Complications and Technical Pitfalls of Titanium Elastic Nail Fixation for Midclavicular Fractures

CHENG-CHANG LU, MD; PING-CHENG LIU, MD; SHIH-HAO HUANG, MD; CHIH-HSIN HSIEH, MD; YIN-CHUN TIEN, PHD; SONG-HSIUNG CHIEN, MD

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Intramedullary titanium elastic nails have been reported to fix displaced midclavicular fractures with excellent functional outcomes and minor complications. This study reports and analyzes the complications and technical pitfalls associated with titanium elastic nail fixation of displaced midclavicular fractures and describes how to prevent these problems. The authors operated on 27 patients (17 men, 10 women; mean age, 45.8 years; range, 16.5-66.9 years) with marked displaced midclavicular fractures using intramedullary titanium elastic nail fixation. The mean Constant score and Disability of the Arm, Shoulder, and Hand score were 93.58 (range, 66.5-100) and 6.22 (range, 0-35), respectively. The mean length difference compared with the contralateral clavicle was a shortening of 0.3 cm (range, -1.5 to 1 cm). Eight patients (30%) had different levels of difficulty at the medial entry point. Clavicular length shortening of more than 1 cm occurred in 5 patients (19%), and all of these patients experienced medial nail tip prominence/protrusion. One patient had 1-cm lengthening of the injured clavicle caused by distraction of the fracture site during titanium elastic nail insertion. Iatrogenic perforation of the posterolateral cortex occurred in 3 patients. Initial misplaced nail insertion occurred in 1 woman who underwent revision with the mini-open method. In 2 patients it was impossible to remove the full nail under general anesthesia. In conclusion, high patient satisfaction and functional outcomes were achieved after titanium elastic nail fixation of displaced midclavicular fractures. However, some complications and technical pitfalls must be considered before titanium elastic nails are used to fix displaced midclavicular fractures.

The authors are from the Department of Orthopaedic Surgery (C-CL, P-CL, S-HH), Kaohsiung Municipal Hsiao-Kang Hospital, Kaohsiung Medical University, Kaohsiung; College of Medicine, Kaohsiung Medical University (C-CL, Y-CT, S-HC), Kaohsiung; and the Department of Orthopaedic Surgery (C-HH, Y-CT, S-HC), Kaohsiung Medical University Hospital, Kaohsiung, Taiwan.

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Correspondence should be addressed to: Song-Hsiung Chien, MD, Department of Orthopaedic Surgery, Kaohsiung Medical University Hospital, No. 100, Tzyou 1st Rd, San-Min District, Kaohsiung 807, Taiwan (cclu0880330@gmail.com).

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Figure: Preoperative anteroposterior radiograph of the left shoulder of a 62-year-old man with a displaced fracture of the left clavicle with multiple fragments and shortening that was then fixed with a titanium elastic nail.
More than 80% of clavicular fractures involve the middle third of the clavicle, and indications for surgical fixation of displaced midclavicular fractures have been proposed. Operative methods involve either plate fixation or intramedullary device fixation, of which plate fixation is the standard procedure. Plate fixation requires a large operative wound and stripping of soft tissue that may lead to complications, such as infection, nonunion, wound breakdown, local numbness, and loss of reduction. The Canadian Orthopaedic Trauma Society concluded that most complications associated with plate fixation of midclavicular fractures were related to hardware. Several types of intramedullary devices have been proposed to minimize surgical wound size and soft tissue stripping during fixation of displaced midclavicular fractures.

Titanium elastic nails have been used successfully in the treatment of diaphyseal long bone fracture in children and adolescents, using minimally invasive techniques. Jubel et al first described the use of titanium elastic nails for midclavicular fracture fixation. The use of titanium elastic nails to fix midclavicular fractures requires a minimally invasive method, using a small incision and minimal soft tissue dissection under fluoroscopic guidance. The reported advantages of titanium elastic nails for midclavicular fractures include low infection rates, high union rates, early restoration of shoulder motion, early pain relief, good patient satisfaction, and high functional scores.

From the onset of titanium elastic nail use in the authors’ hospital, unexpected intraoperative and postoperative complications occurred. This study reports and analyzes the complications and technical pitfalls of titanium elastic nail fixation of displaced midclavicular fractures and discusses how to prevent these complications.

**Materials and Methods**

From January 2007 to April 2008, 27 patients (17 men, 10 women; mean age, 45.8 years; range, 16.5-66.9 years) with marked displaced midclavicular fractures (no cortical contact between the proximal and distal fragments apparent from radiographic analysis, an excess of 2 cm shortening, or both) underwent fixation with titanium elastic nails (Synthes, Umkirch, Germany). The mechanism of injury in these patients included traffic accidents (20 patients), slipping incidents (4 patients), and industrial incidents (3 patients). These fractures occurred on the right side in 11 patients and on the left side in 16 patients. Thirteen patients had simple transverse or oblique fractures, and 14 patients had comminuted fractures with more than 3 fragments. Thirteen patients had isolated clavicular fractures with marked displacement, greater than 2 cm shortening, or severe skin tenting. Fourteen patients had associated injuries that necessitated fixation of the fractured clavicle to allow for early rehabilitation and stabilization of the chest wall (multiple trauma or bone fractures with or without head injuries in 8 patients; chest wall injuries combined with scapular or multiple rib fractures in 6 patients). All fractures were fresh, and no open fractures or bilateral fractures occurred.

**Surgical Technique**

The procedure for titanium elastic nail fixation of displaced midclavicular fractures has been described in the literature. Briefly, a patient lying on a radiolucent table with the ipsilateral arm freely movable received general anesthesia. Skin incision (1-2 cm) was made approximately 2 cm lateral to the sternal clavicular joint. An entry hole was made with a 3-mm pin over the center of the ventral cortex and enlarged with an awl. A titanium elastic nail fixed to a T-handle was inserted into the medullary canal via the sternal entry point. The size of the nail (range, 2-3 mm) was determined by the diameter of the clavicular canal and the patient’s stature. As the nail tip approached the fracture site, closed reduction was attempted using a manual or percutaneous reduction clamp. If closed reduction was successful, then the nail tip was inserted into the distal fragment under fluoroscopic guidance. If closed reduction was unsuccessful, then a transverse small accessory incision over the fracture site was made. The nail tip was then advanced into the distal fragment under direct vision. During open reduction, fragments affecting the stability of length maintenance were fixed with heavy sutures or wires. The nail tip was advanced as far as possible into the distal fragment with oscillating motions, either manually or with gentle hammer tapping, and then stopped when the “end point” was felt. During nail insertion, counterforce was applied by pressing on the shoulder with a hand or by using a percutaneous clamp to resist the distraction force.

After the nail tip reached the end point, its position was checked under fluoroscopic monitoring from at least 2 views to avoid nail tip perforation. Under fluoroscopic monitoring, the arm was pulled forcefully to check the stability of fixation. The nail was then cut off at the site of its insertion near the cortex to prevent soft tissue irritation.

**Postoperative Management**

Postoperatively, the ipsilateral arm was placed in a sling. For patients with simple or oblique fractures, the sling was discontinued after suture removal to allow for early free motion of the injured shoulder. For patients with comminuted fractures, the sling was worn for 4 to 6 weeks. Active abduction and elevation were avoided to prevent rotational forces from occurring at the fracture site that would induce impairment of the comminuted fragments and medial migration of the nail.

**Follow-up**

All patients were scheduled to receive regular clinical follow-up postoperatively at 2 weeks, 6 weeks, and then monthly until the bone was healed. Patients were fol-
lowed up for at least 1 year. This regimen included those who had early nail remov-

a shortening of 0.09 cm (range, -1 to 1 cm; SD=0.49) in the simple fracture group and a shortening of 0.5 cm (range, -1.5 to 0 cm; SD=0.4) in the comminuted fracture group \( P=.091 \). No significant differences were observed between the 2 groups. At final follow-up, the mean Constant score was 93.58 \( (\text{range, 66.5-100; SD=0.49}) \) and the mean Disabilities of the Arm, Shoulder, and Hand score was 6.22 \( (\text{range, 0-35; SD=11.11}) \) for all patients. The mean Constant scores were 96.64 \( (\text{range, 86-100; SD=5}) \) and 91 \( (\text{range, 66.5-100; SD=10.93}) \) for the simple and comminuted fracture groups, respectively \( P=.114 \). The mean Disabilities of the Arm, Shoulder, and Hand scores were 7.73 \( (\text{range, 0-35; SD=12.54}) \) and 4.94 \( (\text{range, 0-35; SD=10.08}) \) for the simple and comminuted fracture groups, respectively \( P=.552 \). There were no significant differences between the mean Constant score and the mean Disabilities of the Arm, Shoulder, and Hand score between these 2 groups.

Eight patients (30%) had different levels of medial entry point difficulty. These included medial nail tip irritation and pain without obvious prominence in 3 patients, mild medial nail tip prominence/protrusion with skin tenting without complaint in 2 patients, and severe nail tip promi-

nent removal of the nail.

Figure 1: Preoperative (A) and immediate postoperative (B) anteroposterior radiographs of the left shoul-

den of a 62-year-old man with a displaced fracture of the left clavicle with multiple fragments and shortening that was then fixed with a titanium elastic nail. Six-month follow-up (C) anteroposterior radiograph showing solid union of the fracture site with shortening compared with the right clavicle. Clinical photograph (D) of the patient at follow-up showing severe prominence and protrusion of the medial nail tip (arrow). The patient requested removal of the nail.
medial nail tip prominence/protrusion. One patient had 1-cm lengthening of the injured clavicle that was caused by distraction of the fracture site during nail insertion.

Iatrogenic perforation of the posterolateral cortex occurred in 3 patients. Of these, 1 patient returned to work and exercise without any complaint, 1 patient requested removal of the nail because of entry point pain and medial nail tip prominence, and 1 patient complained of a “clicking” sound over the distal clavicle area during shoulder motion. Initial misplaced nail insertion occurred in 1 patient who had undergone revision using the mini-open method and with the nail inserted under direct vision. The patient reported weakness in the injured shoulder even after the fracture site was healed. Eight patients requested removal of the nail. In 2 patients (10 and 15 months postoperatively), the nail could not be removed under general anesthesia; to resolve this problem, the protruding nail tip was cut close to the cortex to prevent soft tissue irritation (Figure 2). Two women who had been scheduled to undergo titanium elastic nail implantation for midclavicular fracture were excluded from this study because of failed nail insertion as a result of a small clavicular canal. Instead these patients underwent plate fixation of the midclavicular fractures. The Table summarizes the complications associated with titanium elastic nail fixation of displaced midclavicular fractures.

**Discussion**

Intramedullary titanium elastic nails have been reported to fix displaced midclavicular fractures with excellent functional outcomes and minor complications. In this study, a minimally invasive method was used to insert titanium elastic nails to fix displaced midclavicular fractures in patients with traumatic injuries. High patient satisfaction and functional results were reflected in a mean Constant score of 93.58 and Disabilities of the Arm, Shoulder, and Hand score of 6.22; there was no significant difference between simple and comminuted fracture groups. Mueller et al performed a 1- to 5-year follow-up of 32 patients with mean Constant and Disabilities of the Arm, Shoulder, and Hand scores of 95 and 5, respectively. Kettler et al reported surgical outcomes for 87 patients with average Constant and Disabilities of the Arm, Shoulder, and Hand scores of 81 and 6.8, respectively. However, some complications and technique pitfalls occurred in the current study of titanium elastic nail fixation of displaced midclavicular fractures.

The most common complications in the current study were nail tip medial migration and prominence and shortening of the injured clavicle. Eight patients (30%) reported entry point pain and medial nail tip prominence. Three patients with comminuted fractures had severe medial nail tip prominence and irritation. The mean injured clavicular length shortening for all patients was 0.3 cm, and in 5 patients (19%), shortening was greater than 1 cm. Literature showed that the rate of medial entry point irritation varies from 5.4% to 33.3%,. In a study by Kettler et al, 2 patients (n=87) reported medial side irritation as a result of protrusion of the medial nail end and 2 patients experienced clavicle length shortening of more than 1 cm. Kettler et al concluded that the lower rates of entry point irritation and prominence were caused by stable jamming of the flat enlarged distal end of the titanium elastic nails located in the lateral clavicular fragment. Mueller et al reported that 8 patients (n=32) sustained migration of the titanium elastic nails and

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*Figure 2: Preoperative (A) anteroposterior radiograph of the right shoulder of a 48-year-old man showing a displaced midclavicular fracture with a third fragment. Ten-month follow-up (B) anteroposterior radiograph of the right shoulder showing solid union of the fracture site with clavicular shortening after titanium elastic nail fixation. Clinical photograph (C) of the patient at follow-up showing a prominent nail tip with skin tenting. Clinical photograph (D) during surgery showing that the protruding nail tip was cut as close to the cortex as possible due to inability to remove the complete nail under general anesthesia.*
5 of these required secondary shortening of the protruding medial nail end. Six clavicles healed with shortening of more than 1 cm. The authors proposed that changing the entry point from the center of the medial clavicle to the lower end would decrease the incidence of skin irritation. Frigg et al reported that using an end cap over the nail tip significantly blocks medial migration and thus reduces medial pain.

In the current study, nail tips were cut as close to the cortex as possible to prevent medial irritation, without using end caps. The authors found that nail tip medial migration, which causes nail tip irritation and protrusion, is usually associated with clavicular shortening, particularly in patients with a comminuted fracture pattern. Of the study cohort, 5 patients had injured clavicular length shortening of greater than 1 cm. Of these patients, 1 (7.7%; n=13) had a simple fracture and 4 (28.6%; n=14) had comminuted fractures. All 5 patients had concomitant medial nail tip prominence/protrusion. No significant difference was observed in clavicular shortening between the simple and comminuted fracture groups in the current study (P=.091), although this may be because of the limited number of cases. The distal flat end of the titanium elastic nail ordinarily engages on the posterolateral cortex of the distal clavicle (Figure 3A). Titanium elastic nail fixation cannot withstand rotation or migration of the fracture fragments during shoulder motion because the titanium elastic nail lacks a threaded end and has no locking mechanism to provide purchase at the ventral medial cortex. After titanium elastic nail fixation of a comminuted midclavicular fracture, unstable comminuted fragments migrate and impact, which can result in medial migration and protrusion of the nail tip and shortening of the injured clavicle (Figure 3B). Therefore, the key to preventing nail tip medial migration and clavicular shortening after titanium elastic nail fixation is to ensure that the fracture fragments remain stable, especially in the case of comminuted fracture. For this reason, the authors propose making an accessory incision to fix large fragments that affect the stability of length maintenance with heavy sutures or wires. In patients with multiple small fracture fragments, titanium elastic nail fixation may not be appropriate because of the high risk of nail tip medial migration and clavicular shortening. In such cases, plate fixation is suggested.

Lengthening of the clavicle occurred in 1 patient who returned to work and sports without any restriction or complaint. Lengthening may be caused by distraction of the fracture site during titanium elastic nail insertion. To prevent such complications, the authors suggest applying counterforce on the ipsilateral shoulder to prevent distraction during insertion. Iatrogenic perforation of the posterolateral cortex occurred in 3 patients, and initial misplacement of the nail occurred in 1 patient. The clavicle is a complex S-shaped bone; the thinnest regions are the medial ventral cortex and the dorsal acromional (posterolateral) cortex.

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. (%)</th>
<th>Comments</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial entry point pain and medial tip prominence/ protrusion</td>
<td>8 (30)</td>
<td>Three patients with comminuted fracture pattern sustained severe prominence of nail tip</td>
<td>Maintain stability of comminuted fracture fragments and prevent clavicle shortening; remove TEN after bone healing or remove protruding tip</td>
</tr>
<tr>
<td>Shortening ≥1 cm</td>
<td>5 (19)</td>
<td>Lack of locking mechanism in TEN; all 5 patients had problems associated with medial nail tip prominence/protrusion</td>
<td>Consider accessory wound and fix fragments to improve length maintenance</td>
</tr>
<tr>
<td>Lengthening 1 cm</td>
<td>1</td>
<td>Distraction of fracture site during TEN insertion</td>
<td>Apply counterforce on ipsilateral shoulder during TEN insertion</td>
</tr>
<tr>
<td>Iatrogenic perforation of posterolateral cortex</td>
<td>3</td>
<td>Posterolateral cortex is thinnest cortex region of clavicle</td>
<td>Advance into distal fragment as far as possible until end point is felt; insert TEN gently; always check distal nail tip from at least 2 fluoroscopic views</td>
</tr>
<tr>
<td>Initial misplacement of nail</td>
<td>1</td>
<td>Unable to determine nail placement; use only anteroposterior fluoroscopic view</td>
<td>Reinsert nail under mini-open procedure; always check distal nail tip from at least 2 fluoroscopic views</td>
</tr>
<tr>
<td>Unable to remove full nail</td>
<td>2</td>
<td>Osseous integration between distal end of TEN and distal clavicle canal</td>
<td>Cut protruding tip as close to cortex as possible</td>
</tr>
<tr>
<td>Unable to perform TEN</td>
<td>2</td>
<td>Female patients with small clavicular canal</td>
<td>Shift to plate fixation</td>
</tr>
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</table>

Abbreviation: TEN, titanium elastic nail.
Forceful insertion may cause the distal nail tip to perforate the posterolateral cortex, particularly in patients with a thin cortex or osteoporotic bone. Thus, the amount of nail advancement into the lateral fragment must be defined to prevent perforation and provide adequate fixation stability. Kettler et al\textsuperscript{31} wrote that the nail must be inserted “as far as possible,” and Frigg et al\textsuperscript{30} reported that it must be inserted “as far as necessary” into the lateral fragment. The authors performed manual or gentle hammer-aided insertion of titanium elastic nails into the distal fragment as far as possible until the “end point” was felt. The distal nail tip must be monitored by fluoroscopy from at least 2 views during insertion to prevent nail misplacement or perforation. The stability of fixation should always be checked by pulling the forearm forcefully under fluoroscopic guidance.

The authors did not routinely remove the titanium elastic nails from the healed clavicle. Eight patients in the current study requested removal of the nail. The nail could not be removed in 2 patients under general anesthesia (10 and 15 months postoperatively), possibly because of osseous integration\textsuperscript{32,33} between the widened curved distal end of the titanium elastic nail and the narrow distal clavicle canal. In these 2 cases, the protruding nail tip was cut close to the cortex at the sternum entry point. These patients have had no further complaint since this procedure was performed (Figure 2). Most authors who use titanium elastic nails to fix midclavicular fractures recommend removal of implants from all patients at 4 to 8 months to prevent medial nail migration and irritation when patients return to work or sports.\textsuperscript{21,23,24,30} However, there are reports of complications, including refracture after nail removal and nonunion after premature implant removal.\textsuperscript{23,24} Thus, the authors do not recommend routine implant removal in all patients after bone healing, except for those who experience medial entry point pain or nail tip prominence.

The relationship between clavicle diameter and nail size is another concern in titanium elastic nail fixation of midclavicular fractures. Mueller et al\textsuperscript{24} stated that the diameter of the cross-section of the titanium elastic nail should be no less than 50% of that of the clavicular canal. Nail breakage occurred in 2 patients in the study of Mueller et al\textsuperscript{24} and in 1 patient in the study of Frigg et al.\textsuperscript{30} In the current study, nail size ranged from 2 to 3 mm, according to the patient’s body stature and clavicular diameter. No implant breakage occurred in these patients. Two female patients with small clavicular canals required accessory wounds to aid nail (2 mm) insertion into the distal fragment. Another 2 female patients with small clavicular canals were excluded from this study because titanium elastic nails could not be inserted into the distal fragment, even under open reduction. These 2 female patients instead underwent plate fixation. Therefore, the possibility of open reduction or plate fixation should be considered before titanium elastic nail fixation is performed in female patients with short stature or small clavicular diameter.

The current study did not report some complications that have been described in the literature, such as superficial infection, nonunion, nail breakage, nail dislocation, refracture after nail removal, or secondary revision to plate fixation.\textsuperscript{21,23,24,30} This study had some limitations, such as limited case numbers, short follow-up time, and lack of a comparison group. A prospective randomized comparison study is needed to compare titanium elastic nail treatment of displaced midclavicular fractures with the use of other fixation devices.

**CONCLUSION**

In this study, titanium elastic nails were used to treat displaced midclavicular fractures. The technique has good functional outcomes, is facile to perform, and offers high patient satisfaction. However, some pitfalls and complications associated with this technique must be considered before titanium elastic nails can be used to fix displaced midclavicular fractures. The authors suggest that titanium elastic nail fixation in midclavicular fractures should be used in patients with simple or oblique displaced fractures, patients who have comminuted fractures with fragments that could be fixed by heavy sutures or wire, patients who require early shoulder motion, athletes, and those who require cosmetic consideration. It is important to pay attention to the potential for nail tip medial migration and clavicular shortening after titanium elastic nail fixation, particularly in patients with comminuted midclavicular fractures.

**REFERENCES**

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