



Limited incision plating of midshaft clavicle fractures: a case series of 1,038 patients

Harrison Faulkner, MD, BSci (Med) Hons, MTrauma^{a,b,*},
Ariella Smith, MD, MTrauma^b, Deborah Hermans, RN^c,
David Duckworth, MBBS, FRACS^{b,c,d}

^aFaculty of Medicine, University of New South Wales, Sydney, Australia

^bDepartment of Orthopaedic Surgery, Hornsby Ku-Ring-Gai Hospital, Hornsby, NSW, Australia

^cDepartment of Orthopaedic Surgery, Sydney Adventist Hospital, Sydney, Australia

^dSpeciality Orthopaedics Upper Limb Surgery Research Foundation, Sydney, NSW, Australia

Background: Clavicle fractures are a common injury in young and active patients. Nonoperative management has historically been preferred; however, recent studies have challenged this paradigm with evidence of lower nonunion rates and improved functional outcomes following surgical treatment. This article describes a limited incision approach to clavicle plating and reports long-term functional and radiographic outcomes for a large cohort of operative midshaft clavicle fractures.

Methods: A prospectively maintained database was used to identify 1,038 patients who underwent surgical treatment for midshaft clavicle fractures. All operations were performed using a minimally invasive, 3–5 cm incision to expose, reduce, and plate the fracture, with retractors used to lever the skin and allow lateral and medial drilling. Clinical and radiographic follow-up included measurement of the Disabilities of the Arm, Shoulder and Hand score, patient-reported questionnaires, and serial X-rays until union.

Results: For 1,038 acute fractures treated surgically, the mean Disabilities of the Arm, Shoulder and Hand score at last follow-up was 0.8 (range: 0–46). Full range of shoulder movement was achieved in a mean time of 6.1 weeks (range: 1–52 weeks). The mean time to union was 10.6 weeks (range: 6–61 weeks) and the nonunion rate was 0.3%, in all cases due to infection. Deep and superficial infections occurred in 8 (0.6%) and 13 (1.3%) cases, respectively. Significant peri-clavicular numbness and plate irritation were rare (1.6% and 2.6%, respectively) and 94.3% of patients felt that their shoulder was ‘normal’ with a mean follow-up duration of 17.7 months (range: 39.0 days–79.2 months).

Conclusions: In this large cohort with long-term follow-up, a limited incision approach for plating of acute midshaft clavicle fractures achieved good functional and radiographic outcomes with a low complication rate comparable to the reported rate for standard incision techniques.

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

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Keywords: Clavicle; minimally invasive surgery; open reduction internal fixation; outcomes; fracture; shoulder

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*Reprint requests: Harrison Faulkner, MD, BSci (Med) Hons, MTrauma, Department of Orthopaedic Surgery, Hornsby Ku-Ring-Gai Hospital, Palmerston Rd, Sydney, NSW 2077, Australia.

E-mail address: Harrison.Faulkner1@health.nsw.gov.au (H. Faulkner).

Fracture of the clavicle is a common traumatic injury, accounting for 2%–5% of all adult fractures.^{30,33,35} Of these, approximately 69% are fractures of the clavicle midshaft, with medial and lateral clavicle injuries being

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relatively less common.^{2,29,32} Nonoperative management has traditionally been the mainstay of treatment for midshaft clavicle fractures;^{28,38} however, recent evidence demonstrating poor outcomes with this approach has supported a trend toward operative fixation.^{8,25} Notably, several studies^{11,41} and a large systematic review⁵⁰ have reported high nonunion rates for displaced midshaft clavicle fractures treated nonoperatively, with figures ranging from 15%-24%. Clinical outcomes following nonoperative management may be similarly poor, with potential sequelae including pain, paresthesia, cosmetic deformity, and clavicular shortening with consequently decreased strength and functionality. The incidence of these complications is likely to be higher than traditionally cited, with recent studies reporting patient dissatisfaction rates as high as 31%.^{11,20,23,22,31,46} Operative treatment has been shown to achieve reliable union, rapid return to below shoulder activity, good clinical outcomes, and an increasingly favorable cosmetic result with improving plate technology. The benefits of operative management, however, must be weighed against the introduction of surgical and implant risks and additional considerations such as the frequent need to remove hardware. In one recent meta-analysis comparing operative and nonoperative management for displaced midshaft clavicle fractures, operative management achieved a lower nonunion rate and better functional scores at 6 months; however, by 12 months, the difference in functional outcome was not statistically significant.¹ The optimum management strategy therefore remains controversial and depends on a range of radiographic and patient factors.

The operative management of midshaft clavicle fractures can be achieved via several techniques, with fixation either by plate or intramedullary pin. Plate fixation provides immediate rigid fixation, allowing early mobilization and reliable construct stability. It is however a traditionally more invasive procedure, with longer incisions and greater periosteal stripping resulting in complications such as infection, scarring, and anterior chest wall numbness due to violation of supraclavicular nerves.⁴ These complications have a significant impact on long-term outcomes. For example, anterior chest wall numbness is common (occurring in up to 52% of patients at 1 year postoperatively⁶) and in some studies has been associated with poor patient satisfaction outcomes.⁴⁵ Similarly, large scars may result in irritation with clothing and shoulder straps, and in some patients raise cosmetic concerns. To address this, several techniques have been proposed to minimize tissue disruption. These include minimally invasive plate osteosynthesis (MIPO), which involves percutaneous plating through medial and lateral windows without exposure of the fracture,^{15,21,42} and mini-open plating, which incorporates a small incision over the fracture site with additional stab incisions for drilling of the medial and lateral screws.^{3,13}

This article presents a novel limited incision approach for plate fixation for midshaft clavicle fractures and reports

radiographic and clinical outcomes for the largest series of operative midshaft clavicle fractures in the literature to date.

Materials and methods

The prospectively maintained database of a senior surgeon was used to identify consecutive patients treated operatively for acute midshaft clavicle fractures between December 2010 and October 2023. Patients treated for malunion or nonunion were excluded, as were those lost to follow-up. There were no body mass index restrictions.

Data collection

Routine follow-up was performed at 2 weeks, 6 weeks, and 3 months postoperatively, with further in-person follow-up if required until union was achieved. Collected data included demographic information (sex and age at surgery), radiographic information (number of fracture parts and time to union), and clinical information (mechanism of injury; postoperative Disabilities of the Arm, Shoulder and Hand [DASH] score;¹⁰ scar size; return to work; return to sport; paresthesia; plate irritation; complications; and patient satisfaction). Time to union was assessed by the senior author (D.D.) and defined by the presence of bridging callus and disappearance of the cortical fracture line. The DASH score was completed at 1 year postoperatively and opportunistically thereafter. The remaining postoperative clinical outcomes were patient-reported and collected through a survey (Fig. 1) completed at 6 weeks and at each subsequent follow-up appointment. All data were collected and stored in accordance with local ethics protocols.

Operative technique

All operations were performed by the senior author (D.D.). The patient is placed in the beach-chair position with the arm free in a sterile stockinet and the shoulder and chest wall prepared and draped. The fracture site is determined by palpation and a limited, 3-5 cm transverse incision is made directly over the fracture site and immediately inferior to the subcutaneous border of the clavicle to reduce scar irritation. Superficial dissection is performed to identify the fracture, with sharp transection of the platysma and sparing of the supraclavicular nerves where possible. Hohmann retractors are placed to expose the fracture. The fracture is reduced using reduction forceps, and when the fracture involves 3 or 4 parts, the butterfly fragments are reduced individually to try to turn it from a 4-part fracture to a 3-part and then 2-part fracture. The 2 main parts of the fracture can then be reduced with crab claws bringing the fracture out to length, which then makes it possible to insert an anatomical, contoured plate across the fracture site. Bicortical or locking screws are then inserted on either side of the comminution, with drilling of at least 6 cortices on either side of the fracture. To reach the medial and lateral screw insertion points, Hohmann retractors are used at the edge of the plate to lever the skin and allow drilling (Figs. 1 and 2). Intraoperative imaging is used to confirm the alignment and length of the clavicle and the fixation of the plate. The site is washed and then closed in layers and dressed.

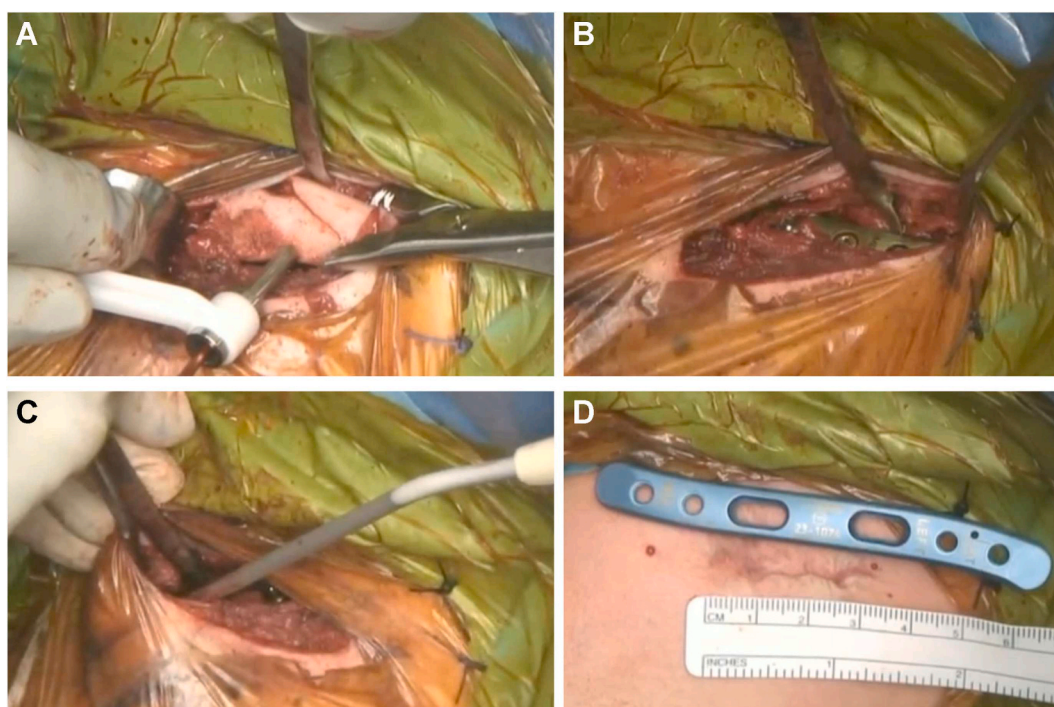


Figure 1 Operative technique including (A) lag screw fixation of comminuted fragments, use of Hohmann retractors to lever skin for access to (B) medial and (C) lateral screw holes, and (D) closure of limited incision wound resulting in a scar size of 3 cm.

Patients are immobilized in a sling for 1 week and then allowed to gradually commence movement as tolerated. Return to full and unrestricted activity occurs following clinical and radiological healing of the fracture. Examples of preoperative and post-operative imaging and the surgical scar are included in [Figure 3](#).

Data analysis

All statistical analysis was performed using the Statistical Package for the Social Sciences (IBM, Armonk, NY, USA). Descriptive statistics included means (for continuous variables) and proportions (for categorical variables).

Results

A total of 1,232 patients underwent surgical treatment for midshaft clavicle fractures during the 13-year period, of which 1,038 patients treated for acute injuries with clinical and/or radiographic follow-up were included in the study population. The mean age at surgery was 31.9 years (range: 10-82 years) and the population was 81% male.

The mechanism of injury was sporting in 442 cases, bicycle accident in 280 cases, motorbike accident in 113 cases, fall in 142 cases, car accident in 21 cases, and other injury in 40 cases. Fractures were classified based on AO/OTA system, with 36% simple fractures, 18% 3-part wedge fractures, and 46% complex multifragmentary fractures. Patients were followed up for a mean time of 17.7 months (range: 39.0 days-79.2 months) ([Table I](#)).

Clinical outcomes

For the 740 patients reporting a DASH score at last follow-up, the mean DASH score was 0.8 (range: 0-46).

The mean scar size was 4.4 cm (range: 2.5-10.0 cm). Patients wore a sling for a mean time of 7.4 days (range: 0-42 days), returned to work or school in a mean time of 9.4 days (range: 0-210 days), and to sport in a mean time of 5.3 weeks (range: 0-24 weeks). Full range of shoulder movement was achieved in a mean time of 6.1 weeks (range: 1-52 weeks).

Patients reported significant peri-clavicular numbness in 16 cases (1.6%), slight numbness in 214 cases (21.4%), and no numbness in 769 cases (77.0%). Irritation around the plate was described as significant in 26 cases (2.6%) and slight in 210 cases (21.0%), with no irritation reported in 764 cases (76.5%). When asked if their shoulder felt normal, 14 patients responded 'no' (1.4%), 43 responded 'almost' (4.3%), and 954 responded 'yes' (94.3%). All but 2 patients reported that they would undergo the surgery again if indicated (99.8%) ([Table II](#)).

Radiographic outcomes

895 patients had complete radiographic follow-up, with a mean time to union of 10.6 weeks (range: 6-61 weeks). The 143 included patients without complete radiographic follow-up were all progressing to union at the time of last X-rays, generally with >80% callus formation.

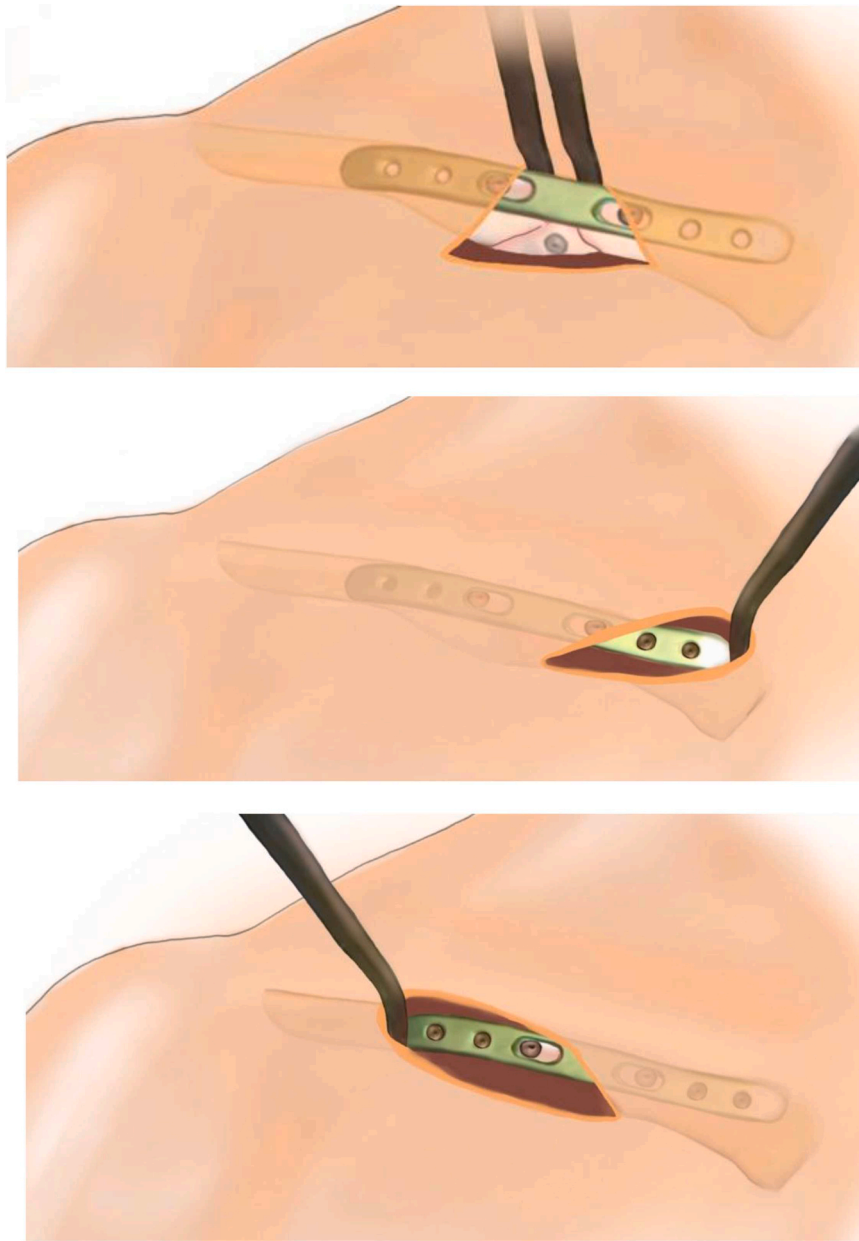


Figure 2 Illustration of Hohmann retractor positioning and skin levering to expose medial and lateral screw holes.

Complications

Nonunion occurred in 3 cases (0.3% of the 895 cases with complete radiographic follow-up), in all instances due to infection. Each of these patients underwent débridement, removal of hardware, and subsequent revision fixation following a period of intravenous antibiotics, and in all cases, union was achieved following this process. Delayed union (union occurring between 6 and 12 months) was observed in 9 cases (1.0% of the 895 cases with complete radiographic follow-up),

although in each case, union was achieved without further intervention.

Deep infection not resulting in nonunion but requiring intravenous antibiotics, washout, and often removal of hardware occurred in 5 cases (0.5%), giving a total of 8 deep infections (0.6%), including cases resulting in nonunion. Superficial infection requiring oral antibiotics was observed in 13 cases (1.3%), plate lifting requiring revision or removal occurred in 9 cases (0.9%), capsulitis occurred in 5 cases (0.5%), and refracture through screw holes following plate removal occurred in 5 cases (0.5%).

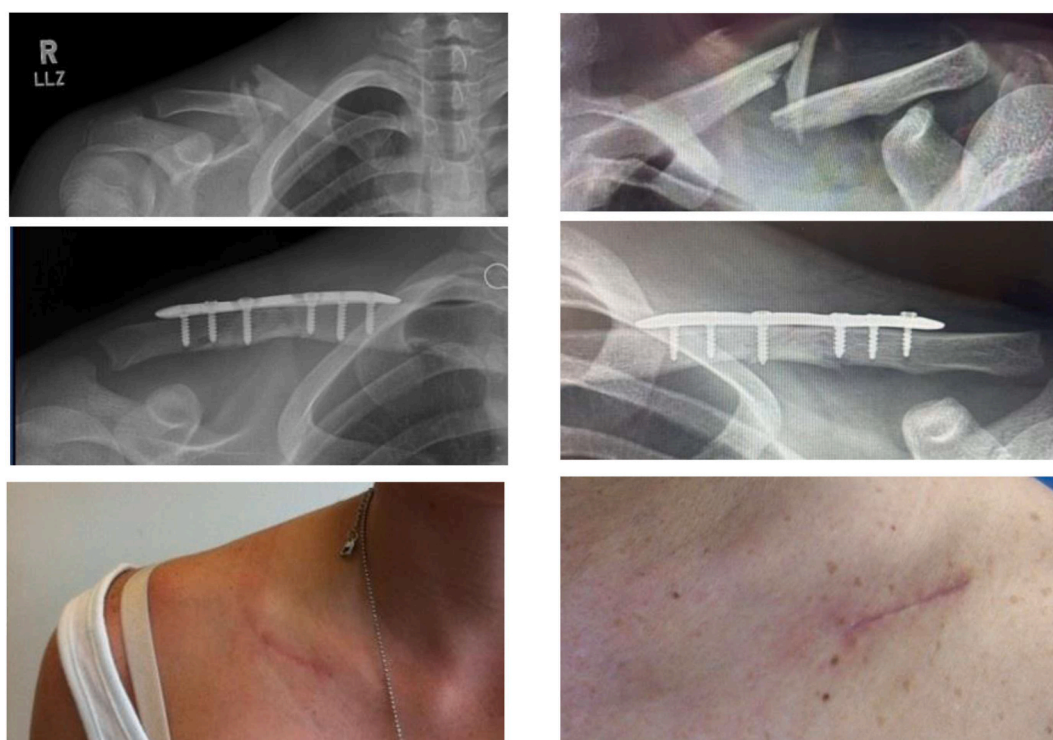


Figure 3 Case examples demonstrating preoperative X-rays (*top row*), postoperative X-rays (*center row*), and the healed scar at follow-up (*bottom row*).

Table I Study population characteristics

	Study population
Age (yr)	
Mean	31.9
Range	10-82
Sex	
Male, n (%)	842 (81)
Female, n (%)	196 (19)
Injury side	
Left, n (%)	576 (55)
Right, n (%)	462 (45)
Fracture classification (AO/OTA)	
A (simple), n (%)	445 (36)
B (wedge), n (%)	226 (18)
C (complex), n (%)	561 (46)
Mechanism of injury	
Sporting	442
Bicycle	280
Motorbike	113
Fall	142
Car accident	21
Other injury	40
Follow-up duration	
Mean (mo)	17.7
Range	39.0 d-79.6 mo

Discussion

This series describes good clinical and radiographic outcomes, a low complication rate, and high patient satisfaction achieved using a limited incision approach for plating of midshaft clavicle fractures. The mean postoperative DASH score of 0.8 reported in our series compares favorably with the outcomes reported in the literature, which range from 3.3-8.6^{7,18,26,34,36,39,43} in articles reporting on standard incision operations. This may relate in part to the long follow-up of our series (many studies have a defined follow-up period of 12 months postoperatively), suggesting ongoing improvement in shoulder functionality beyond the immediate postoperative phase. The 0.3% nonunion rate in our series is consistent with previously reported data, with other operative series describing rates from 0%-4%.^{5,36,40,43,44,46} Notably, in their large meta-analysis with a combined 705 patients, Guerra et al⁹ reported a nonunion rate of 1.4% following surgery.

The benefits of minimally invasive surgery are well documented in many areas, and in general include decreased tissue disruption, decreased blood loss, decreased pain, faster recovery times, and improved cosmetic outcomes.³⁷ In the context of midshaft clavicle fractures, several advantages to minimally invasive surgery have been shown. In their study describing ‘mini-open plating’, a

Table II Clinical outcomes

	Study population
DASH at last follow-up	
Mean	0.8
Range	0-46
Scar size	
Mean (cm)	4.4
Range (cm)	2.5-10
Time wearing sling	
Mean (d)	7.4
Range (d)	0-42
Return to school/work	
Mean (d)	9.4
Range (d)	0-210
Return to sport	
Mean (weeks)	5.3
Range (weeks)	0-24
Peri-clavicular numbness	
Significant, n (%)	16 (1.6)
Slight, n (%)	214 (21.4)
None, n (%)	769 (77.0)
Plate irritation	
Significant, n (%)	26 (2.6)
Slight, n (%)	210 (21.0)
None, n (%)	764 (76.5)
Shoulder feels normal	
No, n (%)	14 (1.4)
Almost, n (%)	43 (4.3)
Yes, n (%)	954 (94.3)
Would undergo operation again	
Yes, n (%)	1,005 (99.8)
No, n (%)	2 (0.2)

DASH, Disabilities of the Arm, Shoulder and Hand.

technique incorporating a small central incision with additional medial and lateral stab incisions, Beirer et al³ demonstrated a significantly smaller area of anterior chest wall numbness with this approach compared to conventional plating. This benefit was preserved at 6 months of follow-up and was independent of plate size. In a study comparing a similar 'mini-open plating' approach to conventional plating, Jiang & Qu¹³ demonstrated reduced rates of dysesthesia and hypertrophic scarring and improved patient satisfaction. The low rate of anterior chest wall numbness in our study (23%) supports the use of minimally invasive techniques and compares favorably to reported rates for conventional plating, which range from 52%-86%.^{6,12,48} Minimally invasive approaches are also thought to achieve lower nonunion and deep infection rates due to preservation of the periosteum and surrounding soft tissues,¹⁷ which is consistent with the low infection rate observed in our series. Although scar size is generally not associated with functional outcome,¹⁹ the prominent position of large clavicle scars may cause irritation with clothing and shoulder straps, and the typically young

demographic of clavicle fracture patients is more prone to cosmetic concerns.

The reported outcomes of MIPO for midshaft clavicle fractures similarly describe improvements in numbness and cosmesis.⁴⁹ However, achieving anatomical reduction is difficult without exposing the fracture site, particularly in instances of significant displacement or comminution, and one comparative study in adolescents showed worse length and angulation outcomes with MIPO than with open plating.¹⁶ A systematic review comparing MIPO with conventional open plating reported similar functional outcomes and time to union between the techniques, however did not comment on fracture characteristics or directly compare nonunion rates.⁴⁹

The positive outcomes in this series contribute to the growing body of evidence supporting operative management for displaced midshaft clavicle fractures. The historical preference for conservative management of this injury was based largely on studies by Neer²⁸ and Rowe³⁸ in the 1960s, which reported low nonunion rates with nonoperative treatment. However, recent data from a number of comparative studies^{5,7,27,36,43} suggest high nonunion rates and poor functional outcomes with this approach. Several reviews have collated these studies, with meta-analyses by Woltz⁴⁶ (614 patients), Virtanen⁴⁴ (1,190 patients), Guerra⁹ (1,546 patients), McKee²⁴ (412 patients), Xu⁴⁷ (471 patients), and Zlowodzki⁵⁰ (619 patients) all demonstrating a decreased nonunion risk and improved functional outcomes with operative compared to nonoperative management of displaced midshaft clavicle fractures. There does however remain a degree of controversy, particularly surrounding the potential for operative complications. In one prospective randomized trial by Judd et al,¹⁴ for example, the operative group experienced a high complication rate of 41% compared to 8% in the nonoperative group. Many of these complications were however mild, such as pin site prominence or irritation, and in our series, the rate of more serious adverse events was relatively low. There also remains some uncertainty regarding the long-term outcomes of surgery. In one meta-analysis by Ahmed et al,¹ the improved functional outcomes seen with operative management at 6 months postinjury were no longer statistically significant at 12 months. The functional improvement achieved by surgery was also shown to plateau in a long-term follow-up study by Schemitsch et al,³⁹ and although operative patients retained a statistically significant benefit compared to nonoperative patients, there was little improvement between 12 and 24 months postinjury.

This series represents the largest single cohort of operative midshaft clavicle fractures reported to date and provides long-term follow-up data. It is however a single-surgeon study, which provides consistency in terms of operative technique and follow-up protocol but does limit to some degree the external validity and generalizability of the findings. At the time of data collection, the senior author had been using the described minimally invasive

technique for several years (after performing conventional plating and intramedullary techniques for 6 years), and the reported outcomes therefore reflect this experience. As with any new technique, other surgeons could expect to experience a 'learning curve' period of increased complications and surgical time when adopting this approach. In this study, there was a relatively large number of patients lost to follow-up, reflecting a predominantly young and male population that is highly mobile and relatively unreliable. This limitation is not uncommon within the orthopedic literature but does raise the possibility of selection bias. Comparative analysis of injury types was limited by the small number of malunion and nonunion injuries relative to acute fractures.

Conclusion

A limited incision approach to plate fixation of acute midshaft clavicle fractures provides a minimally invasive surgical technique that can achieve good functional and radiographic outcomes. In this large cohort of operative patients, long-term DASH scores suggest minimal disability, the nonunion rate is low, and patient satisfaction is high.

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