

## Case Report

# Managing Recurrent Clavicle Nonunion and Construct Failure: A Case Report

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### Case

A 36-year-old male who suffered a left midshaft clavicle fracture, following a fall from a mountain bike, was treated unsuccessfully with two ORIF surgeries. Smoking cessation and management of hypovitaminosis was addressed preoperatively before final revision with a dual plate construct and tibial autologous bone graft. Follow-up radiographs taken at 12 months from the initial surgery showed intact hardware and full bone healing.

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## Conclusion

Successful management of clavicle nonunions can be optimized through optimal plate selection, plate positioning, number of plates, construct biomechanics, biologic augmentation, and preoperative risk optimization. Efforts to minimize controllable risk factors for nonunion, such as smoking cessation or vitamin D supplementation, should be utilized both preoperatively and postoperatively.

## INTRODUCTION

Treatment of midshaft clavicle fractures is either non-operative immobilization or operative with recent literature suggesting open reduction and internal fixation (ORIF) leads to better union rates and functional outcomes. A meta-analysis comparing non-operative and operative treatment of midshaft clavicle fractures found the nonunion rate to be 14.5% and 1.4% respectively.<sup>1</sup> Although nonunion of clavicle fractures following ORIF is an uncommon complication, when symptomatic, it can result in poor outcomes and debilitation of the upper extremity. Risk factors for nonunion include smoking, comminution, older age, and fracture displacement greater than 2cm.<sup>2</sup> The preferred treatment for symptomatic nonunion is surgical intervention, however, persistent nonunion can occur and has been associated with hardware failure, plate placement, type of implant utilized, and various patient specific risk factors.<sup>3,4,5</sup>

With operative treatment of clavicle fractures increasing in frequency, understanding the modes of failure of clavicular constructs is critical given the variety of plate options and positions. In this report, we present a unique case of a comminuted midshaft clavicle fracture treated multiple times with plate osteosynthesis following recurrent plate breakage. This case highlights the need for a holistic approach to clavicular nonunion, optimizing construct design as well as patient risk factors to achieve optimal bone healing. We also review the literature and discuss the incidence, causes, and treatment of clavicle nonunion.

## CASE REPORT

A 36-year-old male presented with left shoulder pain after a high impact fall from a mountain bike. The patient had no other known illnesses and no previous injuries. Social history was significant for tobacco usage. On physical exam, there were no signs of neurovascular injury and AP and lateral radiographs confirmed the presence of a closed, comminuted, and displaced midshaft fracture of the left clavicle ([Figure 1](#)). Due to the degree of comminution and displacement of the fracture, surgical treatment was indicated. The two comminuted fragments were fixed with two lag screws and an 8-hole superior clavicle specific plate ([Figure 2](#)) without intraoperative complications.

The patient returned two and a half months after the initial surgery with discomfort in his left shoulder after hearing a snapping sound while exercising. Radiographs demonstrated persistence of the fracture at the original site with plate breakage ([Figure 3-A](#)). Given failure of fixation, the patient elected to proceed with a revision surgery which was performed two weeks later. Intraoperative examination of the clavicle showed fibrous nonunion with significant mobility. The fracture ends were debrided, and the clavicle was reduced and fixed with a 10-hole superior clavicular locking plate ([Figure 3-B](#)).

He initially did well following revision surgery, however 3 months later and 6 months following his initial surgery, the patient presented with discomfort and persistent pain over his left clavicle. Repeat radiography of the primary fracture site revealed a delayed union of the clavicle with plate breakage and fixation failure ([Figure 4-A](#)). The patient

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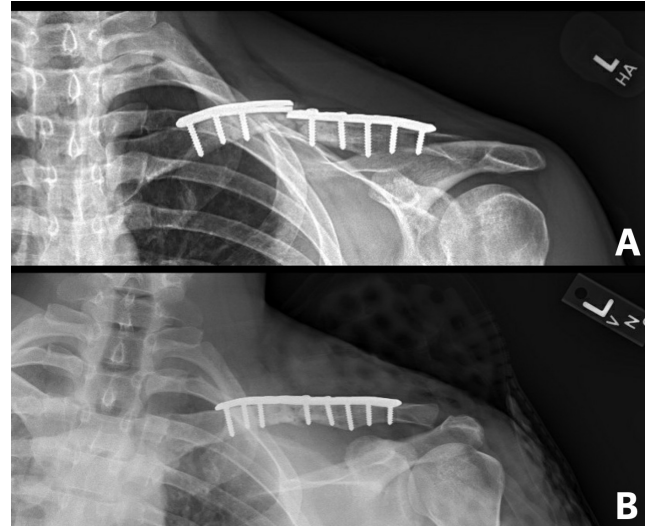


**Figure 1. Xray (AP) of the left clavicle showing a closed comminuted displaced midshaft fracture**



**Figure 2. Postoperative X-ray (AP) of left clavicle showing an 8-hole superior clavicle locking plate with screw fixation with continued visualization of fracture line.**

reported continued smoking throughout his postoperative period, and laboratory studies revealed no signs of infection and low levels of Vitamin D and alkaline phosphatase. After two surgical failures, non-operative interventions including supplementation to correct low vitamin D levels, activity modifications, and smoking cessation were implemented. Low intensity pulsed Ultrasound (LIPUS) bone stimulator was considered but was cost-prohibitive given lack of insurance coverage.



**Figure 3. A. Xray (AP) of left clavicle 2.5 months after initial surgery showing remaining midshaft clavicle fracture with midplate breakage, and no loss of fixation; B. Radiograph taken after second revision surgery demonstrates a reduced clavicle fracture fixed with 10-hole superior clavicular locking plate.**

Seven months following the initial surgery and after one month of nonoperative management and smoking cessation, repeat radiographs showed no change ([Figure 4-B](#)). A third surgical intervention of ORIF with plate fixation with cancellous tibia bone autograft was planned for two weeks later. Smoking cessation was verified, and vitamin D supplementation was initiated prior to repeat revision surgery. Intraoperatively, the fracture site showed poor bone quality and significant fracture comminution. Existing hardware was removed, and a locking plate was provisionally placed anterior-inferiorly and secured with two bicortical screws ([Figure 5-A](#)). An Avitus bone graft harvester was then used to harvest cancellous bone and liquid bone marrow from the left proximal tibia crest. A small 1cm incision was made on the medial border of the tibial crest after which the pilot hole creator was used to create an 8mm cortical window in the tibia ([Figure 5-B](#)). The Avitus harvester was attached to standard OR suction and inserted into the tibia. Approximately 18-20ccs of autograft was harvested. The graft was used to fill the posterior and superior fracture gap and augment bone healing at fractures site ([Figure 5-D](#)). Three locking screws on each side of the fracture line were placed



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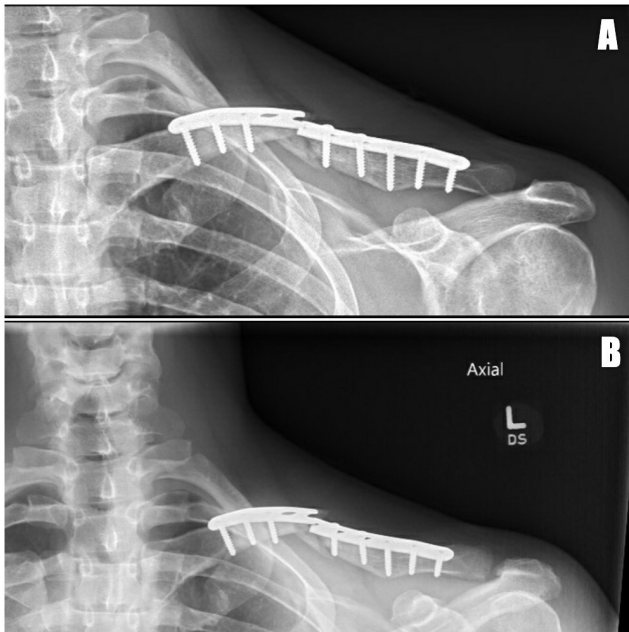
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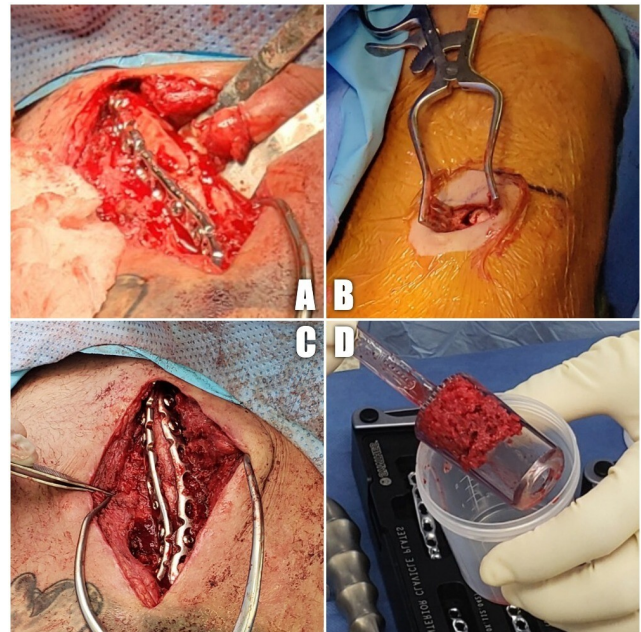
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**Figure 4. A. Xray (AP) 6 months after initial operation showing delayed nonunion at the primary fracture site and repeat plate breakage with failure of fixation; B. Xray at 7 months demonstrated no change from the previous visit.**

and then a second 7-hole locking plate was positioned on the superior aspect of the clavicle and secured with cortical and locking screws ([Figure 6-A](#)). The tibial cortical window site was filled with cancellous bone chips and back filled with Hydroset bone substitute followed by closure of the cortical window ([Figure 5-C, D](#)).

Two months after the third surgical intervention and nine months after initial surgery, follow up radiographs showed intact hardware without interval change, appropriate alignment, and good interval healing at the fracture site ([Figure 6-B](#)). The treatment plan continued with electromagnetic bone growth stimulator, oral Vitamin D supplementation, graduated physical therapy, and continued to-



**Figure 5. A. In the third operation, initial left clavicle fixation by anterior plate prior to autogenous bone graft; B. Proximal tibial graft site following collection of autogenous bone graft; C. Left clavicle dual plate fixation by anterior and superior plates; D. Autogenous cancellous bone and bone marrow graft collected by Avitus bone harvester.**

bacco smoking cessation. One and a half years after initial surgery, radiographs showed intact hardware and good bone healing ([Figure 6-C](#)).

## DISCUSSION

Historically, incidence rates of nonunion following nonoperative management of clavicle fractures have been cited as less than 1% however recent studies have found that for specific fracture subtypes, the incidence rate may be much

higher.<sup>6789</sup> Although nonunion rates following ORIF are significantly lower than nonoperative treatment, a systemic review of 11 studies found that clavicular nonunion after plate fixation of a displaced midshaft clavicular fracture (DMCF) occurs in less than 10% of cases for all studies except one.<sup>10</sup> Nonoperative management of clavicle nonunion consists of fracture bracing/immobilization supplemented with LIPUS or other external bone stimulator. Rates of fracture healing in chronic bone nonunion with LIPUS have been reported as high as 82%.<sup>11</sup> The majority of clavicle nonunions are treated with revision ORIF however reoperation is associated with a higher rate of short-term complications compared to ORIF of acute fractures.<sup>12</sup> Given this higher rate of complications and the patient burden associated with surgical correction of nonunion, it is imperative to understand the factors that predispose to nonunion and optimize success in revision surgery.

## RISK OPTIMIZATION

Bone healing is a complex interplay between osteogenic cells, osteoconductive scaffolding, adequate growth factors, and mechanical stability.<sup>13</sup> Patient specific factors, such as

smoking and low vitamin D levels, increase the risk of failed osteosynthesis due to deleterious effects on bone healing. Jarvis et al. highlighted smoking as the only identifiable risk factor for postoperative failure of osteosynthesis regardless of the fixation device.<sup>14</sup> Systematic reviews have shown that smoking increases the time to union and risk of nonunion by 40% when compared to non-smokers and thus recommend smoking cessation at least 4 weeks prior to surgery.<sup>151617</sup> In addition to smoking, studies have shown low levels of vitamin D delay bone union clinically.<sup>18 19 20</sup> In a recent study of over 300,000 fractures, nonunion was significantly increased in patients with vitamin D deficiency for all 18 bones analyzed (OR, 1.14; 95% CI, 1.05-1.22) and the nonunion rate was higher in clavicle fractures when compared to the average fracture (8.2% vs 4.9%).<sup>21</sup>

## DUAL PLATING

Dual plating with reconstruction plates is biomechanically superior to single plating.<sup>22</sup> A commonly used plate combination is a 2.7mm or 3.5mm reconstruction plate placed anteriorly with a 2.0mm or 2.4mm mini-fragment plate placed superiorly.<sup>23</sup> Use of a mini-fragment plate superiorly leads

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**Figure 6. A. Postoperative X-ray showing a second 7-hole locking plate secured to the superior aspect of the clavicle, in addition to the previously fixed anterior locking plate, which was sequentially secured with cortical and locking screws; B. Follow-up radiographs taken at 9 months from the initial fracture showed intact hardware without interval change, appropriate alignment without displacement, and positive callous formation; C. Follow-up radiographs taken at 12 months from the original fracture showed intact hardware and continuous bone recovery.**

to low rates of implant irritation. Several studies in the literature have found higher union rates, lower incidence of

implant irritation, and lower nonunion rates with dual plating when compared to single plating.<sup>24,25,26</sup> However, a retrospective review of 20 patients with symptomatic clavicular non-union by Sadiq et al found no difference in the use of single or dual-plate constructs with all patients achieving bony union.<sup>27</sup>

## PLATE TYPES

The most common implants utilized in midclavicular ORIF are anatomic specific locking/nonlocking plates, locking plates, dynamic compression plates (DCPs), pre-contoured locking compression plates (LCPs), and reconstruction plates. While reconstruction plates have a lower profile and fit the contour of the clavicle, the reduced plate stiffness can lead to implant failure.<sup>28</sup> In two multi-center randomized controlled studies, pre-contoured LCPs had failure rates much lower at 1.1% and 0.6%.<sup>29</sup> DCPs are stronger, but their straight shape causes implant prominence and irritation.<sup>30</sup> Since LCPs are anatomically contoured, they cause less irritation and their resistance to deformity may decrease implant failure.<sup>31</sup> DCPs and LCPs both feature increased stiffness and cantilever bending failure load when compared to reconstruction plates.<sup>32,33</sup>

## BONE GRAFT SUPPLEMENTATION

While autologous bone grafts remain the gold standard for treating delayed union and nonunion of fractures, bone grafts and cell-based therapies can be also be utilized to treat delayed union or nonunions. The Reamer-Irrigator-Aspirator (RIA) system, developed in the 1990s, was designed to harvest intramedullary bone graft from femoral and tibial donor sites. While it offers continuous irrigation

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and suction during the reaming of bone, several studies have reported donor site complications and disruption in the integrity of the collected graft.<sup>34,35,36,37,38,39,40,41,42</sup> More recently developed devices with similar capabilities, such as the Avitus Bone Harvester, have been introduced. To the best of our knowledge, this is the first instance of its use for clavicle nonunion described in the literature. A benefit of the Avitus Bone Harvester is it allows for the collection of a graft of cancellous bone from a small cortical access window using standard OR suction without irrigation diluting biologically active factors. Similar to other autograft harvesting techniques, there is a risk of donor site morbidity.

Open surgery with internal fixation and bone grafting for clavicle nonunion has been reported to be an acceptable technique that provides good final clinical outcome. While autogenous iliac crest bone graft is considered the gold standard, it has disadvantages such as limited volume of

available bone and donor site morbidity.<sup>43</sup> Endrizzi et al reported 47 patients with clavicle nonunion treated with plate fixation. All patients were treated with local bone graft or demineralized bone matrix alone, and 44 (93%) of patients were found to have fracture union.<sup>44</sup> Similarly in 2017, Rollo et al examined 36 patients with clavicle nonunions managed with clavicular allograft and found all cases except 1 healed within 3 months.<sup>45</sup> Future studies could perform comparative analyses of plate type, size, position, dual plating, and use of adjuvants such as bone graft or stimulators on outcomes for nonunion.

## CONCLUSION

This case is a unique example of a recurrent clavicular nonunion complicated by repeat construct failure. Though

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overall incidence is rare, clavicular nonunion is a difficult complication for patients that can likely be prevented by strategic management and screening of patients with high preoperative risk. Our primary recommendation is that efforts be made to minimize controllable risk factors for nonunion preoperatively. We recommend patients be advised on smoking cessation advice both preoperatively and postoperatively.

Given the high rates of union following bone grafting currently reported by literature and the modern availability

of harvesting devices with minimal complication rates, it is reasonable to consider bone grafting following a first incidence of nonunion. In addition, increased reporting of clavicular nonunion cases is warranted and should focus on determining a causative relationship between nonunion and construct failure following ORIF.

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