Outcome of Intramedullary Fixation of Clavicular Fractures

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Abstract

We conducted a retrospective, single-center (tertiary referral center with associated level I trauma center) review to evaluate the outcome of open reduction and internal fixation (ORIF) with intramedullary (IM) clavicle pin of displaced clavicular fractures.

Sixty-eight displaced midshaft clavicle fractures in 68 patients underwent ORIF with IM clavicle pins. Patients were identified through a perioperative database by searching for Current Procedural Terminology (CPT) codes. Union was the primary outcome. Secondary outcomes included time to union, pain, incidence of nonunion and delayed union, postoperative range of motion, and incidence of complications.

Sixty-six fractures (97%) went on to union. Complications included painful hardware (44%), deep and superficial wound infections (10%), and hardware failure (4%), including pin breakage and extrusion. Postoperative shoulder pain was present in 10% of patients and limited shoulder range of motion in 12%. IM pin fixation can provide good outcomes, even for fractures with a significant amount of shortening and comminution.

Midshaft clavicle fractures are very common injuries, accounting for 5% of all fractures and representing 35% to 45% of all shoulder girdle injuries.[1-3] Annual incidence of clavicle fractures is estimated to be 29-64/100,000. These fractures typically occur in young men (aged 30 years); there is a secondary peak incidence in the elderly years (age >80 years).[2]

The middle third of the clavicle is the part that is injured most often (80% of all clavicle fractures). Situated between the proximal prismatic end of the clavicle and the distal flattened end, it is the thinnest portion of the bone and has the least resistance to compressive and torsional loads.[4] This is the only area of the clavicle that is not protected or reinforced by muscle or ligament attachments.

The primary goal of fracture care is to restore function to a level consistent with preinjury status. Historically, clavicle fractures have been treated conservatively, even with fracture displacement. Indications for open reduction and internal fixation (ORIF) were evidence of skin compromise, polytrauma, open fracture, or neurovascular compromise.[3,4]

Very few studies have examined functional outcome of, or satisfaction with, clavicle treatment. Patient outcome measures, including the Constant Score, the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36), and the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, have more recently been incorporated into the literature. Studies that have used these patient-based functional data sources have indicated that, particularly with nonoperative treatment, functional outcomes are not always as good as radiologic outcomes.[5,6]

There continues to be general agreement that nondisplaced fractures should be treated nonoperatively. Treatment of displaced or comminuted fractures, using either intramedullary (IM) or plate techniques for fracture fixation, is more controversial. More recent data indicate a decrease in clavicle nonunion and improved functional improvement and cosmesis of the shoulder girdle after operative fixation.[7] Few studies have detailed the outcomes of IM fixation of acute midshaft clavicle fractures with IM pins.[1,4]

Methods

After obtaining institutional review board approval, we used Current Procedural Terminology (CPT) codes for IM fixation of the clavicle to identify 123 patients treated at the Duke University Medical Center between 2004 and 2007. Patients identified as having acute midshaft clavicle fractures treated with a Hagie or Rockwood IM pin were included. Open fractures, fractures associated with ipsilateral upper extremity trauma, and fractures in patients younger than age 18 were also included.

Patients were excluded if the clavicle was fractured outside the middle third (n = 10), if operative fixation was performed with plate osteosynthesis (n = 17), if the fracture was more than 4 weeks old (n = 12), or if follow-up was incomplete (n = 16). Sixty-eight clavicle

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Am J Orthop. 2011;40(6):E99-E104.

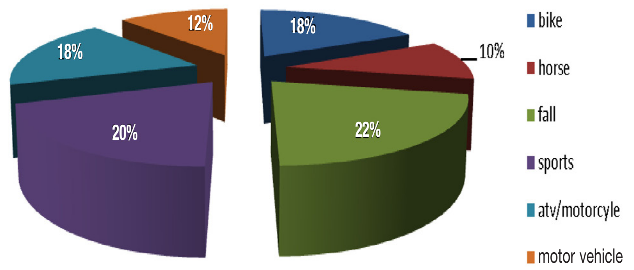

Figure 1. Mechanisms of injury.

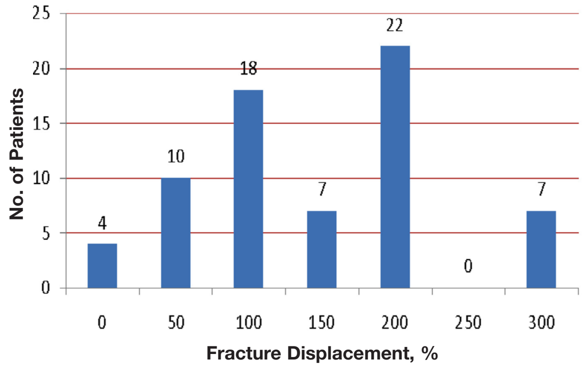

Figure 3. Delayed union and nonunion.

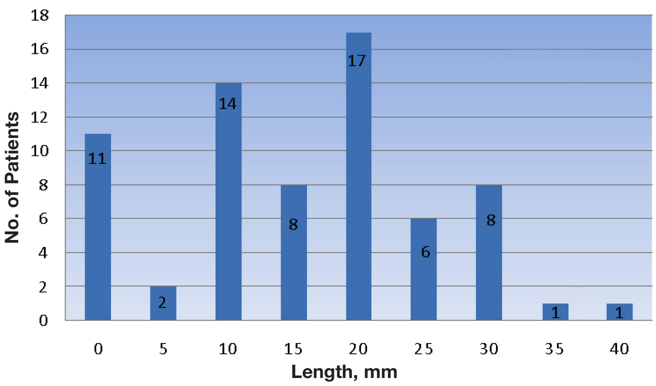

Figure 2. Fracture shortening, mm.

fractures in 68 patients were ultimately included in the study.

Allman[8] group I fractures were subcategorized using the Robinson fracture classification system[9]: 2A1 (nondisplaced), 2A2 (slightly angulated), 2B1 (simple or single butterfly fragment), or 2B2 (segmental, comminuted).

Charts were retrospectively reviewed to identify date of injury; date of surgical fixation; date of clinical union; date of hardware removal; implant type; motion limitations; and complications, such as malunion, nonunion, infection, and painful hardware. Mean time between fracture fixation and hardware removal was then determined.

Operative Technique

Rockwood or Hagie IM pins (Depuy, Warsaw, Indiana) were used for IM fracture fixation. Ninety percent of the fractures were managed by 2 primary surgeons, and the other 10% were managed by other surgeons within the same group.

The Rockwood pin, which consists of 1 pin and 2 locking nuts, is provided preassembled. This pin has cancellous threads at one end and machine threads at the other. Both nuts are applied to the machine-threaded end; one to compress and one to lock the first nut in place. The machine-thread end also has a trocar point for exiting the clavicle posterolaterally. Pin diameters are 2.5, 3.0, 3.8, and 4.5 mm (length in each case, 152 mm). The nuts have slightly different outer diameters, so one nut is tightened on the pin to compress the fracture and prevent migration, and the other is used to lock the first nut in place on the machine-thread end.

The Rockwood and Hagie pins are very similar and are used for the same purpose. Both are stainless steel. The pins differ in where the trocar point is located: machine-thread end (Rockwood) or cancellous thread end (Hagie). The Rockwood pin can be inserted from a medial or lateral direction, whereas the Hagie pin can be inserted only from a lateral direction.

The surgeon used the same surgical technique for each patient. This technique includes preparing the patient in a semi-upright position with the head of the bed elevated approximately 30° to 40°. A rolled towel is placed under the operative shoulder, and the upper extremity is draped to allow visualization of the sternoclavicular joint to the posterolateral aspect of the shoulder.

A small incision is made using Langer lines over the fracture site. As there is little subcutaneous fat in this region, care is taken to prevent injury to the underlying platysma muscle. The muscle is split in line, and the middle branch of the supraclavicular nerve is identified near the midclavicle and protected (the middle branch is often seen in the fracture site). Interposed muscle is removed from the fracture site, and any small butterfly fragments, usually found anteriorly, are left attached to their soft-tissue envelope.

The proximal medial clavicle is elevated through the incision using a forceps, and, with care taken to protect the anterior cortex, the bone is drilled and tapped by hand. The lateral fragment is then elevated through the incision and drilled, with the drill passing through the posterolateral cortex of the clavicle, posterior and medial to the acromioclavicular joint, about the level of the coracoid. Care is taken to keep the drill exit no higher than the middle of the posterolateral clavicle to avoid prominence of the pin nuts. The lateral fragment is then tapped. Tapping reduces

Table I. Demographic Data (N = 68)

No. of male patients	44
No. of female patients	24
Mean age, y	31
No. of associated fractures	5
No. of smokers	2
Mean fracture shortening, mm	15
Mean fracture displacement, %	144.8
Mean time to fixation after injury, d	14
Mean time to clinical union, d	101
Mean follow-up, wk	14

Table II. Delayed Radiographic Union[a] or Nonunion of Fractures (N=68)

	No. (%) of Patients
Delayed union	8 (12%)
Infection	2 superficial
	1 deep
Fracture	4 type 2B1[b]
	4 type 2B2[c]
Nonunion	2 (3%)
Infection	1 deep
Fracture	1 type 2B1
	1 type 2B2

[a]Delayed more than 1 month after hardware removal. [b]Defined as simple or single butterfly fragment, according to Robinson fracture classification system.[9] [c] Defined as segmental, comminuted, according to Robinson fracture classification system.[9]

the torque required to insert the pin and reduces the possibility of pin failure.

The pin is inserted into the medullary canal of the distal fragment and exits through the previously drilled posterolateral cortex and out the skin. The pin is then driven across the fracture site into the medial clavicle. Care is taken to insert the pin inferior and posterior to yield a more anatomical reduction. The pin is advanced until all medial threads are across the fracture site, with care taken to retain anatomical correction with the pin. The nuts are placed, and the pin is cut and advanced farther into the clavicle.

Butterfly fragments are reapproximated to the clavicle body using a suture cerclage technique with figure-8 sutures. Attempts are made to close the periosteum overlying the fracture, and the platysma is closed using a simple absorbable stitch. Incisions are closed using a running subcuticular suture.

Postoperative Care

Patients were instructed to resume activities of daily living as tolerated but to avoid strenuous activities, such as pulling, lifting, and pushing. Arm elevation higher than shoulder level was limited for 4 to 6 weeks. When necessary, sutures were removed 7 to 10 days after surgery. Patients were followed clinically and radiographically over 4 to 6 weeks.

Patients were allowed to advance their activities as tolerated after 6 to 8 weeks. Pins were removed 8 to 12 weeks after surgery, if radiographic evidence of fracture healing was present. Patients were seen 2 weeks after hardware removal, and most were discharged from the clinic at that time. Mean follow-up was approximately 14 weeks.

Postoperative complications were recorded. These included painful hardware, hardware failure, wound breakdown, wound infection, incision numbness, and incision tingling. Functional outcomes recorded were range of motion and return to activities.

Fracture Healing

Fractures were considered clinically healed when they were no longer tender to palpation and had bridging of 2 cortices as seen on plain radiographic imaging, including anteroposterior and cephalic tilt views. Delayed unions were identified as showing no evidence of fracture callus after pin removal and remaining clinically tender to palpation over the fracture site. Patients were scheduled for operative pin removal either in an outpatient surgery center or clinical setting.

Results

Sixty-eight patients met the study inclusion criteria. Sixty-five percent were male. Mean age was 31 years (Table I). Mean follow-up was 14 weeks.

Most injuries (42%) were sustained in falls or sports, such as soccer, football, and lacrosse (Figure 1). Biking injuries (18%) and motorcycle and all-terrain vehicle accidents (18%) were the next most common injury mechanism, followed by motor vehicle accidents (12%) and falls from a horse (10%).

According to the Robinson classification, most fractures fell into the 2B category or, more specifically, 2B1 (53%) and 2B2 (40%). Fractures were further characterized according to amount of shortening and amount of displacement. Fifty-one percent of fractures were shortened less than 20 mm, and 49% were shortened 20 mm or more (Figure 2). Amount of displacement was then estimated from clavicle width on the anteroposterior and cephalic view radiographs. Of the 68 fractures, 14 (21%) were displaced less than 100%, and 54 (79%) were displaced 100% or more (Figure 3). Amount of fracture displacement was compared with amount of fracture shortening. Of the fractures that were shortened 20 mm or more, 16 were also displaced 200% or more. No gross shortening was noted after surgery, and all the clavicles that were fixed retained their anatomical alignment.

Sixty-six fractures (97%) went on to union. Fracture nonunion occurred in only 2 patients (3%) after IM pin placement. One of these cases went on to union after revision with plate and bone grafting. The patient in the other case had a deep wound infection that required early hardware removal. She then underwent plate fixation, which also failed secondary to wound infection. Eventually, clavicle excision was performed.

Mean time to surgery was 14 days (range, 1-27 days), and mean time to union was 101 days (range, 23-420 days).

Table III. Postoperative Complications and Fracture Healing (N = 68)

Complication	No. (%) of Patients
Painful hardware	30 (44)
Lateral	28 (41)
Medial	2 (3)
Postoperative pain or dysfunction	15 (22)
Shoulder girdle pain	7 (10)
Shoulder range-of-motion limitation	8 (12)
Wound issues	7 (10)
Deep infection	2 (3)
Superficial infection	5 (7)
Numbness or tingling	4 (6)
Early hardware removal	8 (12)
Wound	6 (9)
Pain	1 (1.5)
Hardware failure	1 (1.5)
Hardware failure	3 (4)
Broken	1 (1.5)
Extruded	2 (3)

All 5 superficial infections (7%) resolved without surgical debridement. Two patients (3%) developed a deep infection that required surgical incision and drainage. Both had delayed fracture healing. One of these patients later developed a nonunion (already described), and the other healed after the incision and drainage. For all patients with a superficial infection, their fracture healed, but 2 had a delayed union (Table II).

The most frequent patient report was pain over the lateral aspect of the clavicle, where the locking nuts are fairly superficial. Forty-one percent of patients reported pain in this region with the pin in place (Table III). Only 2 of the 68 patients (3%) reported pain over the more medial aspect of the clavicle. Seven patients (10%) had reports of pain in the shoulder girdle after pin removal, and 8 patients (12%) had a documented decrease in postoperative shoulder girdle range of motion. Of this total of 15 patients, all but 2 (3% of all 68 patients) improved with therapy.

Four patients (6%) reported numbness and tingling over the surgical incision. Hardware failure occurred in 3 patients (4%). Two pins were extruding, 1 medial and 1 lateral, causing symptoms that required early removal. One pin was broken, and the lateral portion was removed. Eight patients (12%) had hardware removed early because of hardware failure, infection, or lateral pin pain.

Radiographic delayed union was identified in 8 fractures (12%) that failed to demonstrate increased fracture callus on follow-up radiographs after pin removal. Of these fractures, 3 had infections (2 superficial, 1 deep) (Table II). The 8 delayed unions were equally distributed between fracture types 2B1 (4 fractures) and 2B2 (4 fractures) (Table II). All subsequently went on to union.

Discussion

The rate of patient dissatisfaction with clinical and functional results is higher when clavicular fractures with significant shortening or displacement are treated nonoperatively.[10] Recent literature also indicates that the nonunion rate is higher for nonoperative treatment than for surgical treatment for displaced midshaft clavicle fractures.[2,5,11-13] Midshaft fractures that are displaced or have significant comminution, that are shortened 20 mm or more, or that occur in women are associated with higher risk of nonunion and poor clinical outcome.[12,14] The nonunion rate for nonoperative treatment of these fractures has been reported to be as high as 15%.[2,12,14,15] Other factors associated with trends toward nonunion include lack of cortical opposition, age, severity of initial trauma, and soft-tissue interposition.[3]

The Canadian Orthopaedic Trauma Society[5] conducted a multicenter clinical trial involving 132 patients with displaced clavicle fractures randomized to either plate fixation or nonoperative treatment. According to the trial data, operative fixation of significantly displaced and shortened fractures improved functional outcomes and resulted in lower malunion rates and nonunion rates in comparison with nonoperative treatment at 1-year follow-up. Among 132 cases, 2 nonunions (3.2%) and no malunions occurred in the operative group, and 7 nonunions (14%) and 9 malunions (20%) occurred in the nonoperative group. The operative group had improved patient-oriented outcomes and earlier returns to function. Such data support operative intervention for significantly displaced and shortened midshaft clavicle fractures.

Various methods have been described for fracture fixation. These include IM fixation with pins or flexible nails and plate fixation. When compared with nonoperative treatment, all appear to decrease the relative risk for nonunion or malunion in a displaced type I fracture.[12] Supplemental bone graft is commonly used, and it may help in facilitating fracture healing with either technique.[2]

Plate fixation provides immediate rigid stabilization and facilitates early motion.[2] Dynamic compression or locked plating can be used, and more recently, anatomically contoured plates have been developed. Low-contact dynamic compression plates preserve the blood supply to the underlying bone fragments through their structured undersurface, and use of these plates has been advocated. Complications associated with plate techniques include damage to underlying neurovascular structures during drilling and screw insertion, infection, plate failure, hypertrophic or dysesthetic scars, implant loosening, nonunion, need for plate removal, and refracture after plate removal and intraoperative vascular injury.[2]

IM fixation involves using a narrow, somewhat flexible implant that passes through the medullary canal of the clavicle. Various devices have been used, including Knowles pins, Hagie pins, Rockwood pins, and elastic titanium nails. The advantages of IM fixation over plate fixation include smaller incisions, decreased soft-tissue stripping, improved cosmesis, and easier hardware removal.[3] These devices are less invasive but still require that the fracture site be opened and exposed to allow antegrade and retrograde insertion of the pin.

Anatomical features should be taken into account when considering placement of an IM pin for clavicle fracture fixation. As the clavicle is a sigmoid bone, pin insertion can be difficult. In 80% of fractures, the break in the bone is where the diameter of the medullary canal is narrowest. The female clavicle is shorter and less curved than the male clavicle, and cortical thickness is at a minimum at the medial ventral portion and the dorsal acromial portion, which correspond to where the pin can perforate.[16]

In our study of 68 clavicles, 66 (97%) united, and 2 (3%) went on to nonunion. These results are comparable to those of other studies of plate fixation and IM fixation.[5,12] In a recent meta-analysis by Zlowodzki and colleagues,[12] the overall nonunion rate for displaced acute fractures was 15% for nonoperative treatment vs 2.2% for plating and 2% for IM pinning.

Delayed unions occurred equally between minimally comminuted fractures (2B1) and more comminuted and possibly segmented fractures (2B2). Fractures that were shortened 20 mm or more and fractures that were shortened less than 20 mm also occurred equally. The nonunions in our patient population occurred in fractures that were comminuted (2B2), but only 1 of the 2 was shortened 20 mm or more. Given our data, it is difficult to draw conclusions about fracture type and delayed union or nonunion of the fracture.

The question remains as to whether an IM implant can maintain axial length and rotational stability in the same manner as a plate. In our study population, the IM implant seemed to be able to maintain both axial and rotational stability in nontransverse, comminuted fractures. Anatomical reduction was maintained without a significant amount of fracture shortening in that there was no significant fracture shortening noted on postoperative radiographs. There were no malunions in our study. Reported malunion rates for plates range from 0% to 6%.[5,17]

Complications associated with IM pinning are numerous. In a report on 16 IM implants, Strauss and colleagues[4] found a 100% union rate but a 50% complication rate, with most of the complications directly related to the implant. These included skin breakdown (21%), hardware failure (14%), decreased sensation and site dysesthesia (14%), and persistent pain (7%). Given the complication rate, the investigators felt that IM pins should not be used. Ring and Holovacs[18] reported 3 cases of brachial plexus palsy after IM fixation, all of which resolved completely.

Pain over the superficial lateral locking nuts of the IM pin was the most common complication (41%) in our patient population. This pain resolved with pin removal in all but 10% of the patients who retained some amount of residual shoulder girdle pain at time of final follow-up. In a plate-fixation study by Shen and colleagues,[17] 21 of 232 patients (9%) had persistent pain. Pain is multifactorial and also may have a component related to the original fracture and associated shoulder girdle trauma. Nonetheless, it is prudent when implanting this device to keep the pin at, or below, the equator of the lateral clavicle to try to prevent superficial abrasion at the lateral shoulder girdle.

Other complications of note included hardware failure in 3 patients (4%) and these numbers are very comparable to those in the plate-fixation literature.[4,5] The rate of fixation failure in a review by Zlowodzki and colleagues[12] was 2.2% for plating and 3.9% for IM pins.

Wound dysesthesia occurred in 4 patients (6%). In the study by Shen and colleagues,[17] 28 of 232 patients (12%) had residual skin numbness. Other large studies have found neurovascular-related patient reports in 8 of 62 patients (23%).[5] Although use of an IM pin means another procedure must be performed to remove the pin, up to 73% of patients who undergo plate fixation ultimately undergo a removal procedure.[17]

In the review by Zlowodzki and colleagues,[12] the infection rate for plating was 4.6% and the rate for IM pins was 6.6%. Our study distinguished deep and superficial infections. The rate of deep infection was 3%, and the rate of superficial infection was 7%. Other studies of plate fixation have found a deep-infection rate of less than 1% and a superficial-infection rate of 2%.[17] Our infection rate was substantially different from the 20% rate found by Grassi and colleagues[1] for 40 IM clavicle pins.

Limitations of this study are its retrospective nature and its lack of long-term follow-up. Patients were followed for a mean of 12 weeks after pin insertion and then were seen 2 weeks after pin removal, for a total mean of 14 weeks. Patients who were doing well were followed up on an as-needed basis. Often, by 14 weeks, patients were again participating in their normal daily activities and sports. Additional clinic visits were not justified. Therefore, we do not know what the true long-term outcomes were, and we do not have validated outcome data, such as Constant-Murley Shoulder Outcome Scores and DASH scores.

Conclusion

Our study results indicate that significantly displaced midshaft clavicle fractures treated with an IM pin fixation technique can result in a high rate of fracture union (97%) with results consistent with those reported in the plate-fixation literature. For IM fixation devices, there was no trend toward a poor outcome for any specific fracture type. Despite the increased risk for prominent and tender lateral hardware, this technique proves reliable in providing a reproducible method of fracture fixation.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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