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REVIEW ARTICLE

Management of clavicle nonunion and malunion

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Background: Clavicle fractures are common injuries of the shoulder girdle and occasionally result in nonunion or symptomatic malunion. When present, these chronic injuries can result in considerable shoulder dysfunction. A number of surgical techniques have been described for the management of these injuries. Current literature suggests that supplemental bone grafting may not be necessary in all cases but should be considered in the setting of atrophic nonunion. However, optimal treatment is controversial, as discussed in the literature. This article highlights the current treatment options based on the existing literature and describes our preferred techniques.

Methods: We carried out a comprehensive review of the PubMed and Medline databases using multiple-keywords (eg, clavicle fracture, clavicle nonunion, and clavicle malunion) to identify the relevant literature regarding this topic. Reference lists of the relevant articles were reviewed for additional important articles.

Conclusion: Nonunion and malunion of the clavicle remain challenging problems. Reliable bony union and improved shoulder function can be expected with thoughtful surgical planning, appropriate implant choice, and meticulous surgical technique.

Level of evidence: Narrative Review.

Keywords: Clavicle fracture; clavicle nonunion; clavicle malunion; bone grafting; clavicle shortening

Clavicle fractures are common injuries and are reported to represent 2% to 5% of all adult fractures.[45] More than two-thirds of these fractures involve the mid shaft of the clavicle, and as compared with medial- and lateral-third fractures, these are more likely to be displaced. It is traditionally suggested that clavicle fractures uniformly heal with nonsurgical management and result in good functional outcomes. More recent evidence suggests that specific subsets of patients may be at higher risk for nonunion, symptomatic malunion, or suboptimal functional outcomes.[7,20,32,41,49,55]

A recent meta-analysis suggests that the incidence of clavicle nonunion after nonsurgical treatment is approximately 5.9%, but the incidence may be as high as 15% for some fracture subtypes.[27,34,66] Moreover, nonsurgical treatment universally results in some degree of malunion; however, symptomatic malunion is fortunately less frequently observed.[55] Both nonunion and malunion of the clavicle are capable of resulting in persistent pain and loss of shoulder function.[33,34] Although surgical intervention is capable of improving these symptoms, patients are also reported to be at higher risk for complications.[26] Surgical management of clavicle nonunion or malunion is often

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challenging but can result in union and improved shoulder function. The purpose of this article is to review operative techniques for, and outcomes of, clavicle nonunion and symptomatic malunion management.

Clavicle nonunion and malunion

Traditionally, the majority of clavicle fractures have been treated nonoperatively, primarily because of historically reported nonunion rates of less than 1% and suboptimal surgical outcomes in the 1960s.[38,51] Subsequently, implant technology and surgical techniques have improved. This has resulted in enhanced surgical outcomes and fewer complications. It has also become apparent that certain fracture subtypes are at higher risk for nonunion as compared with others.[32,33,48] Moreover, as patient-centric outcome measures are more routinely analyzed in the setting of malunited clavicle fractures, it is apparent that functional deficits in these patients may be greater than previously realized.[24]

It is established that nonunion of the clavicle can result in functional shoulder impairment and pain. To this end, attempts have been made to better understand characteristics that may predispose these injuries to suboptimal outcomes.[34,40,66] Several studies have shown that older age, female sex, shortening greater than 2 cm, and fracture comminution are associated with clavicle nonunion.[7,41,49,63] Others have reported that nonsurgical treatment of Neer type II fractures results in nonunion rates of 22% to 33%, likely because of the large amount of displacement common to these injuries.[37] Although these characteristics do not represent absolute surgical indications, they should be considered when nonoperative management is being contemplated in the acute setting (Table I).

Although nonunion of the clavicle is relatively uncommon after nonoperative management of clavicle fractures, some degree of malunion universally occurs if any fracture displacement is present.[55] Whereas many of these malunions result in minimal functional deficit, recent literature suggests that symptomatic malunion may be more common than previously reported.[32,41] Moreover, patient-reported outcome measures indicate that clavicle malunion may result in functional impairment in some circumstances.[2,44] To this end, Hill et al[20] reported that shortening of 2 cm or more is predictive of higher nonunion or symptomatic malunion rates.

A prospective randomized series suggests that operative fixation results in improved functional outcomes and lower nonunion and malunion rates.[8] Therefore, appropriate initial treatment of at-risk clavicle fractures may minimize the necessity of nonunion or malunion management. Despite best efforts, however, nonunion and symptomatic malunion of fractures will occur. The indications for surgical intervention in these patients are primarily clinically based. Persistent discomfort or functional shoulder impairment is considered an operative indication.

Table I Risk factors for clavicle nonunion

Clavicle shortening >15-20 mm
Female sex
Fracture comminution
Fracture displacement
Older age
Severe initial trauma
Unstable lateral fractures (Neer type II)

Data from references 20, 33, 38, 41, and 48.

Surgical management

Nonunion

Resection procedures

Resection of part of the clavicle or the entire clavicle as a salvage procedure was popular when the necessary implant technology for anatomic reconstruction was not yet available. Of primarily historic importance, resection of the clavicle should be avoided to maintain shoulder girdle stability and function. Although minimal data exist, poor results have been reported after excision of the lateral clavicle fragment whereas internal fixation frequently results in union and good clinical outcomes.[14,22,36] It is occasionally necessary, however, to perform a distal clavicle excision in the setting of post-traumatic acromioclavicular arthrosis.[54] In this setting, good functional outcomes can be expected.

Reconstructive procedures

Implant considerations

Primary or revision internal fixation of clavicle fracture malunion or nonunion has been accomplished with multiple implant types. These include intramedullary fixation with Steinmann,[9] Rush,[16] or Hagie pins[5]; Kirschner wires[39] or titanium elastic nails[27]; external fixators[4,59]; and various plate types. Although each technique is reported to provide good results and high union rates, it is important to ensure that the implant possesses the biomechanical characteristics necessary to facilitate fracture union. Studies comparing intramedullary and plating techniques show similar union and complication rates. These studies provide limited insight because they are largely retrospective, do not account for fracture severity, and are of small sample sizes.[65]

Perhaps more importantly, it is critical that the implant chosen be properly aligned with fracture characteristics. To this end, stable and rigid fixation should be the goal when hypertrophic nonunion is present. In this circumstance, biomechanical testing suggests that plate fixation provides greater rigidity than intramedullary fixation.[13] Therefore, currently available literature does not provide evidence to

guide implant choice because implants have been inadequately studied in the setting of clavicle nonunion or symptomatic malunion.

Plating considerations

Plate fixation provides immediate rigid fixation, is appropriate for many fracture patterns, and can be applied in an anterior or superior position. Because of the curved shape of the clavicle, reconstruction plates have traditionally been used because of their ability to be anatomically contoured; however, fatigability of these plates remains a concern. Limited-contact compression plating provides more robust fixation, but such plates are more difficult to contour. For this reason, anterior and superior anatomically precontoured plates have been introduced and may decrease the need for hardware removal.

Superior plate placement is generally thought to be more prominent and may pose a greater risk to neurovascular structures. By contrast, anterior plating may require greater fracture stripping for application but less prominent hardware placement. Biomechanical studies suggest that superior plating may offer greater rigidity than anterior plating in a transverse fracture model. By contrast, anterior plating may be more biomechanically sound if an inferior cortical defect is present. Both anterior plating and superior plating have resulted in good clinical outcomes, and dual plating of clavicle fractures has also been reported.[52,57] To date, no clinical studies have concluded that outcome is associated with anterior or superior plate placement.

It is currently our preference to use a modern, low-profile, precontoured plate using a superior plating technique for most fracture types. This technique is useful for nearly all fracture types, provides excellent stability, and is relatively simple technically.

Bone grafting

Because of its osteogenic, osteoconductive, and osteoinductive properties, autogenous iliac crest bone graft is considered the gold standard of bone grafting.[58] Disadvantages including the limited volume of available bone,[23] increased operative time and blood loss,[1] and donor-site morbidity[47,53] limit its usefulness to some degree. Bone graft alternatives such as allograft bone or demineralized bone matrix minimize many of these disadvantages but are generally only osteoconductive in nature. They may also show greater infection and resorption rates, varying levels of immune response, and slower union times compared with autogenous bone.[60] Therefore, the use and type of bone graft used should be individualized to patient and fracture characteristics.

Open reduction–internal fixation with autologous bone grafting is an accepted technique for treatment of clavicle nonunion in cases with atrophic fracture ends and/or shortening of the fracture site to regain the necessary clavicle length. Several studies report reliably good clinical results after this procedure.[25,42,43] By contrast, others suggest that bone grafting may be unnecessary in every case of clavicle nonunion.[3] Endrizzi et al[15] reported a series of patients treated with plate fixation for clavicle nonunion. Of 47 patients treated with local bone graft or demineralized bone matrix alone, 44 (93%) had fracture union. Similarly, Ramoutar et al[46] reported 11 patients with clavicle nonunion treated without bone graft using fragment decortication and compression plating. Though a small series, they reported a 100% union rate using this technique. Therefore, based on currently available literature, autologous bone grafting may not be necessary in all cases.

In the setting of hypertrophic nonunion, decortication and compression plating, with or without supplemental bone graft, are likely sufficient to achieve bony union. However, in cases of segmental bone loss or atrophic nonunion after surgical fixation, the addition of autologous bone graft may be beneficial. It is important to realize that the level of evidence describing the value of bone grafting for clavicle nonunion remains low, and bone grafting should therefore be used if dictated by nonunion type or patient characteristics (Fig. 1).

We currently favor compression plating with supplemental bone grafting in cases of existing segmental bone loss or bone loss after resection of an atrophic nonunion after failed fixation.

Free vascularized bone grafting

In cases of recurrent nonunion after failed operative reconstruction, some authors advocate a vascularized bone graft reconstruction.[17,35,62] Momberger et al[35] described vascularized fibula transfer in 3 patients in whom an average of 3.7 surgical reconstructions failed. Each case was characterized by segmental bone loss that failed to unite despite traditional surgical techniques. At a mean follow-up of 2.8 years, all clavicles showed bony union and improvement in pain and shoulder function. Similarly, authors have reported successful reconstruction of clavicle nonunion with bony defects using a free vascularized corticoperiosteal flap harvested from the medial aspect of the femoral condyle[17] or vascularized rib transfer.[62] Each report concluded that vascularized bone transfer is a reliable tool when a supportive vascular supply is necessary for healing. In most cases, the thyrocervical artery and a branch of the external jugular vein can be used for the recipient vessels.[35] Because the technique is rarely necessary and infrequently performed in the management clavicle nonunion, it should only be used after failure of first-line fixation methods and be performed by surgeons familiar with vascularized bone transfer (Figs. 2 and 3).

Adjuvant treatment options

Achieving bony union is a biomechanical and biologic process. Although implant technology has improved our ability to provide an appropriate biomechanical environment for healing, techniques that influence the biologic environment continue to evolve. To this end, attention to surgical technique is important to minimize vascular

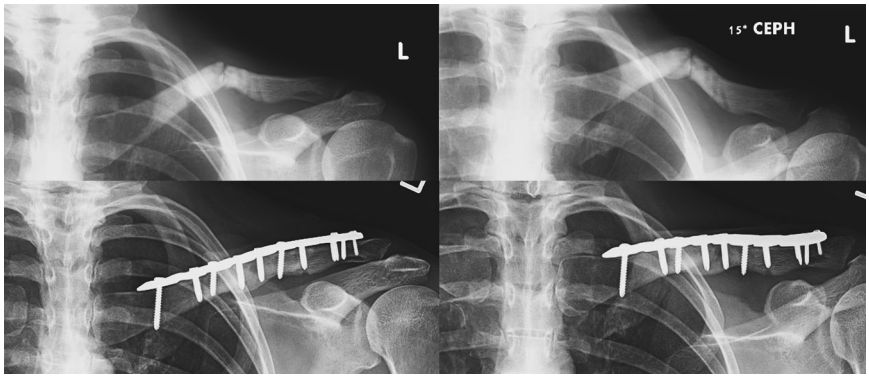

Figure 1 *Top*, Failed bony union after plate fixation of middle-third clavicle fracture. *Bottom*, Result 6 months after revision surgery with bone grafting and plate fixation showing bony healing.

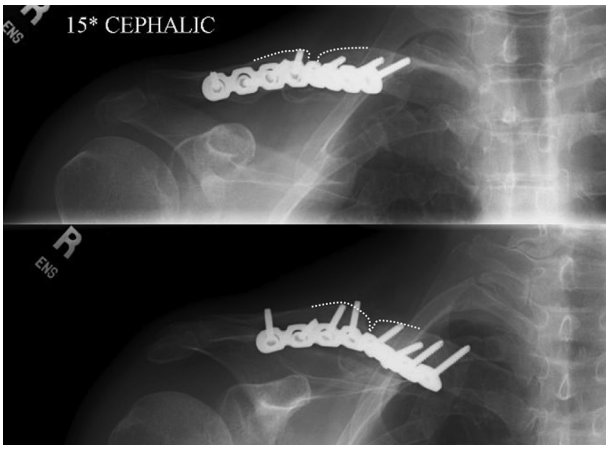

Figure 2 Nonunion with resorption of bone graft after several attempts at internal fixation. The *dotted lines* indicate the nonunited fracture sites.

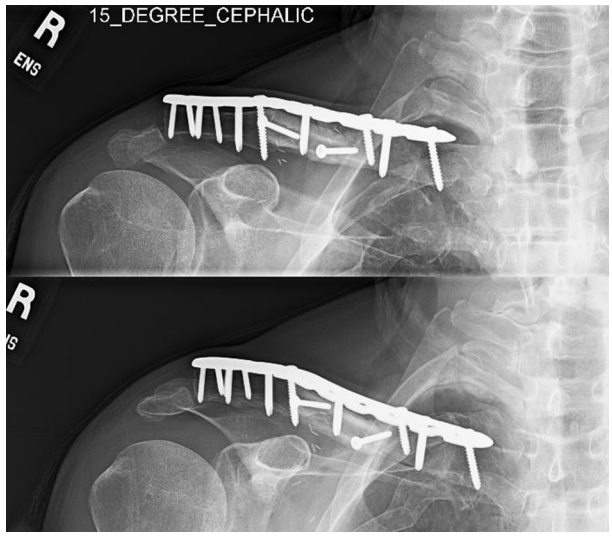

Figure 3 Radiographs (same patient shown in Fig. 2) at 1 year after vascularized fibula graft transplantation, showing stable fixation and bony healing.

disruption of fracture fragments. Recombinant bone morphogenetic protein (BMP) has been developed and used successfully in both animal and clinical studies.[19] However, a current review of the literature highlights the paucity of data on the use of BMP in the setting of clavicle nonunion.[18] Therefore, further investigation will be necessary to better understand the role of BMP in the setting of clavicle nonunion, but it may be a reasonable option in managing atrophic nonunions or in the revision surgical setting.

Symptomatic clavicle malunion

Some degree of clavicle malunion uniformly occurs after conservative treatment of displaced fractures.[55] Despite the ubiquity of clavicle malunion after non–surgically treated clavicle fractures, only some are persistently symptomatic. However, recent emphasis on patient-reported outcome measures illustrates that clavicle malunion may result in greater disability than previously regarded.[29,30,33,61,66] Matsumura et al[31] suggested in a biomechanical study that clavicle shortening of 10% or more altered scapular kinematics, which may be sufficient to produce clinical symptoms.

To this end, the treatment of symptomatic clavicle malunion often requires an osteotomy in an effort to restore anatomic length and rotation prior internal fixation. Both compression plating[6,10,32,50] and intramedullary fixation[11,55,56] are described in this setting with or without supplemental bone grafting. McKee et al[32] performed a corrective osteotomy and internal fixation with compression plating in 15 patients with clavicle malunion. At a mean follow-up of 20 months, all but 1 fracture united. Similarly, other authors report successful corrective osteotomy and intramedullary fixation of clavicle fractures.[55] At final follow-up, each series reported improved outcome scores, clavicle length, and alignment. It therefore appears that symptomatic clavicle malunion can be successfully treated by corrective osteotomy and either compression plating or intramedullary fixation.

Compression plating is currently our preferred technique for surgical management of symptomatic clavicle malunion or nonunion because dissection sufficient for plate application is frequently necessary to reduce fracture fragments in this setting.[13] Moreover, clavicle nonunion is frequently hypertrophic, and compression plating is capable of providing a rigid and length-stable construct in nearly all situations.

Surgical outcomes

Available literature suggests that bony union can be reliably achieved after surgical management of clavicle nonunion or malunions.[14,42,43] Both superior and anteroinferior plating techniques have resulted in satisfactory union rates in the setting of clavicle nonunion. McKee et al[32] described 15 patients at a mean of 20 months' follow-up after osteotomy and refixation for symptomatic malunion. They reported significant improvements in Disabilities of the Arm, Shoulder and Hand scores; clavicle length; and union in 14 of 15 patients. Similarly, Rush pin fixation of midshaft clavicle nonunion resulted in bony union in 13 of 14 patients in one reported series.[9,16] It is important to note, however, that while considerable symptomatic improvement reliably occurs, it is apparent that some degree of residual shoulder dysfunction can be expected in some patients.[28,42] To this end, Rosenberg et al[50] suggests that only 46% of patients return to their previous level of professional or recreational activity and Constant scores for the affected extremity remain lower than those for patients' normal extremity.

Surgical complications

Surgical management of clavicle nonunion and symptomatic malunion is associated with a number of potential complications. These most commonly include persistent nonunion in 3% to 8% of patients, soft-tissue complications (keloid, hyperesthesia, and so on) in 15%, and hardware complications in 6%.[12] Though infrequent, fracture deformity or callus has been reported to cause brachial plexus or subclavian vessel compression in some circumstances.[21,51,64] Der Tavitian et al[12] concluded that approximately two-thirds of reported complications were avoidable technical complications. To this end, careful surgical planning, appropriate implant choice, and meticulous surgical technique may decrease the incidence of these complications.

Summary

Symptomatic nonunion and malunion of the clavicle are relatively uncommon. However, they can result in persistent pain and impairment of shoulder function. In this setting, the goal of surgical intervention is restoration of clavicle length and alignment in an environment conducive to bony union. Various intramedullary or plating techniques can be used to achieve stable fixation and may require supplemental bone grafting in some situations. In rare circumstances of segmental bone loss or recalcitrant nonunion, vascularized bone transport may be necessary. With appropriate planning, surgical fixation of symptomatic clavicle nonunion and malunion reliably results in satisfactory patient outcomes.

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