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SYMPOSIUM: FRACTURES OF THE SHOULDER GIRDLE

Can Complications of Titanium Elastic Nailing With End Cap for Clavicular Fractures Be Reduced?

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Abstract

Background We found treatment of clavicular midshaft fractures using titanium elastic nails (TENs) in combination with postoperative free ROM was associated with a complication rate of 78%. The use of end caps reduced the rate to 60%, which we still considered unacceptably high. Thus, we explored an alternative approach.

Questions/purposes We investigated whether (1) the complication rate could be reduced by cautious lateral advancement of the TENs, intraoperative oblique radiographs to rule out lateral perforation, and limited ROM postoperatively; (2) fluoroscopy time could be reduced; and (3) shoulder function would be reasonable.

Patients and Methods From March 2006 to December 2009, we treated 44 patients with midshaft clavicular fractures with TENs and end caps. In the first group (n = 15), the TEN was advanced laterally using an oscillating drill. The patients were permitted free ROM. In the second group (n = 29), the TEN was advanced by hand, conversion to open reduction followed two failed closed attempts and lateral perforation was checked with an intraoperative oblique radiograph. Furthermore, anteversion and abduction of the shoulder were limited to 90° for the first 6 weeks. Minimum followup was 12 months (mean, 16.7 months; range, 12–28 months).

Results The total complication rate was reduced from nine of 15 in the first group to five of 29 in the second group. Medial perforations ceased with the use of the end cap. Fluoroscopy time was reduced from a mean of 10 to 4 minutes by converting to open reduction after two failed closed attempts. All but three patients exhibited full shoulder ROM at three months and these three had a slight deficit of 10° to 20° in anteversion and/or abduction. At last followup, the mean American Shoulder and Elbow Surgeons score was 92 (range, 88–100) and the Disability of the Arm, Shoulder, and Hand score 1.4 (range, 0–12.5).

Conclusions Cautious insertion of the TENs, intraoperative oblique radiographs, and limiting the ROM for 6 weeks postoperatively reduced the complication rate. Using TENs with end caps for midshaft clavicular fractures is minimally invasive while associated with comparable complication rates and function to plate osteosynthesis.

Level of Evidence Level III, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
This work was performed at Davos Hospital.

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Introduction

Clavicular fractures account for around 10% of all fractures, making them one of the most common bone injuries in the human body. They occur predominantly in sports, particularly skiing, snowboarding, and competitive cycling [3, 17, 21]; 80% of the fractures involve the middle third of

the clavicle [11, 21]. Midshaft clavicular fractures are primarily treated nonoperatively with a rucksack bandage for 3 weeks [25]. However, this procedure is associated with a number of problems: nonunion [1, 9], poor cosmetic outcome [4, 14], and shortening of the shoulder girdle with sequelae such as increased load on adjacent joints [4, 14]. For these reasons, various authors recommend operative management of young patients with sports injuries in the following cases: complete displacement, imminent skin perforation, shortening of the clavicle by more than 2 cm, and neurovascular lesions [1–4, 12, 14, 19, 23].

Some surgeons consider plate osteosynthesis as the gold standard when surgery is indicated [1, 27]. A number of studies have reported on minimally invasive fixation using intramedullary splinting (eg, titanium elastic nailing) [2, 6–10, 15, 23, 26]. The advantage of this method is that it is a minimally invasive procedure reported to allow relatively pain-free shoulder mobilization immediately after the operation [8, 16]. Although the literature [6, 8–10, 15, 16, 26] suggests a complication rate of 9% to 56% with postoperative free ROM and a resumption of sports activities within a few days after using a titanium elastic nail (TEN), we encountered a complication rate of 78% (Table 1) for the same regimen. Problems were located mainly on the medial side (13 of 18 patients: medial perforation or pain) [2]. To reduce this high complication rate related to the medial side, we developed an end cap primarily for intramedullary nailing of pediatric fractures [2]. Thereafter, the total complication rate still remained at 60% [2], which we considered unacceptable. Given the potential advantages of a minimally invasive operation with few complications that achieves normal shoulder function after surgery [6, 10, 15, 16, 26], we thought it important to develop an approach to reduce the complication rate. Because mechanical complications (migration, breakage, dislocation) were most frequent, we considered which possible technical errors during surgery or mechanical overuse problems during the followup could cause these complications.

We therefore determined (1) whether this unacceptably high complication rate could be reduced by careful lateral advancement of the TEN by hand, obtaining intraoperative oblique radiographs to rule out lateral perforation, and limiting ROM postoperatively; (2) whether the fluoroscopy time could be reduced by changing to open reduction after two unsuccessful closed attempts instead of aiming for closed reduction in as many cases as possible; and (3) what the American Shoulder and Elbow Surgeons (ASES) and Disability of the Arm, Shoulder, and Hand (DASH) scores were at 1- to 2-year followup.

Patients and Methods

Our study reflects a retrospective case-control study of all 44 patients with clavicular midshaft fractures treated with a TEN using an end cap (Synthes GmbH, Oberdorf, Switzerland) (Fig. 1) from March 2006 to December 2009.

Fig. 1 A photograph shows a titanium elastic nail with an end cap.

Table 1. Overview of complications reported in the literature using TENs

Study	Number of patients	Number of complications	Type of complications
Jubel et al. [8]	65	6 (9.2%)	Medial migration (n = 4), nonunion (n = 1), secondary shortening of 1.5 cm (n = 1)
Kettler et al. [10]	87	10 (11.5%)	Lateral (n = 3) and medial (n = 1) migration, nonunion (n = 2), secondary shortening of > 1 cm (n = 2), malunion (n = 2)
Meier et al. [15]	14	4 (28.5%)	Medial migration (n = 1), medial skin irritation (n = 2), fracture dislocation (n = 1)
Müller et al. [16]	45	25 (55.5%)	Lateral (n = 2) and medial (n = 8) migration, TEN breakage (n = 2), wound infection (n = 1), secondary shortening of > 4 mm (n = 12)
Walz et al. [26]	35	6 (22.2%)	Lateral (n = 1) and medial (n = 5) migration
Frigg et al. [2]	34	23 (70%)	Lateral (n = 7) and medial (n = 7) migration, TEN breakage (n = 1), TEN dislocation (n = 1) medial and lateral pain (n = 7)

TEN = titanium elastic nail.

Table 2. Patient and injury demographics

Variable	Group A	Group B
Number of patients	15	29
Sex (male/female)	13/2	24/5
Age (years)*	33 ± 17	30 ± 17
Operative technique	TEN advanced with oscillating drill	TEN advanced carefully by hand; 30° oblique radiograph to rule out lateral perforation
Postoperative ROM	Free	Limited to 90° of anteversion and abduction for 6 weeks
Fracture type (OTA 1996, 2007) [13, 18]		
A (15-B1)	6	13
B (15-B2)	2	7
C (15-B3)	7	9
Additional trauma (eg, concussion, pneumothorax)	7	3
Indications		
Risk of skin perforation	3	1
Shortening > 2 cm, dislocation	11	23
Additional pneumothorax	1	1
Delayed union after nonoperative treatment		1
Persistent pain union after nonoperative treatment		2
Refracture union after nonoperative treatment		1
Time to surgery (days)*	1.3 ± 0.9 (0–3)	6.3 ± 16.1 (0–66)†
Hospital stay (days)*	3.5 ± 4.1 (1–18)	3.1 ± 2.6 (1–14)
Followup (months)*	19 ± 4.1 (15–28)	16 ± 3.4 (12–27)

* Values are expressed as mean ± SD, with range in parentheses; †surgery late due to refracture (56 days), delayed union (66 days), and pain after prior nonoperative treatment (26 days); TEN = titanium elastic nail; OTA = Orthopaedic Trauma Association.

There were 37 males and seven females with an average age (± SD) of 31 ± 17 years (Table 2). Study size was determined by the total number of patients treated with a TEN and end cap at the authors' institution from March 2006 to December 2009 with a minimum followup of 1 year. No patients were lost to followup and there were no missing data. No patients were recalled specifically for this study. All data were obtained from medical records and radiographs. The minimum followup was 12 months (mean, 17 months; range, 12–28 months). The average time waited before surgery was 5 ± 13 days and the average hospital stay was 3 ± 3 days for all patients, including treatment of additional injuries (Table 2). The average hospital stay for isolated clavicle fractures was 2 days (range, 1–5 days).

Indications for surgery were displacement or shortening of more than 2 cm (n = 33), imminent skin perforation (n = 5), refracture 2 months after previous nonoperative treatment (n = 1), delayed union after nonoperative treatment (n = 1), marked pain after initial nonoperative therapy (n = 2), or multiple rib fractures to improve respiratory mechanics (n = 2) (Table 2). All patients had suffered accidents during sporting activities (skiing, snowboarding, skating, mountain biking), and six patients (14%) had concomitant injuries (one had a knee sprain, two an ankle fracture, two pneumo-/hemothorax, and one brain concussion). The contraindications for surgery were (1) skeletal immaturity, (2) pathologic fractures, (3) healed ipsilateral clavicle fractures in the past, and (4) possible noncompliant patients (eg, alcohol and drug addiction, dementia). All fractures were located in the middle third of the clavicle (Type 2, 15-B) [13, 18]. Under the Orthopaedic Trauma Association classification from 1996 [18], 43% of the cases were Type A fractures (simple), 21% Type B fractures, and 36% Type C1 fractures (Table 2). Types C2 and C3 fractures were managed using plate osteosynthesis and were therefore excluded from this study.

Patients were treated by one of two approaches for advancing the TEN and postoperative ROM: Group A (n = 15) was treated by advancing the TEN with the oscillating drill and postoperative free ROM. Group B (n = 29) was treated with careful lateral advancement of the TEN by hand, with 30° oblique intraoperative radiographs (standard 30° cephalic view taken from 30° below the horizontal) to rule out lateral perforation, as well as limited ROM postoperatively (Table 2). As three patients were converted to plating due to complications in Group A, the number of subjects at the 3-month and last followup was reduced to 12 in Group A.

The operation was conducted under general anesthesia with the patient in a supine position on a radiolucent operating table. All operations were carried out by three surgeons (PR, CR, TP). Intravenous antibiotics were applied. After routine skin preparation and draping, an incision was made 2 cm lateral to the sternoclavicular joint over the medial end of the clavicle. A 2.5-mm drill hole was made in the cortex 2 cm lateral to the sternoclavicular joint and then enlarged with the awl. A 2- to 3-mm TEN (depending on the size of the medullary canal) was then inserted under fluoroscopic monitoring using a drill with oscillating movements (Group A) or a T-handle (Group B). A 2.0-mm TEN was used in five cases, a 2.5-mm TEN in 30 cases, and a 3.0-mm TEN in nine cases. When closed reduction could not be achieved, an attempt was made to manipulate and reduce the fragments using percutaneous pointed reduction forceps. If this was also unsuccessful, a 2-cm incision was performed over the fracture site. This enabled the tip of the nail to be introduced under direct view into the lateral fragment and advanced until 2 cm medial to the acromioclavicular joint. In Group A, a closed reduction was attempted in as many cases as possible, and multiple attempts were made to advance the TEN closed. This consequently required using more fluoroscopy. To reduce the lengthy fluoroscopy times we encountered for Group A, we changed our operative plan in Group B by converting to an open reduction after two failed closed attempts.

After final advancement under fluoroscopic monitoring, the position of the TEN was confirmed under AP fluoroscopy for Groups A and B and an additional 30° oblique view for Group B only (standard 30° cephalic view taken from 30° below the horizontal [Fig. 2]). Thereafter, the nail was shortened and the end cap was placed on the medial end of the TEN (Fig. 3). The end cap has a thread on the outside that keeps it in position in the clavicle. The end cap also blocks medial migration of the TEN and reduces skin irritation by covering the spiky nail with a rounded surface. On the first postoperative day, an AP/oblique radiograph was taken and the patient discharged. There was no outer fixation used (eg, sling). Patients were instructed by the surgeon as to the allowed ROM (free in Group A, limited to 90° in Group B). No physiotherapy was applied.

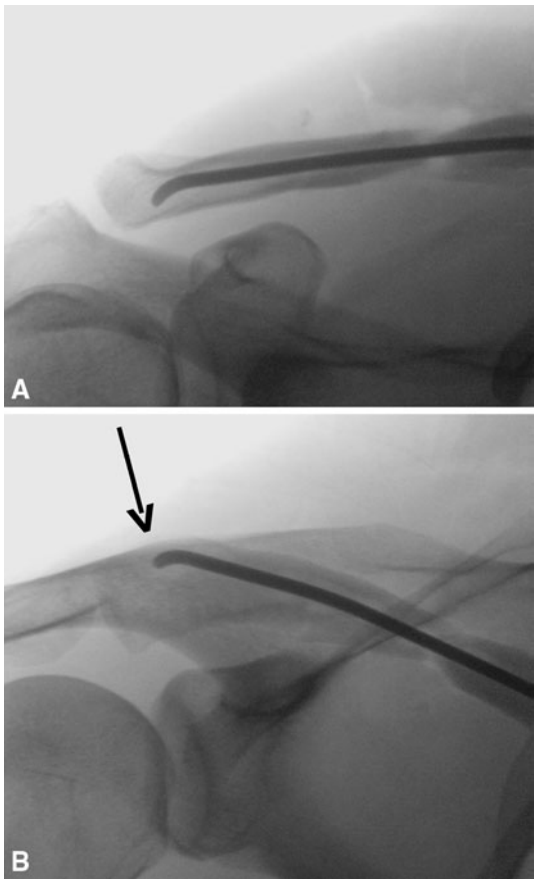

Fig. 2A–B Intraoperative radiographs show (**A**) a correct lateral advancement of the TEN in the AP view and (**B**) a possible lateral perforation in the oblique view (*arrow*). TEN = titanium elastic nail.

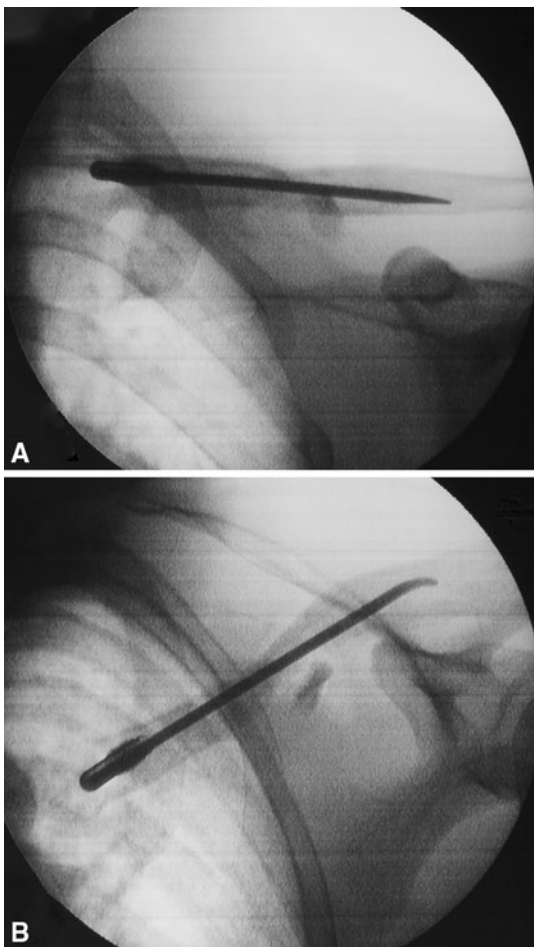

Fig. 3A–B Intraoperative (**A**) AP and (**B**) oblique radiographs show a TEN with an end cap. TEN = titanium elastic nail.

Table 3. Summary of complications and perioperative parameters

Variable	Group A (n = 15)	Group B (n = 29)	p Value
Complications (number of patients)			
Total	60%	17%	< 0.001
Major	6/15 (40%)	3/29 (10%)	< 0.001
Lateral perforation	4†	1	
Nail breakage	1†	0	
Nail dislocation	1†	0	
Subclavian vein thrombosis	0	1	
Nonunion	0	1	
Minor			
Medial or lateral pain	3/15 (20%)	2/29 (7%)	0.007
Operating time (minutes)*			
Total	37 ± 27 (10–105)	47 ± 19 (20–80)	0.16
Closed reduction	22 ± 13 (n = 6)	34 ± 13 (n = 15)	0.05
Open reduction	47 ± 29 (n = 9)	60 ± 15 (n = 14)	0.16
Fluoroscopy time (minutes)*			
Total	10.4 ± 7.9	4.0 ± 2.2	< 0.001
Closed reduction	8.2 ± 11.2 (n = 6)	3.6 ± 1.8 (n = 15)	0.12
Open reduction	10.5 ± 6.5 (n = 9)	4.4 ± 2.6 (n = 14)	0.004
Visual analog scale (0–10)*			
Preoperative	6.1 (5–9)	5.7 (1–8)	0.08
Postoperative	2.3 (0–4)	1.5 (0–3)	0.32
6 weeks postoperatively†	1 (0–5)	1.7 (0–6)	0.27
3 months postoperatively†	0.1 (0–1)	0.6 (0–3)	0.07
ROM 3 months postoperatively†			
Anteversion free	100% (11/11)	97% (28/29)	0.53
Abduction free	91% (10/11)	97% (28/29)	0.47
Time to bony healing (months)*	3.2 ± 1.2 (1.5–5)	3.7 ± 1.7 (1.5–8)	0.32
Hardware removal (months)*	6 (3–12)	6 (2–13)	
ASES score (at final followup) (points)*,†	88 (0–100)	98 (88–100)	0.4
DASH score (at final followup) (points)*,†	1.5 (0–12.5)	1.3 (0–4.2)	0.87

* Values are expressed as mean or mean ± SD, with range in parentheses; †numbers in Group A are reduced to n = 12 because three cases were converted to plating due to complications during the postoperative course; ASES = American Shoulder and Elbow Surgeons; DASH = Disability of the Arm, Shoulder, and Hand.

In Group A, from March 2006 to March 2007, patients were allowed free ROM postoperatively with resumption of sporting activities as soon as possible. After the detection of a 60% complication rate in Group A (Table 3), we modified the postoperative rehabilitation in Group B from December 2007 to December 2009. Abduction and anteversion were limited to 90° for the first 6 weeks and patients were instructed to refrain from sporting activities for 6 weeks.

All patients were seen routinely 6 and 12 weeks postoperatively and AP/oblique radiographs were taken. Hardware removal was performed routinely 4 to 6 months postoperatively after radiographic confirmation of bone healing. The criterion for union was bridging trabeculae on all four cortices on the AP/oblique radiograph observed by two independent doctors. All patients were seen 1 to 2 years after the operation for a final assessment. If no problems were noted, the patient file was then closed.

The postoperative followup for this study consisted of assessment of a visual analog scale (VAS) for pain (0–10, 0 = no pain) and measurement of anteversion (motion anteriorly upward) and abduction (laterally upward) at the 3-month consultation. The ASES (0–100 points, optimal 100) [20] and DASH (0–100 points, optimal 0) [5] scores and radiographs were obtained at the last followup. All complications were recorded during this time period. Major complications were defined as those needing any form of medical treatment (eg, reoperation, anticoagulants) in addition to the standard treatment as described. Minor

complications required no additional treatment (eg, skin irritation).

The outcome variables included all major and minor complications during the followup, operating and fluoroscopy time, VAS, and ROM during the first 3 months postoperatively, as well as ASES and DASH scores at the final followup. Complications, VAS, and ROM were recorded during the routine clinical visits. Operating and fluoroscopy time were recorded in the surgical protocol. ASES and DASH scores were assessed at the final followup 1 to 2 years postoperatively.

We determined differences in the complication rate between Groups A and B using the chi square test and analyzed differences in fluoroscopy time and ASES/DASH, as well as other parametric variables (eg, operating time), between Groups A and B with the unpaired Student's t test. To analyze our data, we used STATISTICA® statistical software (Version 8; StatSoft, Inc, Tulsa, OK).

Results

The total complication rate was less ($p < 0.001$) in Group B (17%) than in Group A (60%) (Table 3). Six of 15 patients in Group A exhibited major complications: nail perforation occurred in four patients at the lateral end of the clavicle requiring early removal (one at 6 weeks, two at 12 weeks postoperatively; all with bony union by 3 months) or plating (one patient); nail breakage was observed in one patient and converted to plating; and nail dislocation occurred in one more patient, requiring conversion to plate osteosynthesis (Fig. 4). Three patients in Group A had minor complications such as pain on the medial or lateral clavicle (Table 3). In Group B, only three of 29 patients exhibited a major complication, which was less ($p < 0.001$) than for patients in Group A: one lateral perforation leading to early hardware removal after 2 months (with bony union by then), one postoperative thrombosis of the subclavian vein requiring 3 months of anticoagulation, and one nonunion after 13 months with conversion to plating occurred. In another noncompliant patient, buckling of the TEN occurred 3 weeks postoperatively when he fell while snowboarding (Fig. 5). Because the patient had undertaken this activity against medical advice, we did not include this event as a complication. Two patients (7%) exhibited minor complications in Group B, including postoperative irritation of the brachial plexus, which was resolved after a few days without treatment, and a medial skin irritation by the end cap. This was also less ($p = 0.007$) than in Group A (Table 3).

The average operating time was 44 ± 22 minutes (range, 10–105 minutes) (Table 3). The average operating time for closed procedures (37 ± 14 minutes; n = 21) was shorter ($p < 0.001$) than for open reduction (55 ± 22 minutes; n = 23). The average operating time in Group A (37 ± 27 minutes) was shorter ($p = 0.16$) than in Group B (47 ± 19 minutes). The average fluoroscopy time was 5.7 ± 5.3 minutes overall. Fluoroscopy in Group B (4 ± 2.2 minutes) was shorter ($p < 0.001$) than in Group A (10 ± 7.9 minutes) (Table 3).

At 3 months postoperatively, 93% of patients exhibited full shoulder ROM; only three patients had a slight deficit of 10° to 20° in anteversion and/or abduction. The mean VAS after 3 months was 0.5 ± 0.8. Average time to union was 3.6 ± 1.5 months (Table 3). Hardware removal was performed on average after 6 ± 2.7 months. At the

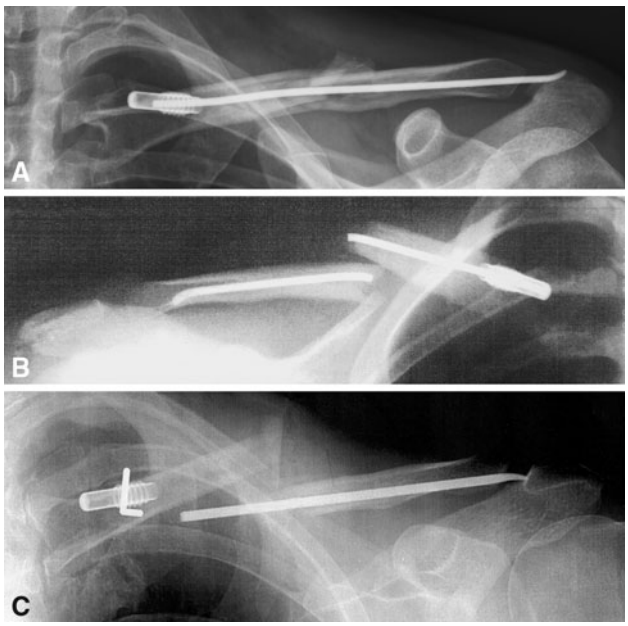

Fig. 4A–C Complications after use of a TEN with postoperative free ROM include (**A**) lateral perforation caused by migration of the nail during free ROM postoperatively, (**B**) TEN breakage, and (**C**) TEN subluxation. Reprinted with permission of Sage Publications Inc from Frigg A, Rillmann P, Gerber M, Perren T, Ryf C. Intramedullary nailing of clavicular midshaft fractures with the titanium elastic nail. *Am J Sports Med.* 2009;37:352–359. TEN = titanium elastic nail.

Fig. 5 TEN bending 3 weeks postoperatively after a snowboard injury is shown in a noncompliant patient. TEN = titanium elastic nail.

followup conducted at an average of 17 ± 5 months, the ASES score was 92 (range, 88–100) and the DASH score 1.4 (range, 0–12.5) (Table 3).

Discussion

The gold standard for surgical management of clavicular midshaft fractures is plate osteosynthesis, for which open reduction with a conventional skin incision is required [2, 26]. Several studies have reported on minimally invasive fixation using intramedullary splinting (eg, titanium elastic nailing) [2, 6–10, 15, 23, 26]. Although a complication rate of 9% to 56% with postoperative free ROM and a resumption of sporting activities within a few days were reported in the literature [6, 8–10, 15, 16, 26], we encountered a complication rate of 78% [2]. To reduce this complication rate, an end cap was used for the first time as described in an earlier study, but the complication rate remained unacceptably high at 60% [2]. We therefore determined (1) whether this unacceptably high complication rate could be reduced by careful lateral advancement of the TEN by hand, obtaining intraoperative oblique radiographs to rule out lateral perforation, and limiting ROM postoperatively; (2) whether the fluoroscopy time could be reduced by changing to open reduction after two unsuccessful closed attempts instead of aiming at closed reduction in as many cases as possible; and (3) ASES and DASH scores at 1- to 2-year followup.

The study has several limitations. First, this is a single-institution study and its generalizability may be limited owing to the relatively large number of fractures treated operatively. Randomized multicenter studies might clarify the relative merits of intramedullary nailing with a TEN. Although several studies reporting few complications and normal postoperative shoulder function have been published [6, 8, 9, 15, 26], this technique has not found general acceptance and is not yet widely practiced, possibly due to technical difficulties and postoperative complications encountered by individual surgeons. Second, comparing Groups A to B, three factors in treatment (advancement of the TEN, intraoperative oblique radiographs, limited postoperative ROM) were changed. Therefore, it is impossible to determine which factor was the most effective in reducing the complication rate. Third, while the number of patients is limited, given the background of the high complication rate, we believe it important to first establish whether the use of a TEN is an acceptable treatment before embarking on a larger series.

A 10% major complication rate in Group B was low compared to the literature (Table 1). Furthermore, we encountered our first nonunion and subclavian vein thrombosis in Group B, which are not implant-related problems. The encountered nonunion was hypertrophic and the fracture was reduced open. Retrospectively, the nonunion might have occurred because the TEN was not advanced laterally enough in this case. One could therefore argue the implant-related complication rate would even be only one of 29 (3%). Other authors reported higher complication rates of 9% to 78% (Table 1). This high complication rate might explain why the TEN has not yet achieved widespread application, despite its theoretical benefits and the fact that other authors have reported good results [7, 8, 26]. Using the TEN in combination with an end cap and restricted postoperative ROM exhibited even better results than plate osteosynthesis (complication rate, 37%) [1]. The two most common complications of the TEN are medial and lateral migration or perforation. Lateral perforation was reduced to just one case by reducing technical errors using intraoperative oblique radiographs and manual implant passage, as well as limited postoperative ROM. Medial migration was observed on average in 10% (1%–18%) in the literature (Table 1) [8, 10, 16, 26]. In our study, no medial migration of the TEN occurred since this was prevented by the end cap. The complication rate was also reduced to 10% by adjusting postoperative restrictions on ROM. Resumption of sports involving overhead activities such as swimming, tennis, skiing, and snowboarding was permitted after 6 weeks, in contrast to the reports by Meier et al. [15] and Jubel et al. [8], where resumption of sports was permitted within days or a few weeks. It is our opinion this is too soon and associated with an unacceptably high complication rate as the clavicle moves and rotates, especially with shoulder movements over the horizontal plane. While some authors claim the minimal invasiveness of the TEN allows early free ROM, our results support the contrary as early ROM resulted in a higher complication rate [8, 16].

The operation is regarded as a quick and simple procedure in the literature [8, 15, 26]. Our average operating time was 44 minutes with an average fluoroscopy time of 5.7 minutes. The mean operating time reported in the literature ranged from 18 minutes (range, 11–48 minutes) to 62 minutes (range, 20–123 minutes) [14, 26]. Fluoroscopy time was reduced from 10.4 minutes in Group A to 4.0 minutes in Group B as a result of converting to open reduction earlier, after two failed closed attempts to advance the TEN into the lateral fracture fragment. Even though the rate of open reduction was higher in Group A (60%) than in Group B (48%), the fluoroscopy time was reduced in Group B by limiting the attempts for closed reduction to two. Jubel et al. [6] reported an average fluoroscopy time of 3.5 minutes (range, 0.2–7.4 minutes) in 12 patients with a Type A fracture (five of 12 open reduction), and Müller et al. [16] reported an average fluoroscopy time of 3 minutes (range, 0.2–6 minutes, 56%

open reduction). These findings are comparable with the results of our second patient group. As a minimally invasive method, titanium elastic nailing causes considerably less damage to soft tissue than plate osteosynthesis, with nonunion rates of 0% to 2.6% for titanium elastic nailing and 3.2% for plate osteosynthesis [1, 8, 10, 16, 26].

The results of the ASES and DASH scores are comparable to those reported in the literature for intramedullary nails [7, 24] and plating [1, 22], representing a normal shoulder function. The hospital stay for isolated clavicular fractures was 2.4 days (range, 1–5 days). As the hospital is paid according to the length of stay and there are patients with private insurance in the Swiss health system, our hospital stay was probably longer than it would have been in other health systems.

Our data suggest the complication rate using a TEN in combination with an end cap can be reduced by cautious intraoperative manual advancement of the TEN with intraoperative oblique radiographs to rule out lateral perforation as technical errors and by limiting postoperative ROM to 90°. The resulting total complication rate was 17% (10% major), which is comparable to other TEN studies (Table 1). This procedure represents a treatment option for select clavicular midshaft fractures comparable to the current gold standard of plate osteosynthesis [1, 7, 27].

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