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Comparison of clinical and functional outcomes of patients who underwent plate osteosynthesis and intramedullary nailing for forearm fractures

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ABSTRACT

Aims: The aim of this study was to compare the functional and radiographic results of patients with forearm diaphyseal fractures after intramedullary nailing (IMN) and plate and screw osteosynthesis.

Methods: A total of 58 patients, including 31 patients operated on with the plate osteosynthesis method and 27 patients operated on with the IMN method for forearm diaphyseal fractures between 2017 and 2022, were retrospectively analyzed. The mean age was 35.9±14.5 years in the plate group and 33±13.1 years in the IMN group. The mean follow-up period was 157±83 days in the IMN group and 220±97 days in the plate group. Evaluation criteria for functional outcomes were forearm pronation; supination range of motion; the Disabilities of the Arm, Shoulder, and Hand (DASH) score; and the Grace-Eversmann score.

Results: The mean union time was 66.7 days in the plate group and 54.4 days in the IMN group (p=0.039). The mean length of hospitalization was 3.9±3.44 days in the plate group and 2.93±1.49 days in the IMN group. The mean supination range was 72.5±9.9 degrees in the plate group and 72.2±11.8 degrees in the IMN group. The mean pronation range was 81.2±11.7 degrees in the plate group and 80.3±15.5 degrees in the IMN group. The mean follow-up period was 157±83 days in the IMN group and 220±97 days in the plate group (p=0.011). According to the Association for Osteosynthesis/Orthopedic Trauma Association (AO/OTA) classification, 30 cases were classified as type A, 21 cases as type B, and 7 cases as type C. According to the Grace-Eversmann classification, 2 cases in the plate group were classified as unacceptable, 2 were classified as acceptable, 10 were classified as good, and 16 were classified as excellent, while 2 cases in the IMN group were classified as unacceptable, 4 were classified as acceptable, 5 were classified as good, and 16 were classified as excellent. The mean DASH score was 14.74±10.49 in the plate group and 15.11±12.7 in the IMN group.

Conclusion: With the advantages of minimal incision, less soft tissue damage, and no evacuation of the fracture hematoma, the union time and follow-up periods were found to be shorter in the IMN group. Thanks to the bearing force of intracanal intramedullary nails, patients were able to move earlier and satisfactory functional outcomes were obtained.

Keywords: Forearm fracture, intramedullary nailing, plate osteosynthesis, ulna fracture, radius fracture

INTRODUCTION

Forearm fractures occur as a result of falls, traffic accidents, sports activities, and occupational accidents and are common in young adults. The kinematics between the proximal and distal radioulnar joints are critical for load transfer throughout the upper limb.[1] Due to the functional and anatomical structure of the forearm bones, diaphyseal forearm fractures are considered as intraarticular fractures.[2,3] Formerly, these fractures were treated with nonsurgical methods such as casts. However, surgical interventions are performed to restore axial and rotational stability lost due to reasons such as nonunion, shortening, or false union.[4,5] Plate osteosynthesis is the most common treatment method for adult diaphyseal fractures.[6-8] Although this method provides adequate fixation, excellent union rates, and functional outcomes, it has some disadvantages. Among these are large surgical incisions, soft tissue stripping, periosteal stripping, skin irritation due to implants, delayed union due to fracture hematoma evacuation, and cosmetic problems.[6-8]

Intramedullary nailing surgeries using older models of intramedullary nails are not a preferred treatment method for forearm fractures due to high nonunion rates and insufficient stability. However, more recent locking intramedullary nails do provide adequate stabilization and rotation, which has made IMN a more frequently

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used method.[9-11] The locking and compression abilities of the more recent intramedullary nails help achieve high union rates, less soft tissue dissection, less bleeding, and better cosmetic appearance.[12,13] We suggest that IMN using new-generation intramedullary nails is not only an alternative to plate osteosynthesis, but also a better option for fixation in the treatment of forearm fractures.

The aim of this study was to retrospectively review patients who underwent plate osteosynthesis and IMN for forearm diaphyseal fractures and to compare their radiographic and functional outcomes and patient satisfaction. Our hypothesis was that IMN treatment, which has been used more frequently recently, is more feasible and more satisfactory in terms of outcomes than plate osteosynthesis.

METHODS

Ethics

Institutional approval was obtained for the study. Ethical approval was obtained from the Clinical Researches Ethics Committee of Gazi Yaşargil Training and Research Hospital where all imaging and patient procedures were performed in a single center (Date: 21.07.2023, Decision No: 466). The study had no financial incentives. All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Patients

A total of 58 patients, including 31 patients operated on with the plate osteosynthesis method and 27 patients operated on with the IMN method for forearm diaphyseal fractures between 2017 and 2022, were retrospectively analyzed. Forty-eight of the patients were male and 10 were female. Of the patients, 22 underwent operation for the right arm and 36 for the left arm. In plate group 16 patients had fractures as a result of falls, 9 as a result of traffic accidents, 3 as a result of assault, 1 as a result of gunshot injury, and 2 as a result of occupational accidents. In IMN group 14 patients had fractures as a result of falls, 8 as a result of traffic accidents, 1 as a result of assault, 1 as a result of gunshot injury, and 3 as a result of occupational accidents. Posteroanterior (PA) and lateral forearm radiographs of the patients, which were taken at the time of admission, postoperatively, and every 15 days until union and every 3 months after union, were evaluated. Fractures were classified according to the Association for Osteosynthesis/Orthopedic Trauma Association (AO/OTA) classification.[14] Ten of the fractures were opened. According to the Gustilo-Anderson classification,[15] 6 patients had type 1, 2 patients had type 2, and 2 patients had type 3 fractures. Absence of pain at the fracture line and cortical trabeculation and callus formation in at least 3 cortices evident by radiographs were considered as signifying union. Absence of union after 6 months was considered as nonunion. Patients were evaluated for shortening, rotational deformity, and malunion. For functional evaluation, forearm supination pronation angles were measured after union and Disabilities of the Arm, Shoulder, and Hand (DASH)[16] and Grace-Eversmann[17] scores were calculated. Time of union, presence and type of complications, open fractures, length of hospitalization, and etiologies were recorded. Complications encountered were radial nerve injury in 2 cases, radial and median nerve injury in 1 case, ulnar nerve injury in 1 case, median nerve neuropraxia in 1 case, and malunion of 10 degrees in 1 case.

Patients under 18 years of age, patients with open epiphyses, patients with pathological fractures, patients with Galeazzi and Monteggia fracture dislocation, patients with head trauma, and patients who did not attend regular follow-up appointments were excluded from the study. Two patients were excluded from the study because they died due to multiple trauma, while 5 patients in the plate group and 2 patients in the IMN group were excluded because they did not attend regular follow-ups.

Surgical Technique

All patients received a long arm splint until surgery. Surgeries were performed in the supine position using a radiolucent hand surgery table and a pneumatic tourniquet with 250 mmHg pressure. C-arm fluoroscopy was utilized to assess fracture reduction. The operations were performed by 4 different surgeons. All patients were operated on under general anesthesia or axillary block. All patients received 1 g of intravenous cefazolin 30 minutes before the operation. Patients with open fractures were operated on early to allow irrigation and debridement simultaneously with bone fixation on admission.

The surgical procedure was performed through separate incisions for patients who underwent plate osteosynthesis. Patients in the plate group were operated on with 3.5-mm limited-contact dynamic compression plates (TST Rakor Tıbbi Aletler Sanayi ve Ticaret Limited Şirketi, İstanbul, Turkiye). The volar Henry approach was used for middle and distal 1/3 fractures and the Thompson approach was used for proximal fractures. Operations for ulnar fractures involved an incision to the subcutaneous ulnar border. Only the area where the plate was to be placed was prepared subperiosteally. Soft tissue connections were retained whenever possible. Blood, clots, and soft tissues were removed from the fracture line, the fracture was reduced, and plates were placed. At least 3 screws (6 cortices) were placed distal and proximal to the fracture line. More screws were used

for osteoporotic and comminuted fractures. At the end of the surgery, the tourniquet was removed, the incisions were closed after controlling bleeding, and the operation was terminated.

In the IMN reduction group, patients were operated on using a single type of intramedullary nail (TST Rakor Tıbbi Aletler Sanayi ve Ticaret Limited Şirketi, İstanbul, Turkiye). The nails and plates used were made of titanium alloy.

The radius nail was solid and oval. Its 3-cm proximal part had a parabolic shape with a 10-degree angle towards the front. It was applied without carving. It provided three-point contact stability in the fracture line and had a distal 15-degree angled static locking hole. This angle prevented the locking screw from moving towards the joint. Preoperative radiographs were evaluated in order to determine the appropriate sizes of nails. Nail length was calculated by subtracting 2-3 cm from the distance between the radial styloid and the radial neck. Nail thickness was calculated as the narrowest point of the bone according to the PA radiograph. Although there were different diameter options for nails, the same nails were used for both right and left limbs. The operation was initiated through a 2-cm incision over the Lister tubercle. The second compartment was opened. An awl was used to drill the radius by excising the extensor carpi radialis longus and brevis tendons laterally. The entry point was advanced into the intramedullary space with a curved awl. A radius nail of appropriate length and diameter was advanced into the canal with rotational movements using a holder. When the nail tip reached the fracture line, it was advanced in the intramedullary direction after closed reduction. In cases where closed reduction was not successful, the fracture was reduced through a miniature open incision. After fluoroscopic evaluation, the distal locking screw was locked.

The 4-cm proximal part of the ulnar nail was tubular and its distal part was solid. Different locking options were available for both the distal and proximal part. The same nails are used for both right and left limbs. The proximal part was a standard 6 mm, but there were different length options for the distal part. Titanium allows for bending and twisting due to its elastic structure. Measurements for ulnar procedures were made similarly to those for radial procedures. The length of the ulnar nail was calculated by subtracting 2 cm from the distance between the ulnar styloid process and the olecranon. The operation was initiated through an incision of 2-3 cm at 90 degrees of flexion from the tip of the olecranon. The incision was advanced towards the canal using a straight awl. The K wire was inserted into the intramedullary canal and a 3-cm partial zone was opened with a cannulated drill. A nail of appropriate length and diameter was then advanced into the canal. When the fracture line was reached, the fracture was reduced without an incision or using a mini-incision and the nail was advanced distally. Proximal static or dynamic locking was performed. Distal locking was performed depending on the surgeon's preference. Patients were discharged 2-4 days after surgery according to pain control in the early postoperative period. The plate group was followed with a long arm splint for 3 weeks. All patients in the plate group had their splints removed and were allowed to perform passive movements of the wrist and elbow in the 3rd week. The IMN group did not receive splints postoperatively and were allowed to move their limbs on postoperative day 1.

Statistical Analysis

Statistical analyses were performed using the NCSS (Number Cruncher Statistical System) 2007 Statistical Software package program (NCSS LCC, Kaysville, UT, USA). The data were analyzed using descriptive statistical methods (mean, standard deviation, median, and interquartile range). The distribution of the variables was examined with the Shapiro-Wilk normality test. The independent t-test was used in the comparisons of paired groups of normally distributed variables, while the Mann-Whitney U test was used in comparisons of paired groups of variables that did not show normal distribution. The chi-square test was used in the comparison of qualitative data. Values of $p<0.05$ were considered statistically significant.

RESULTS

Of the 58 patients, 48 (83%) were male and 10 (17%) were female. The mean age was 35.9±14.5 years in the plate group and 33±13.1 years in the IMN group. The mean length of hospitalization was 3.9±3.4 days in the plate group and 2.9±1.4 days in the IMN group (p=0.525). Ten of the patients (17%) had open fractures (Table 1). The mean pronation range was 81.2±11.7 degrees in the plate group and 80.3±15.5 degrees in the IMN group (p=0.799) (Table 1).

Table 1. Evaluation of parameters between groups

	Plate group n=31		IMN group n=27		p
Age Mean±SD	35.9±14.5		33±13.1		0.426*
Sex					0.249+
Male	24	77.4%	24	88.9%	
Female	7	22.6%	3	11.1%	
Laterality					0.501+
Right	13	41.9%	9	33.3%	
Left	18	58.1%	18	66.7%	
Follow-up period (days) Mean±SD	220.6±97.5		157.7±83		0.011*
Supination Mean±SD	72.58±9.9		72.22±11.8		0.901*
Pronation Mean±SD	81.2±11.7		80.3±15.5		0.799*
Hospitalization time (days)					0.525‡
Mean±SD	3.9±3.4		2.9±1.4		
Median (IQR)	3 (2-4)		2 (2-4)		

*: Independent t-test; ‡: Mann-Whitney U test; +: Chi-square test

The mean follow-up period was 157±83 days in the IMN group and 220±97 days in the plate group. Follow-up duration was significantly longer in the plate group than in the IMN group (p=0.011). (Table 2).

Table 2. Etiology of fractures

	Plate group n=31		IMN group n=27		p
Etiology					0.891+
Gunshot injury	1	3.3%	1	3.7%	
Assault	3	9.6%	1	3.7%	
Fall	16	51.6%	14	51.9%	
Occupational accident	2	6.5%	3	11.1%	
Traffic accident	9	29%	8	29.6%	

+: Chi-square test

Complications were observed in 3 patients in the plate group and 3 patients in the IMN group (p=0.858). The mean union time was 66.7±27.3 days in the plate group and 54.4±13.8 days in the IMN group, being significantly shorter in the IMN group (p=0.039) (Table 3). According to the Grace-Eversmann classification, 2 cases in the plate group were classified as unacceptable, 2 were classified as acceptable, 10 were classified as good, and 16 were classified as excellent, while 2 cases in the IMN group were classified as unacceptable, 4 were classified as acceptable, 5 were classified as good, and 16 were classified as excellent. (p=0.673) (Table 3). The mean DASH score was 14.74±10.49 in the plate group and 15.11±12.7 in the IMN group. There was no significant difference between the two groups in terms of DASH scores (p=0.755) (Table 3).

Table 3. Comparison of results between groups

	Plate group n=31		IMN group n=27		p
Fracture					0.199+
Double fracture of the forearm	12	38.7%	14	51.9%	
Radius shaft fracture	7	22.6%	8	29.6%	
Ulna fracture	8	25.8%	5	18.5%	
Ulna shaft fracture	4	12.9%	0	0.00%	
Union time (days) Mean±SD	66.7±27.3		54.4±13.8		0.039*
AO classification					0.798+
A	17	54.8%	13	48.2%	
B	10	32.3%	11	40.7%	
C	4	12.9%	3	11.1%	
Complications					0.858+
No	28	90.3%	24	88.9%	
Yes	3	9.7%	3	11.1%	
Type of complication					0.199+
Malunion of 10 degrees	1	33.3%	0	0.00%	
Median neuropraxia	1	33.3%	0	0.00%	
Radial injury	0	0.0%	2	66.7%	
Radial + median injury	0	0.0%	1	33.3%	
Ulnar nerve injury	1	33.3%	0	0.00%	
Open fracture					0.810+
No	26	83.9%	22	81.5%	
Yes	5	16.1%	5	18.5%	
Open fracture type					1+
Type 1	3	60.0%	3	60.0%	
Type 2	1	20.0%	1	20.0%	
Type 3	1	20.0%	1	20.0%	
Grace-Eversmann classification					0.673+
Unacceptable	2	6.4%	2	7.4%	
Acceptable	3	9.7%	4	14.8%	
Good	10	32.3%	5	18.5%	
Excellent	16	51.6%	16	59.3%	
DASH score					0.755‡
Mean±SD	14.7±10.4		15.1±12.7		
Median (IQR)	12 (7-20)		12 (8-18)		

*: Independent t-test; ‡Mann-Whitney U test; +: Chi-square test

DISCUSSION

In the current study, union time and follow-up duration were found to be shorter in patients who underwent IMN for forearm fractures compared to patients who underwent plate osteosynthesis. However, there was no significant difference between patients who underwent plate osteosynthesis and patients who underwent IMN in terms of functional outcomes and patient satisfaction. Good results were obtained in both groups (Figure 1, Figure 2).

In a study conducted by Polat et al.[18] with a group of 46 patients who underwent new-generation IMN and plate osteosynthesis for forearm fractures, the mean union time was 10.9 weeks in the IMN group and 13.2 weeks in the plate group, with union being faster among patients who underwent IMN. In their study including 100 patients, Savajiyani et al.[19] achieved adequate union in 88 cases using IMN and reported union times compatible with other studies in the literature. In a study by Özkaya et al.[12] union time was found to be 10 weeks in the IMN group and 14 weeks in the plate group. In their study, Kibar et al.[13] achieved a mean union time of 12.1 weeks in the IMN group and 12.2 weeks in the plate group. In the present study, the mean union time was 54 days in the IMN group and 66 days in the plate group, being significantly shorter in the IMN group. These results are consistent with the literature. The follow-up periods of IMN patients were shorter due to earlier union. As in cases of lower extremity fractures, we suggest that this difference occurs because nailing both allows micro-movement in the fracture and better retains normal anatomy.

In a study by Visna et al.[20] that included 115 fractures and 80 patients, no difference was found between the post-union DASH scores, Grace-Eversmann scores, and supination and pronation ranges of patients according to surgery method. Weckbach et al.[21] found a mean DASH score of 14 for forearm fractures treated with IMN. In a study conducted by Köse et al.[10] including patients who underwent IMN, the mean DASH score was 15, while 14 patients had excellent, 3 had good, and 1 had an acceptable Grace-Eversmann classification. Lee et al.[22] found no significant difference between the DASH scores, Grace-Eversmann scores, and supination and

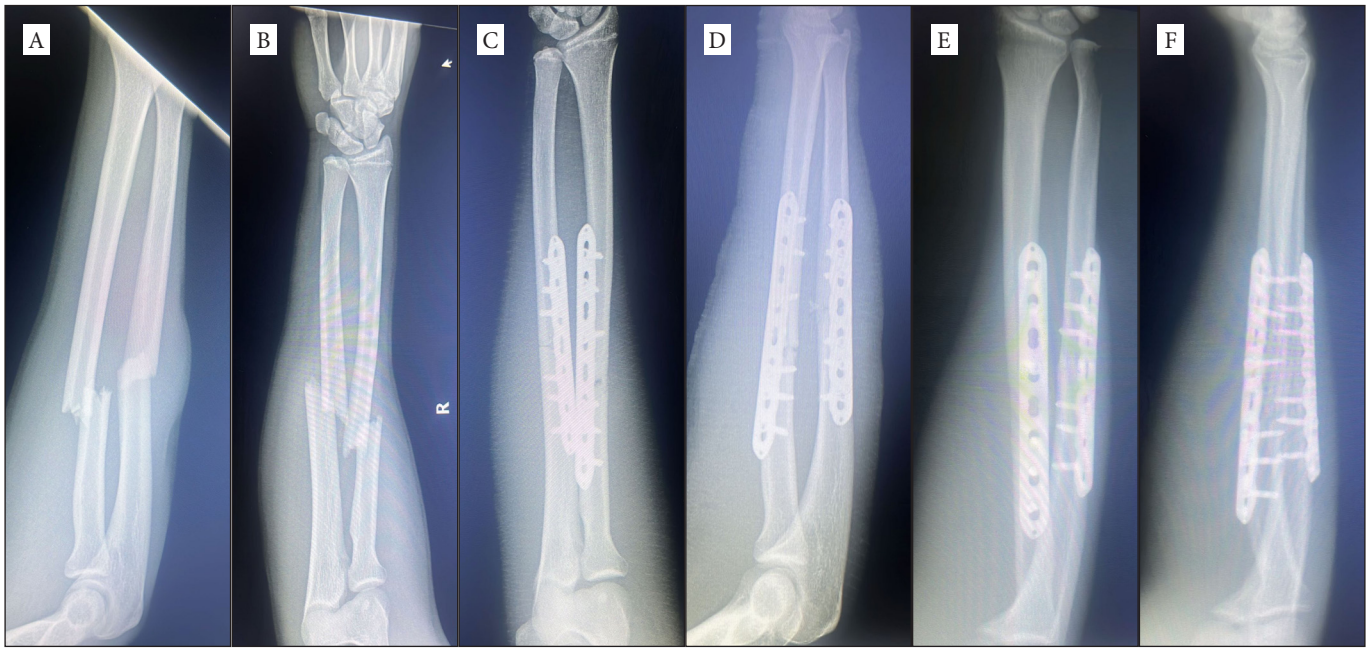

Figure 1. Preoperative posterior-anterior and lateral radiographs of a 34-year-old male patient who underwent plate osteosynthesis due to right diaphyseal forearm fracture (A, B); postoperative posterior-anterior and lateral radiographs at 2 weeks (C, D); postoperative posterior-anterior and lateral radiographs at 12 months (E, F).

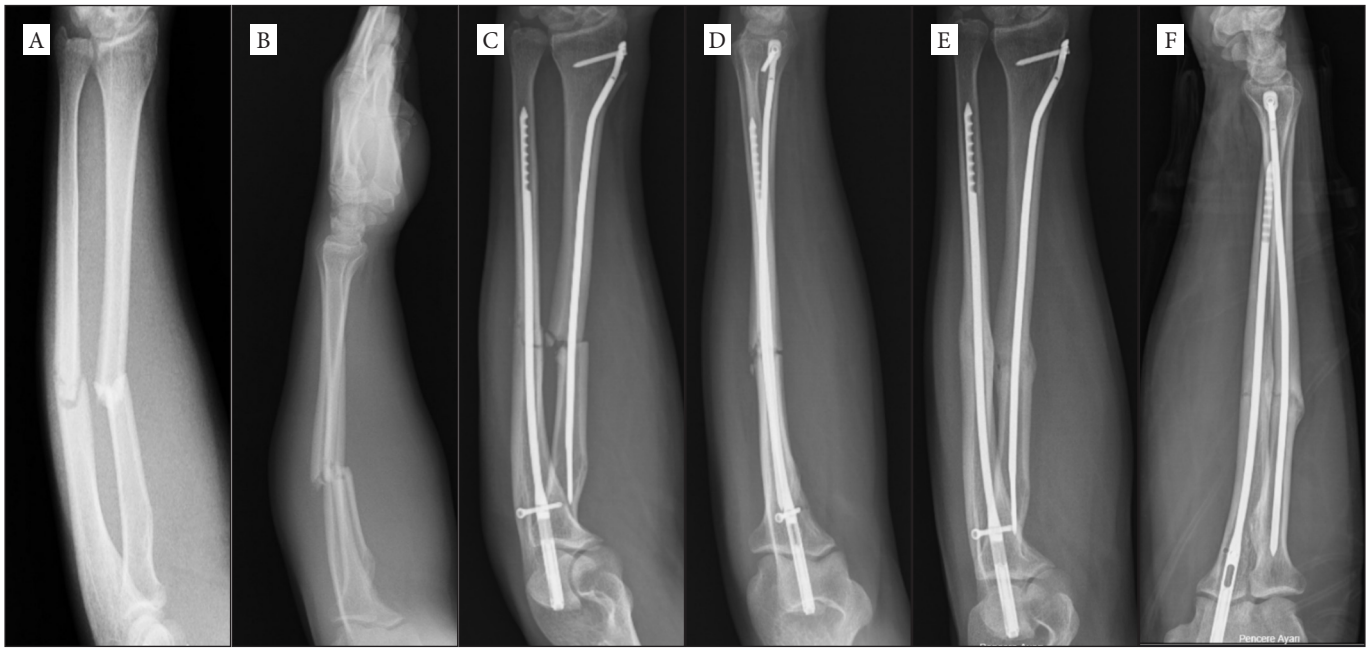

Figure 2. Preoperative posterior-anterior and lateral radiographs of a 34-year-old male patient who underwent IMN due to right diaphyseal forearm fracture (A, B); postoperative posterior-anterior and lateral radiographs at 2 weeks (C, D); postoperative posterior-anterior and lateral radiographs at 12 months (E, F).

pronation ranges of patients in the plate group and the IMN group. In the present study, no difference was found between functional scores according to surgery method. It was found that new-generation IMN achieved functional outcomes comparable to plate osteosynthesis.

In their study comparing fracture types and open and closed fractures, Polat et al.[18] classified 9 cases as type A, 9 cases as type B, and 3 cases as type C in the IMN group and 11 cases as type A, 9 cases as type B, and 5 cases as type C in the plate group according to the AO/OTA classification, and they found no significant differences between the groups in terms of union time. In the study by Lee et al.[22] 16 cases were classified as type A and 19 as type B in the IMN group while 14 cases were classified as type A and 18 as type B in the plate group, and no significant difference was found between the groups in terms of union time and operation time. Both of these studies reported no significant difference between open and closed fractures in terms of union time. The present study also found no difference between classifications and open and closed fracture types in terms of union time, and union times were compatible with those of other studies in the literature.

Elastic titanium nails were used in this study. Radius instability was the most common problem of old-generation nails. By establishing three-point contact and distal locking, new-generation nails provide better rotational stability and radial bow. Distal locking allows compression up to 7 mm. Both dynamic and static locking provide adequate stabilization in the ulna and allow for earlier postoperative motion compared to plate osteosynthesis.[10,11,23] The proximal locking of new-generation intramedullary nails reduces the risk of nerve damage in radius nailing.[24] In their study, Lee et al.[22] did not find any difference between the functional and clinical outcomes of patients who underwent plate osteosynthesis and IMN, although their radial bow restoration and the location of the maximum radial bow significantly differed. That study guided us to emphasize the use of IMN instead of plate osteosynthesis. In addition, since implant discomfort in patients treated with IMN is very low compared to patients who undergo plate osteosynthesis, requests for implant removal have decreased among these patients and most patients have not undergone reoperation. Despite the many advantages of IMN, its main disadvantage is excessive exposure to radiation due to excessive use of scopes during surgery.

Limitations

The main limitations of this study are its retrospective design and the small number of patients included. In addition, since the study was retrospective, the patient distribution was not homogeneous. Patients who did not attend regular postoperative follow-up had to be excluded from the study. The fact that the operations were performed by different surgeons is another limitation. In addition, forearm fractures could not be evaluated separately as radius, ulna, and forearm double fractures due to the small number of patients. Other limitations include the lack of standardization of follow-up periods and the unequal numbers of screws used for the patients.

CONCLUSION

With the advantages of a minimal incision, less soft tissue damage, and no evacuation of the fracture hematoma, the union time and follow-up periods were found to be shorter in the IMN group. Thanks to the bearing force of intracanal intramedullary nails, patients were able to move earlier and satisfactory functional outcomes were obtained. We suggest that IMN should be the treatment of choice rather than merely an alternative to plate osteosynthesis due to better union times, good functional outcomes, good cosmetic results, and fewer implant-related problems.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of University of Health Sciences Gazi Yaşargil Training and Research Hospital Clinical Researches Ethics Committee (Date: 21.07.2023, Decision No: 466).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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