J Shoulder Elbow Surg (2019) 28, e97–e103

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

ONLINE ARTICLES

# Displaced medial end clavicular fractures treated with an inverted distal clavicle plate contoured through 90 degrees

**Andrew Titchener, FRCS Orth, Tr, Abbas See, BA, Lee Van Rensburg, FRCS Orth, Tr, Graham Tytherleigh-Strong, FRCS Orth***

*Division of Orthopaedics, Addenbrooke's Hospital, Cambridge University Hospitals Trust, Cambridge, UK*

**Background:** This study assessed whether treating medial end clavicular fractures using an inverted distal clavicle locking plate, twisted through 90° around its axis, would allow for a less invasive surgical approach and improve screw trajectory insertion.

**Materials and methods:** We searched the databases of the 2 senior authors for patients who had sustained an acute, displaced fracture of the medial end of the clavicle and had undergone operative fixation using an inverted distal clavicle plate contoured through 90°. Through an inferior incision, a contoured locking plate was positioned on the anterior surface of the medial end of the clavicle. Up to 8 unicortical screws were inserted from anterior to posterior through the medial end of the plate. The lateral end was contoured and fixed to the superior clavicular surface. The patients were assessed preoperatively and at 1 month, 4 months, and final follow-up. Preoperative and postoperative plain x-ray images and computed tomography scans were reviewed.

**Results:** The study included 8 patients (average age, 31.3 years; range, 15-59 years) with displaced fractures who underwent fixation. The median follow-up time was 30.5 months (range, 24-45 months). All patients reached clinical and radiographic union at 4 months. The mean 11-item version of the Disabilities of the Arm, Shoulder, and Hand score was 0.6 (range, 0-2.3). All of the patients had returned to their preinjury level of sport and activity. None of the patients had a complication.

**Conclusion:** Contouring an inverted distal clavicle plate through 90° may improve fixation options by allowing access to the anterior clavicle when treating medial clavicular fractures.

**Level of evidence:** Level IV; Case Series; Treatment Study



**Keywords:** Clavicular fracture; intra-articular fracture; locking plate; unicortical screws; fracture union; sternoclavicular joint

Fractures of the medial end of the clavicle are rare and have traditionally been treated nonoperatively.[13,14,16] However, the nonunion rate for medial clavicular fractures has been reported as 8.3%, and for those fractures that do heal, problems with function and on-going pain occur in more than 50% of cases.[11,15,19]

Traditionally, nonoperative treatment of medial clavicular fractures has been preferred, with a relatively high threshold

The Cambridge University Hospitals Trust Quality and Information Safety System approved this study (PRN7510)

*Reprint requests: Graham Tytherleigh-Strong, FRCS Orth, Division of Orthopaedics, Addenbrooke's Hospital, Cambridge University Hospitals Trust, Hills Rd, Cambridge CB2 2QQ, UK.

E-mail address: graham.tytherleigh-strong@addenbrookes.nhs.uk (G. Tytherleigh-Strong).

1058-2746/$ - see front matter 
https://doi.org/10.1016/j.jse.2018.08.047

before considering surgical fixation. This has been partly due to concerns with the close proximity of the posterior mediastinal structures and the technical difficulties of adequately stabilizing and fixing the relatively small medial fragment.

A number of fixation methods, including various types of sutures, wires, screws, and plate configurations, have been described to treat medial end clavicular fractures.[2,4,5,7,12,17,18] These have generally been as case reports or very small cases series with varying levels of success.

More recent case reports have described the successful use of an inverted lateral clavicle locking plate positioned on the superior surface of the clavicle to treat fractures of the medial end.[9,17,20,22] However, there are concerns with how well the plate actually fits, plate positioning, and access for accurate screw insertion. Fixing the plate onto the superior surface of the medial end of the clavicle may compromise or damage the clavicular insertion of sternocleidomastoid (SCM) muscle and, due to the close proximity of the patient's head and neck, compromise and limit the number of precisely positioned screws.

To avoid potential damage to the SCM muscle, better contour the plate, and aid accurate screw insertion, we have used a lateral clavicle locking plate that is twisted through 90°. This allows for the medial end of the plate to be fixed to the anterior surface of the clavicle with multiple small locking screws and the lateral end of the plate to be twisted and fixed to the superior surface of the clavicle.

This study describes the operative rationale and technique for using a contoured, inverted lateral clavicle locking plate to treat medial clavicular fractures. The results of a case series of medial clavicular fractures that have been stabilized using this technique is presented.

## Materials and methods

We searched the senior 2 authors' (GTS and LVR) surgical databases for patients who had undergone fixation of a displaced medial clavicular fracture using a contoured locking plate between August 2014 and August 2016. The study included patients who had sustained an acute medial fracture or fracture dislocation of their clavicle. Exclusion criteria included an additional associated injury to the shoulder girdle (clavicle or scapula), previous clavicular fracture or injury to the sternoclavicular joint (SCJ), and a delayed or established nonunion. All of the patients had a preoperative plain x-ray image and computed tomography (CT) scan of their clavicle, SCJ, and sternum. All of the procedures were undertaken by 1 of the 2 senior authors, having obtained informed consent.

### Surgical procedure

All of the procedures were undertaken with the patient under general anesthesia with routine intravenous antibiotic prophylaxis. The patients were positioned supine with a sandbag between their scapulae on a fully radiolucent table to allow for intra-operative fluoroscopic images.

### Surgical approach

When considering the surgical approach to access the medial end of the clavicle, we took into account protection of the posterior mediastinal structures, the SCM muscle, and soft tissue structures adjacent to the superior surface and the exposure and the drill trajectory for the medial end screws.

An oblique transverse incision was made parallel and just inferior to the medial end of the clavicle, stopping just before the midline. Dissection was taken through platysma to expose the anterior surface of the medial end of the clavicle, the anterior SCJ ligament and joint capsule, and the medial edge of the sternum. More laterally, the dissection was developed superiorly to expose the superior surface of the clavicle.

### Locking plate

We used the Acumed (Hillsboro, OR, USA) short (13-hole) and long (16-hole) distal locking clavicle plate to fix medial end clavicular fractures. The plates are side-specific; our method uses the ipsilateral plate (eg, a left-sided plate for a left-sided injury). With helical bending of the plate through 90° around its axis, at the junction between the flared and shaft parts, it can be contoured and fitted in a reverse configuration to the medial clavicle with the 2.3-mm hole flared segment positioned over the anterior surface of the medial clavicle and the shaft section spiraling to fit along the more lateral superior surface (Fig. 1).

A mixture of unicortical locking and nonlocking screws was inserted into the flared medial end of the plate from anterior to posterior. Bicortical cortex screws were inserted from superior to inferior into the lateral end of the plate (Figs. 2 and 3).

Comminuted and intra-articular fractures were reduced and held in position using bone clamps or Kirschner wires. The multiple locking screw holes in the plate were used to secure the fragments using multiple screws in a locked or nonlocked fashion as was required (Fig. 4).

Postoperative follow-up was performed at 4 weeks, 4 months, 6 months, 1 year, and final follow-up. A plain x-ray image was taken at each follow-up appointment. These were assessed retrospectively by the 2 senior authors. Due to the overlap of the vertebral column behind the clavicle and the plate "wrapping" around the fracture site on the plain x-ray image, consistently assessing each x-ray image for all 3 criteria of radiographic union (bridging callus, bridging of the fracture site at 3 cortices, cortical continuity) was not possible.[10] However, we endeavored to determine the progress and maintenance of fracture bridging, fracture obliteration, and cortical continuity at visible areas on serial x-ray images. To attempt to obtain consistent views we asked the radiographers to, where possible, match the orientation of the lateral, horizontal end of the plate for each x-ray image. We did not consider a routine CT scan to be clinically or ethically indicated; however, 2 patients did have a postoperative CT scan for clinical reasons.

The primary outcomes were clinical union of the fracture, the 11-item version of the Disabilities of the Arm, Shoulder and Hand score, and range of motion of the sternoclavicular and glenohumeral joints.[6,21] Clinical nonunion was deemed if, after 6 months after surgical fixation, the patient had persistent pain on palpation of the fracture site.[3] The secondary outcome was evidence of radiographic union on serial x-ray images.

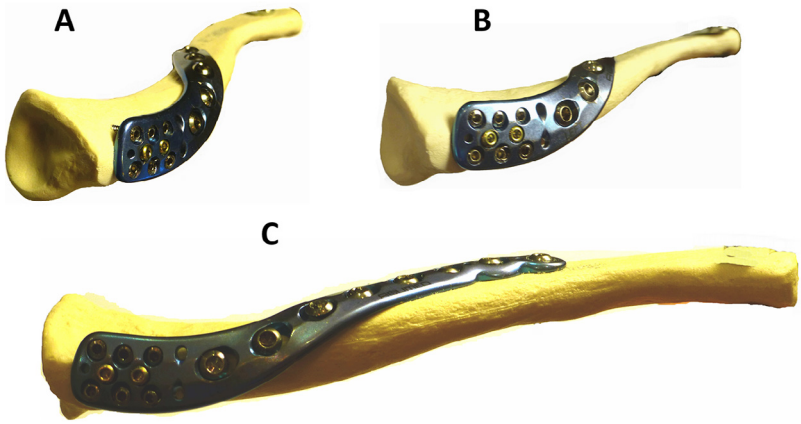


**Figure 1** Contoured lateral clavicle locking plate. The plates have been twisted around their axis through 90° at the junction between the flared and shaft parts. An ipsilateral plate has been positioned in a reverse configuration with the flared end of the plate over the anterior surface of the medial end of the clavicle and the shaft curving up onto the superior surface. (**A** and **B)** A short (13-hole plate) fixed to the medial end of the clavicle. (**C**) A long (16-hole plate) fixed to the medial end of the clavicle and extending more laterally.

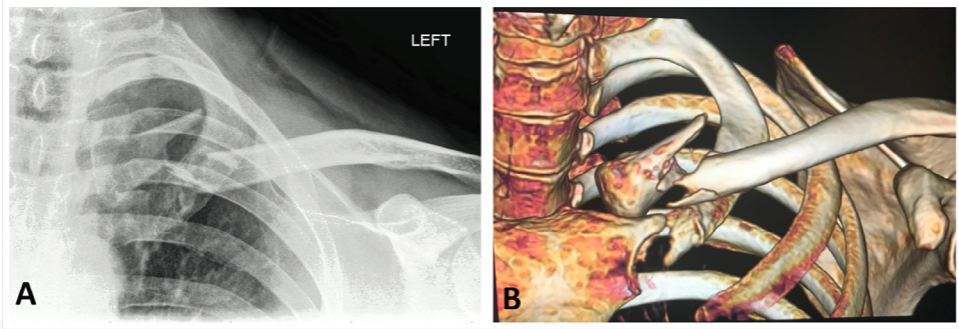


**Figure 2** A preoperative anteroposterior (**A**) x-ray image and (**B**) 3-dimenstional reconstruction computed tomography scan demonstrate a comminuted fracture of the medial end of the left clavicle.

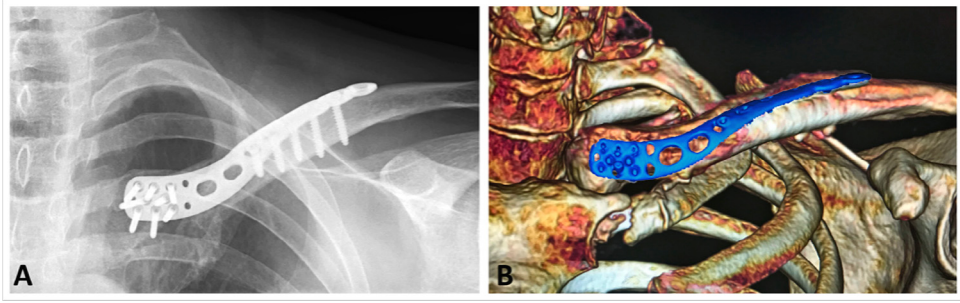


**Figure 3** A postoperative anteroposterior (**A**) x-ray image and (**B**) 3-dimensional reconstruction computed tomography scan of the patient in Fig. 2, 6 months after surgery demonstrate the contoured clavicle plate in position and the united fracture.

Any postoperative complications were recorded at each follow-up, and patients were asked whether they had any irritation from the plate, had returned to full preoperative activities, and whether they would have the same procedure again if a similar injury were to occur on the contralateral side. The minimum follow-up time was 24 months.

## Results

We identified 8 patients who underwent an open reduction and internal fixation using a contoured locking plate for an acute displaced medial fifth clavicular fracture. All of the procedures were undertaken by 1 of the 2 senior authors using the technique described above. Patient demographic and outcome data are included in Table I.

The median age at injury was 30 years (range, 15-59 years), with 7 male patients. There were 5 right-sided and 3 left-sided fractures. The main mechanisms of injury were contact sports or bicycle accident. Three patients had fractures with an intra-articular extension, and 4 patients had extra-articular fractures only. One patient had a Salter-Harris II fracture that was displaced posteriorly. Due to his relative maturity (16

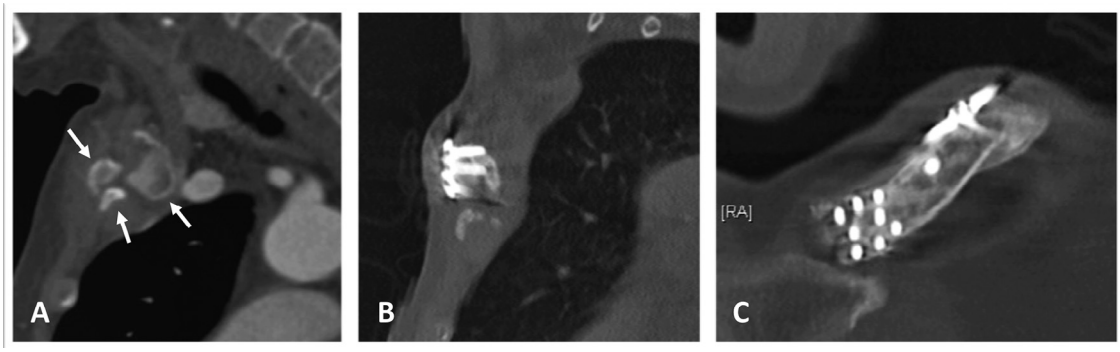


**Figure 4** Preoperative and postoperative computed tomography scans of a left comminuted, displaced, intra-articular fracture of the medial clavicle. (**A**) Sagittal view of the medial end of the left clavicle demonstrates the displaced intra-articular fragments (*white arrows*). (**B**) Sagittal view of the same fracture, 6 months after fixation. The locking plate can be seen on the anterior surface of the clavicle with 3 screws passing backwards into the bone. (**C**) Coronal view demonstrates 8 locking screws passing through the medial end of the healed comminuted fracture.

**Table I** Demographics

| Patient | Sex | Age (yr) | Mechanism of injury | Fracture/ IA/EA | Side | Time to surgery (days) | Time to union (mo) | Follow-up (mo) | *Quick*DASH |
|---|---|---|---|---|---|---|---|---|---|
| 1 | M | 15 | Rugby | #/EA | R | 15 | 4 | 45 | 0 |
| 2 | M | 16 | Soccer | #/EA | R | 8 | 4 | 40 | 2.3 |
| 3 | M | 16 | Rugby | SH II | R | 14 | 3 | 39 | 0 |
| 4 | M | 34 | Motorbike | #/EA | L | 22 | 4 | 33 | 0 |
| 5 | M | 29 | Bicycle | #/IA | R | 6 | 4 | 28 | 2.3 |
| 6 | F | 59 | Fall | #/IA | L | 11 | 4 | 25 | 0 |
| 7 | M | 32 | Bicycle | #/IA | R | 9 | 4 | 25 | 0 |
| 8 | M | 49 | Motorbike | #/IA | L | 17 | 4 | 24 | 0 |
| Mean | | 31.3 | | | | 12.8 | 3.8 | 32.5 | 0.6 |
| Median | | 30 | | | | 14 | 4 | 30.5 | 0 |

*IA*, intra-articular; *EA*, extra-articular; Quick*DASH*, 11-item version of the Disabilities of the Arm, Shoulder and Hand; *M*, male; *R*, right; *SH II*, Salter-Harris II; *L*, left; *F*, female; *#*, fracture.

years), the amount of displacement, and that he was playing rugby at an elite level, there was concern that his fracture, if it were treated nonoperatively and did unite, might not significantly remodel and result in a functionally impairing malunion.

The policy in our institution for all posterior SCJ dislocations or fracture dislocations that require reduction is that, due to issues with potential retrosternal vascular injury, this should be done as an open procedure. We also routinely stabilize the dislocation or fracture with sutures (for juvenile epiphyseal fractures), plate fixation, or a figure-of-8 tendon graft as required.

The median follow-up time was 30.5 months (range, 18-39 months). The patient with the Salter-Harris II fracture was seen at 3 months postsurgery and had obtained clinical and radiographic CT union at that point. The other 7 patients reached clinical union at 4 months. A CT scan in 2 of these patients, 1 at 4 and months and 1 at 6 months, confirming radiologic union. The serial x-ray images of the other 6 patients showed a consistent progress and maintenance of fracture bridging, fracture obliteration, and cortical continuity at visible areas (Fig. 5).

The mean score on the 11-item version of the Disabilities of the Arm, Shoulder and Hand was 0.6 (range, 0-2.3). All patients had returned to their preinjury level of sport, activity, study, or work and had regained a full and equal range of motion at their SCJ compared with the noninjured side. Seven patients had regained a full and equal range of motion at their glenohumeral joint compared with the other side. Before the clavicular injury, 1 patient had undergone a surgical anterior stabilization of the glenohumeral joint on the same side as the fracture. The patient did have some loss of external and internal rotation at the glenohumeral joint compared with the noninjured side but felt that this was no different to the range before the clavicular fracture.

None of the patients had experienced or reported a complication. Two patients felt that their metalwork was slightly prominent but chose not to have this removed (Fig. 6). All patients said that they would be happy to undergo the

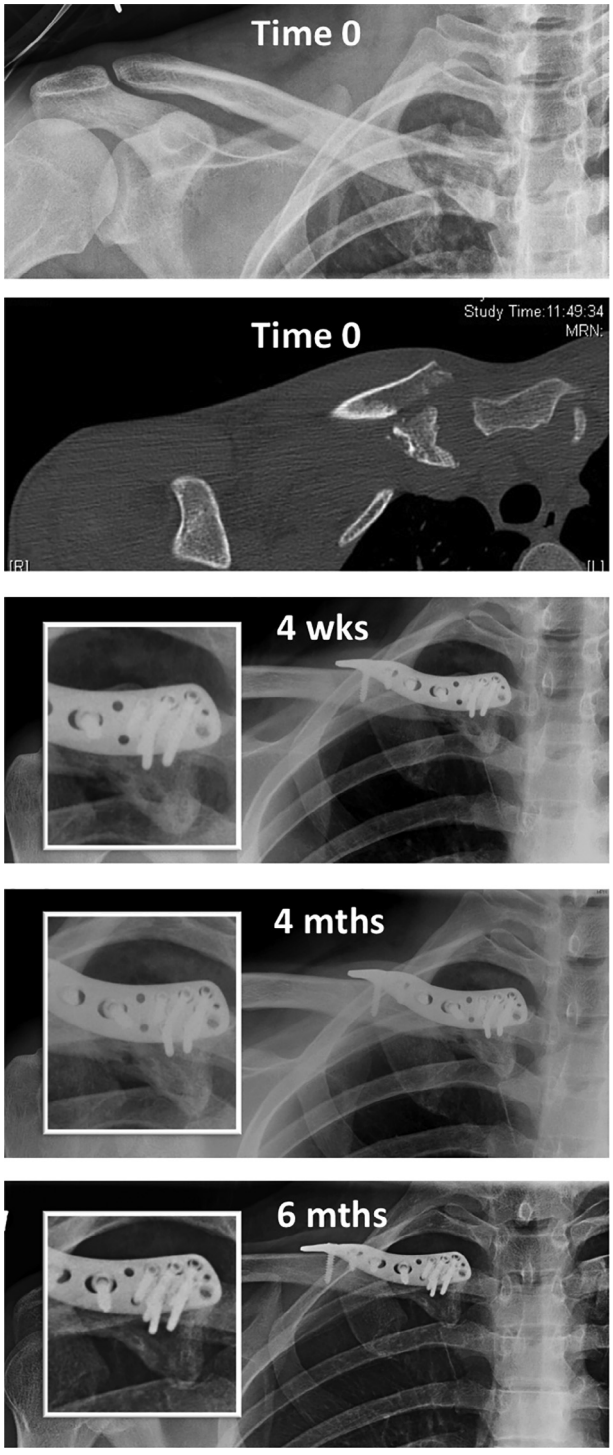


**Figure 5** Serial plain x-ray images and an axial computed tomography scan of a right medial end clavicular fracture before and after fixation. At 4 weeks after fixation, there is still evidence of an inferior cortical discontinuity. At 4 months after fixation, callus can be seen inferiorly bridging the fracture with cortical continuity. At 6 months there has been further consolidation of the fracture healing.

procedure again if a similar fracture were to occur on the contralateral side.

## Discussion

Fractures to the medial third of the clavicle are rare and have previously been reported as representing between 2% and 4% of all clavicular fractures.[11,14-16] In addition, interpretation of a single radiographic view can be difficult, potentially leading to an underappreciation of medial third fractures.[19]

Previously, the tendency was to treat medial third clavicular fractures nonoperatively. This is likely to be due to concerns with the hazards associated with the surgical approach around the SCJ and the medial end of the clavicle and also with achieving adequate fixation of the relatively small medial side bony fragment. However, the nonunion rate was found to be 6.3% for nondisplaced medial third fractures and 14.3% for displaced fractures at 24 weeks after injury.[15] Early anatomic reduction and fixation has been shown to reduce the time to functional recovery, with excellent outcomes and few complications.

Various fixation methods have been advocated to fix medial clavicular fractures. Kirschner wires have been used alone, but these tend to be insufficient and may migrate.[2,4] A hook plate has been used, with the hook in the sternum itself inducing a temporary arthrodesis; this also requires removal.[5] Tension band sutures have been used, offering limited stability. They are less suitable for larger fragments, although they may be used in combination with a T plate, which may also be used alone.[7] Even a staged procedure of medial clavicular fixation and middle clavicular offloading osteotomy with delayed osteotomy fixation has been attempted.[1]

The use of locking plates has been reported with successful results.[9,17,20,22] The most recent and largest series fixed 19 of 20 displaced adult medial clavicular fractures by using a plate. A reversed lateral clavicle plate, made by 3 different manufacturers, was contoured to the anatomy of the superior surface of the clavicle and the medial end fixed with unicortical screws.[17] None of the patients sustained intraoperative damage to any of the surrounding vital soft tissue structures, and all of the fractures healed. Of the 25 patients in their series, including 6 patients who had an osseous suture fixation, 17 reported symptoms of plate or wound irritation, although 3 patients felt this to be sufficiently severe to undergo elective removal of the hardware.

In all of the aforementioned series using a reversed lateral clavicle locking plate to fix a medial third clavicular fracture, the plate has been positioned on the superior surface of the clavicle. However, we were concerned that this position risked interference and irritation of the sternal head of SCM muscle and other soft tissue structures around the superior surface of the medial end of the clavicle and SCJ. We also felt that the proximity of the patient's head and neck would potentially hinder and compromise the ability to obtain the correct drill and screw trajectory into the medial end of the

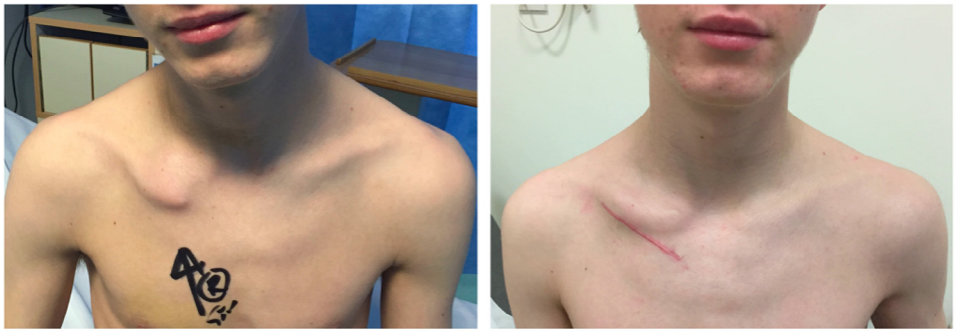

**Figure 6** **(A)** Preoperative appearance of lateral end of the clavicle displaced inferiorly and anteriorly. **(B)** Postoperative oblique incision scar with the clavicle reduced and fixed into an anatomic position. The incision is distant from the plate, potentially diminishing issues with wound irritation.

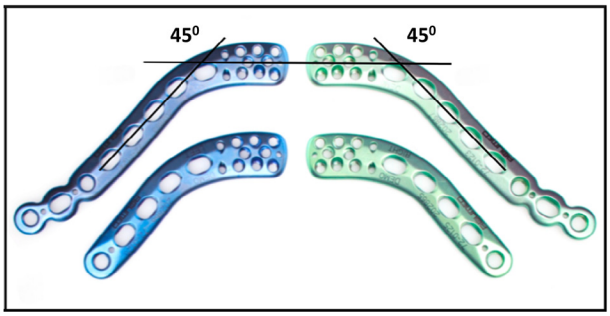


**Figure 7** Acumed Lateral Clavicle (Hillsboro, OR, USA) short (13-hole) and long (16-hole) locking plates demonstrate the 45° preset angle between the flared and straight ends of the plate.

clavicle to accurately drill all of the potential locking slots available within the flared end of the plate. There was no mention of these concerns in these series.

In addition, although some authors felt that a reversed lateral clavicle plate exactly matched the anatomy of the medial clavicle, we did not find this to be the case.[20,22] A CT anatomy study looking at 418 clavicles in 209 patients found that the average sternal curvature of the clavicle in the axial plane was 34° compared with an average acromial curvature of 46°.[8] The "built-in" curvature for commercially available anatomic lateral clavicle plates is between 44° and 46° (Fig. 7).

Although it is possible to potentially accommodate the angular mismatch between an inverted, short lateral clavicle plate over the medial end of the clavicle by positioning the medial, flared end of the plate as posteriorly as possible over the superior, medial end of the clavicle, compromising optimal fixation, it is not the case for a long lateral plate. Despite positioning the medial, flared end of an inverted long lateral clavicle plate as posteriorly as possible over the superior, medial end of the clavicle, the last 3 screw holes at the lateral end of the plate will be off of the posterior edge of the clavicle.

To address these concerns, we bent same-sided lateral clavicle plates through 90° around their axis at the junction between the flared and shaft parts. By carefully contouring and controlling the bend, it was possible to align the shaft end of the plate along the superior surface of the clavicle, accurately accommodating the sternal curvature for both short and long plates (Fig. 1). We used an Acumed distal locking plate because this is the plating system that we use in our institution for clavicular fractures. However there is no specific reason why any other proven clavicle distal locking plate made by another manufacturer could not have been used.

Through an inferior anterior approach, to improve cosmesis and minimize wound irritation, the flared end of the plate could be positioned over the anterior surface of the medial end of the clavicle, permitting an unhindered drill trajectory and screw insertion to every screw hole available within the plate. The only compromise is that the preset peripheral locking screw angles in the plate are divergent to accommodate the broader, superior surface of the lateral clavicle (Fig. 8). The anterior surface of the medial end of the clavicle is less broad, and some of the peripheral holes may require nonlocking screws.

We consider the contoured, inverted, anterior-superior plate technique to have a number of advantages over an inverted, superior plate technique, but it does have some disadvantages. Although there are a number of benefits in drilling and

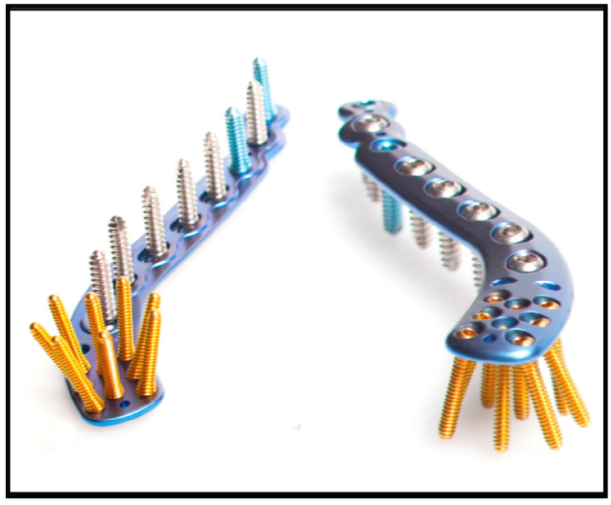

**Figure 8** End-on view of a lateral clavicle plate demonstrates the preset divergent angle of the flared-end 2.3-mm locking screws.

inserting the screws into the anterior surface of the medial clavicle, it is essential that the drill does not penetrate the posterior cortex of the clavicle and that the screws remain unicortical. The technique also requires significant and careful contouring of the plate around its axial plane.

This study has a number of limitations. The sample size is small, and the patient population is relatively heterogeneous. It is also a retrospective study with a relatively short follow-up and a single-unit case series.

## Conclusion

Management of displaced lateral third clavicular fractures with an inverted lateral clavicle plate has been shown to be beneficial with regards to union, time to recovery, and outcome.[9,17,20,22] Contouring the plate through 90° and attaching the flared end to the anterior surface of the medial clavicle may improve the fixation options and protect the superior clavicular soft tissue structures.

## Disclaimer

The authors, their immediate family, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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