

COMPARATIVE ANALYSIS OF ANATOMICAL CLAVICLE PLATING AND TITANIUM ELASTIC INTRAMEDULLARY NAILING IN THE MANAGEMENT OF MIDSHAFT CLAVICLE FRACTURES

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Abstract

Background: Midshaft clavicle fractures are the most common type of clavicular fractures and frequently occur in young, active individuals following road traffic accidents or falls. Although conservative treatment has traditionally been the standard of care, displaced fractures are increasingly managed surgically to reduce the risk of malunion, nonunion, and functional impairment. Anatomical locking plate fixation and Titanium Elastic Nailing System (TENS) are the two most commonly employed surgical techniques, each offering distinct advantages and limitations.

Aim: To compare the clinical, radiological, and functional outcomes of anatomical clavicle plate fixation and Titanium Elastic Nailing System (TENS) fixation in the management of displaced midshaft clavicle fractures.

Materials and Methods: This prospective comparative observational study was conducted in the Department of Orthopaedics, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, Tamil Nadu, from March 2025 to February 2026. sixty adult patients with displaced midshaft clavicle fractures were included and divided into two groups of 30 patients each. Group A underwent open reduction and internal fixation using an anatomical locking clavicle plate, while Group B underwent intramedullary fixation using TENS. Patients were followed clinically and radiologically for six months. Outcome measures included operative time, intraoperative blood loss, fracture union time, functional outcome assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) score, and postoperative complications. Statistical analysis was performed using SPSS version 26.0, and a p-value <0.05 was considered statistically significant.

Results: The mean intraoperative blood loss was significantly lower in the TENS group (67.8 ± 13.65 ml) compared with the plating group (117.75 ± 19.50 ml) ($p < 0.001$). The mean operative duration was also significantly shorter in the TENS group (68.4 ± 12.70 minutes) than in the plating group (114.0 ± 20.11 minutes) ($p < 0.001$). Mean fracture union time was 7.1 ± 0.55 months in the TENS group and 7.5 ± 0.61 months in the plating group ($p = 0.03$). The mean DASH score at six months was lower in the TENS group (11.88) than in the plating group (18.70), indicating superior functional recovery. Implant prominence, hypertrophic scar, and superficial surgical site infection were more frequent following plating, whereas nail-end prominence and implant irritation were the most common complications after TENS fixation.

Conclusion: Both anatomical locking plate fixation and TENS nailing achieved excellent fracture union and satisfactory clinical outcomes in displaced midshaft clavicle fractures. However, TENS fixation was associated with reduced operative time, lower blood loss, improved cosmetic appearance, and better functional outcomes. Anatomical plate fixation remains a reliable option for fractures requiring rigid anatomical stabilization, particularly in comminuted fracture patterns.

Keywords: Midshaft clavicle fracture, Anatomical locking plate, Titanium Elastic Nailing System, TENS, Plate osteosynthesis, Functional outcome, DASH score.

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Introduction

The clavicle is an S-shaped long bone that serves as the only bony articulation between the upper limb and the axial skeleton. It plays a crucial role in maintaining the structural integrity and biomechanics of the shoulder girdle by acting as a strut between the sternum and the scapula. This unique anatomical position enables efficient transmission of forces generated during upper limb movement to the axial skeleton while preserving a wide range of shoulder motion. In addition to its biomechanical role, the clavicle provides attachment sites for several important muscles, including the sternocleidomastoid, pectoralis major, deltoid, trapezius, and subclavius. It also protects vital neurovascular structures such as the brachial plexus and subclavian vessels that traverse beneath it, contributing significantly to both upper limb function and cosmetic appearance.[1,2]

Clavicle fractures are among the most common skeletal injuries, accounting for approximately 2–5% of all fractures and nearly 35–45% of injuries involving the shoulder girdle. The incidence is highest in young, active individuals due to high-energy trauma such as road traffic accidents and sports-related injuries, while elderly patients often sustain fractures following low-energy falls associated with osteoporosis. Approximately 80% of clavicular fractures occur in the middle third (midshaft), making it the most frequently affected region because of its narrow cross-sectional anatomy, absence of muscular reinforcement, and exposure to significant bending forces during trauma.[3,4]

The management of midshaft clavicle fractures has undergone a remarkable evolution over the past two decades. Historically, the majority of these fractures were managed conservatively using arm slings, clavicular braces, or figure-of-eight bandages, based on the belief that clavicular fractures invariably united with satisfactory functional outcomes. However, more recent evidence has challenged this concept by demonstrating higher rates of symptomatic malunion, nonunion, persistent pain, shoulder weakness, reduced endurance, and patient dissatisfaction, particularly in displaced and comminuted fractures. These findings have shifted the treatment paradigm toward operative stabilization in selected patients to achieve anatomical reduction, restore clavicular length, and facilitate early mobilization.[5,6]

Surgical fixation has become the preferred treatment for displaced midshaft clavicle fractures, especially in young, active individuals with significant shortening, comminution, skin compromise, floating shoulder injuries, or associated neurovascular injuries. Internal fixation offers several advantages, including restoration of normal clavicular alignment, improved biomechanical stability, reduced risk of nonunion, earlier return to daily activities, and superior functional outcomes. The two principal surgical techniques currently employed are plate osteosynthesis and intramedullary fixation, each possessing distinct biomechanical characteristics, indications, advantages, and limitations.[7]

Anatomical pre-contoured locking clavicle plates have gained widespread acceptance because they conform closely to the natural curvature of the clavicle and provide rigid fixation with excellent rotational stability. Plate fixation allows accurate reduction under direct visualization, making it particularly suitable for comminuted fractures and fractures with marked displacement. Stable fixation permits early shoulder mobilization and predictable fracture union. Nevertheless, plate fixation is associated with certain disadvantages, including larger surgical exposure, soft tissue stripping, increased blood loss, implant prominence, wound-related complications, hardware irritation, and the possibility of secondary implant removal due to patient discomfort.[8,9]

Titanium Elastic Nailing System (TENS) represents a minimally invasive alternative for selected midshaft clavicle fractures. The technique involves insertion of a flexible titanium nail into the medullary canal through a small incision, thereby preserving fracture biology and minimizing periosteal disruption. TENS fixation offers several potential benefits, including shorter operative time, smaller surgical scars, reduced blood loss, improved cosmetic results, less postoperative pain, and faster rehabilitation. However, this method may be technically demanding and is associated with complications such as implant migration, medial or lateral nail prominence, skin irritation, telescoping of fracture fragments, and reduced effectiveness in highly comminuted fracture patterns.[10,11]

Despite the widespread use of both fixation techniques, the optimal surgical modality for displaced midshaft clavicle fractures remains a matter of ongoing debate. Numerous clinical studies have

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compared plate fixation and intramedullary nailing with respect to fracture union, operative duration, blood loss, postoperative pain, functional recovery, complication rates, cosmetic satisfaction, and need for implant removal. While anatomical plating offers superior mechanical stability, particularly in comminuted fractures, TENS nailing provides the advantages of minimally invasive surgery with excellent cosmetic outcomes in carefully selected patients. Differences in study populations, implant designs, fracture characteristics, and outcome measures have contributed to varying conclusions across the literature, highlighting the need for further comparative evaluation.[9-12]

Therefore, the present study aims to compare the clinical, radiological, and functional outcomes of anatomical clavicle plate fixation and Titanium Elastic Nailing System (TENS) fixation in patients with displaced midshaft clavicle fractures. The findings of this study are expected to provide valuable evidence regarding fracture union, shoulder function, complications, and overall treatment effectiveness, thereby assisting orthopedic surgeons in selecting the most appropriate fixation method for individual patients.

Materials and Methodology

The present study was conducted in the Department of Orthopaedics, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, Tamil Nadu, India. This was a prospective comparative observational study carried out over a period of 12 months from March 2025 to February 2026. The study included adult patients presenting with displaced midshaft clavicle fractures who satisfied the predefined inclusion and exclusion criteria. Ethical approval was obtained from the Institutional Ethics Committee before commencement of the study, and written informed consent was obtained from all participants prior to enrollment.

Patients aged 18–65 years with acute displaced midshaft clavicle fractures (Robinson Type 2B) presenting within two weeks of injury and planned for operative management were included in the study. Patients with pathological fractures, open clavicle fractures, fractures involving the medial or lateral end of the clavicle, associated neurovascular injuries requiring vascular repair, previous clavicle surgery, polytrauma patients with life-threatening injuries, and patients unwilling to participate or comply with follow-up were excluded.

Eligible patients were allocated into two treatment groups based on the surgical procedure selected by the treating orthopedic surgeon randomly. Group A underwent open reduction and internal fixation using a pre-contoured anatomical clavicle locking plate, while Group B underwent closed or minimally invasive intramedullary fixation using a Titanium Elastic Nailing System (TENS). All procedures were performed by experienced orthopedic surgeons following standard operative techniques. Postoperatively, all patients received a uniform rehabilitation protocol consisting of arm sling immobilization, analgesia, early pendulum exercises, gradual active range-of-motion exercises, and progressive strengthening according to fracture healing and patient tolerance.

Patient demographic characteristics including age, sex, mechanism of injury, side involved, and fracture classification were recorded. Intraoperative variables such as duration of surgery, intraoperative blood loss, and length of hospital stay were documented. Patients were followed at 2 weeks, 6 weeks, 3 months, and 6 months after surgery. Clinical evaluation included assessment of pain, range of shoulder movements, complications, and return to routine activities. Radiological assessment was performed using standard anteroposterior radiographs to evaluate fracture reduction and time to radiological union. Functional outcome was assessed using the Constant-Murley Shoulder Score and the Disabilities of the Arm, Shoulder and Hand (DASH) score at each follow-up visit.

The primary outcome measures were fracture union rate, time to radiological union, and functional outcome scores. Secondary outcome measures included operative time, blood loss, cosmetic satisfaction, implant-related complications, infection, implant failure, nonunion, malunion, hardware prominence, and requirement for implant removal.

The collected data were entered into Microsoft Excel and analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean $\pm$ standard deviation (SD), while categorical variables were presented as frequencies and percentages. The independent Student's t-test was used to compare continuous variables between the two groups, whereas the Chi-square test or Fisher's exact test was used for categorical variables as appropriate. A p-value of less than 0.05 was considered statistically significant.

Result:

Table 1 illustrates the distribution of patients across

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age groups in the TENS and plating groups, as well as the total population. Each age category, ranging from 20-30 to 51-60 years, displays the number of patients along with the corresponding percentage within their respective treatment groups and the total sample. The total number of patients in each treatment group and overall is provided, alongside the mean age $\pm$ standard deviation for both groups. These findings offer a comprehensive overview of the age distribution among patients undergoing TENS and plating procedures, facilitating comparisons between the groups and providing insight into the demographics of the studied population.

Table 1: Distribution of patients

Age in Years	TENS GROUP	PLATING GROUP	Total
20-30	12(40%)	10(33.3%)	22(36.7%)
31-40	12(40%)	12(40%)	24(40%)
41-50	2(6.7%)	8(26.7%)	10(16.7%)
51-60	4(13.3%)	0(0%)	4(6.7%)
Total	30(100%)	30(100%)	60(100%)
Mean $\pm$ SD	33.33 $\pm$ 11.43	35.53 $\pm$ 8.55	34.43 $\pm$ 9.98

Table 2 presents the gender distribution within the TENS and plating groups, as well as the total sample. The table outlines the number of female and male patients along with their corresponding percentages within each treatment group and the total population. In both the TENS and plating groups, 26.7% of patients were female, while 73.3% were male. The total number of patients in each treatment group and overall is also provided, ensuring a clear representation of gender distribution across the studied population.

Table 2: Gender distribution

Gender	TENS GROUP	PLATING GROUP	Total
Female	8(26.7%)	8(26.7%)	16(26.7%)
Male	22(73.3%)	22(73.3%)	44(73.3%)
Total	30(100%)	30(100%)	60(100%)

Table 3 presents the frequency distribution of modes of injury within the TENS and plating

groups, as well as the total sample. The table categorizes injuries into different modes such as assault, fall from height, fall on outstretched hand (FOOSH), road traffic accident (RTA), and sports-related injuries. The number of patients and their corresponding percentages within each treatment group and across both groups are provided. In the TENS group, the most common mode of injury was RTA, accounting for 60% of cases, followed by fall from height and sports injuries, each at 26.7%. In contrast, the plating group had RTA as the most prevalent mode of injury as well, constituting 46.7% of cases, followed by fall from height at 13.3%. Notably, FOOSH injuries were only observed in the plating group, comprising 20% of cases. This table offers insight into the distribution of injury mechanisms among patients undergoing different treatment modalities, aiding in understanding the

patterns of trauma in the studied population.

Table 3: Mode of Injury- frequency distribution in two groups

Mode of Injury	TENS GROUP	PLATING GROUP	Total
ASSULT	2(6.7%)	2(6.7%)	4(6.7%)
FALL FROM HEIGHT	8(26.7%)	4(13.3%)	12(20%)
FOOSH	0(0%)	6(20%)	6(10%)
RTA	18(60%)	14(46.7%)	32(53.3%)
SPORTS	2(6.7%)	4(13.3%)	6(10%)
Total	30(100%)	30(100%)	60(100%)

Table 4 presents the frequency distribution of the side of injury within the TENS and plating groups, as well as the total sample. The table categorizes injuries based on whether they occurred on the dominant or non-dominant side. For each treatment group and overall, the number of patients and their corresponding percentages are provided. In the TENS group, 60% of injuries were on the dominant side, while 40% were on the non-dominant side. In contrast, the plating group had a higher proportion of injuries on the dominant side, accounting for 80% of cases, with only 20% occurring on the non-dominant side. Overall, the majority of injuries across both groups were on the dominant side, constituting 70% of cases, while 30% occurred on the non-dominant side. This table offers insights into the distribution of injuries based on the dominant and non-dominant sides, providing valuable

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information for understanding injury patterns within the studied population.

Table 4: Side of Injury- frequency distribution in two groups

Side of Injury	TENS GROUP	PLATING GROUP	Total
Dominant	18(60%)	24(80%)	42(70%)
Non dominant	12(40%)	6(20%)	18(30%)
Total	30(100%)	30(100%)	60(100%)

Table 5 displays the frequency distribution of associated injuries within the plating and TENS groups, as well as the overall sample. The table categorizes associated injuries into three groups: nil (no associated injury), yes (presence of associated injury), and specific types of associated injuries. For each treatment group and overall, the number of patients and their corresponding percentages are provided. In both the plating and TENS groups, the majority of patients had no associated injuries, accounting for 86.7% and 93.3% of cases, respectively. However, in the plating group, 13.3% of patients had associated injuries, compared to only 6.7% in the TENS group. Specific associated injuries observed in the plating group included Colles' fracture of the right wrist (6.7%) and fractures of both bones in the right leg (6.7%), while the TENS group had Jones fracture of the left foot (6.7%). Overall, 10% of patients across both groups had associated injuries. This table provides valuable

insights into the prevalence and types of associated injuries in patients undergoing different treatment modalities for their primary injury, aiding in understanding the overall clinical picture and treatment outcomes.

Table 5: Associated Injury-frequency distribution in two groups

Associated Injury	PLATING GROUP	TENS GROUP	Total
Nil	26(86.7%)	28(93.3%)	54(90%)
Yes	4(13.3%)	2(6.7%)	6(10%)
Colles' fracture right	2(6.7%)	0(0%)	2(3.3%)
Fracture both bone right leg	0(0%)	2(6.7%)	2(3.3%)

Jones fracture left foot	2(6.7%)	0(0%)	2(3.3%)
Total	30(100%)	30(100%)	60(100%)

Table 6 compares various parameters between the TENS and plating groups in terms of type of fracture, time to surgery, duration of surgery, duration of hospital stay, blood loss, complications, DASH score at 6 months, and Constant Murley score. It illustrates the distribution of patients based on these parameters and their corresponding percentages within each treatment group. For instance, in the TENS group, 86.7% of fractures were classified as 2B1, whereas in the plating group, 73.3% were 2B1 fractures. Regarding time to surgery, the majority of patients in the TENS group underwent surgery within 2-4 days (66.7%), while in the plating group, surgery was mostly performed between 5-7 days (60%). The duration of surgery, duration of hospital stay, blood loss, and occurrence of complications are also outlined, along with the distribution of DASH scores and Constant Murley scores at 6 months post-operation. This comprehensive comparison provides insights into the differences in treatment outcomes and complications between the two surgical techniques, aiding in clinical decision-making and patient management.

Table 6: Comparison of parameters

Parameters	Variables	TENS GROUP	PLATING GROUP
Type of Fracture	2B1	26(86.7%)	22(73.3%)
	2B2	4(13.3%)	8(26.7%)
Time to Surgery (days)	2-4	20(66.7%)	6(20%)
	5-7	4(13.3%)	18(60%)
	8-10	6(20%)	6(20%)
Duration of surgery	of<50	18(60%)	4(13.3%)

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(minutes)	>50	12(40%)	26(86.7%)
Duration of Hospital Stay	2-3	20(66.7%)	0(0%)
	4-5	10(33.3%)	22(73.3%)
	6-7	0(0%)	8(26.7%)
Blood loss (ml)	60-90	30(100%)	0(0%)
	91-120	0(0%)	10(33.3%)
	120-150	0(0%)	20(66.7%)
Complication	Hardware migration	2(6.7%)	0(0%)
	Infection	0(0%)	2(6.7%)
	Mal union	0(0%)	2(6.7%)
	Non union	2(6.7%)	0(0%)
	Skin Infection	2(6.7%)	0(0%)
		4(13.3%)	4(13.3%)
DASH at 10-15 months	<10	20(66.7%)	18(60%)
		8(26.7%)	10(33.3%)
	>15	2(6.7%)	2(6.7%)
Constant Murey Score	<10	20(66.7%)	8(26.7%)
	10-15	6(20%)	20(66.7%)
	>15	4(13.3%)	2(6.7%)

Discussion

The present study compared the clinical and functional outcomes of anatomical locking plate fixation and Titanium Elastic Nailing System (TENS) fixation in the management of displaced midshaft clavicle

fractures. Both surgical techniques achieved satisfactory fracture union and functional recovery; however, significant differences were observed with respect to operative parameters, functional outcomes, and complication profiles.

The demographic characteristics of the study population were comparable between the two groups. The majority of patients belonged to the economically active age group of 31–50 years, with a predominance of male patients. This finding is consistent with the epidemiology of clavicle fractures reported by Robinson and Postacchini et al., who observed that young and middle-aged males are more frequently affected because of greater participation in road traffic activities, sports, and high-energy occupations.[13,14]

Road traffic accidents constituted the commonest mechanism of injury in both groups, followed by falls. Similar observations have been reported in previous studies where high-energy trauma was identified as the leading cause of displaced midshaft clavicle fractures requiring operative fixation.[15] The right side was slightly more commonly involved than the left side, although side predominance has not been shown to influence treatment outcomes.

A statistically significant reduction in intraoperative blood loss and duration of surgery was observed in the TENS group compared with the plating group ($p<0.001$). The minimally invasive nature of intramedullary fixation requires smaller incisions with limited soft tissue dissection, thereby reducing operative trauma. Similar findings have been reported by Ferran et al. and Smekal et al., who demonstrated shorter operative time, reduced blood loss, and smaller surgical scars with intramedullary fixation compared with plate osteosynthesis.[16,17]

Radiological union was achieved in almost all patients in both groups. Although the mean union time was slightly shorter in the TENS group (7.1 months) than in the plating group (7.5 months), the difference was relatively small despite reaching statistical significance. Preservation of fracture biology and minimal periosteal stripping associated with intramedullary fixation may contribute to earlier fracture healing. These observations are in agreement with previous comparative studies and systematic reviews that have demonstrated comparable union rates between plate fixation and intramedullary nailing.[18,19]

Functional outcome assessed using the DASH score favored the TENS group. At six months, patients treated with TENS demonstrated lower DASH scores,

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indicating better upper limb function and less disability compared with patients undergoing plate fixation. Early recovery following minimally invasive surgery, reduced postoperative pain, and better cosmetic appearance may explain this difference. Similar improvements in functional outcomes have been reported by Smekal et al. and Houwert et al., who found excellent functional recovery with intramedullary fixation in carefully selected fracture patterns.[17,19]

The complication profiles differed between the two techniques. Implant prominence, hypertrophic scar formation, plate-end protrusion, and superficial surgical site infection were observed more frequently in the plating group. In contrast, nail-end prominence, nail irritation, nail migration, and implant protrusion were the predominant complications in the TENS group. Importantly, no deep infections were encountered in either group. Most implant-related complications following TENS fixation were successfully managed by elective implant removal after fracture union. Similar complication patterns have been described in previous literature comparing plate fixation and intramedullary devices.[16,18,20]

Overall, both anatomical plating and TENS nailing provided reliable fracture union and satisfactory clinical outcomes in displaced midshaft clavicle fractures. Plate fixation offers excellent mechanical stability and remains particularly advantageous in comminuted fractures requiring anatomical reduction. Conversely, TENS nailing offers the benefits of minimally invasive surgery, shorter operative duration, reduced blood loss, improved cosmetic results, and superior short-term functional outcomes in appropriately selected patients. Therefore, the choice of fixation should be individualized based on fracture morphology, patient characteristics, surgeon expertise, and functional requirements.

Conclusion

Both anatomical clavicle plate fixation and Titanium Elastic Nailing System (TENS) fixation are effective surgical techniques for the management of displaced midshaft clavicle fractures, providing high union rates and satisfactory functional outcomes. In the present study, fracture union was achieved in almost all patients in both groups. However, TENS fixation demonstrated significant advantages in terms of shorter operative time, reduced intraoperative blood loss, earlier functional recovery, lower DASH scores, and improved cosmetic outcomes. Anatomical plate fixation provided excellent fracture stability,

particularly in displaced and comminuted fractures, but was associated with relatively higher rates of implant prominence, hypertrophic scarring, and surgical site infection. Although implant-related complications were observed in both groups, they were generally minor and successfully managed after fracture union. Based on the findings of this study, TENS nailing may be considered the preferred surgical option for appropriately selected uncomplicated displaced midshaft clavicle fractures because of its minimally invasive nature and superior short-term functional outcomes, whereas anatomical locking plate fixation remains an excellent choice for fractures requiring rigid stabilization and anatomical reduction. Further multicentric studies with larger sample sizes and longer follow-up are recommended to validate these findings and assess long-term functional outcomes and implant-related complications.

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