Plate fixation of displaced clavicle fractures has proven to be reliable and reproducible, leading to high union rates and a low rate of associated complications. However, the decision of whether to place the plate superiorly or anteroinferiorly on the clavicle has remained controversial. The authors performed a retrospective review on a consecutive series of patients who underwent plate fixation for a displaced midshaft clavicle fracture at a Level I urban trauma center. A review of surgical records identified 138 patients with a displaced midshaft clavicle fracture requiring operative stabilization. A total of 105 patients who met the inclusion criteria were included in the analysis. Both superior and anteroinferior techniques resulted in a similar time to radiographic union (12.6±4.8 vs 11.3±5.2 weeks, respectively) and identical union rates (95%). At final follow-up, patient-reported implant prominence was nearly double in patients with a retained superior plate (54% vs 29%, respectively; P=.04). No significant difference existed in mean visual analog scale score at a mean of 2.77 years postoperatively, although a significant difference existed in the Oxford Shoulder Score questionnaire, with a mean score of 41.4 in the superior group and 44.4 in the anteroinferior group (P=.008). Implant removal occurred more frequently after superior plating but was not significant. Both superior and anteroinferior clavicle plating are safe treatment methods for displaced clavicle fractures. Superior plating leads to an increased rate of patient-reported implant prominence and may prompt more requests for implant removal.

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Figure: Preoperative anteroposterior radiograph showing a completely displaced right midshaft clavicle fracture with significant angulation and apparent soft tissue tenting (A). Anteroposterior radiograph showing that the displaced clavicle fracture achieved union 14 weeks postoperatively with a 3.5-mm superior clavicular plate and supplementary 2.7-mm lag screw (B).
Clavicle fractures are common orthopedic injuries, representing approximately 2.6% to 5% of all fractures, and they involve the middle third of the clavicle in up to 82% of fractures.\(^1\)\(^-\)\(^3\) Traditionally, these fractures were managed nonoperatively after early studies reported that conservative treatment led to a high union rate without compromise of patient satisfaction or function.\(^4\)\(^,\)\(^5\) However, more recent literature has shown increased rates of nonunion, symptomatic malunion, and unsatisfactory patient outcomes with nonoperative management of displaced midshaft clavicle fractures.\(^5\)\(^-\)\(^9\) The incidence of high-energy clavicle fractures is increasing and may contribute to these findings because increased initial fracture displacement, shortening, and comminution have been shown to be predictive of nonunion and poor patient outcomes with nonoperative care.\(^10\)\(^,\)\(^11\) Consequently, there has been an increasing trend toward operative fixation of displaced midshaft clavicle fractures (Figure 1).

Numerous clavicle fixation methods exist, but plate and screw constructs lead to predictable outcomes with a low nonunion rate.\(^7\)\(^,\)\(^8\) Currently, 2 methods of clavicle plating are used, in which a plate is contoured to either the superior or anterioinferior surface of the clavicle. Regardless of placement, the subcutaneous position of the plate may induce implant prominence and scar-related pain after fracture union, which may lead to patient requests for implant removal.\(^12\)

The most common benefit of anterioinferior plating is that it avoids the most superficial, superior aspect of the clavicle and is hypothesized to reduce complaints associated with implant prominence.\(^13\)\(^-\)\(^15\) Several recent case series have evaluated the results of an anterioinferior plating technique for midshaft clavicle fractures or nonunions and share similar conclusions that this plating position is safe, leads to high union rates, and is associated with few implant-related patient complaints (Figure 2).\(^13\)\(^-\)\(^15\) In addition, drilling and screw placement in an anterioinferior to posterior direction is thought to reduce risk to the underlying neurovascular bundle while also allowing the use of longer screws due to the larger anterioinferior to posterior diameter of the clavicle.\(^13\)\(^,\)\(^16\) However, the commonly accepted concept of increased safety with anterioinferior plating has been questioned in several recent studies that reported that the risk of iatrogenic neurovascular injury is possible regardless of plate position.\(^17\)\(^,\)\(^18\) Other recent studies have focused on the biomechanical properties of these 2 plating methods with varying results. One initial biomechanical comparison revealed overall improved mechanical stability with the use of a superior plate.\(^19\) However, newer literature has shown advantages to both plating methods depending on the type of stress being exerted on the clavicle.\(^20\)\(^,\)\(^21\) Despite the abundance of biomechanical literature contrasting these fixation techniques, the current authors are not aware of any studies directly comparing radiographic and functional outcomes between these plating positions on a large patient population to better determine whether an optimal plate position exists.

The current study was designed to retrospectively review a consecutive series of patients who underwent fixation of a displaced midshaft clavicle fracture at the authors’ institution with either a superior or anterioinferior plate and screw construct. The hypothesis was that anterioinferior plating may have benefits over superior plating in regard to decreased complications, improved patient outcomes, and a reduced incidence of implant removal after fracture union.

**Materials and Methods**

The authors retrospectively reviewed a consecutive series of patients who under-
went open reduction and internal fixation of a displaced midshaft clavicle fracture at a Level I urban trauma center. All surgeries were performed by 1 of 8 orthopedic trauma fellowship-trained surgeons (B.C.T.). Institutional review board approval was obtained prior to initiating the study.

A review of the authors’ surgical records identified 138 patients who had sustained a displaced midshaft clavicle fracture requiring open reduction and internal fixation between June 2005 and December 2010. All patients received a 2.7- or 3.5-mm plate and screw construct in either a superior or anteroinferior position. Plate position and implant selection were at the discretion of the surgeon and were nonrandomized. After meeting the inclusion and exclusion criteria listed below, a total of 105 patients were included in the analysis.

**Inclusion Criteria**

Patients were included if they had an acute, displaced midshaft clavicle fracture; a fracture treated with plate fixation and at least 3 screws in the proximal and distal fragment; an age of 18 years or older; and sufficient follow-up to confirm fracture union clinically and radiographically with return to full weight bearing and activities of daily living.

**Exclusion Criteria**

Patients were excluded if they had an age of younger than 18 years, a proximal or distal third fracture, a previous surgery on the same clavicle, initial presentation with a nonunion, and insufficient postoperative follow-up in which a patient was lost to follow-up prior to confirmation of fracture union and return to full weight bearing and activities of daily living.

**Data Collection**

A chart review was initiated, and a database was created to record multiple variables for each patient, including age, sex, involved side, injury mechanism, medical comorbidities, tobacco use, whether the fracture was open or closed, and associated orthopedic injuries. The time from initial injury to operative management was documented, as were intraoperative data, including the number of holes in the plate used, number of screws per fracture segment, lag screw(s) used, bone grafting, operative time, estimated blood loss, and perioperative complications.

All radiographs were reviewed, and fractures were classified using the Orthopaedic Trauma Association (OTA) Fracture Classification system by 2 of the authors (N.F., J.B.) not involved with the initial care of the patients. Union was defined by radiographic evidence of healing on at least 3 cortices and review of clinical examinations indicating absence of fracture site tenderness. Malunion was defined as a fracture with a loss of reduction and greater than 20° of angulation during fracture healing. Nonunions and any additional procedures related to the clavicle were recorded for each patient. Disagreements between the 2 authors regarding the aforementioned variables were settled by the senior author (B.C.T.).

In addition, all patients were contacted to obtain additional information regarding implant pain, prominence, peri-incisional numbness, or paresthesias. Patients also completed an Oxford Shoulder Score (OSS) questionnaire and visual analog scale (VAS) assessment to evaluate subjective outcomes. The OSS questionnaire was chosen because is sensitive to surgical intervention around the shoulder and has excellent correlations with the Constant Score and Short Form 36.22-24

**Statistical Analysis**

Statistical analysis was performed, with means, ranges, and confidence intervals calculated for continuous variables and compared using Student’s t tests. Frequencies were calculated for continuous variables and compared using Fisher’s exact test for increased accuracy in small proportion analysis. A P value greater than .05 was considered statistically significant, with a trend defined as a P value being between .05 and .1.

**RESULTS**

A total of 138 patients underwent open reduction internal fixation with either a superior (n=82) or anteroinferior (n=56) plate for the treatment of an acute midshaft clavicle fracture between June 1, 2005, and December 31, 2011, at the authors’ institution. Twenty patients in the superior group and 13 patients in the anteroinferior group lacked sufficient follow-up to confirm a radiographic union of their clavicle fracture and were excluded. The remaining 105 patients, of which 62 had a superior plate and 43 had an anteroinferior plate, were included.

No significant difference existed between the 2 groups in regard to age, sex, or involved side (Table 1). Other orthopedic injuries were common, with 24 (38.7%) of 62 patients in the superior group and 16 (37.2%) of 43 patients in the anteroinferior group sustaining additional long bone fractures at the time of clavicle injury. Two (3.2%) open fractures occurred in the superior group and 1 (2.3%) occurred in the anteroinferior group. Orthopaedic Trauma Association 15-B1 and 15-B2 clavicle fractures represented the majority of injuries in each group; although significantly more 15-B1 fractures underwent treatment with an anteroinferior plate (P=.01) (Table 1). However, when each OTA subgroup was broken down and compared regarding the position of plate, no significant differences existed in the postoperative variables.

Both groups had similar times from injury to fixation, plate lengths, use of lag screws, bone grafting, and estimated blood loss (Table 2). Superior plating was associated with a significant increase in operative time (104.1±39.1 vs 85.5±21.9 minutes, respectively), with a statistically but not clinically significant higher number of screws being used per fracture segment (3.7±0.7 vs 3.4±0.4 screws, re-
spectively) (Table 2). Both superior and anteroinferior techniques led to a similar time to radiographic union (12.6±4.8 vs 11.3±5.2 weeks, respectively) and identical union rates (95%) (Table 2). Two nonunions occurred in each group, which subsequently underwent revision with bone grafting and went on to union with no further complications. All 4 patients with nonunion had a history of tobacco use. Superior plating demonstrated a higher incidence of malunion (10% vs 2%; \( P = .277 \)) and implant failure (3% vs 0%; \( P = .234 \)) but did not meet the criteria to be considered statistically significant (Table 2).

One postoperative infection occurred in a closed fracture in the anteroinferior group. Two patients in each group had symptomatic acromioclavicular arthrosis after fracture union and underwent distal clavicle resection. One major complication occurred in the superior plating group in which the subclavian vein was directly penetrated during

### Table 2

<table>
<thead>
<tr>
<th>Data</th>
<th>Superior (n=62)</th>
<th>Anteroinferior (n=43)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time from injury, d</td>
<td>NA</td>
<td>14.9±16.6</td>
<td>NA</td>
</tr>
<tr>
<td>Plate length, No. of holes</td>
<td>NA</td>
<td>9.2±2</td>
<td>NA</td>
</tr>
<tr>
<td>Screws per fracture segment</td>
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<td>3.7±0.7</td>
<td>NA</td>
</tr>
<tr>
<td>Lag screw used</td>
<td>41 (66)</td>
<td>NA</td>
<td>30 (70)</td>
</tr>
<tr>
<td>Operative time, min</td>
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<td>NA</td>
</tr>
<tr>
<td>Bone graft used</td>
<td>6 (10)</td>
<td>NA</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Estimated blood loss, mL</td>
<td>NA</td>
<td>46.5±47.9</td>
<td>NA</td>
</tr>
<tr>
<td>Bony union</td>
<td>60 (95)</td>
<td>NA</td>
<td>41 (95)</td>
</tr>
<tr>
<td>Time to union, wk</td>
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<td>12.6±4.8</td>
<td>NA</td>
</tr>
<tr>
<td>Malunion, loss of reduction</td>
<td>6 (10)</td>
<td>NA</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Postoperative infection</td>
<td>0 (0)</td>
<td>NA</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Implant failure</td>
<td>2 (3)</td>
<td>NA</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Implant removal</td>
<td>12 (19)</td>
<td>NA</td>
<td>4 (9)</td>
</tr>
</tbody>
</table>

**Abbreviation:** NA, not applicable.
drilling of the clavicle, prompting vascular surgery consultation and repair. No significant difference existed when comparing postoperative complications between the 2 plating techniques; however, the implant removal rate demonstrated a nonsignificant increase toward implant removal in the superior vs anteroinferior group (19% vs 9%; $P=.257$) (Table 2).

Thirty-nine (62%) patients in the superior group and 28 (64%) in the anteroinferior group completed the final follow-up survey,VAS, and OSS questionnaire at a mean of 2.77 years postoperatively. A statistically significant difference existed in the mean follow-up for these subjective data between the superior and anteroinferior groups ($P=.003$), but both groups averaged 2 years or more (Table 3). At final follow-up, patient-reported implant prominence was almost double in patients with a retained superior plate compared with patients with an anteroinferior plate (54% vs 29%; $P=.04$). Reports of pericisional numbness or dysthesias were common and similar between the groups (Table 3). No significant difference existed in the mean VAS; however, a significant difference existed in the OSS questionnaire, with a mean score of 41.38 in the superior group and 44.36 in the anteroinferior group ($P=.008$) (Table 3).

**Discussion**

Clavicle fracture management has evolved over the past 2 decades. Reports in the literature have demonstrated poor outcomes with nonoperative management of certain fracture characteristics, and a resurgence has occurred in operative fixation for displaced midshaft clavicle fractures. Although various treatment methods exist, plate fixation of displaced clavicle fractures has proven to be reliable and reproducible, leading to union rates ranging from 94% to 100% and a low rate of associated complications. However, the decision of whether to place the plate superiorly or anteroinferiorly on the clavicle is controversial.

The authors are unaware of studies that have directly compared anteroinferior with superior plating in a large patient population; reports of clinical and patient outcomes are absent and prevent the determination of whether an ideal plate position exists. The authors found that anteroinferior plating had equal union rates compared with superior plating, significantly fewer reports of implant prominence, and higher overall subjective outcome scores, whereas the other major parameters were not different between the groups.

Healing rates in this study compare favorably with the current literature, with an overall union rate of 95% and time to union of less than 14 weeks in both groups. The authors found higher malunion and implant failure rates in the clavicle fractures treated with superior (10% and 3%, respectively) vs anteroinferior plating (2% and 0%, respectively), but these findings did not reach statistical significance.

Six malunions and 2 implant failures occurred in the superior group, and these findings parallel the reports of recent biomechanical studies. Hamroongroj and Vanaduergwan plated fresh cadaveric clavicles in both positions and found that anteroinferior plating provided a more stable construct against deformation with the addition of an inferior cortical defect simulating fracture comminution. Partial et al and Favre et al reported other biomechanical studies showing that anteroinferior plating led to a more stable construct in bending rigidity and induced deformation modes similar to the intact clavicle and concluded that anteroinferior plating would be less likely to fail during normal physiological loading. This literature and the current findings give support to the current hypothesis that implant stresses in vivo, especially in fractures with comminution, may be better resisted by a plate in the anteroinferior position. No differences were noted between the use of 2.7- and 3.5-mm plate and screw constructs in the current series; however, the majority of the constructs used independent lag screw(s), which may limit the outcome differences between these constructs.

Perioperative complications between the 2 groups were similar and low in incidence, with no acute wound healing issues and only 1 postoperative infection occurring of these 105 surgeries. One major complication occurred in the superior plating group when the underlying subclavian vein was directly injured during drilling through the middle third of the clavicle. Sinha et al conducted a radiological study using computed tomography arteriograms to better define the adjacent vascular anatomy relationship to the clavicle. They found that the major vessels are most prone to injury with a superior to inferior screw trajectory at the middle one-third of the clavicle. This anatomical relationship posed a potentially limb- or life-threatening complication for 1 patient in this study and using anteroinferior plat-

<table>
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<tr>
<th>Patient-reported Symptoms and Subjective Outcome Scores</th>
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<tr>
<td><strong>Subjective Data</strong></td>
</tr>
<tr>
<td>Follow-up, y, mean ± SD</td>
</tr>
<tr>
<td>Patient-reported implant prominence, %</td>
</tr>
<tr>
<td>Peri-incisional numbness or dysthesias, %</td>
</tr>
<tr>
<td>Visual analog scale score, mean ± SD</td>
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<td>Oxford Shoulder Score, mean ± SD</td>
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ing for midshaft clavicle fixation with a drill and screw trajectory directed away from the underlying vessels could potentially reduce this risk in this region.\textsuperscript{18} However, placement of a plate in either position carries the risk of iatrogenic neurovascular injury, and neither position has had significantly decreased risks.\textsuperscript{16-18}

Anteroinferior placement has recently gained popularity, partly due to decreased implant prominence and subsequently improved clinical satisfaction.\textsuperscript{13,22,27,29} In a systematic review of 2144 clavicle fractures, Zlowodzki et al\textsuperscript{22} reported that the anteroinferior position caused less postoperative symptoms compared with the superior position. Similarly, the current results indicated that anteroinferior plating was associated with significantly fewer patient reports of implant prominence (29\% vs 54\%, respectively) and fewer implant removal surgeries (9\% vs 19\%, respectively) than superior plating. Patients treated with an anteroinferior plating technique also had significantly higher OSS scores, but the clinical significance of this is unknown because both groups reported scores that were in the excellent range.

This study had several limitations. First, the review of these cohorts contains bias inherent to the retrospective nature of the study. The implants were chosen by the surgeons with no randomization, and differing patient or fracture characteristics may have been present and not identified by the authors retrospectively. This could lead to a potentially significant confounding variable. Another potential weakness is the follow-up length; it is unknown whether these fractures and related implants can become more symptomatic over time or if a different recovery arc occurs with either plate positioning. If a difference exists, this would lead to some erroneous conclusions. Lastly, despite multiple attempts, the long-term follow-up for the 2 groups was greater than 60\%, which is in line with other trauma-related studies.\textsuperscript{30,31} Loss of patients from follow-up was approximately equal in each group, but as with any similar observational study, this loss poses a threat to the internal validity of the study because important variables cannot be captured in these individuals.

Despite having several weaknesses, this study has several strengths that merit discussion. To the authors’ knowledge, this is the first study to objectively compare relatively large patient groups of surgical treatment for this injury and the first to obtain objective information regarding patient-reported outcomes. The authors achieved a fairly significant percentage of patients for long-term follow-up, which strengthened the power of the study. The surgeries were performed by 8 fellowship-trained surgeons, and the larger number of surgeons involved may allow this to be better extrapolated to the general orthopaedic surgeon public than a single-surgeon review.

\textbf{CONCLUSION}

To the authors’ knowledge, this study is the first to subjectively and objectively compare the outcomes of plate position of a concurrent series of patients. According to the current data, anteroinferior and superior clavicle plating both appear to be safe treatment methods for displaced clavicle fractures. The largest difference between the 2 groups was a significantly lower rate of patient-reported implant prominence at long-term follow-up in patients treated with an anteroinferior plate. Although not statistically significant, notably fewer implants were removed in the anteroinferior patient group. Further research in this area is necessary because clavicle fracture fixation is increasingly becoming the standard of care for particular fractures.\textsuperscript{7} Future studies, including prospective randomized analyses, would help determine whether either plate position should be favored.

\textbf{REFERENCES}