



# Comparison between locked intramedullary nailing and anatomical locking plating in the treatment of displaced clavicular midshaft fractures

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**Objective:** The aim of this study was to compare the results of expandable flexible locked intramedullary nailing and anatomical locking plating in clavicular midshaft fractures.

**Methods:** Thirty-three patients (21 male, 12 female) who had displaced fractures and at least 2-cm shortening fixed with expandable flexible locked intramedullary nailing and 38 patients (24 male, 14 female) who underwent anatomical locking plating were recruited. Duration of surgery, incision size, duration of hospital stay, union time, and early and late complications were compared between the groups. Functional results were compared with Constant scoring system.

**Results:** Mean duration of surgery was 32.4±9.1 minutes (range: 20–42 minutes) in the nailing group and 54.1±11.9 minutes (range: 42–70 minutes) in the plating group. The incision was 4.1±0.9 cm (range: 3–5 cm) in the nailing group and 9.5±1.7 cm (range: 7–12 cm) in the plating group. Mean union time was 14.8 weeks (range: 10–24 weeks) in the nailing group and 21.3 weeks (range: 12–33 weeks) in the plating group. Mean duration of hospital stay was 3.6±1.1 days (range: 2–4 days) in the plating group, whereas it was 2.3±0.8 days (range: 1–3 days) in the nailing group. In the plating group, an average of 2.7-mm (range: 0–7 mm) shortening was determined in the clavicles that underwent surgery as compared to the intact clavicles, whereas shortening was 2.3 mm (range: 0–6 mm) in the nailing group.

**Conclusion:** Expandable flexible locked intramedullary nailing can provide more successful outcomes than plating in displaced clavicular midshaft fractures, due to advantages such as shorter union time, lower complication rate, and better cosmetic outcomes.

**Keywords:** Clavicle; midshaft fractures; nailing; plating.

**Level of Evidence:** Level III, Therapeutic Study.

Most clavicular fractures occur in the mid-third of the bone, with more than half being displaced. Although conservative methods are standard in the treatment of such fractures, in recent years, consensus has emerged

that applying surgical methods to displaced fractures provides better outcomes, due to reasons such as high rates of nonunion, malunion, and shortening in conservative treatments, as well as reduced strength and

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functions in the upper extremities in patients with demanding physical requirements.<sup>[1-9]</sup> Surgical treatment is also recommended for fractures that have been 100% displaced and have shortening of 2 cm.<sup>[10]</sup>

Unfavorable outcomes such as nonunion, permanent shoulder pain, loss of strength, and poor cosmetic appearance have led to a shift in treatment from conservative therapy to surgery.<sup>[11,12]</sup>

The most appropriate surgical approach for displaced clavicular midshaft fractures is debatable.<sup>[2]</sup> Although plating procedure, which is now recognized as the standard, is the most frequently performed method,<sup>[13,14]</sup> intramedullary nailing is becoming increasingly widespread, as it is a minimally invasive method that has a low complication rate and high level of patient satisfaction.<sup>[1,15,16]</sup>

In the present study, the results of expandable flexible locked intramedullary nailing (Sonoma Orthopedics, Buffalo Grove, IL, USA) and anatomical locking plating were evaluated in adult cases of clavicular midshaft fractures.

## Patients and methods

The present study retrospectively evaluated the results of 71 patients who underwent surgery for clavicular midshaft fracture with 100% displacement and at least 2-cm shortening between November 2010 and March 2013 (Figure 1). Cases with open fracture, pathological fracture, concurrent vascular and/or neurological injury, and another injury in the shoulder line in addition to clavicular fracture were excluded from the study.

In the intramedullary nailing group, a total of 33 patients (21 male, 12 female) underwent fixation with expandable flexible locked intramedullary nailing (Figure 2). Mean age of patients at time of surgery was  $33.5 \pm 4.9$  years (range: 17–57 years). Mechanism of injury was direct fall in 20 cases (60.6%), traffic accident in 9 cases (27.2%), and sports injury in 4 cases (12.2%).

A total of 38 patients (24 male, 14 female) underwent anatomical locking plating (Figure 3). Mean age of patients at time of surgery was  $38.4 \pm 5.8$  years (range: 19–65 years). Mechanism of injury was direct fall in 27 cases (71.1%), traffic accident in 9 cases (23.7%), and direct trauma in 2 cases (5.2%).

Following examination, standard anteroposterior radiographs of the shoulder were obtained. Informed consent was obtained from all patients prior to intervention, which was performed within 24 hours following injury. Antibiotic prophylaxis was administered with first-generation cephalosporin (cefazolin), and surgery was per-



**Fig. 1.** Radiological image of 100% displaced clavicular midshaft fracture with more than 2-cm shortening.



**Fig. 2.** Postoperative radiological image of a patient who underwent expandable flexible locked intramedullary nailing.



**Fig. 3.** Radiological image of a patient who underwent anatomical locking plating.

formed under general anesthesia with the patient in the beach chair position so that the injured upper extremity would be completely accessible.

In the intramedullary nailing procedure, the skin was accessed through a 2-cm incision made perpendicular to the clavicle over the fracture line (Figure 4) and dissection of the soft tissues until the fracture was reached. Subsequently, the medial aspect of the clavicle was elevated us-



**Fig. 4.** Image of the incision scar made to perform expandable flexible locked intramedullary nailing. [Color figures can be viewed in the online issue, which is available at [www.aott.org.tr](http://www.aott.org.tr)]

ing a bone clamp, and the medullary canal was prepared under fluoroscopy using the appropriate drills in the nail set. The lateral aspect of the clavicle was then elevated by bone clamp, and the medullary canal was prepared with the appropriate drills so that the clavicle would reach the exterior of the posterolateral cortex. Subsequently, a pin that was extended intramedullary through the medial margin of the lateral aspect was exposed from the posterolateral edge of the clavicle, and a skin incision was made in this region under the guidance of this pin. Following reduction of the fracture, the pin was pushed into the medial aspect, and the medulla was drilled with flexible drills over the pin. After measuring the intramedullary length of the nail, an expandable intramedullary nail with flexible lock was inserted, and medial fixation was performed under fluoroscopy guidance by opening the wings found in the medial aspect of the nail, whereas lateral fixation was performed under fluoroscopy guidance using a guided screw. It was made certain that the flexible part of the nail passed through the fracture line.

In the plating procedure, access was achieved through an incision of appropriate length in accordance with the size of plate, which was applied parallel to the Langer lines so that it would be in the center of the fracture line. The fascia and periosteum were passed through in the same direction as the clavicle. Only the soft tissues in the fracture tips were removed by precise subperiosteal dissection. The fracture tips were appropriately reduced, and the plate was placed. After temporary fixation, 3.5-mm locked cortical screws were used to complete the fixation so that there would be at least 6 cortices in the lateral and medial aspects of the fracture line. Free fragments that were suitable for fixation were fixed with lag screws. The layers were closed in strata after internal fixation was obtained.

Shoulder-arm suspension was applied to the upper extremities of all patients for 2 weeks postoperatively. Early movement with active support as much as tolerated was started on postoperative day 2. Complete movement was achieved in the second week, and patients were monitored for nonsupported active movements after the second week. Shoulder strengthening exercises were started after the sixth week. Follow-up examinations were performed at 4, 8, and 12 weeks after surgery and every 3 months thereafter. After each follow-up examination, a further shoulder examination and functional evaluation were performed by a specialist who was unaware of the patients' study history. Duration of surgery and wound size were recorded. Patients were evaluated in terms of nonunion, infection, implant failure, thoracic outlet syndrome, refracture, cosmetic problems, and duration of postoperative hospital stay. Both clavicle lengths were measured. The length was considered to be the distance between the most medial aspect on the sternal tip of the clavicle and the most lateral aspect on the acromial tip. Absence of callus tissue, pain, and pathological movement in the fracture line were evaluated as nonunion, whereas callus tissue formation at more than 24 weeks was evaluated as delayed union.<sup>[13,17]</sup> Compromised reduction, broken or bent implant, and loose screws were accepted as implant failure.<sup>[17]</sup> Functional assessment was performed in accordance with Constant shoulder scoring.<sup>[18]</sup>

Analyses were applied with Mann-Whitney U test and chi-square test using SPSS software (version 15.0, SPSS Inc., Chicago, IL, USA). A  $p$ -value of  $<0.05$  was considered statistically significant.

## Results

Mean follow-up duration was 15.3 months (range: 10–27 months) in the nailing group and 16.7 months (range: 11–30 months) in the plating group. Mean duration of surgery was  $32.4 \pm 9.1$  minutes (range: 20–42 minutes) in the nailing group and  $54.1 \pm 11.9$  minutes (range: 42–70 minutes) in the plating group. There was a significant difference between the 2 groups in terms of duration of surgery ( $p < 0.001$ ).

Fluoroscopy was used during nailing to visualize the fracture reduction and for placement of the nail. Mean fluoroscopy time in the nailing group was  $12.32 \pm 2.10$  seconds. In the plating group, fluoroscopy was applied only at the end of surgery to assess fixation, with 2 images obtained from different angles.

Incision length was significantly smaller in the nailing group ( $4.1 \pm 0.9$  cm; range: 3–5 cm) compared to the plating group ( $9.5 \pm 1.7$  cm; range: 7–12 cm) ( $p < 0.001$ ).

Union time was shorter in the nailing group (14.8 weeks; range: 10–24 weeks) compared to the plating group (21.3 weeks; range: 12–33 weeks) ( $p=0.02$ ). Nonunion was not observed in any patient. There were 2 cases of delayed union in the plating group.

The nailing group showed an additional benefit of shorter hospital stay ( $2.3\pm 0.8$  days; range: 1–3 days) compared to the plating group ( $3.6\pm 1.1$  days; range: 2–4 days) ( $p=0.034$ ).

An average 2.7-mm (range: 0–7 mm) shortening was determined in the clavicles that underwent surgical procedure compared to the intact clavicles in the plating group. The average shortening was 2.3 mm (range: 0–6 mm) in the nailing group. No significant difference was found between the operated side and the intact side or between the 2 groups in terms of shortening ( $p>0.05$ ).

Mean Constant score of patients in the sixth postoperative week was significantly better in the nailing group ( $70.2\pm 8.6$ ) than in the plating group ( $63.1\pm 11.2$ ) ( $p=0.03$ ). No significant difference was determined between the 2 groups in terms of 6-month Constant scores (plating group:  $90.2\pm 7.3$ ; nailing group:  $94.3\pm 5.3$ ;  $p>0.05$ ) and scores at final follow-up.

In the nailing group, 1 patient (3.03%) did not achieve cosmetic satisfaction. Two patients (6.06%) had mild shoulder pain while lying in the lateral recumbent position. No infection or neurovascular complication was encountered in any patient. Pain over the incision scar, implant irritation, migration, or palpation was not observed in any patient. Removal of the implant was requested by 1 patient (3.03%). Implant failure was encountered after the second postoperative month in 1 patient, where it was observed that the elastic part of the implant had been left in the fracture line and had broken at the junction of elastic and rigid parts.

In the plating group, 14 patients (36.8%) expressed dissatisfaction with the cosmetic outcome. Eight patients (21.05%) had mild shoulder pain while lying in the lateral recumbent position. The implant was palpable in 5 patients (13.1%). Pain over the scar was present in 11 patients (28.9%). Superficial infection, which improved with wound care and antibiotic therapy, was encountered in 2 patients (5.2%). No neurovascular complication was observed in any patient. Removal of the implant was requested by 15 patients (39.4%), and implant failure was observed in 1 patient (2.6%) in the third postoperative month.

Cosmetic outcomes were better in the nailing group ( $p<0.001$ ).

## Discussion

Complications such as movement restriction and shoulder asymmetry can occur due to impaired anatomical relationships around the shoulder after possible malunion following clavicle fractures.<sup>[19,20]</sup> Although clavicular third midshaft fractures can be treated by extra-surgical methods, studies have revealed numerous disadvantages of conservative treatment.<sup>[2,10,21,22]</sup> Therefore, surgical therapy has become the preferred method for treatment of clavicular third midshaft fractures.<sup>[2,10,23]</sup>

Plate-screw is the standard surgical technique for clavicular third midshaft fractures.<sup>[14,15]</sup> It has been reported that fixation using a plate provides more rigid biomechanical stabilization and enables earlier rehabilitation. The absence of need for removal of the implant is also considered an advantage.<sup>[2]</sup> However, a substantial amount of soft tissue needs to be exposed to perform the plate-screw procedure. This may lead to impaired blood circulation and may prevent healing. Moreover, complications such as hypertrophic wound scar, nonunion, loose implant, refracture, and irritation have been reported. In patients who underwent plating, complication rates of 43% have been reported—with major complication rates of 15%—and rate of implant removal has been reported from 0% to 74%.<sup>[2,10]</sup>

There are various products such as Knowles pin, Rockwood pin, elastic stable intramedullary nail, and titanium elastic nail for intramedullary fixation. Although intramedullary fixation has many advantages—including preservation of soft tissue, preservation of the periosteum and vascular structures, low incidence of infection, better callus formation, minimal nonunion rates, and rapid improvement in shoulder functions—it also has the disadvantages of technically difficult implementation, migration of the implant, need for open reduction in approximately 50% of cases, inability to produce compression on the fracture line, and need for removal of the implant.<sup>[2,10]</sup> However, it has been reported that these complications are primarily a result of the implant design and that complications could be reduced by the new generation of implants.<sup>[10]</sup> Another disadvantage of intramedullary fixation is the need for fluoroscopy.<sup>[24]</sup> While, to the best of our knowledge, there are no studies in the literature comparing intramedullary fixation with extramedullary fixation in terms of fluoroscopy times, in the current study—as only 2 images were taken in the plating group and mean fluoroscopy time of the nailing group was  $12.32\pm 2.10$  seconds—the use of fluoroscopy can be considered disadvantage.

In the present study, expandable flexible lock intramedullary nailing was applied to 33 patients. No nail

migration or bending, implant-related irritation, medial protrusion, infection, nonunion, malunion, hypertrophic scar, or shortening was observed in any patient. Only 1 patient requested removal of the implant, and no problem concerning implant removal was encountered. Since nail migration did not occur, no implant removal was required in any of the other patients. Implant breakage was encountered due to technical error in 1 of the earliest cases. Similarly, King et al. used Sonoma CRx intramedullary device (Sonoma Orthopedics, Buffalo Grove, IL, USA) on 47 patients with clavicular fractures and reported that in 2 cases where the implant broke, 1 in the first week and 1 in the first month, the breakages occurred where the flexible and nonflexible parts joined. There were no findings of implant migration, and no irritation of the skin or soft tissue caused by the implant wings was observed.<sup>[25]</sup>

Although significant comparisons related to time to union have not been stated in the literature,<sup>[2]</sup> in a prospective study of 88 patients with midclavicular fracture where Knowles pinning and plate fixation were compared, Lee et al. reported no significant difference in union times.<sup>[26]</sup> In a study by Assobhi et al., plate and retrograde nailing were compared in 38 patients with midclavicular fractures, and—similar to the results of the current study—it was reported that average bone union time was significantly shorter in the retrograde titanium elastic nail group ( $5.2 \pm 1.7$  months; range: 3–9 months) than in the plate group ( $7.3 \pm 3.1$  months; range: 3–12 months).<sup>[1]</sup> Although King et al. did not define union time in the Sonoma nail group, all patients achieved union from the sixth week onwards.<sup>[9]</sup> This is a minimally invasive nailing technique which provides less soft tissue stripping than the plating technique and results in good biological fracture healing.

Ferran et al. compared plate fixation and intramedullary fixation in 32 patients with midclavicular fractures and reported no significant difference between Constant scores at 12 months postoperatively.<sup>[27]</sup> Similarly, in a study by Liu et al., 110 patients were compared, and no significant difference was reported between the 2 groups in respect to Constant scores at 18 months.<sup>[28]</sup> Böhme et al. compared 2 groups of 73 patients, also reporting no significant difference in Constant scores at 8 months.<sup>[29]</sup> In the current study, Constant scores were significantly higher in the early period in the nail fixation group (plating group:  $63.1 \pm 11.2$ ; nailing group:  $70.2 \pm 8.6$ ), thus indicating the possibility of earlier and easier rehabilitation.

Due to the anatomical structure of the clavicle, intramedullary implants must be flexible and thin enough to pass through the narrow medulla of the clavicular midshaft.<sup>[1]</sup> Therefore, despite complications such as

migration, implant failure, and shortening of more than 5 mm—which have been reported for implants used in intramedullary fixation—it has been reported that complications have been reduced and excellent cosmetic and functional outcomes have been obtained with the new generation of implants.<sup>[3,8,17,18]</sup> However, nail migration, shortening, necessity of nail removal, and other complications remain significant problems.<sup>[17,24,30–32]</sup> No comparison could be made, as there is no study in the literature investigating the same type of intramedullary nail used in the present study.

Although studies have reported that intramedullary nailing is more advantageous than plate-screw procedure in clavicular midshaft fractures,<sup>[1,2,10,17,33]</sup> plate-associated complications can be reduced by the new generation of locked plating procedures.<sup>[34]</sup>

In the present study, better outcomes were obtained with expandable flexible locked intramedullary nailing compared to plating procedure in terms of incision length, union time, duration of hospital stay, complications, cosmetic outcomes, and early-term functional outcomes. These superior outcomes might result from the nail's capacity for fixation in the lateral and medial aspects and its minimally invasive application.

As there is nail fixation from the medial and lateral aspects, migration and shortening do not develop; therefore, the nailing procedure can be easily implemented owing to its flexibility. A mini incision is adequate for the procedure without incurring substantial soft tissue cleavage. Excellent cosmetic and functional outcomes can be obtained when the procedure is performed in accordance with the method described in the present study. Although exposure of the fracture line appears to be a disadvantage, other intramedullary fixation methods also require exposure of the fracture line in at least 50% of cases; additionally, the nailing procedure does not require as much soft tissue cleavage as the plate-screw procedure.<sup>[2,24]</sup>

A limitation of the current study is that no assessment could be made regarding comminuted fractures, as none were included. It is clear that studies including such fractures are needed. Further long-term follow-up studies are required in order to investigate whether problems result from removal of the nail due to the wing formations in the medial aspect of the nail.

If there is separation or shortening, closed reduction is rarely successful in clavicular midshaft fractures, which are usually seen in young adults.<sup>[35,36]</sup> Malunion and clavicular shortening may restrict shoulder functions by leading to rotation in the glenoid fossa together

with impairment in the glenohumeral joint relationship and by enhancing anterior scapular version,<sup>[11,19,37]</sup> which may explain the trend towards surgical treatment, although the most appropriate surgical approach has not yet been identified.<sup>[2,10]</sup>

Thyagarajan et al. used clavicle pins (Rockwood Clavicle Pins, DePuy, Warsaw, IN, USA) on 17 patients with midclavicular fractures, and full union was achieved in all patients of the patient group in the eighth post-operative month. All patients were satisfied cosmetically, but no data were available regarding rate of implant removal.<sup>[10]</sup> Lee et al. used Knowles pins on 56 patients with midclavicular fractures. Full union was observed in all patients at 6 months postoperatively, and the wound incision was  $4.1 \pm 0.31$  cm. However, 12 patients reported dissatisfaction due to hardware problems; consequently, the implants were removed in these patients following union.<sup>[26]</sup> Assobhi et al. reported that after the use of titanium elastic nailing in 19 patients with midclavicular fractures, the wound incision was  $4.3 \pm 0.8$  cm (range: 3–6 cm), and it was necessary to remove the implants from 4 patients due to cosmetic dissatisfaction.<sup>[1]</sup> Frigg et al. used titanium elastic nails in 34 patients with midclavicular fractures and reported a complication rate of 70% (7 medial perforation, 7 lateral penetrations, 1 nail breakage, 1 nail dislocation, and 7 hardware irritations) and that revision surgery was necessary in 36% of patients.<sup>[38]</sup> Smekal et al. used titanium endomedullary nailing in 60 patients and reported implant breakage in 2, irritation in 5, nail migration in 7, and nail protrusion in 12. Routine nail removal was not applied to any patient.<sup>[17]</sup> Judd et al. used Hagie pins in 29 patients and reported nonunion in 1 patient and implant breakage in 9; routine nail removal was applied to 26 patients.<sup>[39]</sup>

In the current study, no union problems were experienced, similar to the previous studies made using Rockwood Clavicle Pins and Knowles pins. Incision lengths in the current study were  $4.1 \pm 0.9$  cm (range: 3–5 cm), and were similar in the Knowles pin group and the retrograde titanium elastic nail group. Cosmetic dissatisfaction was expressed by 1 patient, which, in comparison with other nail types, is a very low rate. As there was a requirement to remove the implant in only 1 patient in the present study, locked intramedullary nailing can be considered to be more advantageous than Knowles pin, retrograde titanium elastic nail, classic titanium elastic nail, and Hagie pin.

As union was successfully achieved in all patients in both the nailing and plating groups and good functional results were obtained, it should be considered that these techniques can be applied in the treatment of displaced clavicular shaft fractures with shortening.

**Conflicts of Interest:** No conflicts declared.

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