Operative Treatment of Neer Type-II Distal Clavicular Fractures

An Overview of Contemporary Techniques

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Abstract

» Deforming forces make it difficult to reduce and maintain reduction of Neer type-II distal clavicular fractures.

» Contemporary surgical techniques are associated with high rates of union and good and excellent outcomes.

» Plate fixation of distal clavicular fractures does not address horizontal and vertical instability.

» Hook-plate fixation has the highest complication rate.

» Augmentation of the coracoclavicular ligament is recommended to neutralize the opposing forces.

Neer originally described a type-II distal clavicular fracture as one in which the conoid ligament and the medial part of the trapezoid ligament have been torn from the shaft fragment; these fractures have inherent instability[1]. In an earlier report, Neer correctly identified the principal deforming forces that interfere with spontaneous union, including the trapezius muscle, the weight of the arm, the trunk muscles that are attached to the humerus and the scapula, and the scapular ligaments, which result in rotatory displacement of the lateral fragment[2]. In his later report, Neer defined these deforming forces in more detail, explaining that the weight of the arm pulls the lateral fragment inferiorly and anteriorly, mainly because the trapezoid ligament remains attached to the lateral fragment and the acromion[1]. The pectoralis major and trapezius muscles displace the lateral fragment medially, resulting in overriding of the fracture fragments. The trapezius muscle further displaces the medial fragment posteriorly and into the muscle substance, and this soft-tissue interposition further inhibits fracture-healing. These principles have not changed and can still be applied in understanding how displacement of these unstable injuries occurs. More importantly, the deforming forces must be taken into account when treatment options are considered.

Distal clavicular fractures were later divided into 2 types. A type-IIA fracture occurs medial to the conoid ligament, with coracoclavicular ligaments remaining intact (Fig. 1-A). A type-IIB fracture occurs between the conoid and trapezoid ligaments, with the conoid ligament becoming torn and the trapezoid ligament presumably remaining attached to the distal fragment[3,4] (Fig. 1-B). Despite the difference of fracture-pattern characteristics, identical deforming forces affect both fracture types.

For uneventful healing of the fracture to occur, both fracture ends must have contact and remain apposed, but the weight of the arm on the lateral fragment and the

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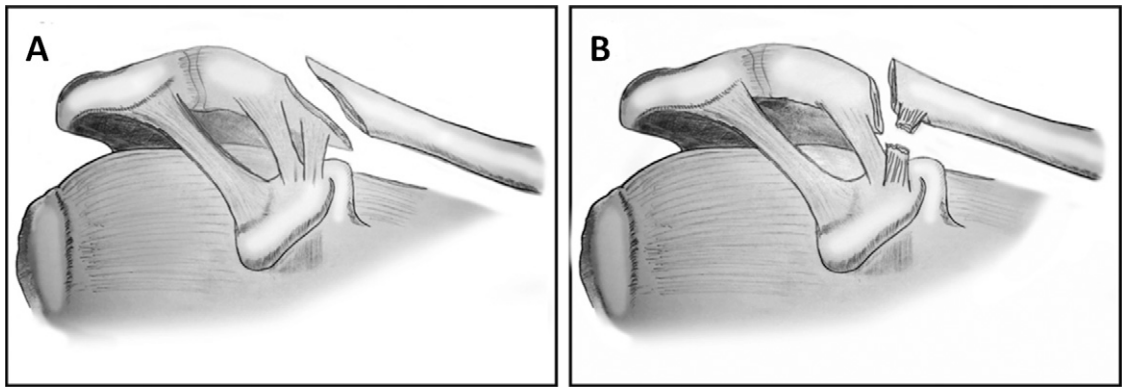

Fig. 1

Figs. 1-A and 1-B Illustrations depicting Neer type-II fractures. **Fig. 1-A** Type-IIA fractures occur medial to the conoid ligament, and the coracoclavicular ligaments remain intact. **Fig. 1-B** Type-IIB fractures are located between the conoid and trapezoid ligaments; the conoid ligament is torn and the trapezoid ligament presumably remains attached to the distal fragment.

muscle pull of the trapezius on the medial fragment tend to cause displacement. Given these conditions, it is difficult to maintain reduction with nonoperative treatment, making nonunion a common complication. In the systematic review by Oh et al., the overall nonunion rate was 33% following nonoperative treatment, compared with 1.6% after operative fixation[5].

Historically, many surgical techniques have been described, mostly in small retrospective case series. These surgical techniques have included suspension fixation with use of strong sutures or wires, use of tension band wires, Kirschner-wire fixation, transfer of the acromioclavicular ligament (the modified Weaver-Dunn procedure), use of hook plates, double plating, coracoclavicular screw fixation, intramedullary fixation with Knowles pins, or use of intramedullary screws[5,6]. Contemporary surgical techniques can be divided into 4 broad categories. Three treatment options involve rigid plate fixation with use of contoured plates, hook plates, or smaller low-contact plates such as distal radial plates. These plates can be used alone or in conjunction with suspension fixation. Two other options involve suspension fixation using sutures and double-button devices to augment the torn coracoclavicular ligament complex. The repair or reconstruction can be performed with use of an open, arthroscopically assisted, or all-arthroscopic technique.

The main goals of the present review are to describe the advantages and disadvantages of each technique and to discuss current concepts related to Neer type-II distal clavicular fractures, including management, surgical indications, techniques, and results from studies in the literature.

Surgical Techniques

Contoured Plates with or without Supplemental Fixation

The potential advantage of an angular, stable, precontoured lateral locking plate is the ability to treat fractures in patients with poor bone quality and short metaphyseal segments while avoiding impingement in the subacromial space[7,8]. Seven studies have described the use of contoured plates (Table I)[7-13]. Additionally, Hanflik et al. described a surgical technique involving the use of a distal clavicular plate (Arthrex) in combination with coracoclavicular ligament augmentation with use of the TightRope device (Arthrex)[14] (Fig. 2-A). Andersen et al., in a study of 20 patients who were managed with a PERI-LOC plate (Smith & Nephew), reported a union rate of 95% and a final American Shoulder and Elbow Surgeons (ASES) score of 86.7 after a mean duration of follow-up of 13 months[7]. Liu et al., in a study of 18 patients (mean age, 32 years) who were managed with a newly developed micromovable and anatomical acromioclavicular plate, reported that 78% of the patients had an excellent outcome according to the Karlsson criteria, that 22% had a good outcome, and that only 1 nonunion occurred[9]. Schliemann et al., in a study of 14 patients who were treated with contoured locking plates and double-button augmentation, reported that union was achieved in all cases and that the mean Constant score was 93.5 after a mean duration of follow-up of 38 months[10]. Johnston et al., in a study of 6 patients who were managed with contoured locking plates and augmentation with a suture button, reported a union rate of 100% and a mean ASES score of 98 after a mean duration of follow-up of 15.6 months[11]. Fleming et al., in a study of 19 patients who were managed with contoured locking plates, reported a union rate of 100% and a final Oxford Shoulder Score of 46 of 50 after a mean duration of follow-up of 25 months[8]. Shin et al., in a study of 28 patients who were managed with a contoured locking plate, reported a union rate of 100% and a mean Constant score of 89 after a mean duration of follow-up of 25 months[12]. Tiefenboeck et al., in a study of 7 patients who were managed with a combination of an AO locking compression plate and coracoclavicular screw fixation, reported a final mean Disabilities of the Arm, Shoulder and Hand (DASH) score of 0.57 and a final mean ASES score of 99 after a mean duration of follow-up of 67 months[13].

TABLE I Studies Involving Contoured Plates with or without Augmentation*

Study	No. of Patients	Age† *(yr)*	Fixation Methods	Duration of Follow-up† *(mo)*	Union Rate *(%)*	Outcome Scores‡	Complications§
Andersen et al.[7] (2011)	20	45.6 (23-66)	PERI-LOC plate	13 (3-87)	95	ASES 86.7	Infected nonunion (1), peri-implant fracture (1)
Liu et al.[9] (2012)	18	32 (17-45)	MAAP with a flexible joint and acromial screw fixation	18 (12-36)	94	Karlsson criteria: 78% with excellent outcome and 22% with good outcome	Nonunion (1)
Schliemann et al.[10] (2013)	14	38 (22-54)	Synthes T plate, coracoclavicular augmentation with FLIPPTACK (Storz)	38 (8-75)	100	Constant score, 93.5; Taft score, 11.2	Plate irritation (7), imminent skin perforation (1)
Johnston et al.[11] (2014)	6	Not reported	Acumed or Synthes contoured locking plates with coracoclavicular augmentation with suture button	15.6 (12-22)	100	ASES score, 98; SANE score, 96	Painful plate (1)
Fleming et al.[8] (2015)	19	44 (29-55)	Acumed or Synthes contoured locking plates	25 (18-48)	100	OSS, 46	Painful plate (2)
Shin et al.[12] (2016)	28	41.6 (29-78)	Acumed contoured locking plates	25 (24-27)	100	Constant score, 89; UCLA score, 32.1	None
Tiefenboeck et al.[13] (2017)	7	37 (28-51)	AO LCP plate and coracoclavicular screw	67 (11-117)	86	DASH score, 0.57; ASES score, 99; UCLA score, 34.29; SST score, 11.57; VAS score, 0.43	Implant loosening (1), nonunion (1)
Total	112	39.7		28.8	97		15 complications (prevalence, 13.4%); most common complication, implant irritation (11; 9.8%)

*ASES = American Shoulder and Elbow Surgeons, MAAP = micromovable and anatomical acromioclavicular plate, SANE = Single Assessment Numeric Evaluation, OSS = Oxford Shoulder Score, UCLA = University of California at Los Angeles, LCP = locking compression plate, DASH = Disabilities of the Arm, Shoulder and Hand, SST = Simple Shoulder Test, and VAS = visual analog scale. †The values are given as the mean, with the range in parentheses. ‡The values are given as the mean unless otherwise specified. §The number of patients with each complication is given in parentheses.

The authors noted a complication rate of 25% and the need for screw removal in all cases.

When the overall results for the 112 patients who were treated with contoured plates with or without augmentation were pooled, the overall union rate was 97%. A total of 11 patients (9.8%) noted painful implants, and, consequently, 9 plates were removed. The subcutaneous location of the plate often causes local irritation, and all patients should be advised regarding the possible need for plate removal[8,11].

Seyhan et al. compared 3 techniques: the use of a contoured plate with ENDOBUTTON (Smith & Nephew) augmentation (14 patients), the use of a contoured plate and Bosworth-type screw fixation (12 patients), and tension band wiring (10 patients)[15]. After a mean duration of follow-up of 32 months, the mean Constant score in the plate-ENDOBUTTON group was

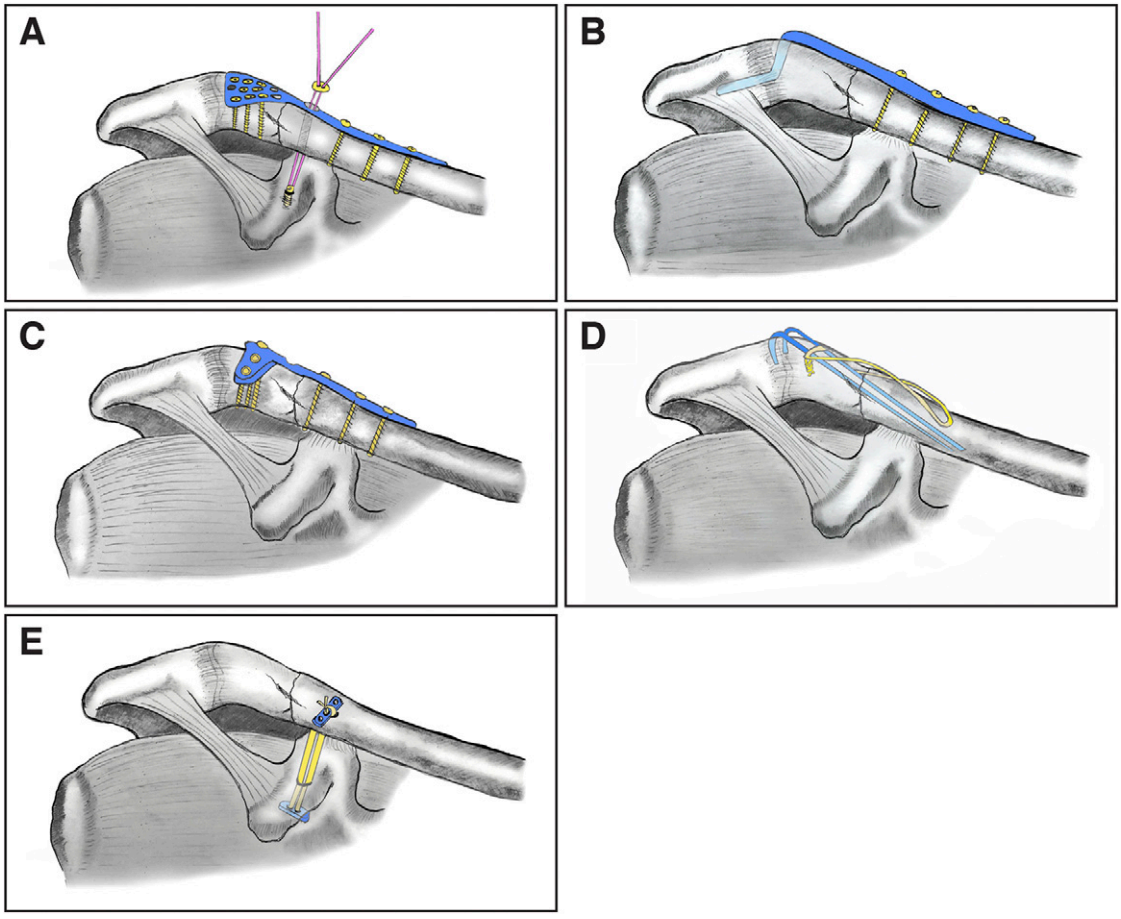

Fig. 2

Illustrations depicting treatment alternatives for operative stabilization of distal clavicular fractures, including an anatomic-specific plate with a supplemental suture anchor (**Fig. 2-A**), hook plate (**Fig. 2-B**), distal radial plate (**Fig. 2-C**), Kirschner wires and tension band wiring (**Fig. 2-D**), and suspension-type fixation with synthetic material (**Fig. 2-E**).

significantly higher than those in the other 2 groups ($p < 0.01$). In addition, the complication rate in the plate-ENDOBUTTON group was lower than the rates in the plate-screw group and the tension-band-wiring group (21% compared with 38% and 31%, respectively).

Fan et al. performed a comparative study of 28 consecutive patients who were managed with an anatomical locking plate with or without additional suture anchor fixation[16]. After a mean duration of follow-up of 18 months, the mean Constant score in the augmentation group was significantly higher than that in the nonaugmentation group (92 vs. 83; $p = 0.004$). No meaningful differences were noted in terms of DASH scores or University of California at Los Angeles (UCLA) Shoulder Scores. However, it should be noted that the significant difference in Constant scores was most likely clinically irrelevant because the minimal clinically important difference for the Constant score is 10[17].

Hook Plates

Since 2009, 3 studies have evaluated the use of hook plates for surgical fixation (Fig. 2-B) (Table II)[18-20]. In addition, Sambandam et al. identified a total of 10 studies that had been published between 2006 and 2013 with a total of 303 patients[6]. Thirty major complications were observed, including hook dislocations and fractures of the medial end of the clavicle; additionally, minor complications included 46 cases of painful implants, 27 episodes of acromial osteolysis, 7 superficial infections, 7 asymptomatic nonunions, 5 minor cases of acromioclavicular joint arthrosis, 2 hypertrophic scars, and 1 case of frozen shoulder, resulting in an overall complication rate of 41%[6]. The 3 studies that are cited in Table II, when pooled, demonstrated an even higher complication rate, with a total of 63 reported complications among 100 patients; implant irritation was the most common ($n = 42$), followed by impingement symptoms ($n = 9$) and acromial osteolysis ($n = 5$)[18-20]. Nevertheless, the average rate of union was 97%. The high rate of implant-related complications and the need for implant removal appear to suggest that this technique should not be selected as a first choice but should be reserved for difficult cases when screw fixation in the distal fragment is not possible[4,21] or when other fixation

TABLE II Studies Involving Hook Plates*

Study	No. of Patients	Age† *(yr)*	Fixation Method	Duration of Follow-up† *(mo)*	Union Rate *(%)*	Outcome Scores‡	Complications§
Renger et al.[20] (2009)	44	38.4 (18-66)	Synthes hook plate	27.4 (18-66)	95	Constant score, 92.4 (after plate removal)	Nonunion (2), hypertrophic scar (2), superficial wound infection (2), acromial osteolysis (3), implant-related symptoms (30)
Tiren et al.[18] (2012)	28	38	Synthes hook plate	65 (15-103)	96	Constant score, 97; DASH score, 3.5	Impingement (9), osteolysis (7), nonunion (1), superficial wound infection (1)
Chen et al.[19] (2014)	28	43.2 (28-78)	Synthes hook plate	37.4 (24-68)	100	OSS, 47; UCLA score, 33	Implanted-related pain (3), acromial osteolysis (2), acromial erosion fracture (1)
Total	100	39.9		43.2	97		63 complications (63%); most common complication, implant irritation (33; 33%%)

*DASH = Disabilities of the Arm, Shoulder and Hand, OSS = Oxford Shoulder Score, and UCLA = University of California at Los Angeles. †The values are given as the mean, with or without the range in parentheses. ‡The values are given as the mean. §The number of patients with each complication is given in parentheses.

techniques are not technically feasible. Of course, it could be argued whether implant irritation should be classified as a complication because the hook plate is designed as a temporary implant that requires removal in all cases.

Two reports have compared the use of hook plates and the use of loop fixation[22,23]. Flinkkilä et al., in a study of 40 patients, reported that the loop-fixation (TightRope) group demonstrated slightly higher Constant scores (93 vs. 89; p = 0.21) and lower DASH scores (6 vs. 11; p = 0.17) compared with the hook-plate group at 62 months of follow-up[22]. Hsu et al., in a study in which coracoclavicular loop augmentation with use of MERSILENE tape (Ethicon) that was looped over the clavicle and around the coracoid (23 patients) was compared with concurrent fracture fixation with a hook plate (49 patients), reported that the coracoclavicular-loop group had significantly higher Constant scores (95 vs. 87) and lower complication rates (0% vs. 24.5%) than the hook-plate group[23]. The authors defined complications as unfavorable events that caused functional impairment, including symptomatic nonunion, loss of reduction, peri-implant fracture, rotator cuff tear, and symptomatic acromioclavicular arthritis.

Distal Radial Plates

Three studies have evaluated the use of distal radial plates for the fixation of lateral clavicular fractures[24-26] (Table III). Distal radial locking plates are generally smaller and thinner than contoured locking plates and therefore should presumably cause less subcutaneous implant irritation (Fig. 2-C). Although the distal fragments are often small, the placement of distal locking screws may be easier because of the ability to place the plates further distally and because of the smaller size of the distal locking screws[26]. Rupture of the coracoclavicular ligament can result in both horizontal and vertical instability of the medial fragment[12,25]. Given the common forces associated with range of motion, simply applying a distal radial locking plate may not adequately stabilize these injuries[25].

Simultaneous augmentation of the coracoclavicular ligament is probably warranted to limit the possibility of fixation failure and nonunion. The failure load for any augmentation device has to be at least equal to the failure load for an intact ligament; for the coracoclavicular ligament complex, the failure load is reportedly between 550 and 725 N[25,27,28]. The ultimate failure load of the trapezoid ligament is approximately 300 N, and the failure load for the conoid ligament is 260 N[29]. Correspondingly, 2 of the 3 studies evaluating the use of distal radial plates also involved the use of coracoclavicular ligament augmentation. Hohmann et al., in a study of 31 patients who were managed with a distal radial plate that was augmented with a TightRope device, reported a mean Constant score of 95 and a mean DASH score of 3 after a mean duration of follow-up of 38.7 months[25]. The authors reported 1 nonunion at 6 months after surgery in a patient with a very comminuted Neer type-IIA fracture, which resolved after revision plating with a bone graft. Martetschläger et al., in a study of 30 patients who were managed with a Synthes T plate and additional coracoclavicular-ligament augmentation with use of polydioxanone (PDS) suture, reported that 40% of the patients experienced implant-related pain that necessitated subsequent implant removal[26]. It may be argued that this plate has different characteristics and is thicker than the plates used by

TABLE III Studies Involving Distal Radial Plates*

Study	No. of Patients	Age† *(yr)*	Fixation Method	Duration of Follow-up† *(mo)*	Union Rate *(%)*	Outcome Scores‡	Complications§
Hohmann et al.[25] (2012)	31	30.3 (14-59)	Synthes distal radial plate, coracoclavicular augmentation with TightRope	38.7 (13-59)	97	Constant score, 95; Taft score, 11; DASH score, 3; SPADI, 2	Nonunion (1), superficial wound infection (1)
Martetschläger et al.[26] (2013)	30	36 (16-68)	Synthes T plate, coracoclavicular augmentation with PDS	12.2 (5-37)	100	Constant score, 92; DASH score, 6; VAS score, 1	Implant-related pain (12)
Abdeldayem et al.[24] (2013)	15	31.6 (18-50)	Locked distal radial plate without augmentation	18.3 (24-68)	100	MSRS, 18.3	Superficial infection (1)
Total	76	32.6		23.1	99		15 complications (20%); most common complication, implant-related pain (12; 16%)

*DASH = Disabilities of the Arm, Shoulder and Hand, SPADI = Shoulder Pain and Disability Index, PDS = polydioxanone, VAS = visual analog scale, and MSRS = Modified Shoulder Rating Scale. †The values are given as the mean, with the range in parentheses. ‡The values are given as the mean. §The number of patients with each complication is given in parentheses.

Hohmann et al.[25] and Abdeldayem et al.[24], which could explain the discrepancy in the rate of implant-related complications. Otherwise, the outcomes were very similar to those reported by Hohmann et al.[25], with Martetschläger et al. reporting a mean Constant score of 92 and a mean DASH score of 6. Abdeldayem et al., in a study of 15 patients who were treated with a locked distal radial plate without augmentation, reported only 1 superficial infection and a union rate of 100%[24] (Table III).

Coracoclavicular Screws, Tension Band Wiring, and Intramedullary Fixation

Coracoclavicular screws were initially described for the treatment of acromioclavicular joint dislocations[30]. The limitations of this technique are the relatively long period of postoperative immobilization, the need for early implant removal, and the risk of screw cut-out. Esenyel et al. performed coracoclavicular screw fixation in 16 patients with Neer type-II distal clavicular fractures[30]. Following routine screw removal at 7 to 8 weeks postoperatively, they reported only 1 implant failure with malunion; no other complications were observed.

Tension band wiring has been successfully used for the treatment of patellar and olecranon fractures, but only a few reports have described the use of this technique for the stabilization of distal clavicular fractures (Fig. 2-D). Zenni et al. reported on the use of a cerclage suture in this fashion in 1981[28]. Since then, various techniques of tension band fixation have been described; because of the small size of the lateral fragment, transacromial wiring often is required as well[6]. Choi et al., in a study of 15 patients who were managed with a combination of coracoclavicular augmentation with a suture anchor and a flip-button device, transacromial Kirschner wires, and tension band wiring with stainless steel wires, reported a union rate of 100%, a mean Constant score of 95, and a return to daily activities at a mean of 3.7 months postoperatively[31]. The authors reported 2 complications: a fracture through one of the drill-holes and clavicular erosion from the flip-button device. Rijal et al., in a study of 16 patients who were managed with transacromial Kirschner wires and a modified tension band with strong ETHIBOND (Ethicon) sutures, observed backing out of only 1 Kirschner wire and reported a union rate of 100% at 11 weeks[32]. Wu, in a study in which tension band wires were compared with Knowles pins for the treatment of persistent nonunions, reported that wire migration was observed in 5 (29%) of 17 cases in the tension-band-wire group[33]; this complication is a concern when using this technique and has been reported in multiple studies[34,35].

We are aware of only 1 recently published report describing the use of intramedullary fixation, which documented the outcomes for 12 patients who were treated with a Knowles pin

that was inserted from the posterolateral margin of the distal aspect of the clavicle[36]. In that study, Jou et al. reported a union rate of 100% but noted a rate of implant irritation of 25%; therefore, they reported that screw removal often is required. Jou et al. speculated that the success of Knowles-pin fixation depends on an undamaged trapezoid or conoid ligament providing additional support to the distal fragment; therefore, in patients with type-IIB injuries, this technique may not provide adequate stability.

Suspension-Type Fixation

Suspension-type fixation enables knotless, protected, and precisely controlled tension for secure stabilization of distal clavicular fractures. The use of coracoclavicular ligament augmentation theoretically can neutralize the opposing forces[25], and, if the fracture ends are apposed, union should occur. Stabilization of the fracture site by isolated looping of sutures or wires around the clavicle and coracoid can avoid the need to drill-holes through them, potentially reducing stress risers and limiting the possibility of iatrogenic fractures[37]. Soliman et al., in a study of 14 patients who were managed with a loop-augmentation technique in which ETHIBOND sutures were passed under the coracoid and around the clavicle, reported a mean Constant score of 96 at the time of the latest follow-up at 25 months[37]. There was only 1 nonunion (7%) and 1 superficial infection (7%). Li et al., in a study of 29 patients who were treated with titanium cables after tunnels had been created through both the coracoid and the clavicle, reported a

TABLE IV Studies Involving Nonarthroscopic Suspension Fixation*

Study	No. of Patients	Age† *(yr)*	Fixation Method	Duration of Follow-up† *(mo)*	Union Rate *(%)*	Outcome Scores‡	Complications§
Li et al.[38] (2011)	29	34 (21-54)	Titanium cables	32 (12-48)	100	Karlsson criteria, excellent/good (21 patients; 72%)	Hardware breakage (1)
Soh et al.[44] (2011)	1	24	TightRope	0.25	100	Full range of motion and pain-free at 12 wk	None
Soliman et al.[37] (2013)	14	34.6 (22-41)	Under-coracoid loop with ETHIBOND 2	24.6 (14-31)	93	Constant score, 96	Nonunion (1), wound infection (1)
Kenyon et al.[45] (2015)	16	Not reported (16-49)	FLIPPTACK	1 (0.1-24.1)	93	OSS, 44.7 (35-48); DASH score, 2.3 (0-36)	Nonunion (1)
Struhl and Wolfson[41] (2016)	8	43 (20-67)	ENDOBUTTON	39 (12-108)	100	UCLA score, 32.5; ASES score, 92.5; SST score, 11.2; Constant score, 95.6	Wound breakdown (1)
Kanchanatawan and Wongthongsalee[39] (2016)	32	37.5 (17-52)	Double loop around the coracoid; double ENDOBUTTON on the clavicle	35.7 (24-47)	100	Constant score, 93.4; ASES score, 91.5	Wound infection (1)
Total	100	36.4		22	98		6 complications (6%); most common complication, wound infection (n = 2; 2%)

*OSS = Oxford Shoulder Score, DASH = Disabilities of the Arm, Shoulder and Hand, UCLA = University of California at Los Angeles, ASES = American Shoulder and Elbow Surgeons, and SST = Simple Shoulder Test. †The values are given as the mean, with or without the range in parentheses. ‡The values are given as the mean, with or without the range in parentheses, unless otherwise specified. §The number of patients with each complication is given in parentheses.

union rate of 100%, with only 1 implant failure and no other complications[38]. According to the Karlsson criteria, 21 patients had good or excellent results[38]. Kanchanatawan and Wongthongsalee, in a study of 39 patients who were managed with 4-stranded FIBERLOOP (Smith & Nephew) in combination with 2 ENDOBUTTONs through the clavicle, reported that all fractures united within 13 weeks and that the final mean Constant score was 93 at a mean of 35 months[39].

Many authors have reported on double-button techniques[4,6], and there has been an increased trend to use these devices arthroscopically[40-42] since the arthroscopic technique was first described by Pujol et al.[43] (Fig. 2-E). These devices also can be used with an open exposure, and 3 independent groups have investigated the associated outcomes[41-43]. Studies in which suspension fixation has been used are listed in Table IV. In a case report, Soh et al. demonstrated osseous union and full range of motion[44]. Kenyon et al., in a study of 16 patients who were managed with an open double-button technique, reported a mean Oxford Shoulder Score of 45 and a mean DASH score of 2 at the time of the latest follow-up at 12 months, with only 1 nonunion (6%)[45]. Struhl and Wolfson, in a study of 8 patients who were managed with an open double-ENDOBUTTON technique, reported that all fractures had united at 3.4 years, with a final mean Constant score of 96[41].

The pooled results of these studies include a total of 100 patients who were treated with these suspension techniques. The overall union rate was 98%, the complication rate was only 6%, and the most common complication was wound infection (3%).

Arthroscopic-Assisted Fixation

In 2008, Pujol et al. proposed fixation of distal clavicular fractures with use of an arthroscopic-assisted double-button

TABLE V Studies Involving Arthroscopic Techniques with Suspension Fixation*

Study	No. of Patients	Age† *(yr)*	Fixation Method	Duration of Follow-up† *(mo)*	Union Rate *(%)*	Outcome Scores‡	Complications§
Takase et al.[46] (2012)	7	41.9 (35-57)	ENDOBUTTON	29 (24-43)	100	UCLA score: excellent (6 patients), good (1 patient)	None
Motta et al.[48] (2014)	14	32 (18-40)	TightRope	24	100	Constant score, 95; SST score, 12	Superficial infection (1)
Flinkkilä et al.[22] (2015)	21	39 ± 14	TightRope	32 ± 16	95	Constant score, 93; DASH score, 6	Early implant failure (1)
Kraus et al.[47] (2015)	23	38 (24-63)	TightRope	23 (13-38)	90	Not reported	Nonunion (2), implant irritation (1), loss of reduction (1)
Loriaut et al.[42] (2015)	21	33 (18-67)	TightRope	35±8.9	95	Constant score, 95; DASH score, 3; VAS score, 0.5	Transient capsulitis (1), symptomatic acromioclavicular joint osteoarthritis (1), early implant failure and nonunion (1)
Blake et al.[40] (2017)	17	41 (21-89)	TightRope	12	82	DASH score, 10.9; VAS score, 0.9; ASES score, 90.1	Nonunion (3), infection requiring debridement (1), frozen shoulder (1), prominent suture (1)
Total	103	37.5		25.8	94		15 complications (14.5%); most common complication, nonunion (6; 6%)

*UCLA = University of California at Los Angeles, SST = Simple Shoulder Test, DASH = Disabilities of the Arm, Shoulder and Hand, VAS = visual analog scale, and ASES = American Shoulder and Elbow Surgeons. †The values are given as the mean, with the range in parentheses. ‡The values are given as the mean, with or without the range in parentheses, unless otherwise specified. §The number of patients with each complication is given in parentheses.

device (the TightRope device) and reported on the early outcomes for 4 patients who were managed with this technique[43]. No intraoperative or postoperative complications were observed, and all 4 patients had achieved osseous union, a full range of motion, and a mean Constant score of 95 at 6 months postoperatively. However, this procedure is technically demanding and success depends on the experience of the treating surgeon[6,43]. A crucial step is identification of the center of the undersurface of the coracoid in order to minimize stress risers, reduce coracoid fractures, limit button slippage, and avoid damage to the adjacent neurovascular structures[43]. Blake et al., in a study of 17 Neer type-II fractures that were treated with arthroscopic-assisted button fixation, reported a mean DASH score of 10.9 and a mean ASES score of 90 at 12 months of follow-up, with 3 nonunions[40].

Six studies including a total of 103 patients have investigated the use of the arthroscopic-assisted double-button technique[22,40,42,46-48]; 5 of these studies investigated the TightRope device[22,40,42,47,48], and 1 investigated the ENDOBUTTON[46] (Table V). The overall union rate was 94%, with 15 complications (14.5%), including 1 early implant failure, 6 nonunions, 1 implant irritations, 1 superficial infection, 1 deep infection requiring surgical debridement, 1 transient capsulitis, 1 frozen shoulder, 1 symptomatic acromioclavicular osteoarthritis, 1 prominent suture, and 1 loss of reduction.

Overview

When Neer first described type-II fractures of the lateral aspect of the clavicle, he recognized that the deforming forces that are present make it difficult to maintain adequate reduction with nonoperative treatment, and, consequently, nonunion is a common complication. Contemporary surgical techniques involving anatomically contoured plates, hook plates, smaller low-contact plates, or ligament-augmentation devices have been associated with high rates of union and reliable restoration of function. Complications vary among the different methods of stabilization and are both implant and access-related. Associated injuries to the coracoclavicular ligament result in a combination of horizontal and vertical instability, with the opposing muscle forces predictably displacing the fracture site. The fundamental principles have not changed over the past 50 years, and augmentation of the coracoclavicular ligament is necessary in order to neutralize the deforming forces and achieve consistent union. The present review is limited by the quality of the included studies. The majority of these studies are nonrandomized comparative studies or case series. Hence, both the internal and external validity of these studies is limited; therefore, the results should be viewed with some caution.

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