Technical Note

Arthroscopic-Assisted Bone Graft Harvest From the Proximal Humerus for Distal Third Clavicle Fracture Nonunion

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Abstract: Clavicle fracture nonunion can lead to persistent pain and loss of shoulder function. Distal clavicle fractures have the greatest risk of nonunion and are often treated surgically. Bone grafting plays a vital role in the treatment of distal clavicle nonunion. Although multiple options for bone graft exist, the iliac crest has long been considered the gold standard for harvest. Despite its extensive use, multiple complications have been associated with iliac crest bone graft harvest. We advocate a surgical technique for arthroscopic bone graft harvest from the proximal humerus with open reduction and internal fixation of an ipsilateral distal clavicle nonunion.

Introduction

Clavicle fractures represent 3% to 5% of all fractures, and fractures of the distal clavicle represent 10% to 15% of all clavicular fractures.[1] Historically, these fractures were managed nonoperatively with the belief that they would yield low nonunion rates and minimal functional impairment.[2] More recent evidence suggests a greater risk of nonunion, symptomatic malunion, and suboptimal function with nonoperative treatment than was previously believed.[3] A recent meta-analysis suggests that the incidence of clavicle nonunion after nonsurgical treatment is approximately 5.9% but may be as high as 15% for certain fracture types[4] (Fig 1). Surgical management of clavicle nonunion is challenging, and bone grafting is a fundamental component of this process. Autologous iliac crest bone graft (ICBG) has a long history of success due to its osteogenic, osteoconductive, and osteoinductive properties.[1,5,6] Unfortunately, ICBG harvesting comes with its own associated complications, including increased operative times, donor-site morbidity, neurologic injury, blood loss, donor-site fracture, and

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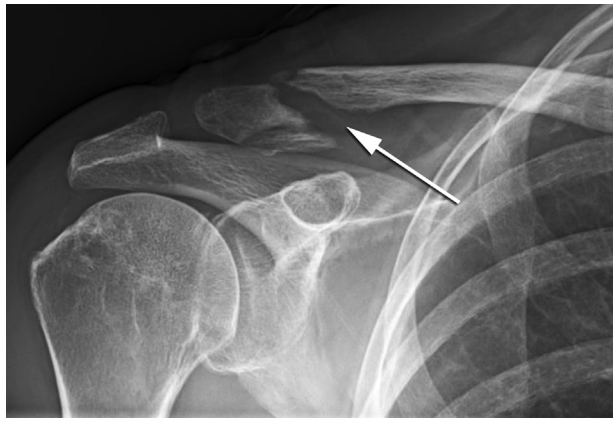

Fig 1. Anterior to posterior radiograph of the right clavicle demonstrates a nonunion of the distal third clavicle fracture (white arrow).

Table 1. Key Steps of Arthroscopic-Assisted Bone Graft Harvest From the Proximal Humerus for Distal Clavicle Fracture Nonunion

1. Arthroscopy of the shoulder to evaluate for additional pathology
2. Identification of the proximal lateral humerus distal to the rotator cuff insertion
3. Careful penetration of the cortex to avoid fracture
4. Hand-power bone harvest with redirection at multiple angles to maximize harvest
5. Slow progression of the harvester with constant turning to avoid bone impaction
6. Arthroscopic evaluation of the harvest site for opposing cortical penetration

deep infection.[7,8] Due to these potential concerns, consideration for alternative harvest sites is necessary, and we endorse a technique for arthroscopic-assisted proximal humerus bone graft harvest for the treatment of clavicle nonunion.

Surgical Technique (With Video Illustration)

Our technique uses the traditional lateral decubitus position for shoulder arthroscopy and bone graft harvesting while taking the arm out of traction during open reduction and internal fixation (ORIF) of the distal clavicle. (Video 1) The beach chair position would certainly be amendable to this technique as well. A standard posterior portal is created, and a diagnostic arthroscopy of the glenohumeral joint is performed (Table 1). Concomitant pathology may be addressed at the same setting. Transition into the subacromial space using the same posterior portal allows visualization of the bursal aspect of the rotator cuff. Customary lateral and anterior portals permit completion of a bursectomy and exposure of the proximal lateral humerus. An arthroscopic probe (Smith & Nephew, Andover, MA) is used to palpate the rotator cuff insertion to ensure that bone graft harvest is carried out distal to the lateral insertion of the rotator cuff tendons (Fig 2). The cortex of proximal humerus is penetrated using the bone graft punch (Acumed, Hillsboro, OR) (Fig 3). The 8-mm bone graft drill (Acumed) is used to harvest bone graft from the proximal humerus (Fig 4). Our preference is to use the bone graft ratcheting T-handle (Acumed) coupled with the Jacobs chuck adaptor (Acumed) for more precise hand control of the harvester. This permits multiple passes at different angles through the same proximal humeral cortical window to maximize the amount of bone graft harvested. As opposed to harvesting using power control, the hand control allows better palpation of the opposing cortex to prevent iatrogenic penetration of the articular surface. Care must be taken to advance the harvester slowly while constantly turning the handle to avoid impacting the soft cancellous bone of the proximal humerus (Table 2). After each harvest, the bone graft drill is uncoupled and the bone graft extractor (Acumed) is used to push the bone graft into a container on the back table (Fig 5). The arthroscopic camera may be placed in the lateral portal to evaluate the presence of additional bone to be harvested and to confirm the integrity of the opposing cortex.

The arm is taken out of traction, and attention is turned to the distal clavicle nonunion. A longitudinal approach is carried down to expose the fracture. Fracture fragments are defined and mobilized using standard surgical technique (Fig 6). The opposing fracture surfaces are stimulated using a 4.5-mm K-wire (Acumed) to encourage a healing response. The

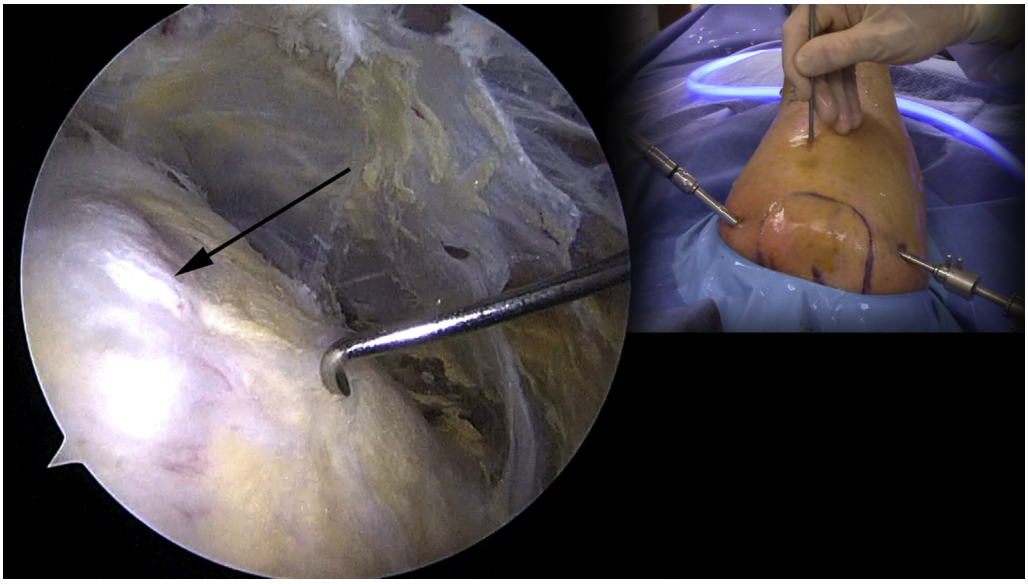

Fig 2. Arthroscopy (left) of the right shoulder in the lateral decubitus position with the distal end of the probe pointing to the lateral aspect of the proximal humerus distal to the rotator cuff insertion (black arrow) in preparation for proximal humerus bone graft harvest. The inset (right) demonstrates the exterior view of the proximal end of the probe in the lateral arthroscopic portal.

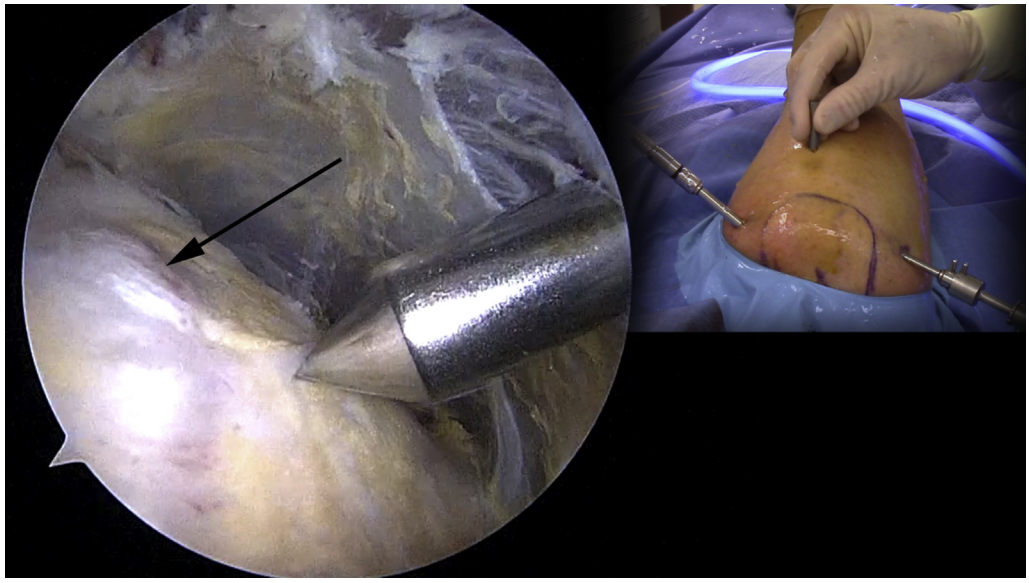

Fig 3. Arthroscopy (left) of the right shoulder in the lateral decubitus position with the distal end of the bone graft punch pointing to the lateral aspect of the proximal humerus distal to the rotator cuff insertion (black arrow) in preparation for proximal humerus bone graft harvest. The inset (right) demonstrates the exterior view of the proximal end of the bone graft punch in the lateral arthroscopic portal.

acromioclavicular joint is identified and marked using an 18-gauge spinal needle. This confirms the distal aspect of the clavicle for proper plate positioning. Using a standard surgical technique, the distal third locking plate (Acumed) is initially fixed to the distal fragment and then adjoined to the proximal fracture fragment. Once stable fixation of an anatomic reduction is achieved, the previously harvested bone graft is strategically placed around the nonunion site (Fig 7). Fluoroscopic images may be obtained to confirm and document reduction. Meticulous hemostasis is attained followed by careful irrigation to protect bone graft placement prior to a layered wound closure. A dry, sterile dressing is applied, and the patient is placed in a traditional sling. The patient is followed postoperatively to obtain radiographs 1 week after surgery (Fig 8) and until final union of the fracture (Fig 9).

Discussion

Historical orthopaedic training promoted nonoperative treatment for all clavicle fractures and implied that malunion and nonunion were well-tolerated. Fortunately, contemporary research has confirmed that not all clavicle fractures heal and many fracture patterns are better treated acutely with ORIF.[9] Although clavicle fracture nonunion is not common, it has been well documented that operative treatment with subsequent fracture union results in improved pain and shoulder

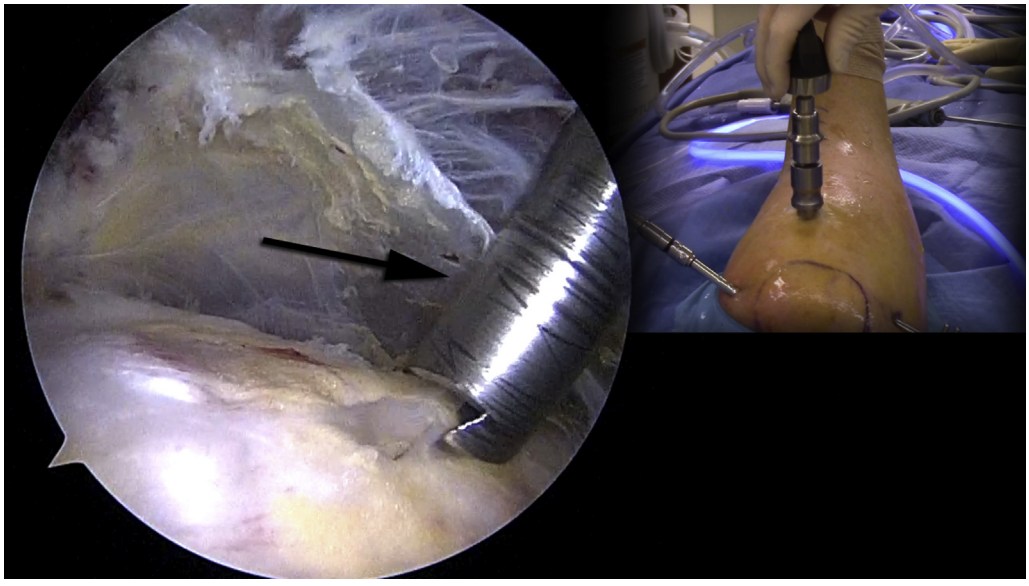

Fig 4. Arthroscopy (left) of the right shoulder in the lateral decubitus position with a bone graft drill (black arrow) positioned to enter the lateral aspect of the proximal humerus in preparation for proximal humerus bone graft harvest. The inset (right) demonstrates the exterior view of the bone graft ratcheting T-handle coupled with the Jacobs chuck adaptor, which is attached to the bone graft drill in the lateral arthroscopic portal.

Table 2. Pearls and Pitfalls of Arthroscopic-Assisted Bone Graft Harvest From the Proximal Humerus for Distal Clavicle Fracture Nonunion

Pearls
1. Mark out clavicle incision before arthroscopy
2. Complete lateral bursectomy to visualize the proximal lateral humerus
3. Penetrate the middle of the humerus to ensure proper exposure for maximal harvest
4. Hand control with slow progression to avoid bone impaction
5. Judicious use of the arthroscope to evaluate the bone harvest and opposing cortex
Pitfalls
1. Improper lateral portal placement makes harvesting more difficult
2. Poor visualization of the rotator cuff insertion may lead to iatrogenic injury
3. Fracture of the lateral cortex
4. Impacting the soft cancellous bone of the proximal humerus minimizes graft quantity
5. Violating the opposing cortex with iatrogenic injury to the articular surface

function.[3,10] ORIF with bone grafting is a widely-accepted technique for the treatment of clavicle fracture nonunion. Although numerous combinations of fixation methods and bone graft sources have been described, successful outcomes with plating and autologous bone grafting have been reported.[11,12]

Bone grafting is of particular importance in patients with an atrophic nonunion. Not only is the biology of the graft critical to provide union but also to offer structural support to restore proper clavicle length.[13] ICBG has traditionally been the most common site of bone graft harvest due the ability to obtain cortical or cancellous graft in large quantities. Despite the long track record of success with fracture union after ICBG harvest, multiple shortcomings exist. Many authors have documented the disadvantages, which include a distant harvest site from the nonunion site, blood loss, increased operative time, and chronic donor-site morbidity.[7,8] These drawbacks have led surgeons to investigate alternatives such as allograft and demineralized bone matrix. These graft substitutes eliminate donor-site and harvesting concerns but are primarily osteoconductive in nature and lack the prominent osteogenic and osteoinductive properties of autograft. Clinical reports of greater infection and resorption rates, greater immune responses, and slower time to union compared with autogenous bone graft are concerning.[14] Although the use of free vascularized bone grafting has been reported for the treatment of clavicle fracture nonunion, this is predominantly reserved for larger defects in the revision setting.[15,16]

Slette et al.[17] recently described a technique using local bone graft harvest for ORIF of the clavicle. They recommend careful collection of the bony remnants during ORIF of the clavicle from the drill holes and the drill flutes prior to placement of the screws. As they note, their technique is limited by the quantity of local bone graft available and the fact that drilling may cause heat-induced osteonecrosis and influence the quality of

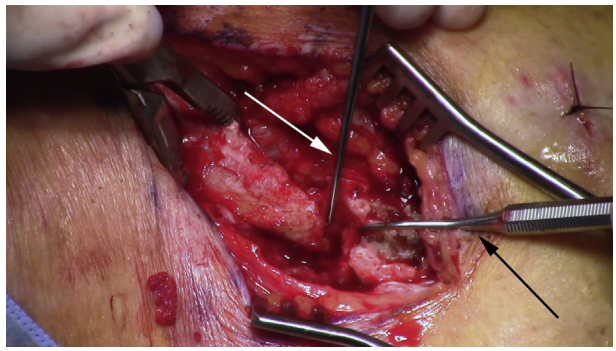

Fig 6. A superior view of a right distal third clavicle fracture with a probe (white arrow) pointing to the fracture site and a dental pick (black arrow) holding the distal segment of the fracture and a clamp holding the proximal segment of the fracture in preparation for open reduction and internal fixation (ORIF) with bone grafting.

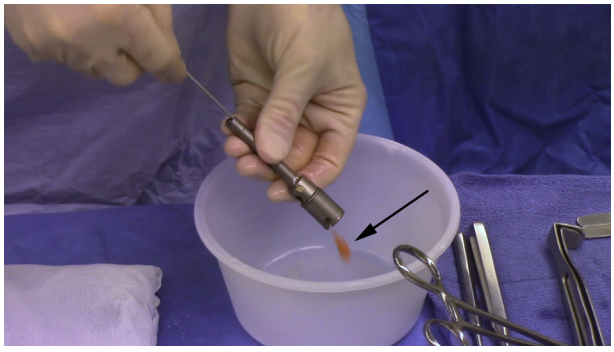

Fig 5. Removal of the bone graft (black arrow) from the bone graft drill (in the left hand) using the bone graft extractor (in the right hand) into a basin on the back table during arthroscopic-assisted bone graft harvest from the proximal humerus.

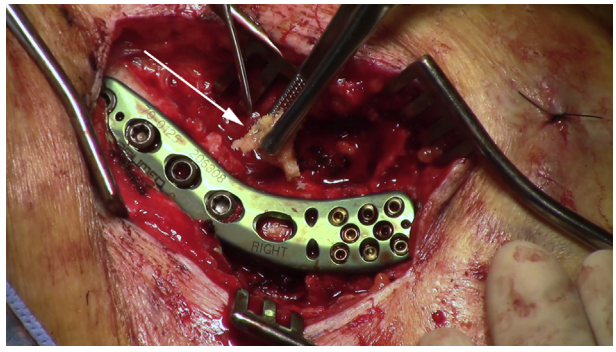

Fig 7. Superior view of a right distal third clavicle fracture nonunion after open reduction and internal fixation (ORIF) with a superior distal third locking plate and bone graft (white arrow) from the proximal humerus being positioned using forceps into the nonunion site.

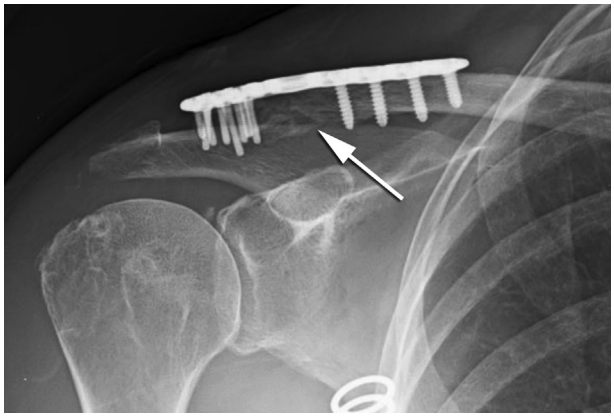

Fig 8. Anterior to posterior initial postoperative radiograph of the right clavicle after open reduction and internal fixation (ORIF) using a superior plate and bone grafting (white arrow) of a nonunion of the distal third clavicle fracture.

the bone graft as well.[17] Our technique features several advantages compared with the previously described literature (Table 3). We endorse a standard shoulder arthroscopy set-up with minimal modifications in the prepping and draping to incorporate the clavicle. This eliminates a separate distant surgical site with potential for infection as well as an additional site of postoperative pain. Glenohumeral injuries associated with clavicle fractures have been reported to be as high as 46%,[18] and arthroscopy enables treatment of concomitant shoulder pathology at the same setting. This technique allows for a minimally invasive harvest-site incision, yet the arthroscopic assistance permits maximal visualization of the harvest site to ensure sufficient harvest of potential graft as well as avoiding iatrogenic injury to the rotator cuff and articular cartilage. We recognize that our technique lacks the ability to harvest cortical graft for structural support and is limited by the amount of cancellous graft available but nonetheless recommend our approach for treatment of clavicle fracture nonunion.

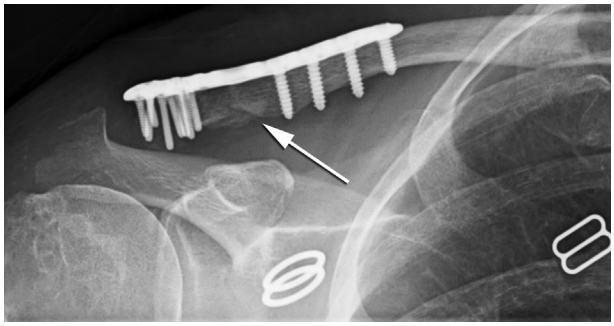

Fig 9. Anterior to posterior final postoperative radiograph of the right clavicle after open reduction and internal fixation (ORIF) using a superior plate and bone grafting of a nonunion of the distal third clavicle fracture demonstrating consolidation of the bone graft (white arrow).

Table 3. Advantages and Disadvantages of Arthroscopic-Assisted Bone Graft Harvest From the Proximal Humerus for Distal Clavicle Fracture Nonunion

Advantages
1. Standard arthroscopic shoulder set-up and portals along with familiar anatomy for bone harvest
2. Ability to address additional shoulder pathology
3. The proximal humerus is a local source of bone graft for shoulder surgery
4. Minimally invasive harvest site with low harvest-site morbidity
5. Visualization of the harvest site to avoid iatrogenic injury to the rotator cuff and articular surface
Disadvantages
1. Additional procedure, equipment, and surgical time for graft harvest
2. Minimal quantity of bone graft available compared with other sites
3. Risk of proximal humerus fracture and injury to the rotator cuff and articular cartilage

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