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Original Research Article

Implantless osteosynthesis of lateral end of clavicle fractures using autologous palmaris longus tendon graft for coracoclavicular ligament reconstruction

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ABSTRACT

Background: Lateral end clavicle fractures require operative management because of significant displacing forces of trapezius, sternocleidomastoid and weight of the arm. Coracoclavicular ligaments are usually torn hampering vertical stability. Currently used implants for osteosynthesis are associated with implant impingement on acromion, poor purchase of lateral fragment and implant cut-out. There is a lack of consensus regarding ideal treatment of these fractures.
Methods: 31 patients with lateral clavicle fracture who were admitted from May 2019 to August 2022 were enrolled in this study and underwent coracoclavicular ligament reconstruction using ipsilateral palmaris longus graft looped around coracoid and tied over clavicle to hold it reduced. Patients were assessed for pain, shoulder range of motion and functional outcome with 6-month follow-up.
Results: All patients showed radiological union with good to excellent outcome in 79.3% patients and mean abduction of 157º. Mean duration of surgery was 104 minutes (SD±12.118) and 10.3% patients showed shoulder stiffness.
Conclusions: The study shows encouraging prospect in purely biological osteosynthesis with functional outcome at par with other methods of fixation while avoiding implant related complications.

Keywords: Lateral clavicle fracture, Palmaris longus, Coracoclavicular ligament, Neer type 3B fracture

INTRODUCTION

Clavicle fractures are common and account for 2-4% of all adult fractures. While most clavicle fractures are midshaft fractures which heal satisfactorily with conservative treatment or anatomic plating, fractures involving the lateral end of clavicle (10–15%) pose some special problems.

Trapezius pulls the proximal fragment upwards while the weight of the arm makes the lateral fragment sag downwards.[1] Conoid and trapezoid ligaments, running between the coracoid and the clavicle are often torn by the deforming forces in Neer type II fracture of lateral end of clavicle fractures. These coracoclavicular ligaments being the major vertical stabilizer of the lateral end of the clavicle, when torn, adds to the instability. Thus, the fragments are significantly displaced making these fractures highly prone to non-union, tenting and prominence of skin, persistent pain and shoulder weakness.

High rate of complications has driven the current consensus towards surgery as the primary treatment.[2] A wide variety of operations implants have been suggested for these fractures, each fraught with their own technical challenges. Acromion hook plates have been known to cause acromion osteolysis, acromion fracture and rotator cuff injury prompting early removal but removal before 6

months can cause refracture and non-union. Pre-contoured lateral clavicle locking plates provide better anatomic reduction but offer doubtful purchase due to flattened anatomy, poor bone quality and comminuted lateral fragment. Tension band wiring is associated with wire migration, loosening, poor holding strength and skin impingement.

Supplemental coracoclavicular fixation using suture anchors and tightropes[3] through coracoid have shown better results recently but these are technically difficult and poor drill positioning has led to coracoid fractures, suture cut out or implant failure. Although there is a plethora of treatment options, a gold standard is yet to be decided. This study proposes the use of autologous palmaris longus tendon graft for reconstructing coracoclavicular ligament and maintain reduction without additional implants.

METHODS

This study aimed to investigate the role of coracoclavicular ligament reconstruction using palmaris longus graft to maintain fracture reduction in lateral third clavicle fractures. It was conducted in Calcutta National Medical College, India following ethical approval and informed patient consent. The study period was from May 2019 to August 2022. This was a hospital based, prospective, descriptive study. 31 patients with isolated lateral end clavicle fracture (Neer type 2) aged between 18-60 years who had presence of palmaris longus were included in the study. Segmental, pathological and open fractures, ipsilateral upper limb injuries and pre-existing shoulder pathologies were excluded from the study.

Shaeffer's test was performed to detect the presence of palmaris longus tendon by asking the patient to touch the thumb to little finger flexing the wrist (Figure 1). If tendon could not be definitively identified clinically, ultrasound was used to confirm it. Injury to coracoclavicular ligaments was clinically evident as tenderness in the coracoclavicular space and tenting of skin by medial fragment. Digital X-ray of affected shoulder AP view confirmed the distal clavicle fracture (Figure 3).

31 patients visiting the institution from May 2019 to August 2022 satisfying the inclusion and exclusion criteria were operated under general anaesthesia. Beach chair position and standard superior 6 cm incision along the clavicle centred around the fracture was used. Fracture edges were cleared to visualize fracture pattern, look for comminution and ligament injury. Blunt dissection was then done antero-inferiorly to reach the coracoid and a tunnel was created underneath it from medial to lateral using finger dissection and right-angled clamp.

Next, palmaris longus was harvested from ipsilateral forearm using a single 2 cm transverse incision along the wrist crease. Palmaris longus lies immediately subcutaneous and above the antebrachial fascia. The tendon was lifted, held with an artery forceps and transversely incised distally. A tendon stripper was introduced over the cut end maintaining tension on the artery forceps and with gentle push on the stripper, the tendon was harvested out. The graft was cleared of muscle fibres and ends were prepared using Krackow suture technique (Figure 1).

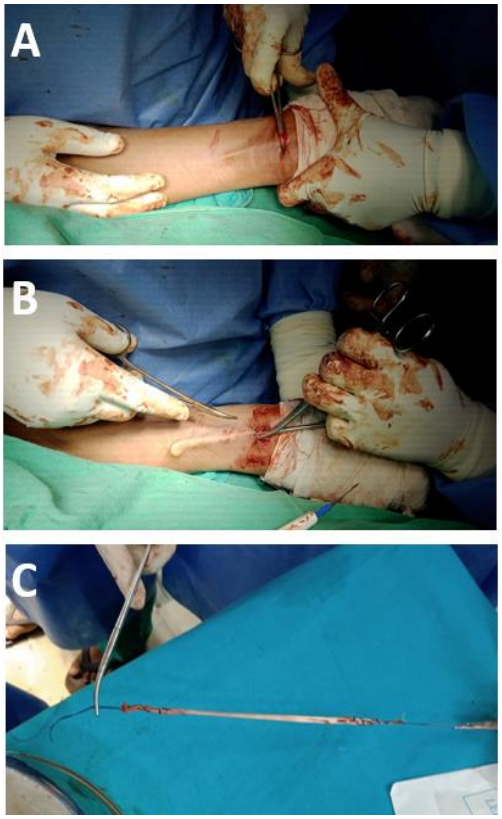

Figure 1: Technique of palmaris longus harvesting (a) 2 cm transverse incision over wrist crease and tendon lifted, (b) tendon stripper introduced maintaining traction on distal end with artery forceps, (c) tendon freed of muscle fibres and ends prepared with Krackow sutures.

The clavicle fracture was provisionally reduced and held with K wires. Two 2.7 mm wide holes were drilled about 30 mm (slightly anterior) and 45 mm (slightly posterior) from lateral end to correspond with conoid and trapezoid ligaments. The graft was then passed under the coracoid from medial to lateral in the tunnel previously created, crossed on itself and threaded through the drill holes in the clavicle.

This forms a figure of 8 shape of tendon graft passing through the clavicle and looping around the coracoid. The two limbs of the graft are pulled firmly above the clavicle, crossed on themselves and sutured to each other using non-absorbable sutures. This holds the medial fragment firmly downwards and maintains reduction. Provisional fixation k wires were removed and the wound was closed in layers (Figure 2). Patients were followed up on 2 weeks, 6 weeks, 3 months and 6 months. The arm was postoperatively supported in shoulder-arm pouch, pendulum exercises

started at 2 weeks but active shoulder abduction was restricted until 6 weeks. Weight lifting was restricted to 2.5 kg until 12 weeks (Table 1). Functional assessment using constant

Table 1: Post-operative protocol after coracoclavicular ligament reconstruction.

Week 0-2	Week 2-4	Week 4-6	Week 6-12	Week 12-20
Upper limb supported in shoulder arm pouch Start elbow, wrist and finger range of motion exercises	Suture removed on day 14, start pendulum exercises of shoulder, avoid shoulder abduction	Start passive shoulder range of motion exercises, avoid active shoulder abduction, discontinue shoulder arm pouch at 6 weeks	Start active shoulder abduction, avoid carrying weight more than 2.5 kg on ipsilateral limb Proceed to full range of motion	Begin strength training, gradual return to sports and full activities of daily living

*Patients were encouraged to wear the shoulder arm pouch at all times during sitting upright, standing and sleeping and to only take it off during exercises. Arm pouch was used till 6 weeks post-operatively

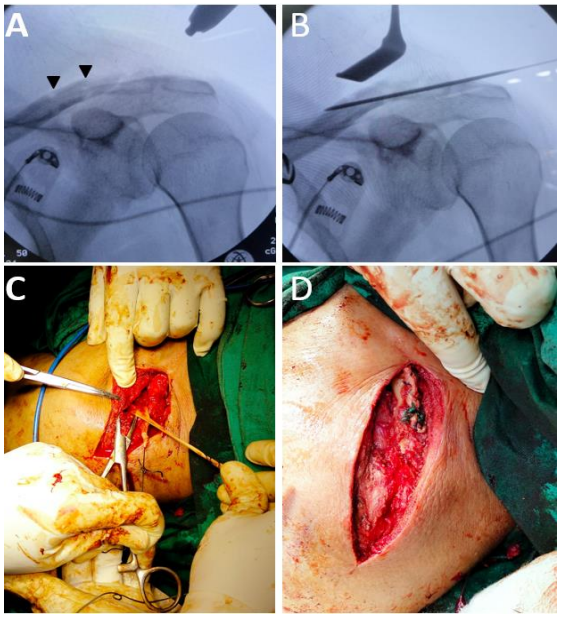

Figure 2: Technique of ligament reconstruction (a) drilled holes through clavicle (arrows), (b) provisional reduction with K wire, (c) graft looped around coracoid, and (d) graft passed through clavicle and sutured on itself.

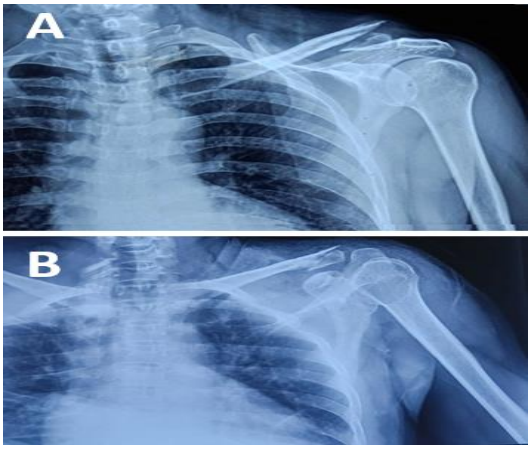

Figure 3: Pre-operative and post-operative X-rays, (a) pre-operative X-ray, and (b) post-operative X-ray.

Murley score, range of motion and radiological union were assessed. Statistical analysis was done using IBM statistical package for the social sciences (SPSS) statistics 27.0.1.

Continuous variables were expressed as mean and standard deviation and categorical variables summarized as count and percentage.

RESULTS

A total of 31 eligible patients were enrolled but 2 were lost to follow-up, so 29 patients were included in the analysis. Mean age of the patients was 40.03 years (SD±10.82) with 20 male (69%) and 9 female (31%).

Left side was predominantly involved (72.4%). Fall on shoulder was the most common mode of injury (69%) followed by RTA (13.8%) and fall on outstretched hand (10.3%) (Table 2). Mean duration of surgery was 104 minutes (SD±12.118) and there was a general trend towards reduction of duration of surgery over time as we became more experienced with the procedure (Figure 4).

Mean post-operative range of motion after 6 months were 157º abduction (SD±23), 48º adduction(SD±5), forward flexion 156º (SD±19) and extension of 56º (SD±4).

Functional outcome was assessed using constant Murley score at 6 months with a mean of 78.31 (SD±14.31). This was interpreted as excellent outcome in 12 (41.4%), good outcome in 11 patients (37.9%) and fair outcome in 6 patients (20.7%) with no patient having poor outcome. Pain was assessed using VAS score 6 months post-operatively. 62.1% of patients had no pain 6 months after surgery. Mean VAS score was 1.03 (SD±1.614). 82.8% patients had no post-operative complications.

Shoulder stiffness was present in 3 patients (10.3%) 6 months after surgery.

There was no donor site complication. 1 patient had infection which required debridement and 1 patient had delayed union which eventually united in 14 months.

Table 2: Demographics and study parameters of the study population.

Parameters	Mean	Standard deviation	Count	Percentage
Age (in years)	40.034	10.822		
Gender				
Male			20.000	68.966
Female			9.000	31.034
Laterality				
Right			8.000	27.586
Left			21.000	72.414
Mode of injury				
Fall on shoulder			20.000	68.966
Direct blow			2.000	6.897
Fall on outstretched hand			3.000	10.345
Road traffic accident			4.000	13.793
Duration of surgery (in minutes)	104.000	12.118		
Abduction (in degrees)	157.103	22.517		
Adduction (in degrees)	47.793	5.024		
Flexion (in degrees)	156.414	19.216		
Extension (in degrees)	56.483	3.879		
VAS score	1.034	1.614		
Constant Murley score	78.310	14.311		
Interpretation				
Excellent			12.000	41.379
Fair			6.000	20.690
Good			11.000	37.931
Complications				
Shoulder stiffness			3.000	10.345
Delayed union			1.000	3.448
Infection			1.000	3.448
None			24.000	82.759

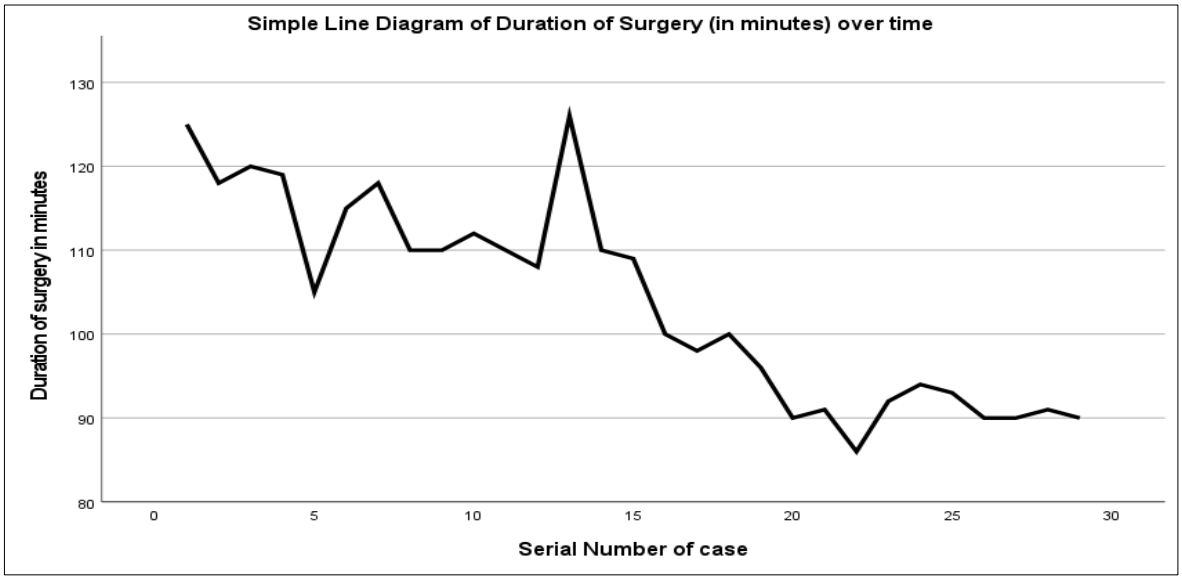

Figure 4: Simple line diagram showing time taken for surgery over time.

DISCUSSION

While most clavicle fractures heal conservatively, lateral end fractures require special consideration because of the deforming forces of the sternocleidomastoid, trapezius and weight of the arm which cause non-union in as high as 40% of fractures.[4] Moreover, the small size of lateral fragment coupled with comminution makes conventional fixation a

technical challenge. Furthermore, the association of coracoclavicular ligament injury causes a persistent instability of lateral clavicle.[5] This has led to the evolution of a variety of surgeries to tackle the challenges with no unequivocal standard management. Tension band wiring and trans-acromial fixation methods report good union rates but have been consistently associated with complications like implant prominence, wire migration, shoulder stiffness and acromioclavicular joint arthrosis, almost always requiring implant removal.[6]

Acromion hook plate which buttresses the lateral end of clavicle reports good union rate with small lateral fragments, but because of high rate of complications including acromion osteolysis, rotator cuff impingement and sub-acromion space inflammation.[7,8] Andreas et al in their meta-analysis no longer considers hook plates adequate for these fractures.[9] Pre-contoured locking plate avoids these complications while offering greater pull out strength but Sujanatheja et al agrees that in comminuted lateral end fractures, it is difficult to achieve enough screw purchase and it is difficult to counter the upward pull of trapezius.[10]

It is becoming evident that maintaining vertical stability by a flexible coracoclavicular fixation provides a dynamic but stable reduction with up-to 75% more fixation strength than traditional fixation methods while enjoying the advantages of better shoulder function and no need for implant removal.[11,12] This has lead to advent of newer fixation methods like endobutton, tightrope systems and fibertape which show excellent shoulder function.[13]

In this study, we have looped a tendon graft under the coracoid, and tied over clavicle through drill holes at attachment sites of conoid and trapezoid ligaments. This construct provides vertical stability, maintains the reduction, countering the upward pull of sternomastoid-trapezius while shoulder arm pouch prevents the downward sag of the distal fragment. Autologous graft and anatomical drill holes reconstruct the normal biology more closely than tightrope constructs while avoiding any foreign material. To our knowledge, this is the first study that attempts a pure biological method of osteosynthesis. Moreover, this method is applicable in cases with poor bone quality or lateral fragment comminution. We also avoid the risks of improper drill hole through coracoid, coracoid fracture, implant failure due to shearing of endobutton which are inherent of modern cc fixation techniques.[14,16] All 29 patients in our study achieved union (one patient having delayed union) with mean constant Murley scores of 78.31 which is at par with other fixation methods.[15] Our patients achieved mean abduction of 157 degrees with good to excellent outcome in 79.3% which is comparable with other studies.[7,16] No implant cost is incurred. A drawback of this method seems to be the mean duration of surgery of 104 minutes compared to 46 minutes for locking plate and 51 minute for acromion hook plate.[7] Shoulder stiffness was present in 10.3% of patients which is slightly more than other methods. Another shortcoming was the relatively small follow up period which cannot account for long-term sequelae such as acromioclavicular arthrosis and graft laxity over time. Further studies are required to compare this method with tightrope and fibertape fixation systems.

CONCLUSION

The findings of this study show encouraging results in distal clavicle fractures where not only osteosynthesis is achieved without an implant but also vertical stability is restored. The construct here is a purely biologic one using autologous tendon graft and the fixation closely resembles the original anatomy. Based on our data, the clinical outcome and rate of fracture union is equivalent to other methods of fixation but avoids the complications associated with implants. Duration of surgery is more than conventional methods but this may be reduced if an assistant performs the tendon harvest while the surgeon prepares clavicular tunnels. This study provides a unique method of addressing lateral end of clavicle fractures by ligamentous reconstruction of coracoclavicular ligament using autologous palmaris longus graft. This fixation is biomechanically sound and does not hamper the normal coracoclavicular motion. It is economic as no implant related cost is incurred. It also avoids complications related to implant osteosynthesis and does not require a second surgery for implant removal.

Recommendations

Further studies are required to compare the outcome with tightrope, suture anchors and fibertape methods of coracoclavicular fixation. Biomechanical studies are required to assess the strength of tendon graft and stress relaxation over time. Long term follow-up is needed to assess bone to tendon healing and acromioclavicular arthrosis.

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