< 30 years) and simpler fractures (Neer II) achieve higher scores.

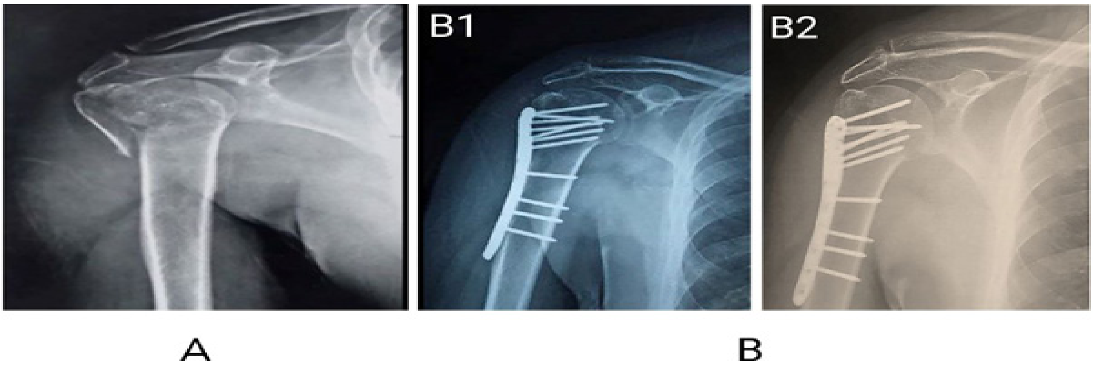

Figure 4: (A): Preoperative radiography of a case of our study with Neer type 3 proximal humerus fracture; (B): Follow-up radiography after 6 months (B1) and 12 months (B2) showing complete union.

Figure 5: Range of shoulder movement after 6 months postoperative showing good results.

Table 4: Relation between the Constant score and the age, sex, Neer's classification of the studied patients:

Age	Constant Score				Total number of cases	*P* value
	Excellent	Good	Moderate	Poor		
20-30< years	7(87.5)	1(12.5)	0	0	8	0.044*
30- 50< years	6(60)	4(40)	0	0	10	
50–70 years	0	0	4(80)	1(20)	5	
Sex						
Females	6(46.2)	4(30.8)	3(23.1)	0	13	0.378
Males	7(70)	1(10)	1(10)	1(10)	10	
Neer's classification						0.008*
Type 2	9(90)	1(10)	0	0	10	
Type 3	4(44.4)	3(33.3)	2(22.2)	0	9	
Type 4	0	1(25)	2(50)	1(25)	4	

DISCUSSION

Managing complicated fractures of the proximal humerus has been a longstanding problem for orthopaedic specialists. While there is general agreement that achieving the anatomical reduction of the tuberosities and early initiation of range of motion during rehabilitation are important for successful outcomes [9].

All fracture fragments, including the greater tuberosity, have the best probability of being reduced and united with open reduction and internal fixation, which leads to satisfactory functional outcomes. This technique has been constrained, however, by the challenge of achieving firm fixation and sufficient exposure without endangering soft tissue structures [10,11].

To avoid impingement from a malreduced fracture or a malpositioned plate, all fractured fragments, especially the greater tuberosity, need to be sufficiently exposed [12].

Over the past 30 years, various surgical methods for the proximal humeral fractures were developed, including DP and deltoid splitting approaches [4,13]. Most experts recommend using a DP approach for managing unstable fractures involving 3 and 4 parts. This approach makes it simple to convert to hemiarthroplasty during surgery if needed. It can be not easy to visualize the fractured greater tuberosity, which is normally externally rotated by the rotator cuff muscles and This may necessitate significant dissection and soft-tissue retraction. Accessing this fragment may involve detaching the pectoralis major insertion and/or the origin or insertion of the deltoid muscle. Notably, releasing 20% of deltoid insertion may result in significant impairment of the anterior deltoid function [13].

Many specialists have utilized the trans-deltoid method for internal fixation of proximal humeral fracture. That procedure plays a significant role in exposing the greater tuberosity fragment and rotator cuff injuries, In addition to facilitating the precise positioning of fixed angle locking plates [4]. Maluta *et al.,* [14] demonstrated that the direct lateral transdeltoid approach offers superior reduction of greater tuberosity displacement compared with the DP approach in treating severely displaced proximal humerus fractures.

The patients in this study were between the ages of 20–70, with a mean age of 39.87 years. The highest incidence of cases was observed among those aged 30–50 (43.5%). This finding is compatible with studies carried out by Neer *et al.,* [15], that reported the average age was 55.3 years old. Additionally, Samuel Haupt *et al.,* [16] noted that 49 years old was the average age of proximal humeral fracture, while Jacob *et al.,* [17] stated that their study's mean age was 49.5 years. In the study conducted by Court Brown *et al.,* [2] the average age was 66 years old, with men averaging 56 years and women averaging 70.

Since 18 of the 23 patients in this study were under 50, the mean age was 39.87 years old. probably because of the smaller sample size. Age was a significant factor affecting the clinical and functional outcomes of the patients (P= 0.044).

Compared with older patients, young adults—particularly men—have been reported to have superior functional outcomes. mostly as a result of early hospitalization, a healthy bone stock, the absence of co-morbid conditions and excellent patient compliance during the rehabilitation program [18].

In this study, females were more than males with a ratio of 56.5–43.5%, this is correlated with the study reported by Fischer *et al.,* [19] who had 35% males and 65% females and Kim *et al.,* [20] reported a high female predominance about 85%.

In this study, falling on the ground was the main cause of injury accounting for 57% of cases, then road traffic accidents about (35%), and electric shock (8%). This result was the same as that reported by Basavanagowda *et al.,* [21] and Shin *et al.,* [6]. However, Gawali *et al.,* [22] stated that road traffic accidents was the main cause of trauma. This could be because of recklessness, particularly among young people which leads to plenty of hazards.

In that research, Neer's classification revealed that 10(43.5%) cases were two-part fractures, nine (39.1%) cases had three-part fracture, four (17.4%) cases had four-part fracture. Fazal *et al.,* [23] reported that 13(48%) cases were two-part fractures, 12(45.5%) cases were three-part fractures and two (7.5%) were four-part fractures. Herscovici *et al.,* [24] reported that 20(50%) cases had two-part fracture, 16(40%) cases had three-part fracture, four (10%) cases had four-part fracture. This reveals that the incidence of fracture type is closely similar to previous studies.

In cases of surgical neck fracture that are classified as two parts, Because the two tuberosities still connected to the head, it maintained its neutral position, but the pectoralis major's tension caused the shaft to shift medially. To reduce the fracture, traction, flexion, and a bit of adduction were necessary. In instances where reduction could not be performed, soft tissue interposition was noted, which prevented the reduction [25].

If the greater tuberosity was connected to the head, it was likely forced into external rotation with the humeral articular surface directed anteriorly, which made displaced three-part fractures challenging to reduce and even harder to hold reduced (unstable fracture). In the situation that it was attached to the lesser tuberosity, the joint surface was oriented posteriorly. The long head of the biceps became trapped between the fracture components and blocked reduction while the pectoralis major moved the shaft medially [12].

Hence, there was a significant reduction in favorable functional outcomes regarding the Constant score with an increase in Neer's fracture classification (P<0.05).

In this study, the functional results were promising. The average Constant–Murley scoring was 83.7 points, excellent results were 56.5% (13 cases), 21.7% (five cases) were good. while moderate results were 17.4% (four cases), and poor results were 4.3% (one case). The deltoid splitting method has produced higher functional scores in the majority of studies comparing the functional results of both the DP and deltoid splitting procedures. This method was used in 16 patients who had proximal humeral fracture by Gardner *et al.,* [26] who discovered that it was effective as well as safe in treating these fractures. In a comparative analysis of 42 patients with proximal humerus fracture, Isiklar *et al.,* [27] found that patients who underwent surgery with the deltoid splitting technique had noticeably higher constant scores sooner than patients who underwent surgery with the DP method. Believed that in comminuted proximal humeral fracture, trans-deltoid technique allowed for more control and, consequently, more effective reduction of the head and tuberosity fragments. Liu *et al.,* [28] claimed that the average Constant score±SD was 86.7±6.06 points.

In comparative analysis of 50 cases with proximal humeral fracture, Fisher *et al.,* [19] found that patients who underwent surgery using the deltoid splitting technique had noticeably higher Constant scores sooner than those who underwent surgery using the DP approach. Constant–Murley score for the deltoid splitting was 81.6±16.1 and for the DP approach it was 76.3±18.6.

Wu *et al.,* [5] conducted a systematic review and meta-analysis comparing the deltoid-split and DP approaches for proximal humerus fractures. The deltoid-split approach demonstrated advantages, including shorter surgical time, reduced blood loss, faster bone union, and improved early postoperative shoulder function, as reflected by higher Constant Shoulder Scores at 3 months postoperative.

The trans-deltoid approach is often restricted by fears of harming the axillary nerve. some authors recommend not splitting the deltoid muscle beyond five centimetres from the acromion to protect the axillary nerve, others suggest that splitting along the raphe is safe, because this is where the axillary nerve could be consistently recognized as one main branch [6,29].

We noticed no negative impacts associated with exposure of the axillary nerve and applying a plate under it during this study's follow-up period. Our method involved identifying and safeguarding the axillary nerve during surgery, leading to improved surgical exposure and minimal complications. It was found that the axillary nerve was always safeguarded and easily palpable in our study.

There were no cases of deltoid muscle weakness or axillary nerve abnormalities reported postoperatively. Previous studies, including those by Gardner *et al.,* [26] seventy cases had been utilizing this technique, he observed no iatrogenic axillary nerve injury. In most of these cases, the nerve was discovered to be entrapped in the fracture and released prior to fracture reduction. He discovered that axillary nerve was located in an expected place when he dissected the anterior deltoid raphe distally from the acromion. Laflamme *et al.,* [30] observed that the axillary nerve was always preserved and easily palpable when they performed deltoid splitting procedure for fixation of 30 cases. Equivalent to this, Lill *et al.,* [31] performed a deltoid splitting method placing locking screws distally while closely monitoring the position of the axillary nerve. These authors did not report any problems with that technique.

In our study, the average length from axillary nerve to the lateral border of the acromion was about 5.7cm (from 5.4 to 7.5cm). It is important to identifying the axillary nerve directly in front of the eyes. Most studies demonstrate that the nerve is presented at 5-7cm from the lateral edge of the acromion. In the situation of a minimally invasive technique, the region crossed by the axillary nerve was safeguarded by keeping a skin bridging in between [32,33]. Abhinav *et al.,* [33] demonstrated that average acromion-axillary length in a cadaveric dissection of 30 shoulders was six cm, with a range between 4.5 to 6.5 cm. Since the nerve is nearer to the acromion by 1.5cm in abduction, they advised against splitting the deltoid during that [32].

In this research we did not detect axillary nerve affection, necrosis of the humeral head, nonunion, or deep infection that required implant removal, and no reoperations were done.

One case developed a postoperative infection in a diabetic patient with low immunity and inadequate wound dressing. The infection was treated with daily dressing and appropriate antibiotic therapy targeting gram-positive and gram-negative bacteria. The patient's condition improved within a few days, and surgical debridement was not required. Underscoring the importance of perioperative glycemic control in diabetic patients.

Malreduction occurred in three (13.04%) cases, in the form of HSA less than 125^{0} and HHH less than 5mm with varus displacement.

Malreduction can occur due to several factors, particularly the complexity of fracture patterns, such as multifragmentary Neer type 4 fractures, which are often characterized by significant displacement and comminution. Inadequate handling of the rotator cuff and surrounding soft tissues can hinder the proper alignment of fracture fragments. Additionally, comminution of the medial calcar may result in instability and varus collapse. Furthermore, improper use of reduction tools and soft tissue interposition can complicate the reduction process. A lack of experience with the modified trans-deltoid approach or in managing complex proximal humerus fractures also increases the likelihood of malreduction. To minimize these risks, it is essential to prioritize meticulous surgical planning, advanced imaging, thorough training for surgical personnel, appropriate handling of soft tissues, and optimized fixation techniques. Restoring the medial calcar is also crucial for achieving a stable reduction [34].

Regarding humeral head osteonecrosis, According to Hertel *et al.,* [35], the most important indicator of humerus head ischemia is a short calcar segment measuring 8mm. Our research demonstrated that certain combinations of fracture planes were linked to compromised head perfusion. Additionally, factors like the length of the posteromedial metaphyseal head extension and the condition of the medial hinge played a crucial role in causing vascular impairment. The medial hinge is the intact bone and periosteal connection on the medial side of a proximal humerus fracture. It acts as a pivot point during fracture reduction and fixation, helping to maintain alignment and stability for optimal healing [36].

The medial displacement of humeral shaft relative to the head was found to be far more significant than lateral displacement. Maintaining the integrity of the medial hinge is essential for proper fracture reduction and stabilization, directly impacting the ease of reduction and the success of fixation [34].

Egol *et al.,* [37] reported that the low rate of avascular necrosis (AVN) might be attributed to surgical techniques that prioritize minimal soft-tissue dissection and the preservation of blood supply.

We recommend that surgeons remain mindful of the potential risk of humeral head osteonecrosis when utilizing the DP method to manage proximal humeral fractures with a short calcar segment. Limiting soft-tissue dissection and maintaining vascular integrity could help decrease the likelihood of avascular necrosis. Xie *et al.,* [3] discovered that the deltoid splitting method was linked with a considerably reduced rate of humeral head necrosis compared with the DP approach.

In this study, we were able to better position the plate, and this led to better placement of the head screws and prevention of impingement.

The importance of physical rehabilitation is undeniable. Adhering to a structured rehabilitation program is essential. With appropriate rehabilitation, patients can achieve favorable functional outcomes. Those who experience stiffness during treatment can benefit from intensive physiotherapy to regain mobility [38].

Our study has several limitations. It is a prospective case series conducted without a control group, which limits direct comparisons with other surgical approaches. Additionally, the sample size is relatively small, and although the last follow-up reached 12 months, the average follow-up duration remains short, restricting the assessment of long-term complications such as osteonecrosis and late malalignment. These limitations highlight the need for future multi-center studies with larger sample size, extended follow-up period, and comparative analyses with other surgical approaches to further validate our findings.

CONCLUSION

Modified trans-deltoid method makes it possible to fix proximal humeral fractures with little damage to the axillary nerve, comorbidities, or loss of function. Modified trans-deltoid method is a practical and simple method for fixing proximal humeral fractures. It offers early range of movement of the shoulder joint, improved surgical exposure, good access for reduction, placement of implants, and little soft tissue damage. This technique is linked to a low rate of malreduction.

ACKNOWLEDGMENTS

Not applicable

Declarations:

Ethical approval/IRB approval: This study was approved by the ethics committee of the Faculty of Medicine-Tanta University. Approval reference code (36264MS136/4/23).

Consent to participate: written informed consent was obtained from all the participants included in our study.

Consent to publish: Written informed consent was obtained from the participants in our study regarding publishing their data and photographs.

Availability of data and materials: The datasets generated during and/or analyzed during the current study are available from the corresponding author on request.

AUTHORS CONTRIBUTIONS

M.K.E.-M.: writing, statistical analysis, and performing surgeries. **M.S.S.:** supervision and coordinator. **M.A.Q.:** patient recruitment, clinical examination, and radiological measurements. **E.-S.M.E.-F.**: clinical examination, radiological measurements, and performing surgeries. All the authors contributed to the study design. All the authors read and approved the final manuscript.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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