



Elastic stable intramedullary nailing for midclavicular fractures in athletes : Indications, technical pitfalls and early results

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This 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 1.7 mm. Overall, elastic stable intramedullary nailing provided good restoration of the length of the clavicle and allowed immediate active mobilisation with early return to normal activity. Functional results were excellent.

Keywords : clavicle fractures ; intramedullary nailing.

sling or figure-of-eight bandage for external fixation. For open fractures, imminent skin perforation, neurovascular involvement, floating shoulder or in combination with multiple ipsilateral rib fractures, open reduction and plating is generally accepted (19).

While fracture healing and functional outcome is generally good for nonoperatively treated midclavicular fractures, a poor cosmetic result due to shortening and angulation is not uncommon (17). Non-unions occur in an average of 5% (19). Furthermore decreased shoulder function due to clavicular shortening of more than 1-2 cm after nonoperative fracture management has been reported (5, 12). Whereas a mild decrease in shoulder function is easily tolerated by most patients, restoration of the clavicle length and early return to full activity with unimpaired function is of great importance for athletes, either professional or amateur.

As nonoperative treatment is successful in most cases for this fracture, relevant clinical benefit may

INTRODUCTION

Fracture of the clavicle is a frequently seen injury which represents about 10-15% of all fractures in adults (8). It is among the most common injuries seen in sports (17). In most cases a fall with a direct trauma causes the clavicle to fracture. About 80% of all clavicular fractures involve the middle third of the bone (17). Standard treatment for this fracture pattern is nonoperative, using an arm

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be limited to a selected group of patients with a high demand on shoulder function. Elastic stable intramedullary nailing (ESIN) 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.

PATIENTS AND METHODS

This prospective case series was initiated in September 2002. Patients were recruited according to particular inclusion and exclusion criteria. Informed consent was obtained. Only isolated closed fractures of the midclavicle (OTA 06-A/B) with a clavicular shortening of at least 1 cm and/or lack of interfragmentary contact were included. Only athletic patients (amateur and professional, 16-50 years) for whom impairment of shoulder function would interfere with their activities were accepted for the study. Multiple injured patients and complicated midclavicular fractures (e.g. open fracture, comminuted fracture (OTA 06-C), neurovascular involvement or floating shoulder) were excluded. Radiographs of the fractured clavicle were obtained in anteroposterior and 45° cephalic tilt views. No additional imaging for the assessment of the clavicle was performed.

Operation time, intraoperative technical problems, local complications and functional outcome were analysed. The patients were encouraged to use their shoulder without restriction immediately after surgery. Only contact sports were restricted for 6 weeks. Standard analgesia was given (Ibuprofen 500 mg and Tramadol 50 mg) when required. Clinical examinations and radiological studies were performed on days 7 and 42, at 3 and 6 months and after hardware removal. Clavicular length was clinically measured when bony consolidation was evident (distance from the centre of the jugular fossa to the lateral tip of the acromion) and compared with the contralateral side. Functional outcome was assessed using the Constant shoulder score (2). Hardware removal was performed once bony consolidation was evident or later according to the patient's preference.

Surgical procedure

The intervention was performed under general anaesthesia. Standard antibiotic single shot prophylaxis (Cefuroxime 1.5 g iv.) was given. The patient was placed on a radiolucent operating table in the supine position. A

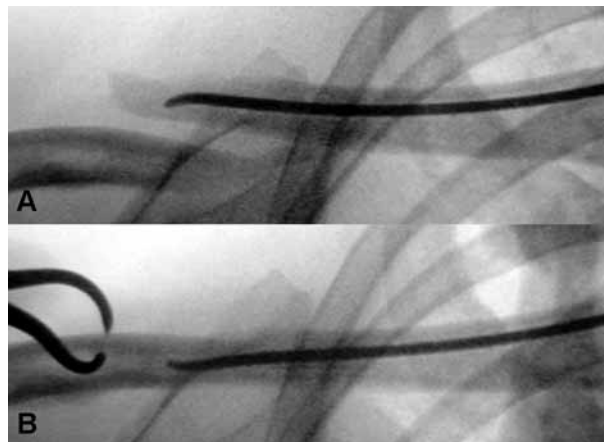


Fig. 1. — Intraoperative fluoroscopy (anteroposterior views). **A.** The Ti nail is advanced to the fracture site under fluoroscopic guidance. Note the grade of displacement of this simple transverse fracture (OTA 06-A3). **B.** Reduction is facilitated using a small reduction forceps which is applied percutaneously to the lateral fragment. The fracture can now easily be aligned and the Ti nail further introduced into the lateral end of the clavicle.

towel roll was placed between the scapulae to provide extension of the shoulder girdle. It is important to scrub the whole ipsilateral upper extremity to allow free manipulation of shoulder and arm during the procedure. A single imagine intensifier was used for the procedure. A short skin incision of about 1cm was made just lateral to the sternoclavicular joint centred above the medial end of the clavicle. The medullary cavity of the clavicle was opened using an awl about 1cm lateral to the sternoclavicular joint. The awl was pointed laterally in-line with the clavicle and angled at about 30° to the coronal plane. Care was taken not to perforate the dorsal cortex in order to avoid major complications. Once the medullary cavity was opened, a preselected TEN® (Titanium Elastic Nail, Stratec Medical, Oberdorf, Switzerland) was carefully inserted. The implanted nails had diameters between 2.0 and 3.0 mm according to the patient's dimensions. No reaming was necessary. The nail was fixed in a universal chuck with a T handle and advanced with oscillating movements. Once the Ti nail reached the fracture site (fig 1), closed reduction by direct pressure on the fragments combined with manipulation of the arm was performed. Usually reduction was facilitated when a small pointed reduction forceps was applied percutaneously to the lateral fragment. The fracture was bridged using the rounded and angled tip to guide the Ti nail into the lateral fragment. To determine

Table I. — The various sports practiced by our patients
All sports are listed. Several sports per patient are possible

	no
Cycling	3
Mountain Biking / Downhill	3
Snowboarding	2
Skiing	2
Soccer	2
Running	2
Motocross	1
Mountain Climbing	1
Gymnastics	1
Martial Arts	1
Dancing	1

the exact position of the Ti nail, fluoroscopy with true perpendicular views is crucial. In some cases closed reduction may not be accomplished. In these cases a short incision directly over the fracture site (2 cm) with minimal dissection is suggested to reduce the fracture. The TEN[®] was then pushed into the distal part of the clavicle close to its extremity. Care was taken to avoid perforation of the dorsolateral cortex of the lateral clavicle, particularly when a hammer was used. The protruding medial end of the nail was left out of the cortex and shortened close to its entry point into the bone followed by wound closure.

RESULTS

A total of 14 patients (12 men, 2 female) qualified for the study according to the inclusion criteria between 09/2002 and 07/2004. No potential candidate refused to enter the study by preferring non-operative treatment. Mean age was 28 years (range : 16 to 40). The mechanism of injury was a direct trauma to the shoulder in 13 patients, 1 patient fell on his extended arm. Ten fractures were caused by road traffic accidents (1 in a car driver, 6 in motorcyclists and 3 in cyclists) and 4 by sports injuries (Soccer (n = 1), Mountain biking (n = 2), Dancing (n = 1)). All patients were amateur athletes practising sports at least twice a week (table I). The fractures were graded according to the Orthopaedic Trauma Association classification (OTA). There were 1 06-A1, 4 06-A2 and 3 06-A3 fractures in our series. Wedge fractures were found in 6 patients (3 06-B2 and 3 06-B3 fractures).

The operation was performed 6 days (1-26 days) after trauma. All procedures were performed by at least 1 of the 3 participating surgeons, all experienced in the operative treatment of clavicular fractures and familiar with the ESIN technique at other body locations. Only Ti nail diameters of 2.0 (n = 1), 2.5 (n = 8) and 3.0 mm (n = 5) were used. Closed reduction was possible in 7 cases. A short incision of about 2 cm above the fracture site was necessary to obtain fracture reduction in 7 patients. Mean operation time was 62 minutes (range : 20 to 123). Operation time was much shorter when closed reduction was successful compared with the open technique (39 minutes (range : 20 to 60) vs. 84 minutes (range : 37 to 123)). No correlation was found between reduction technique and fracture classification. Open reduction was necessary in 4 OTA 06-A fractures. For OTA 06-B fractures 3 closed and 3 open reductions were performed. When the operation was delayed for more than 7 days closed reduction was never achieved suggesting that patients benefit from an early intervention with better chances for successful closed reduction.

In one case the dorsolateral cortex was perforated when the TEN[®] was advanced to the lateral end of the clavicle using a hammer with force. As this problem was realised during the procedure the Ti nail was withdrawn a few centimetres and repositioned. If unnoticed it could lead to implant migration with skin perforation and secondary fracture displacement. We do not recommend using a hammer anymore. A smaller implant should be chosen if it is not possible to advance the Ti nail by oscillating movements only. No metal fatigue failure was observed with either size of implant. No other intraoperative complication occurred. Hospital stay was 1.2 days (range : 1 to 3). Twelve patients were treated as day cases.

Postoperatively, 1 patient was lost to regular follow-up as he left the country shortly after the procedure. He presented in outpatient clinic 2 years after surgery free of complaints with a Constant score of 100. Proposed hardware removal was refused by the patient. All other patients could be followed according to the study protocol. Mean follow-up was 17 months (range : 12 to 24). No

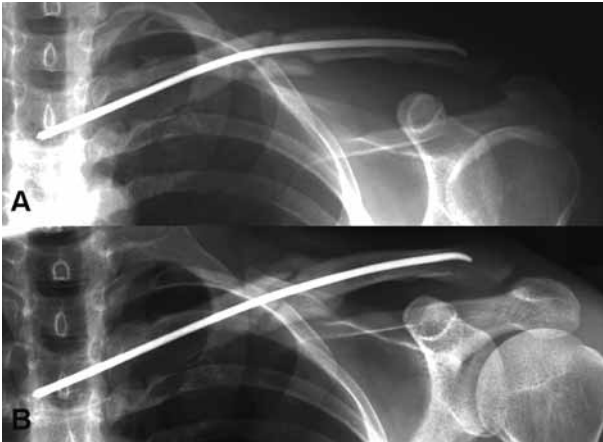


Fig. 2. — Radiographs (anteroposterior view) demonstrate progressive fracture healing (OTA 06-B2) with restored clavicular length. **A.** 7 days postoperatively ; **B.** 6 weeks postoperatively.

infection or migration of the Ti nail was observed. All fractures healed, no delayed or non-union was observed (fig 2). Time to healing was 7.7 weeks (range : 6 to 12) determined by visible osseous callus formation on the radiographs. Clavicular shortening was 1.7 mm (range : 0 to 7) compared with the contralateral side measured after fracture healing. Hardware removal was performed electively in 11 patients within 18 to 56 weeks after implantation (mean : 29 weeks) as day cases.

In one patient, secondary fracture displacement with clavicular shortening of 5 mm was observed 6 weeks postoperatively (fig 3). Subsequently the Ti nail was removed 7 weeks after implantation. As radiographs showed good bony contact of the fragments with callus formation at that time the secondary fracture displacement was treated nonoperatively. Retrospective analysis of this procedure revealed an unnoticed technical error. Closed reduction and insertion of the Ti nail into the medullary cavity of the lateral fragment is routinely performed under fluoroscopic guidance. As fluoroscopic images were only obtained in the standard anteroposterior- and 45° cephalic tilt views, in this particular case instead of true perpendicular views, the exact position of the nail was misjudged. Consequently secondary fracture displacement

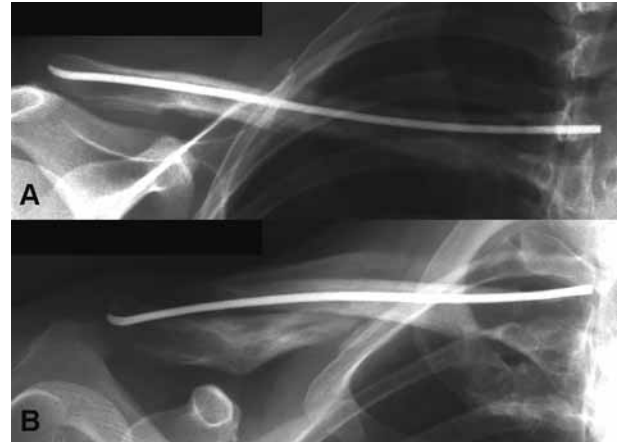


Fig. 3. — Radiographs (**A.** Anteroposterior view, **B.** 45° cephalic tilt view) taken 6 weeks after ESIN. Secondary fracture displacement occurred due to a technical mistake which remained unnoticed intraoperatively. Note the extraosseous position of the nail in relation to the lateral clavicular fragment (OTA 06-A2).

with clavicular shortening developed since the lateral fragment was missed by the Ti nail.

In another patient, the TEN® had to be removed prematurely (11 weeks) after skin perforation of the protruding medial end due to a direct hit during a soccer game. After hardware removal the patient continued to use his shoulder without restrictions or complaints. Three months later radiographs showed complete fracture consolidation without secondary displacement.

Two patients complained about skin irritation above the ipsilateral sternoclavicular joint. The protruding medial end of the TEN® was shortened under local anaesthesia and the skin irritation disappeared within days. This problem was only observed in the first half of our series. After appreciating its cause, the medial end of the nail was kept shorter and skin irritation was no longer an issue.

The Constant shoulder score averaged 81 (range : 37 to 96) after 7 days. Mean Constant shoulder score was 96 (range : 85 to 100) after 6 weeks. After 6 months and after hardware removal, all patients (n = 13) presented with basically normal shoulder function (mean : 98, range : 93 to 100). Until the date of the last clinical follow-up (mean : 17 months, range : 12 to 24) no



Fig. 4. — Free range of motion of the affected shoulder is encouraged following ESIN of the clavicle. This patient presented with symmetrical ROM and a Constant shoulder score of 96 less than 24 hours postoperatively.

refracture was observed. All patients returned to their activities and sports within four weeks after the procedure (fig 4).

DISCUSSION

Simple closed fracture of the midthird clavicle is a frequent injury and mostly treated nonoperatively. Although fracture healing and functional outcome is usually satisfactory (3), significant shortening with mal-union or non-union is described in the literature (7, 21, 22). Whereas some authors report good functional results in patients with clavicular shortening (16), Matis *et al* (12) found an impaired shoulder function in half of their patients with a shortening of 1cm and in 100% when shortening was 2 cm. Hill *et al* (5) reported a clear correlation of non-unions (15%) with clavicular shortening of more than 2 cm. They found unsatisfactory results in 31% of completely displaced midclavicular fractures after nonoperative treatment. Beside non-union residual persistent pain, brachial plexus irritation and poor cosmetic results were observed (13). According to Jupiter and Leffert (7), the initial displacement is one of the most predisposing factors in the development of non-unions. Furthermore nonoperatively treated clavicular fractures cause pain, discomfort and disability which are often not

adequately appreciated by the treating physician (18).

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 nonoperative management.

Open reduction with plate fixation is the operative standard treatment for clavicular shaft fractures (21). Potential complications include deep infection, injury to the subclavian vessels, screw loosening with implant failure, non-union and refracture after hardware removal. Bostman *et al* (1) reported a complication rate of 23% following plate fixation. The cosmetic result is frequently considered unsatisfactory caused by an inevitable and often hypertrophic scar. Due to these problems nonoperative treatment of uncomplicated midclavicular fractures is still favoured by most surgeons.

In contrast ESIN as a 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 half of the interventions closed reduction of the fracture is successful, which provides the best conditions for undisturbed fracture healing. Even when open reduction can not 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 postoperative instructions for the patients include no restrictions regarding range of motion the level of activity is determined only by pain and the patient's motivation for an early resumption of full shoulder function. Despite this rather aggressive postoperative regimen we observed neither implant failure nor migration. We only documented one case with secondary fracture displacement. This failure was clearly the result of the surgeon's misjudgement and could not be attributed to the operation technique itself. All other fractures healed correctly resulting in a symmetrical shoulder girdle.

Resumption of training with full function was achieved by all patients within 4 weeks postoperatively.

Intramedullary fixation of clavicular shaft fractures is not a new idea ; it dates back to Lambotte at the beginning of the last century. Murray (14) published his technique of intramedullary Kirschner wire fixation in 1940. Since then, numerous technical variations have been published (9, 10, 15, 20). Implant migration with fatal complications, implant failure and mal- and non-unions have been described in the literature (4, 19). Due to the complication rate which exceeds the problems of non-operative management, all these techniques have never found general acceptance.

In contrast to Kirschner wire fixation, ESIN is a truly intramedullary stabilisation technique. The flexible Ti nail is firmly anchored in the S-shaped clavicle according to the principles described by Ligier *et al* (11). The largest series of ESIN for mid-clavicular fractures so far was published by Jubel *et al* (6) in 2002. In their case series 65 midclavicular fractures were stabilised applying the ESIN technique. Patient age ranged from 13 to 74 years. Unlike our study, they also included patients with neurovascular involvement, multiple injuries and floating shoulders. No major complications were observed. Only one non-union in a polytrauma patient and one secondary shortening of 1.5 cm in a multifragment fracture were seen.

Intramedullary advancement of the blunt Ti nail makes an injury to the neurovascular structures very unlikely. No such complication has been described in the literature using this technique. Other fatal complications like implant migration into the chest cavity have not been observed either. Migration in a lateral direction would cause damage to the acromioclavicular joint whereas migration medially would simply lead to skin perforation. We observed 1 case of skin perforation, but this complication was caused by a direct blow to the medial end of the Ti nail which lies directly underneath the skin, and it was not related to implant migration.

Despite our enthusiasm for ESIN in midclavicular fractures, we remain restrictive regarding its indications. In our opinion nonoperative manage-

ment is still the gold standard which provides good results in most cases, leaving ESIN 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. For fractures with one intermediary fragment, meticulous analysis of the fracture is crucial. ESIN can be safely performed if the two main fragments have osseous contact after reduction, ensuring correct clavicular length with the Ti nail in place. If the intermediary fragment involves the entire clavicular circumference it is mandatory to string this fragment as well in order to prevent secondary shortening and implant perforation through the skin. ESIN can certainly not be recommended for comminuted fractures as the above principles do not apply in these fracture patterns.

Further studies are necessary comparing ESIN with nonoperative treatment. The cost needs to be justified against the potential patient risk and statistically significant improvements need to be demonstrated for different patient groups.

In selected cases ESIN is a safe and effective method for midclavicular fractures with a 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.

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