Autologous Semitendinosus Tendon Mediated Stabilization of The Coracoclavicular Space Results in Union and Excellent Functional Outcomes in Neer's Type II Distal Clavicle Fractures: A Preliminary Report

S. Kumar Nema, D. Udayakumar, G. Balaji, S. Gandhi B., P. Pasupathy, M. Prabu

Department of Orthopaedics, Jawaharlal Institute of Postgraduate Medical Education and Research, Pondicherry, India

CORRESPONDING AUTHOR:

Udayakumar Devanadhan
Resident Department of Orthopaedics
Jawaharlal Institute of Postgraduate
Medical Education and Research
Jipmer Campus Rd
Dhanvantari Nagar
Puducherry, 605006 India
E-mail: udayakumard33@gmail.com

DOI:

10.32098/mltj.01.2021.08

LEVEL OF EVIDENCE: 4

SUMMARY

Background. The treatment of Neer's type II distal clavicle fractures is challenging because of the high risk of non-union with non-operative management on one hand and complications associated with the operation on other.

Methods. Autologous semitendinosus tendon mediated anatomical coracoclavicular (CC) ligament reconstruction was done in 9 Neer's type II acute distal clavicle fractures. The functional and radiological outcomes were assessed after 12 months of operation.

Results. There were 8 men and 1 woman in the patients assessed at 12 months of operation. At final evaluation of 12 months 7 Neer's type IIA, and 2 IIB fractures were assessed. The mean age of the patients included in the study was 39 years. The mean operating time was 87 minutes. All except one patient achieved radiological union. All patients had excellent functional outcome scores. The mean Constant and Murley (CMS) score at 12 months of follow up was 90.55 ± 57.80 . The CMS score for the case with non-union was 85 at 12 months. The mean CC distance before and after the operation was 19.56 ± 2.80 mm and 11.56 ± 6.7 mm. The difference in the mean CC distance between normal and operated side was less than 5 mm after 12 months of operation in all the cases.

Conclusions. The application of autograft mediated anatomical acromioclavicular joint reconstruction technique to CC stabilization in Neer's II distal clavicle fracture achieves union and excellent functional outcomes.

KEY WORDS

Neer's type II distal clavicle fracture; Constant and Murley scores; nonunion; acromioclavicular; coracoclavicular.

INTRODUCTION

Distal clavicle fractures (DCF) constitute 15-28% of all clavicular bony injuries (1). Though non-union is uncommon in the medial and midshaft fractures of the clavicle its reported incidence in fractures of the distal clavicle is 30-45% (2, 3). Neer, and later Robinson classified DCF based on the location of the fracture and disruption of the coracoclavicular (CC) ligament (4, 5). The classification of DCF into type IIA, B is based on radiographic assumption of

an intact or disrupted conoid part of Coracoclavicular (CC) ligament. However, the interobserver reliability for Neer's classification is slight to fair because no MRI based study has confirmed radiographic correlation in the published literature (1). Neer's type II and Robinson's type 3B DCF have an inherent risk of non-union due to displacement of fracture ends (4, 5). The disrupted CC ligament in these injuries is the primary restraint against the superior displacement of the proximal fracture end (1). The unopposed pull of the

clavicular head of the sternocleidomastoid and trapezius muscle on the proximal fractured end, and weight of the arm results in wider displacements at the fracture site. The factors influencing decisions in the operative management of these injuries are fracture location, displacement, comminution, and intra-articular extension (1). The methods for operative fixation of DCF can be divided into three broad categories based on the site of fixation in the shoulder girdle (6). These are 1) intramedullary fixation using different types of pins (Rush, Knowles, Enders rods, titanium elastic nails, K wires, and screws), 2) surface plates (hook, distal clavicle, and volar radius plates) and 3) CC space stabilization techniques with a screw, button, or a tape). Recently suspensory button-based stabilization of the CC space in acute (< 6 weeks) and autologous/allograft mediated CC ligament reconstructions have yielded excellent outcomes in AC joint dislocations (7). An application of suspensory button-based fixations has also been reported with excellent short-term outcomes in DCF (6). An operative technique using a combination of surface plates and CC space stabilization methods have also been described to address both horizontal and vertical displacements in DCF (8). While pin migration, loosening, loss of reduction, and acromioclavicular (AC) joint degeneration are complications associated with intramedullary fixations, second surgery for removal of the hardware after union in these injuries is common to all the three methods of fixation (6, 9). An overall complication rate of 20% has been reported in the management of DCF, 6.7% and 22.2 % each for nonsurgical and surgical management (6, 9). A comparative summary of the early and late

complications associated with various methods for fixation of DCF described above is presented in **table I**.

Disruption of CC ligaments is common to both AC joint dislocations and DCF. However, autograft/allograft mediated CC ligament reconstructions has not been attempted in DCF. The primary objective of this study was to report functional and radiological outcomes in DCF treated by CC ligament reconstruction with an autologous Semitendinosus (ST) tendon.

METHODS

This prospective interventional case series was conducted from July 2018 to January 2020 at a tertiary referral centre for the treatment of trauma. The institutional review board approved the study. The study has been conducted ethically according to set international standards and meets the ethical standards of the journal (10). Adult patients (18 years or more) with closed Neer's type II DCF were included in the study. Anteroposterior radiograph of the clavicle was ordered for patients suspected of clavicle fracture. The patients with DCF were isolated and classified according to Neer's classification. Neer's type II injuries demonstrating displacement of the proximal bone end of 1 cm or more with or without stress radiography were included in the study. The fractures were classified into IIA and B based on the location of the fracture from the conoid tubercle on the undersurface of the clavicle. Injury of more than two weeks duration, medial and middle third fractures of the clavicle, and concomitant injuries of the upper extremity at other

Table I. Summary of complications associated with various fixation methods in Distal clavicle fractures (1, 6, 8).

Acceptable method for treatment of Distal clavicle fractures	Reported complications (%)	Overall complications in groups (%)
Non-operative management	Non-union and delayed union 20-33% Stiffness and impingement 1.6%	6.7%
Intramedullary fixation: pins, tension band wires, Enders rods, screws, titanium elastic nails, Rush pins, Knowel's screws	Implant irritation 3% Acromioclavicular arthrosis 2% Loss of reduction 3% Infection 4% Broken wire 1%	28%
Surface Plates: Hook plate, pre-contoured distal clavicle plates, and volar radius plates	Hardware removal for irritation 16% to 100% depending on the plate and the study Hardware failure 2% Plate migration 9% Impingement 18% Pain 2%	44.7%
Coracoclavicular space stabilization methods: screw, button, tape autograft/allograft mediated reconstruction	Screw backout 4% Infection 1% Loss of reduction not reported	4.8%

sites, bilateral injuries, and segmental fractures were excluded. Patients thus screened were recruited for operation.

Operative technique

Patients were operated in the supine position with a bean bag under the shoulder for elevation, and general anaesthesia was used. ST autograft was harvested from the prepped same sided lower limb, and whip stitched at both ends with an Ethibond Excel #2-0 Green Braided Suture (non-absorbable, sterile, surgical suture composed of Poly (ethylene terephthalate) J&J medical devices the USA). A technique of CC ligament reconstruction in AC joint dislocations described by Saccomanno *et al.* was used for the operative treatment of DCF (11). The fractured site and the superior surface of the coracoid process were delivered into the surgical wound by a vertical incision of 2-3 cm directly over the fracture site running towards the coracoid process (**figure 1**). The medial and lateral surfaces of the coracoid process were dissected. A suture loop of Ethibond Excel #5-0 Green Braided Suture and ST autograft whip-stitched at both the ends were passed from medial to lateral through the undersurface of the coracoid process by a suture shuttle. Two holes of 4.5 mm diameter, anteromedial and postero-

lateral corresponding to the attachments of the conoid and trapezoid parts of CC ligament were drilled from superior to inferior on the proximal fractured end of the clavicle (**figure 2**). A hole of 4.5 mm was drilled from superior to inferior adjacent to the AC joint in the acromion process of the scapula. Each free end of the ST autograft and the number 5 Ethibond suture loop were passed from inferior to superior through the conoid and the trapezoid tunnels in a figure of eight fashion. The free end of the ST tendon exiting from the trapezoid tunnel was then passed from superior to inferior through the tunnel drilled in the acromion process. The ST free end exiting from the acromion process was again passed from inferior to superior through the trapezoid tunnel in the clavicle. The free ends of the number 5 Ethibond suture loop and the ST autograft exiting from both the conoid and trapezoid tunnels were tied to one another after an attempt to the best possible reduction between the fractured ends. The entire construct was further reinforced with Ethibond number 2 sutures. The surgical wound was closed in layers. The scheme of the operative technique described above is presented in **figure 3**. The shoulder was immobilized for 6 weeks in an arm to chest splint protecting the surgical construct. The shoulder was mobilized after 6 weeks under the supervision of

Figure 1. Patient Positioning and surgical incision (artery forceps) for the operative procedure where Proximal, Distal, Up, and Down represent the head, foot, ceiling, and floor respectively. C Clavicle, A Acromion and Co Coracoid.

Figure 2. The superior surface of the clavicle with conoid and trapezoid tunnels. Proximal, Distal, Up, and Down represent the head, foot, ceiling, and floor respectively.

Figure 3. Diagrammatic representation showing scheme of Semitendinosus (ST) autograft and Ethibond no 5 (E) suture passage through the undersurface of Coracoid process, Conoid (C) tunnel, Trapezoid (T) tunnel, and the Acromion in a Neer's type II distal clavicle fracture.

a physical therapist. Functional assessment of the operated shoulder was done at 3, 6, and 12 months after operation by Constant and Murley scores (CMS) (**figure 4**). The radiological assessment of the union was done at 3 and 6 months after operation (**figure 5**). The radiological union was defined as the disappearance of the fracture line and bridging callus on the AP view.

RESULTS

Radiological and functional assessments were done in 9 patients at 12 months. There were 7 and 2 Neer's IIA, and B, fractures for evaluation at 12 months. There were 8 men and 1 woman in the patients assessed in follow up. The

patients were operated at a mean of 7 days after injury. The mean operating time was 87 minutes. The average stay after the operation was 4 days. All except 1 patient achieved radiological union at a mean of 3 months after the operation. The mean CMS score at 12 months was 90.11. The CMS score in the case with non-union was 85 at 12 months. A description of patient demography and outcome parameters is presented in **table II**.

DISCUSSION

The patients recruited in this study underwent anatomical CC reconstruction with autologous ST graft in DCF and achieved union and excellent functional outcomes. We

Figure 4. Functional outcomes at 12 months in one of the cases.

Figure 5. Anteroposterior views before and after 3 months of operation showing union in a case.

Table II. Patient demography, functional outcomes, and radiological parameters.

Case number	Neer's type	Age in years	Gender	Side Right/Left	Mechanism of injury ¹	Distance of fracture site from AC ² joint in mm	CC ³ space distance before operation in mm	CC ³ space distance after operation in mm	CC space distance normal side in mm	Constant and Murley scores at 12 months after operation
1	IIA	55	M	R	RTA	20.04	20.01	8.1	5.8	98
2	IIA	29	M	R	RTA	20.44	20.44	9	8.1	100
3	IIA	40	F	L	RTA	20.66	15.55	12.6	6.1	82
4	IIB	41	M	L	RTA	20.85	19.0	10	5.1	87
5	IIA	24	M	L	RTA	18.5	19.0	13.7	6.7	89
6	IIA	40	M	L	RTA	20.33	20.03	15.7	8.4	84
7	IIA	38	M	R	RTA	18.6	22.2	10	7.9	98
8	IIB	54	M	L	RTA	20.34	19.8	15	7.6	79
9	IIA	31	M	R	RTA	20.55	20.03	10	8.0	98
Mean $\pm$ SD		39.11 $\pm$ 0.97				20.034 $\pm$ 0.675	19.56 $\pm$ 2.80	11.56 $\pm$ 6.7	7.07 $\pm$ 1.24	90.55 $\pm$ 57.80

¹Road traffic accident (RTA); ²Acromioclavicular (AC); ³Coracoclavicular (CC).

extended the indication of the anatomical CC reconstruction in the AC joint to the treatment of DCF. We hypothesized that the CC stabilization with an autologous ST alone would result in the union at the fracture site and acceptable functional outcomes in DCF. We had one case with non-union at the fracture site in the group studied, but the patient had good CMS scores. Asymptomatic non-unions with excellent functional scores have been reported by the studies after CC stabilization in DCF (12). The concept of anatomic ligament-based reconstructions is not new to the shoulder girdle. Several investigators have reported excellent outcomes after anatomic AC joint reconstructions using a loop of an autograft/allograft around the coracoid process (13). Though the acromioclavicular joint capsule is not disrupted in DCF and, the technique of CC ligament reconstruction employed by us included reconstruction of AC joint, but we believe that the two limbs of the Semitendinosus tendon crossing the fracture site would have prevented significant displacements at the fractured site.

A relative rarity of distal clavicle fractures coupled with case studies with insufficient numbers and lack of control groups in the available literature makes it extremely difficult to deduce the most suitable method for the management of these injuries. Excellent functional outcomes have

been reported uniformly across published studies irrespective of the method of treatment in DCF (6, 8, 12, 14-16). However, on one hand, the published studies report a high risk of non-union (30%) and lower complication rates with non-operative treatment to high union rates and high complication rates with operative treatment of DCF on the other (6-9, 14-16). Surface plates (40.7%) and K wire-based tension band (20%) fixations of the distal clavicle have reported significantly higher complication rates compared to CC stabilization (4.8%) techniques (suspensory button) (6). Recently excellent outcomes in the osteosynthesis of DCF based on open/arthroscopic methods for CC stabilization have been reported by various investigators. Merselene tape, suture button, suture anchors, and screws have been used in these studies for CC stabilization (12, 17-20).

We used the operative technique described by Saccomanno *et al.* for the reconstruction of CC space and AC joint in DCF (11). However, a considerable variation exists in the methods for anatomical reconstruction of the AC joint (21). The differences exist in the type of the construct and the graft, the number of clavicular tunnels, methods of fixation used for the graft in the acromion, and clavicular tunnels in the reported literature. Significant differences in loss of reduction were reported between reconstruction vs no

reconstruction of the AC joint from the excess tendon tissue exiting from the clavicle tunnels favouring the former.

We found one retrospective study which compared outcomes of DCF osteosynthesis between hook plate, and Gracilis tendon with a double-loaded suture anchor. However, the study did not report on the proportion of patients who achieved union in the Gracilis mediated osteosynthesis group (17). Studies have reported ossification in the CC space when screws were used for stabilization; however, another operation is needed for removal of CC screw (18-19). The operative technique of the suture button (tight rope) is promising, but the fate of the disrupted coracoclavicular ligaments in event of non-union in these patients is unknown. Milewski and colleagues reported a lower rate of complications in a loop around the coracoid (autograft with tape) based anatomical CC stabilizations compared to the coracoid tunnel (suture button) in the AC joint disruptions (22). The authors reported clavicle fractures, shoulder stiffness, loss of reduction, and infection as the complications in the group studied. Though it would be unwise to comment on complications associated with the patients in our series because of shorter follow up however, we did not have any incidence of clavicle fracture due to conoid and trapezoid tunnels. The cases in our study united without any infection. We were able to achieve acceptable outcomes by the minimally invasive, biologic, and anatomic osteosynthesis technique described in this paper. The time to radiological union and functional outcomes in our study group was like other studies (6, 8, 14-16).

Limitations of the study

One of the major limitations of this study is the lack of a control group. A comparison to a group of similar treatment (other methods of CC stabilization) would have revealed the true efficacy of semitendinosus based osteosynthesis on the DCF. Another limitation of our study is a very small sample size of the patients recruited to the study. Very limited conclusions can be drawn from studies with limited sample size. One of the limitations associated with our study was donor site morbidity from the harvest of semitendinosus autograft. However, we tried to minimize it by utilizing only one of the hamstrings tendons. A comparative study of our technique of treatment in distal clavicle fractures with other methods will be useful to get more information on the efficacy of the procedure.

CONCLUSIONS

We conclude that the extension of the technique of semitendinosus mediated acromioclavicular joint reconstruction

to CC space stabilization in Neer's type II distal clavicle fractures is effective in achieving union and excellent functional outcomes. The need for the second operation is also obviated by the technique described here. However due to a smaller number of patients and no control group in our study the level of evidence is low.

ACKNOWLEDGEMENTS

The authors acknowledge Dr Swati Nema MDS towards contribution of figure 3 to the manuscript.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

REFERENCES

1. Sandstrom CK, Gross JA, Kennedy SA. Distal clavicle fracture radiography and treatment: a pictorial essay. *Emerg Radiol* 2018;25:311-319.
2. Nordqvist A, Petersson C, Redlund-Johnell I. The natural course of lateral clavicle fracture. 15 (11-21) year follow-up of 110 cases. *Acta Orthop Scand* 1993;64:87-91.
3. Robinson CM, Court-Brown CM, McQueen MM, Wakefield AE. Estimating the risk of nonunion following nonoperative treatment of a clavicular fracture. *J Bone Joint Surg Am* 2004;86:1359-1365.
4. Neer CS 2nd. Fractures of the distal third of the clavicle. *Clin Orthop Relat Res* 1968;58:43-50.
5. Robinson CM. Fractures of the clavicle in the adult. Epidemiology and classification. *J Bone Joint Surg Br* 1998;80:476-484.
6. Oh JH, Kim SH, Lee JH, Shin SH, Gong HS. Treatment of distal clavicle fracture: a systematic review of treatment modalities in 425 fractures. *Arch Orthop Trauma Surg* 2011;131:525-533.
7. Spoliti M, De Cupis M, Via AG, Oliva F. All arthroscopic stabilization of acute acromioclavicular joint dislocation with fiberwire and endobutton system. *MLTJ* 2015;4:398-403.
8. Seyhan M, Kocaoglu B, Kiyak G, Gereli A, Turkmen M. Anatomic locking plate and coracoclavicular stabilization with suture endo-button technique is superior in the treatment of Neer Type II distal clavicle fractures. *Eur J Orthop Surg Traumatol* 2015;25:827-832.
9. Singh A, Schultzel M, Fleming JF, Navarro RA. Complications after surgical treatment of distal clavicle fractures. *Orthop Traumatol Surg Res* 2019;105(5):853-859.
10. Padulo J, Oliva F, Frizziero A, Maffulli N. Muscles, Ligaments and Tendons Journal – Basic principles and recommendations in clinical and field Science Research: 2018 update. *MLTJ* 2018;8:305-307.
11. Saccomanno MF, Fodale M, Capasso L, Cazzato G, Milano G. Reconstruction of the coracoclavicular and acromioclavicular ligaments with semitendinosus tendon graft: a pilot study. *Joints* 2014;2:6-14.
12. Hsu KH, Tzeng YH, Chang MC, Chiang CC. Comparing the coracoclavicular loop technique with a hook plate for the

- treatment of distal clavicle fractures. *J Shoulder Elbow Surg* 2018;27:224-230.
13. Sircana G, Saccomanno MF, Mocini F, *et al.* Anatomic reconstruction of the acromioclavicular joint provides the best functional outcomes in the treatment of chronic instability. *Knee Surg Sports Traumatol Arthrosc.* Epub ahead of print.
 14. Stegeman SA, Nacak H, Huvenaars KH, Stijnen T, Krijnen P, Schipper IB. Surgical treatment of Neer type-II fractures of the distal clavicle: a meta-analysis. *Acta Orthop* 2013;84:184-190.
 15. Jou IM, Chiang EP, Lin CJ, Lin CL, Wang PH, Su WR. Treatment of unstable distal clavicle fractures with Knowles pin. *J Shoulder Elbow Surg* 2011;20:414-419.
 16. Li L, Li TY, Jiang P, *et al.* Clavicle hook plate versus distal clavicle locking plate for Neer type II distal clavicle fractures. *J Orthop Surg Res* 2019;14(1):472.
 17. Yan HW, Li L, Wang RC, *et al.* Clinical efficacies of coracoclavicular ligament reconstruction using suture anchor versus hook plate in the treatment of distal clavicle fracture. *Orthop Traumatol Surg Res* 2017;103:1287-1293.
 18. Jin CZ, Kim HK, Min BH. Surgical treatment for distal clavicle fracture associated with coracoclavicular ligament rupture using a cannulated screw fixation technique. *J Trauma* 2006;60:1358-1361.
 19. Ballmer FT, Gerber C. Coracoclavicular screw fixation for unstable fractures of the distal clavicle. A report of five cases. *J Bone Joint Surg Br* 1991;73:291-294.
 20. Flinkkilä T, Heikkilä A, Sirniö K, Pakarinen H. Tight Rope versus clavicular hook plate fixation for unstable distal clavicular fractures. *Eur J Orthop Surg Traumatol* 2015;25:465-469.
 21. Pill SG, Rush L, Arvesen J, *et al.* Systematic review of the treatment of acromioclavicular joint disruption comparing number of tunnels and graft type. *J Shoulder Elbow Surg* 2020;29(7S):S92-S100.
 22. Milewski MD, Tompkins M, Giugale JM, Carson EW, Miller MD, Diduch DR. Complications related to anatomic reconstruction of the coracoclavicular ligaments. *Am J Sports Med* 2012;40:1628-1634.