Minimal Invasive Fixation of Displaced Midshaft Clavicular Fractures by Flexible Intramedullary Nail


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Abstract

Background: Operative fixation of a displaced fracture of the clavicular shaft results in improved functional outcome and a lower rate of malunion and nonunion compared with non-operative treatment. Hardware removal remains the most common reason for repeat intervention in the operative group.

Methods: In this article, we use a surgical technique for anterograde pinning of displaced midshaft clavicle fractures. This procedure is less invasive and reduces tissue trauma when compared to plate fixation. From May 2009 to June 2011, 25 patients with displaced clavicle fractures have been stabilized with a flexible titanium nail.

Results: Intramedullary flexible titanium nail fixation of midshaft clavicle fractures represents an excellent result alternative to plate and screw fixation for acute fractures and can be performed through a small cosmetically pleasing incision.

Key Words: Less invasive – Nonunion – Intramedullary – Clavicle fractures – Flexible titanium nail.

Introduction

THE clavicular fractures are very common, representing 4% to 5% of all fractures in adults. These injuries are seen across multiple age groups but are most prevalent in the young and physically active. It is estimated that 70% to 75% of clavicle fractures are seen in the middle third of the bone [1]. Because of the energy of the injury and the deforming forces across the shoulder girdle, a significant percentage of injuries results in displacement and shortening at the fracture [2].

Operative treatment provided a significantly lower rate of nonunion and symptomatic malunion and an earlier functional return compared with non-operative treatment. However, there is little evidence at present to show that the long-term functional outcome of operative intervention is significantly superior to non-operative care [3]. Non-operative treatment of displaced clavicular shaft fractures may be associated with a higher rate of nonunion and functional deficits than previously reported. However, it remains difficult to predict which patients will have these complications [4].

Elastic flexible intramedullary nailing of the clavicle is a minimally invasive procedure and aims at exact restoration of the clavicular length with early return to full activity, with a good cosmetic result and minimal morbidity [5].

Historically, the preferred method of treatment of midshaft clavicle fractures has been conservative. The traditional literature regarding conservative treatment of clavicle fractures has shown good results [2].

There are several classification schemes for fractures of the clavicle, ranging from the simple to complex. Although somewhat helpful for description, the benefit of each system in determining a treatment choice or outcome potential is limited. Possibly the most commonly used system is that of Allman. He separated clavicle fractures into three groups: Group I: Middle third fractures Group II: lateral third fractures Group III: Medial third fractures [6].

Hill et al., in a retrospective review, reported a 15% incidence of nonunion and a 31% patient dissatisfaction rate in a group of 52 patients with selected displaced middle-third clavicle fractures treated conservatively [7]. Eskola et al., retrospectively reported the results of a series of clavicle fractures at a minimum of 2 years follow-up. Those fractures associated with more than 15mm of short-
ning were associated with more pain than those without shortening [8].

Likewise, Lazarides and Zafiropoulos correlated shortening of the clavicle to unsatisfactory results after conservative treatment of fractures of the middle third of the clavicle. Patient dissatisfaction was correlated with final shortening of 18 and 14 mm in men and women, respectively [9]. Nowak et al., reported the results of clavicle fractures treated conservatively in a group of 208 patients. This was a prospective series with a 9 to 10-year follow-up. One hundred fifty-one fractures involved the middle third of the clavicle. For all fracture types treated conservatively, the nonunion rate was 7%. Forty-six percent of patients reported some sequelae (pain at rest, pain with activity, or cosmetic deformity) at final follow-up. Lack of boney contact, fracture comminution, and older age significantly increased the risks of residual symptoms [10].

Several authors have advocated treating displaced clavicle fractures with open reduction and internal fixation [11]. Historically, several forms of fixation have been used to stabilize these injuries, including plate-and-screw constructs of various sizes, knowles pins, k-wires, threaded pins, and elastic nails [12]. Jubal et al., in 2003, reported a technique of intramedullary fixation of displaced midshaft clavicle fractures using flexible titanium nails [13]. This technique involves the placement of a flexible blunt-tipped nail across the fracture in an anterograde fashion. This technique is advantageous to plate and screw constructs because it can performed more quickly and with less soft tissue disruption. In addition, the risk of infection and unsightly or painful scars and hardware is minimized. Because the nails are inserted anterograde, the risk for neurovascular injury is much lower. Because of the minimally invasive nature of the procedure, early range of motion and rehabilitation of the extremity are well tolerated [13].

Reported complication of intramedullary fixation include high rates of implant breakage, temporary brachial plexus palsy, poor rotational control of the fracture in the presence of comminution, and skin breakdown over the entry portals [14].

Patients were recruited according to particular inclusion and exclusion criteria. Only isolated closed fractures of the midclavicle (Group 1 Allman classification) with a clavicular shortening of at least 1.5 cm and/or lack of interfragmentary contact were included. Multiple injured patients and complicated midclavicular fractures (e.g. open fracture, comminuted fracture, neurovascular involvement or floating shoulder) were excluded.

Sex distribution: They were 15 males (60%) and 10 females (40%).

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Age distribution:

The age ranged from 16 to 40 years, with a mean age of 28 years.

Affected side distribution: 16 patients had fractures on the right side, while 9 patients on the left side.

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Type of fractures:

A unilateral displaced midshaft clavicular fracture with no cortical contact between the main fragments or comminution at fracture site.

Lag time between trauma and surgery:

Lag time ranged from one day to 5 day with a mean of 2 days.

Inclusion criteria:

- Patient with acute clavicle fractures with complete fracture displacement and shortening of more than 1.5 cm.
- Fractures of the middle third of the clavicle less than 3 weeks.
- Fracture with impending skin compromise secondary to fracture displacement.
Exclusion criteria:
- Established fracture nonunion/malunions, although it is possible to perform an open reduction and anterograde flexible nailing in those cases.
- Fractures associated with neurovascular injury requiring repair are probably best treated with open reduction and internal fixation.
- Fractures clavicle more than three week.
- Patients who are unfit for surgery.

Preoperative planning:
Standard radiographs of the clavicle are obtained. These include an anteroposterior view of the clavicle as well as the cranial and caudal tilt views. These views alone are generally adequate to quantify the degree of displacement, shortening, and comminution of the fracture.

Routine use of advanced imaging such as CT scans is not warranted unless clinical suspicion of injury to the sternoclavicular joint is present. Elastic titanium nail set diameters of 2.5 to 3.5mm.

Surgical technique:
Requirements:
- Power source.
- Radiolucent table.
- Fluoroscopy.
- Basic open orthopedic instruments.

The patient is positioned supine on a flat radiolucent table and slid as far toward the foot of the table as possible to allow more room for maneuver of the C-arm. The trunk is brought to the edge of the table on the operative side. A small rolled towel is placed between the scapulae posteriorly. This promotes reduction of the fracture particularly when shortening is noted. Fluoroscopic images are obtained before sterile preparation. The fluoroscopy unit is positioned to obtain near orthogonal images without moving the base of the machine. Images include a cephalic and caudal tilt view. The extremity is prepared and draped with the arm free. Manipulation of the extremity can help reduce displaced fractures. The drapes should be extended to include the anterior chest to the sternum and the lateral cervical area.

The starting point is obtained with the aid of fluoroscopy. All percutaneous nails are placed from a medial to lateral direction so that they are driven across the fracture site while traveling away from the central neurovascular structures. The entry point in the clavicle is 3 to 4cm lateral to the sternoclavicular joint on the anterior surface of the bone Fig. (1).

This point is localized with fluoroscopy and 5-10mm skin incision is made 2cm medial to the entry point in the clavicle Fig. (2). After skin incision, the subcutaneous tissue is spread, and a drill guide is placed onto the anterior aspect of the bone angled laterally at the desired point of entry in to the bone.

The drill size should be several millimeters larger than the anticipated nail diameter to facilitate passage through the bone. 2.5-to 3.5-mm nail can be used depending on the size of the patient. The nail is advanced through the drill hole into the medullary canal of the clavicle. The nail is advanced a very short distance, and orthogonal fluoroscopic images are obtained to confirm that the pin is within the bone Fig. (3).

A T-handle quick-release chuck is used to advance the nail to the fracture site. Typically, the nail can be advanced by hand when combined with rotational forces but a mallet may be used as needed. The blunt and curved tips titanium nails are ideal for passage in the small canal of the clavicle without penetrating the cortical bone. The nail is advanced to the level of the fracture. The fracture can often be reduced by manipulation of the arm. An army navy retractor can be used to pull inferiorly on the medial fragment and the arm itself pushed proximally to move the lateral fragment superiorly. Frequently, we used percutaneous towel clips to manipulate the fracture fragments into the correct alignment while the nail is advanced Fig. (4).

In some fractures, it is necessary to make an open approach to the clavicle to gain control of the distal fragment. A small incision is made at the level of the fracture. The approach is of sufficient size to access only the bone, which may be grasped with Kocher clamps. Stripping of the fracture fragments is avoided. If opened, it can be helpful to drill the distal fragment to facilitate passage of the nail. The nail is advanced across the fracture, and intramedullary positioning is confirmed on orthogonal fluoroscopic images. The nail is advanced to the lateral end of the clavicle. The fracture will be reduced by the nail acting as an internal splint. The nail comes to rest in the posterior aspect of the lateral clavicle just medial to the acromioclavicular joint. The nail should not be allowed to penetrate the posterior cortex of the distal clavicle.
The tip of the nail is cut medially leaving 3 to 5mm of pin outside the cortical bone. To facilitate this through a small incision, the nail can be cut off at the skin surface before fully seating it, then driving it in another 8 to 10mm with the tamps provided for this in the elastic nail set. Leaving the medial tip of the nail outside the bone facilitates removal of the implant at a later date if needed. The small entrance wound is closed in a single layer.

**Aftercare:**
- The arm is placed in a sling for a few days for support and comfort.
- Early range of motion is initiated immediately.
- Range of motion is advanced as tolerated with no restrictions.
- Strengthening exercises are started once fracture callus is noted on radiographs. Fracture union is usually seen at 6 weeks.
- If desired, the nail may be removed in the operating room when good callus has formed, usually 4 to 6 months after surgery.

![Image](image1.png)
**Fig. (1):** Image is used to localize the skin incision. The point of entrance into the clavicle is 3 to 4cm lateral to the sternoclavicular joint on the ventral aspect of the clavicle.

![Image](image2.png)
**Fig. (2):** Skin is incised about 2cm medial to point of entry into the clavicle after localization with fluoroscopy.

![Image](image3.png)
**Fig. (3):** The fracture will reduce as the nail is advanced within the distal fragment. The nail should come to rest 2 to 3cm medial to the lateral end of the clavicle. Final fluoroscopic images, Caudal tilt.

![Image](image4.png)
**Fig. (4):** Towel clips used to manipulate the fracture fragments.

**Results**

Anterograde minimal invasive pinning has been the preferred method of fixation for those acute midshaft clavicle fractures. We have a limited but growing experience with this technique having performed 25 anterograde clavicles pinning during the last 2 years.

The average age of the patients was 28 years (range 16-40 years). In 15 fractures, reduction of the fracture and placement of the nail was successful closed. The remaining 10 patients required open reduction for passage of the nail across the fracture. Twenty-two of 25 patients were followed to radiographic and clinical healing, and 3 patients were lost to follow-up.

Both radiographic and clinical healing of the fracture was observed in all 22 patients with adequate follow-up. One patient had a delayed union as diagnosed by absence of bridging bone at 4 months after surgery. This fracture later healed by 6 months with no further intervention. Twenty of 22 patients were satisfied with their outcome and were without clinical deformity. Four malunions were seen. In 2 of the 3 patients with small diameter nails (2.0mm), the nail bent before fracture healing, resulting in a modest apex superior angulation of the clavicle.
These small diameter nails were placed before we began cutting the hook off the tip of the nail to allow implantation of larger nails, and we now attempt to place a nail with a minimum diameter of 2.5mm in all patients. Neither of these 2 patients noticed the angulation clinically, and they were both satisfied with their outcomes. The third malunion resulted in significant shortening of clavicle fracture after the pin backed out several centimeters. This was revised with open reduction and plating with placement of a structural autograft. Eight of 22 patients underwent elective nail removal at a minimum of 4 months after surgery secondary to skin irritation at the entry site.

Discussion

Simple closed fracture of the midshaft clavicle is a frequent injury and mostly treated non-operatively. Although fracture healing and functional outcome usually satisfactory [8]. Significant shortening with mal-union or non-union is described in the literature [15]. Whereas some authors report good functional results in patients with clavicular shortening [16]. Hill et al., reported a clear correlation of non-unions (15%) with clavicular shortening of more than 2cm [7]. They found unsatisfactory results in 31% of completely displaced midclavicular fractures after non-operative treatment. Beside nonunion residual persistent pain, brachial plexus irritation and poor cosmetic results were observed by the treating physician [4].

For patients with a high demand on shoulder function, such prospects are barely acceptable. To meet these patients’ expectations a minimally invasive procedure which provides restoration of the clavicular length combined with early resumption of training, complete functional recovery and a good cosmetic result may be an attractive alternative to non-operative management. Open reduction with plate fixation is the operative standard treatment for clavicular shaft fractures [17].

Potential complications include deep infection, injury to the subclavian vessels, screw loosening with implant failure, non-union and refracture after hardware removal. The cosmetic result is frequently considered unsatisfactory caused by an inevitable and often hypertrophic scar. Due to these problems non-operative treatment of uncomplicated midclavicular fractures is still favored by most surgeons.

In contrast the flexible intramedullary nails as potential alternative overcomes several disadvantages of plate fixation. The incision is kept short, providing a better cosmetic result. Restoration of clavicular length can reliably be maintained with minimal exposure and a limited amount of hardware. In about more than half of the interventions closed reduction of the fracture is successful, which provides the best conditions for undisturbed fracture healing. Even when open reduction cannot be avoided, exposure can be kept to a minimum in order to avoid additional tissue damage.

Most patients can be treated as day cases and full mobility of the shoulder is achieved early on. As post-operative instructions for the patients include no restrictions regarding range of motion the level of activity is determined only by pain and the patients motivation for an early resumption of full shoulder function postoperative regimen we observed.

In contrast to Kirschner wire fixation, the flexible intramedullary nails is a truly intramedullary stabilization technique. In our opinion non-operative management is still the gold standard which provides good results in most cases, leaving the flexible intramedullary nails as a valuable technique for selected cases. From a technical point of view simple fractures with a lack of bony contact or with considerable shortening are ideal indications. Flexible Intramedullary nails can be safely performed if the two main fragments have osseous contact after reduction, ensuring correct clavicular length with the nail in place. Flexible intramedullary nails certainly not be recommended for comminuted fractures as the above principles do not apply in these fracture patterns. In selected cases the flexible intramedullary nails a safe and effective method for midclavicular fractures with low complication rate once potential technical pitfalls are appreciated. Restoration of clavicular length is reliable. Cosmetic and functional results are excellent and a quick recovery makes early resumption of training possible.

Christoph et al., a prospective consecutive case series was done to evaluate indications, technical pitfalls and functional outcome of elastic stable intramedullary nailing of displaced midclavicular fractures in 14 athletes. Constant score and radiographs were evaluated after 1 and 6 weeks, 3 months and 6 months in 13 patients. Mean age was 28 years. The average follow-up was 17 months. Mean operation time was 62 minutes. Open reduction through an additional small incision was necessary for 7 fractures. Mean hospital stay was 1.2 days. Secondary fracture displacement was observed in 1 patient. The constant score averaged 81 after 1 week, 96 after 6 weeks and 98 after 6 months. Compared to the contralateral side, average shortening of the clavicle was 1.7mm. Overall,
elastic stable intramedullary nailing provided good restoration of the length of the clavicle and allowed immediate active mobilization with early return to normal activity. Functional results were excellent [5].

Conclusion:
Recent outcome studies have shown that displaced midshaft fractures of the clavicle have higher rates of fracture malunion, nonunion, and patient dissatisfaction than previously recognized with conservative treatment. Anterograde percutaneous pinning of displaced midshaft fractures is a safe means of minimally invasive fixation that minimizes the chance of malunion and nonunion while avoiding the complications of unsightly and painful scars, nonunion, and infection often associated with open reduction and internal fixation. The need for controlled, randomized studies to determine the best method of treatment of these injuries continues.

References