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Distal clavicle fractures with “superior intact cortical bone”: minimally invasive surgery

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Introduction: Distal clavicle fractures represent 12%-26% of all clavicle fractures. For unstable cases, surgical fixation is the preferred method of treatment. To date, there is still controversy regarding the best fixation method with a high reoperation and complication rate reported. The purpose of this article is to describe a minimally invasive method for reduction and stabilization of displaced distal clavicle fractures, using cortical buttons.
Surgical technique: After standard preoperative preparation, a 3-cm incision is made at the coracoclavicular area. Using both coracoid and clavicle tunnels, fracture reduction and fixation is obtained using a cortical fixation button. Standard postoperative care is given.
Results: A total of 21 patients (19 men) with a mean age of 34.7 years were treated using this technique. The follow-up was between 6 and 41 months, with an average of 23.4 months. The mean simple shoulder test score was 79.4 (range 66-91.7), and the QuickDASH score was 11 (range 6.8-15.9). Consolidation of the fracture was confirmed at the 12-week follow-up radiography, with no cases of nonunion or malunion identified. No patients presented infection or complications at the surgical site. Implant removal was not needed in this series. All the patients returned to work.
Conclusion: Minimally invasive button fixation of unstable distal clavicle fractures is a safe and reliable alternative treatment. The initial outcome report is promising with excellent clinical and radiological results and no complications or implant removals.

Clavicle fractures represent 2.6%-4% of adult fractures, mainly affecting the young and active population.[16] Distal clavicle fractures are less frequent than middle third fractures, representing 12%-26% of all clavicle fractures.[16,17]

Approximately, 30%-45% of clavicle nonunions correspond to distal clavicle fractures, thus surgical treatment is preferred in unstable cases.[7,23] In the classification for distal clavicle fractures reported by Charles Neer,[7] type II corresponds to an unstable pattern, owing to the total lack of bone or ligamentous continuity between the proximal fragment and the scapula. According to Cho et al,[9] any pattern with a displacement $\geq$ 5 mm is considered unstable.

Several surgical techniques have been described for distal clavicle fracture treatment: coracoclavicular (CC) fixation (CC screws, subcoracoid suture loops, and cortical buttons) and fracture fixation devices (clavicular hook plate, clavicular locking plate, acromioclavicular screws, tension band, and transacromial fixation with K wires).[7,19,24,29] Despite multiple fixation techniques being available, a relatively high rates of complications and reoperations have been described. Therefore an ideal fixation method is yet to be determined.[2,5] At present, arthroscopic or minimally invasive surgery provides advantages in terms of potentially shorter surgical time, less soft-tissue damage, better aesthetics, and theoretically higher rates of bone union associated with preservation of fracture hematoma.[5]

The purpose of this article is to describe a minimally invasive method for reduction and stabilization of displaced distal clavicle

Clinical Research Ethical Committee of the Pontifical Catholic University of Chile approved patient registry, and all patients provided informed consent before participation.

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fractures, using cortical buttons. This technique is based on the radiological criteria called "superior intact cortical" (Fig. 1).[20] If there is no fracture within ≥ 1 cm of the superior cortex of the clavicle, distal to the conoid tubercule, it is considered "intact." The highest bone mineral density and greatest cortical thickness is mainly at the conoid tubercle and intertubercle space.[8]

Surgical technique

After general anesthesia and brachial plexus blockage, a classic beach-chair position is used, with the clavicular region prepared and draped in a standard orthopedic fashion (Fig. 2*A*). A sterile marker outlines relevant shoulder surface anatomy (Fig. 2*A*).

A 3-cm incision is made, perpendicular to the axis of the clavicle in relation to Langer's skin lines, centered at the base of the coracoid (Fig. 2*B*). Dissection of the subcutaneous plane is performed until reaching the deep fascia, expanding the dissection to achieve a mobile window. The deltotrapezoidal fascia is incised longitudinally to the axis of the clavicle, with electrocautery at the periosteum, approximately at the junction of the anterior third with the posterior two thirds, to obtain clear, resistant edges for fascia closure.

To achieve a minimally invasive approach, dissection is performed without violating the fracture site until the upper surface of the coracoid base is exposed (Fig. 2*C*). The ZipTight device (BIOMET, Warsaw, IN, USA) was used in all patients. This CC fixation system uses 2 cortical buttons connected to a self-locking #7 MaxBraid suture system (ZipLoop), allowing for controlled reduction, while eliminating the need for knots or temporary fixation.

A 2.0 K-wire is passed at the center of the base of the coracoid, slightly inclined 10° anteriorly and 10° medially, to obtain better bone quality. Adequate position and alignment are verified with fluoroscopy, using the "cortical ring sign,"[14] aiming for a center-center position (Figs. 2*D*–3*A*).[12]

After the K-wire is properly positioned, a central bone tunnel is made with a 4.5-mm cannulated drill bit. The inferior cortical button is then passed, flipped, and checked by fluoroscopy. Repetitive tension of the sutures is accomplished, until the button is carefully applied to the inferior cortex of the coracoid (Figs. 3 and 4*A*).

A 2.5-mm bone tunnel is made in the clavicle, centered on the conoid tubercle at the junction of the anterior third with the posterior two thirds (Fig. 4*B*). Final positioning the bone tunnel should be within 20% and 25% of total clavicle length to avoid postoperative clavicle fracture.[10–12]

The ZipLoop system is passed through the clavicle tunnel with traction sutures, or a nitinol guide, as the superior cortical button is secured to the suture loop (Figs. 4*C*–5*A*). In comminuted fractures in which conoid and trapezoid ligaments are avulsed, taking an inferior cortical bone fragment (Neer Type V), with a 1.5- to 2.0-mm drill, passing the device sutures helps the fragment to guide the reduction (Fig. 5*B*). Fragment size and bone quality must be considered before this extra step. For small or comminuted fragments, this tunnel is ignored to avoid further comminution.

A progressive, controlled reduction is achieved by repeatedly and alternately pulling suture loop ends. Implant reduction and position are verified by fluoroscopy in an anteroposterior and axial plane of the clavicle, as the incision is closed. With fascia closure, tension of the affected tissue is restored (Fig. 4*D*).

Postoperative management

Patients are in a sling or shoulder immobilizer for 3 weeks. From the 1st postoperative day, active hand and elbow exercises are prescribed with shoulder pendulation exercises. Limb use for daily activities is encouraged, restricting anterior elevation < 90° until the 4th postoperative week. All patients receive physiotherapy from week 4, with a clinical and radiological follow-up at 4, 12, and 24 weeks.

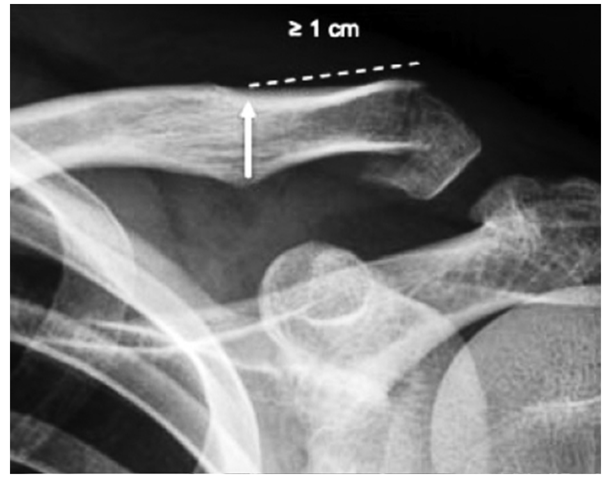

Figure 1 "Superior intact cortical". The superior fracture line is more than one centimeter from the conoid tubercle.

Case series

A retrospective cohort study was performed in patients with a minimally invasive surgery technique, using cortical buttons for distal clavicle fracture. A total of 21 patients (19 men) with a mean age of 34.7 (16 to 71) years were recruited. All patients had a positive superior intact cortical criterion. The follow-up was between 6 and 41 months, with an average of 23.4 months. Clinically, no patients presented infection or complications at the surgical site. Implant removal was not needed in this series. Imageneologically, radiographic consolidation of the fracture was confirmed at the 12-week follow-up radiography, with no cases of nonunion or malunion identified. Functionally, the mean simple shoulder test score was 79.4 (range 66-91.7), and the QuickDASH score was 11 (range 6.8–15.9). The evaluations were performed at the 24-week follow-up. Inferior cortical comminution, rotation, or displacement did not affect clinical or radiological results. All patients returned to work. Regarding the learning curve, this was simple because we use this technique in a similar way for the treatment of acromioclavicular dislocations.

Discussion

Several techniques are described for management of displaced distal clavicle fractures.[9,17,24] We present a minimally invasive technique with cortical buttons, requiring superior cortical indemnity ≥ 1 cm from the conoid tubercle to the distal. Using this criterion, excellent clinical and radiological results were obtained in our case series, without complications or reoperations reported. Our technique's advantages, in contrast to others, are as follows: a minimally invasive procedure; flexible and low-profile device; and direct and fluoroscopic vision of the coracoid and clavicle.

Minimally invasive surgery, such as arthroscopically assisted CC fixation, has gained popularity in recent years. It is believed that preserving soft tissue yields faster recovery and may result in safer procedures.[27] Moreover, it is well-known that minimizing stripping of periosteum and sparing the fracture hematoma reduces the incidence of nonunion, as it presumably allows for enhanced

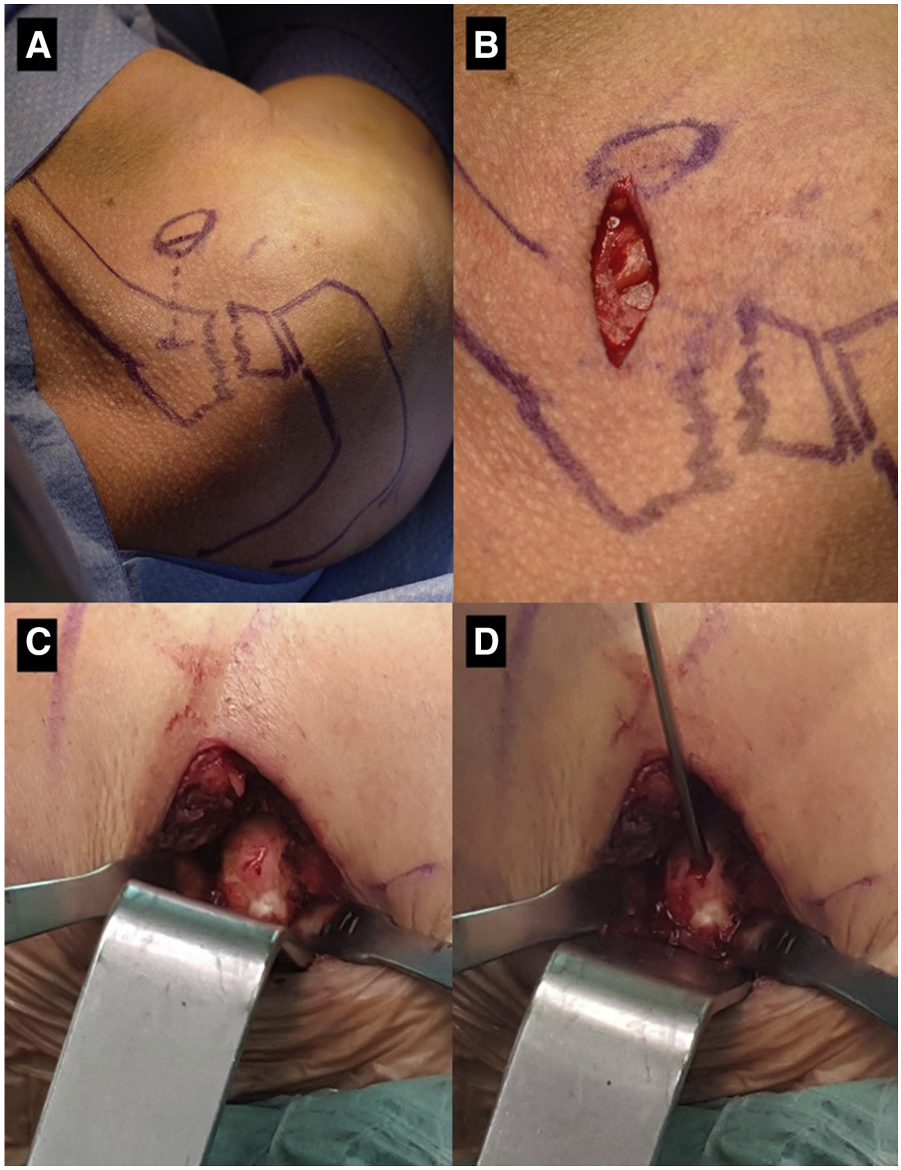

Figure 2 Right shoulder surface anatomy and coracoid approach. (**A**) A sterile marker outlines relevant shoulder surface anatomy. (**B**) A 3-cm incision is made, perpendicular to the axis of the clavicle in relation to Langeŕs skin lines, centered at the base of the coracoid. (**C**) To achieve a minimally invasive approach, dissection is performed without violating the fracture site until the upper surface of the coracoid base is exposed. (**D**) A 2.0 K-wire is passed at the center of the base of the coracoid, slightly inclined 10° anteriorly and 10° medially.

biological activity at the fracture site. In our case series, all patients achieved fracture consolidation in line with previous findings.

Mechanical properties of a button fixation device are ideal for stabilizing distal clavicular fractures. The ZipLoop is a flexible device, particularly resistant to creep under cyclical load, demonstrating only a 5.6-mm change in length, with cyclic loading of up to 250 N at 4500 cycles.[4] Rigid fixation is linked to a higher complication rate. Kona et al[18] reported a 47% complication rate and a 32% nonunion rate using transacromial K-wire fixation. CC stabilization with a CC screw was reported by several authors with good union rates (94%-100%) but was associated with a need for hardware removal.[1,21,30,31] Screw loosening, loss of reduction, iatrogenic clavicle, and coracoid fracture associated with fixation stiffness were reported.[1,21,30,31]

The use of high-resistance sutures and suture tape around the coracoid was proposed to achieve CC fixation in a flexible fashion, although coracoid and clavicle osteolysis (or late fractures) have been described in up to 18% of patients.[22,26] However, it must be considered that these data are extrapolated from ACJ reconstruction studies. Once the clavicle heals, the suture around the coracoid loses tension and this complication is rare.

Regarding device profile and hardware removal, hook plates had the highest reoperation rate (62.5%).[25] Low-profile contoured plates have a lower reoperation rate (16.2%) with suture-only fixation methods (0%) and thus the lowest reoperation rate reported.[15,25,28] In our case series, there were no patients requiring material removal, associated with flexibility and low profile. This may explain the fact that cortical button fixation devices are more cost-effective than other fixation methods, as per available evidence.[13]

Creating a bone tunnel through the coracoid and clavicle is associated with complications. To avoid coracoid tunnel fracture,

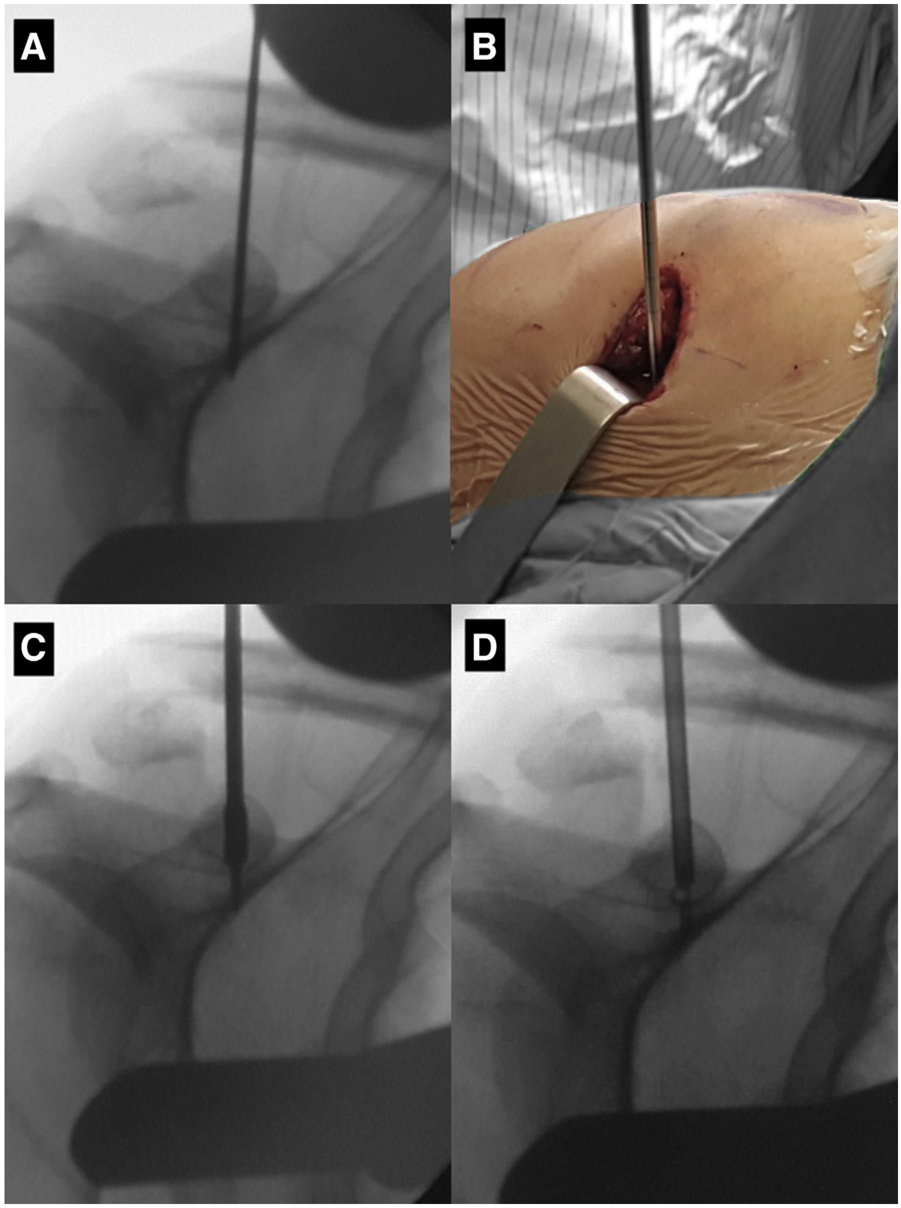

Figure 3 Coracoid tunnel. (**A**) Adequate position and alignment are verified with fluoroscopy, using the "cortical ring sign," aiming for a center-center position. (**B** and **C**): After the K-wire is properly positioned, a central bone tunnel is made with a 4.5-mm cannulated drill bit. (**D**) The inferior cortical button is then passed, flipped, and checked under fluoroscopy.

proper positioning of this tunnel is essential, so a cannulated drill bit is used for all cases. A biomechanical study of a center-center position, or a medial-center position of the coracoid tunnel, showed a higher peak load to failure compared with more lateral tunnel positions (538.2 N vs. 377.03 N, $P < .05$).[12] This suggests that a center-center position to a medial-center position may reduce complication risks. This is relevant in that the arthroscopic technique uses a lateral vision and may lead to a more lateral tunnel position, although no clinical evidence is available to support this. In addition, the use of arthroscopy showed no significant advantage in achieving better tunnel position compared with a mini-open technique in a recent cadaveric study.[3]

Furthermore, the use of the "cortical ring sign" view is described to aid tunnel positioning and can be easily achieved with a standard C-arm.[14] Considering this, we believe that a mini-open approach with direct visualization of the coracoid and fluoroscopic assistance is a safe and reliable technique to ensure adequate tunnel positioning.

Another relevant aspect is the tunnel width, which should be as narrow as possible. Campbell et al[6] showed that the use of a 4.5-mm drill bit results in a stronger construct compared with a 6-mm drill bit (load at ultimate failure; 557.6 ± 48.5 N vs. 466.9 ± 42.2 N, $P < .05$). In our case series, no iatrogenic fracture of the coracoid was reported.

The position of the clavicular button was not studied in a fracture setting. From acromioclavicular joint dislocation, biomechanical studies proposed that medial positioning of the clavicular tunnel (medial to the lateral third) increased the risk by 6 mm of superior clavicle displacement, from immediate postoperative films with an odds ratio of 21 (95% confidence interval, 0.77-562.15].[10,11]

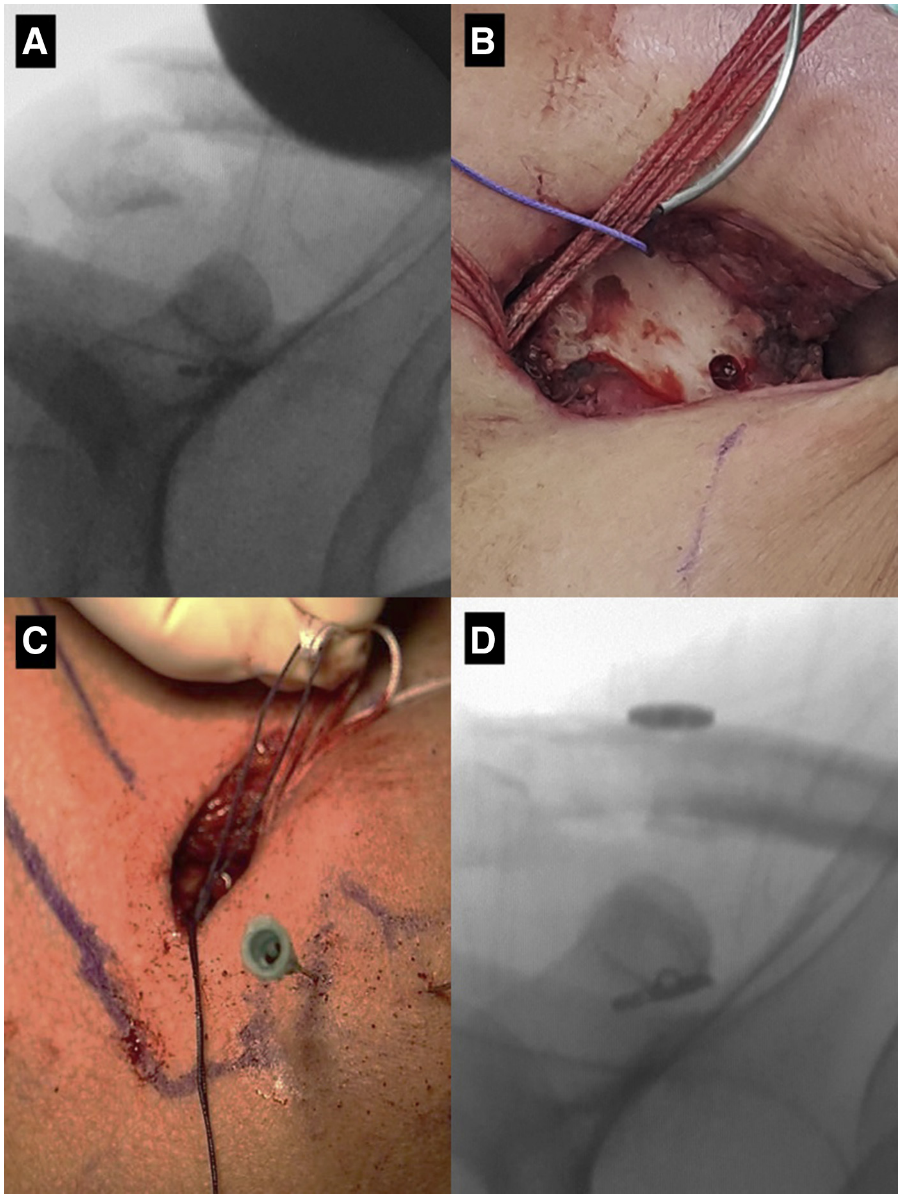

Figure 4 Clavicular tunnel and reduction. (**A**): Repetitive tension of the sutures is accomplished, until the button is carefully applied to the inferior cortex of the coracoid (Figs. 3 and 4*A*). (**B**) A 2.5-mm bone tunnel is made in the clavicle, centered on the conoid tubercle at the junction of the anterior third with the posterior two thirds. (**C**) The ZipLoop system is passed through the clavicle tunnel with traction sutures, or a nitinol guide, as the superior cortical button is secured to the suture loop. (**D**) A progressive, controlled reduction is achieved by repeatedly and alternately pulling suture loop ends. Implant reduction and position are verified under fluoroscopy in an anteroposterior and axial plane of the clavicle.

At the conoid tubercle area (approximately 25% of the clavicle's total length), bone quality is better, enhancing the construct resistance to repetitive loading.

Currently, there is scarce evidence about which surgical technique is clinically superior for distal clavicle fractures. In a systematic review and meta-analysis in 2018 by Boonard et al,[5] only 11 comparative studies assessed this problem. As per this study, CC fixation devices and plating render higher CMS and UCLA scores than hook plates or other techniques. No guidelines are provided when CC fixation can be used.

In summary, we found that the cortical button fixation technique has many advantages from a biomechanical and clinical perspective, making it our treatment of choice for distal clavicle fractures with superior intact cortical. Further investigation is required to refine the indication criteria for this technique. The use of this device in distal clavicle fractures is an off-label indication. However, this injury has similar characteristics to acromioclavicular dislocations. The main disadvantage of the use of this device is the possible fracture at the level of the clavicular or coracoid tunnel. Furthermore, in the presence of comminution with compromise of the superior cortex, its use is not recommended (Table I).

Conclusion

The presented minimally invasive button fixation technique for unstable distal clavicle fractures is a safe and reliable alternative treatment. Appropriate positioning of bone tunnels to ensure integrity of the superior clavicle cortex is key to avoiding

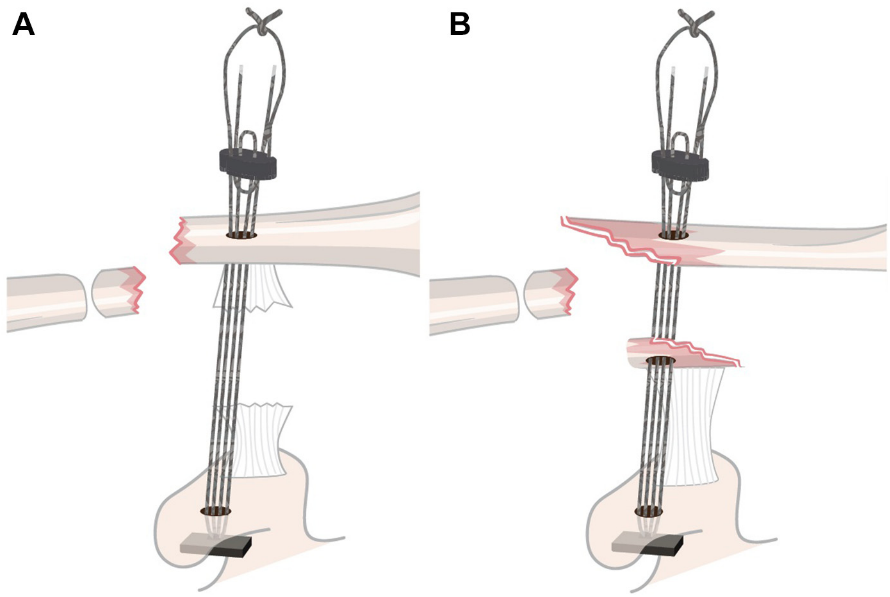

Figure 5 Neer type V fracture. (**A**) The ZipLoop system is passed through the clavicle tunnel with traction sutures, or a nitinol guide, as the superior cortical button is secured to the suture loop. (**B**) In comminuted fractures in which conoid and trapezoid ligaments are avulsed, taking an inferior cortical bone fragment (Neer Type V), with a 1.5 to 2.0 mm drill, passing the device sutures helps the fragment to guide the reduction.

Table I
Pearls and pitfalls of the technique.

Pearls	Fluoroscopy from the contralateral shoulder is more comfortable than from the posterior, as the C-arm does not interfere with controlled reduction maneuvers.
	To preserve the blood supply at the fracture site, the surgeon should not open the fracture site, approaching medially with minimally invasive concepts.
	To reduce the fracture, combine lifting of the arm with lowering of the clavicle.
	Once the device has been passed into the coracoid, pull strongly and repeatedly to ensure flipping and fixation. It is better that the device fails at this point, rather than at definitive reduction and fixation.
	Prefer medial clavicular bone tunnels for better bone quality, close to the conoid tubercle.
	The clavicular tunnel is made with a 2.5-mm drill bit in the direction of the coracoid to easily pass the suture.
	Perform reduction under fluoroscopy to avoid lack of reduction or overcorrection.
Pitfalls	One must be careful with retractors or deep dissection at the medial border of the coracoid.

complications. The initial outcome in our case series is promising, with excellent clinical and radiological results and no complications or implant removals.

Disclaimers

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Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.xrrt.2021.04.007.

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