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Interlocking intramedullary ulna nails in isolated ulna diaphyseal fractures: a retrospective study

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Objective: The aim of this study was to evaluate the results of multifunctional intramedullary (IM) ulna nailing following diaphyseal fracture of the ulna.

Methods: Adult patients with isolated fractures of the ulna treated with closed or mini-open reduction using the new IM ulna nail between May 2008 and January 2011 and who were followed for a least one year were retrospectively reviewed. Patients with a pathological fracture or nonunion after previous surgeries were excluded. Functional outcome was assessed using the Grace and Eversmann rating system, patient-reported outcomes using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire. Wrist flexion and extension was evaluated using a goniometer.

Results: The 18 patients (13 male, 5 female; mean age: 28 years, range: 18 to 64 years) had a total of 20 isolated ulna fractures (two bilateral). Mean time to fracture union was 13 (range: 10 to 14) weeks. No patient had nonunion, deep infection or radioulnar synostosis. Follow-up time ranged from 12 to 36 months. Grace and Eversmann ratings were excellent in 15 patients, good in 2 and poor in one. Mean DASH score was 8.08 (range: 0 to 17.5) points.

Conclusion: The new IM ulna nails may be considered an alternative method for isolated diaphyseal fractures of the ulna. Advantages of this method include its short operative time, insertion by closed and minimal invasive techniques, use of scope only in reduction and locking control, as well as minimal cosmetic defect, small operative scar and early mobilization without additional fixation.

Key words: Intramedullary nail; reduction; ulna diaphyseal fracture.

Fractures of the ulnar diaphysis are relatively common injuries.[1] They most often result from a direct trauma to the ulna as the arm is raised overhead to protect from a blow. The type of fractures changes from minimally displaced 'night-stick' fractures to more extensive injuries with bone and soft tissue loss.[1] The most suitable method of management has not been established, with different authors recommending both surgical and nonsurgical management.[2,3] The goal in the treatment of ulna fractures using the intramedullary (IM) technique is the restoration of length and axial and rotational alignment without anatomic reduction of fracture fragments. However, depending on fracture stability and surgeon preference, treatment may consist of observation, bracing, casting, IM fixation or compressive plating.

Closed locked nailing is successful for the treatment of femoral, tibial and humeral shaft fractures.[4,5] However, IM nails are not routinely used in the surgical treatment of ulna fractures. Distal interlocking is a major problem with ulna nails due to the small distal

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diameter of the ulna. In addition, their use is limited by the high nonunion rates and need for additional fixation in the long-term.[6] However, the recent introduction of newly designed interlocking IM nails has limited some of these concerns.[4,7-10] Surgical treatment of ulna fractures using IM nails reestablishes the near normal relationship of the fractured fragments.[11]

The purpose of this study was to investigate the results of the use of the new IM ulna nail in the surgical treatment of adult ulna fractures.

Patients and methods

Ethical clearance was obtained from the institutional ethics committee and informed consent forms from all patients were received. Patients were enrolled between May 2008 and January 2011. Standard anteroposterior and lateral radiographs of the fractured forearm taken at the time of injury were used to classify the fractures according to the system used by the Arbeitsgemeinschaft für Osteosynthesefragen / Association for the Study of Internal Fixation (AO/ASIF) and as stable or unstable.

Inclusion criteria were isolated ulnar diaphyseal fracture, closed fracture, Grade 1-2 and 3a open fracture or simple segmental fracture. In addition, cases of over 10 degrees of angulation and over 50% of translation, patients with inadequate soft tissue coverage, patients with radioulnar joint injury and potentially unstable patients with increased displacement during their follow-up were included in the surgery group. Patients with pathological fractures or patients with nonunion following previous surgeries were excluded.

The study included 20 injuries of 18 patients (13 male, 5 female; average age: 28 years; range: 18 to 64 years). The right forearm was fractured in 11 patients and the left in 9 (two bilateral). Injury mechanisms were motor vehicle accidents in 4, industrial accidents in 3, sports injuries in 3, and falls in 8 patients. There were 12 Type A (simple) fractures, 7 Type B (wedge) fractures and one Type C (complex) fracture. Fifteen fractures were unstable and 5 were stable ulna fractures. Two open fractures were treated with debridement, irrigation and IM nail fixation on the day of admission. All other fractures were stabilized within 5 (range: 1 to 8) days.

All fractures were stabilized using new interlocking IM ulna nails (TST Rakor Tıbbi Aletler San. ve Tic. Ltd. Şti., İstanbul, Turkey). These nails are made from a titanium alloy. The most significant characteristic of these nails is their ability to provide sufficient bending, axial and rotational stability in the ulna due to their different design. We believe that the new IM ulna nail design has an oblique system feature which eliminates the need for fluoroscopy and guides. In addition, the new ulna nail can compress the fracture line if needed.

The IM ulna nail is solid, round, and unreamed (Fig. 1). Distal locking can be achieved by one or more locking screws passing through the eight transverse grooves on the distal 3 cm of the nail without requiring fluoroscopy (Fig. 2). The nail allows static, dynamic, and single-cortex interlocking by round, oval, and proximal oblique holes (Fig. 3). The IM nail is applied and distal locking applied with the forearm in a neutral

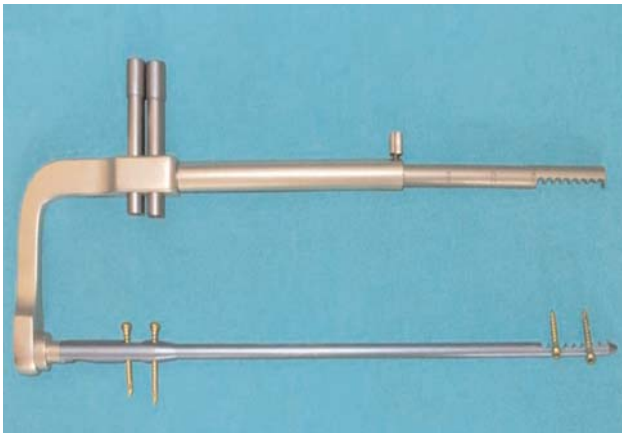

Fig. 1. The ulna intramedullary nail is solid, round, and unreamed. Distal locking can be achieved by passing one or more locking screws through the eight transverse grooves on the distal end. The nail allows static, dynamic, and single-cortex interlocking through round, oval, and oblique proximal holes. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

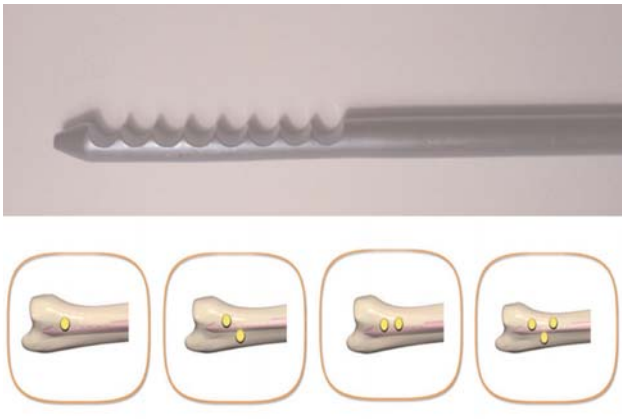

Fig. 2. The distal end and locking options of the interlocking intramedullary ulna nail. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

position. Using the oblique hole, interlocking can be performed in any direction (360°) with an angle of 20° from the proximal part of nail (Fig. 4). Transverse, lateromedial, and posteroanterior dynamic interlocking can be made through the oval hole, which allows 7-mm compression 30 mm distal to the proximal part of nail. To provide the compression effect, a 3-mm interlocking screw is first applied through the oval hole of 10×3 mm in the proximal of the nail. Then, by applying compressive end-cup, the gap in the fracture line can be closed or the desired compression performed through interlocking screw. Transverse, lateromedial and posteroanterior static interlocking can be achieved through the round hole at 40 mm distal from the proximal nail. Proximal diameter is 6 mm. Diameter choices for the distal part are 3.5, 4, 4.5, 5, and 6 mm, and 22 different lengths are available. The same nail can be used for the right and left ulna.

Cephalosporin was used in all patients for the purpose of prophylaxis. All patients received an axillary block or general anesthesia. In all cases, closed reduction was attempted first. If closed reduction could not be achieved, open reduction by placing a 2-cm mini-incision at the fracture line was performed. The nail for an ulnar fracture was selected based on the length and diameter of the medullary canal as measured on anteroposterior and lateral radiographs of the uninjured forearm.

A 2-cm, longitudinal incision was made from the tip of the olecranon and a 2-mm K-wire introduced into the medulla 6.5 mm proximal and 3 mm lateral to the most prominent part of the olecranon tip.[12] A cannulated drill was advanced 5 cm into the medulla over the K-wire and the nail was screwed to the guide. The direction of the nail and guide grooves should be kept in mind as it is important in terms of the direction of proximal oblique locking (anterior or posterior). The nail was advanced distally by partial rotations. Following closed or mini-open reduction, two cortices were drilled using a 2.5-mm drill for the distal lock screw (Fig. 5) The groove was found by applying minimal rotation or push and distal interlocking made using a 3-mm cortical screw. Proximal interlocking can be performed as preferred. Dynamic, static, oblique interlocking or compression can be established (Figs. 6 and 7).

Closed reduction was achieved in 14 of 20 fractures and 6 were reduced through mini incisions. Early motion was immediately allowed in all patients without additional immobilization with a cast or splint.

Mean length of hospital stay was 4 (range: 3 to 10) days. Follow-up was at least 12 (range: 12 to 36) months for all 18 patients.

Mean operative and fluoroscopy times showed variation with the learning curve (Table 1). Mean recovery times did not differ significantly between patients undergoing open reduction and those undergoing closed reduction.

Union was assessed clinically and radiographically. The fracture was defined as clinically united when the fracture site was no longer tender. Radiographic union was defined as evident bridging callus on anteroposterior, lateral, and oblique radiographs of the forearm.

Postoperative hand and the forearm strength were assessed with a dynamometer (Baseline hydraulic hand dynamometer, Hixson, TN, USA). Grip strength was measured with the patient seated, shoulder in adduc-

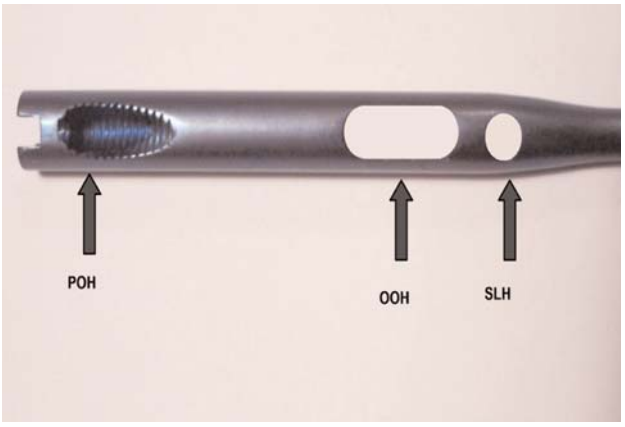

Fig. 3. Proximal design of the interlocking intramedullary ulna nail. OOH: oval oblique hole, POH: proximal oblique hole, SLH: static locking hole. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Fig. 4. The distal end and locking options of the interlocking intramedullary ulna nail. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

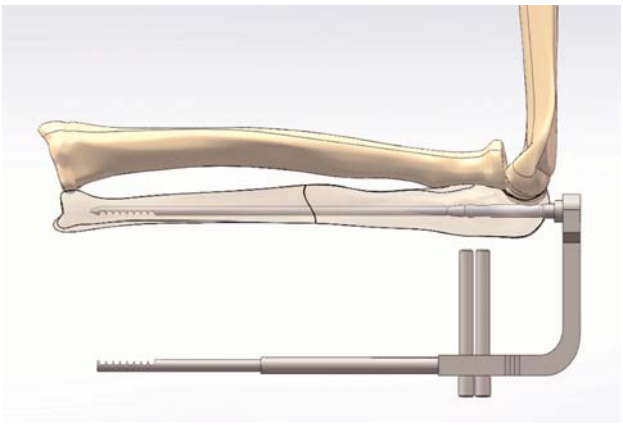

Fig. 5. By the help of a guide, the nail with appropriate length and diameter inserts into the olecranon tip. After the reduction is established, the nail is passed from the fracture line to the distal part of the fracture with rotational movements. At the distal side, via the eight transverse grooves on the nail, anti-rotational distal locking is applied with one or more locking screws, without using fluoroscopy or guide. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

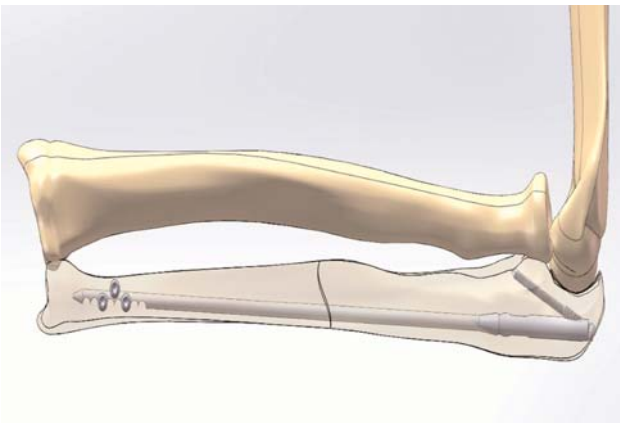

Fig. 6. At the proximal side, oblique locking applies over the nail with an angle of 20 degrees, without using fluoroscopy or guide. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

tion and neutral rotation, elbow flexed at 90°, and the forearm and wrist in the neutral position. The average of three measurements was recorded. To avoid muscle fatigue, all measurements were taken within 2 minutes. The uninjured forearm was used as a control for each patient. All measurements were performed at least 12 months after the surgery.

Functional outcome was assessed using the Grace and Eversmann rating system.[13] Patient-reported outcomes were assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire scores.[14] Wrist flexion and extension were measured with a goniometer.

Table 1. Surgical characteristics of 18 patients with 20 isolated ulna fractures treated with the new intramedullary nail.

Variable	Ulna fractures (n=20)
Mean operative time in minutes (range)	25 (20 to 45)
Mean fluoroscopy time in seconds (range)	20 (10 to 90)
Mean recovery time in months (range)	13 (10 to 14)

Grip strength was compared between the fractured and uninjured forearms using the paired-samples test. Relationships between grip strength, pronation and supination were assessed with the Pearson's correlation coefficient and those between AO fracture classification and forearm rotation (supination-pronation) were

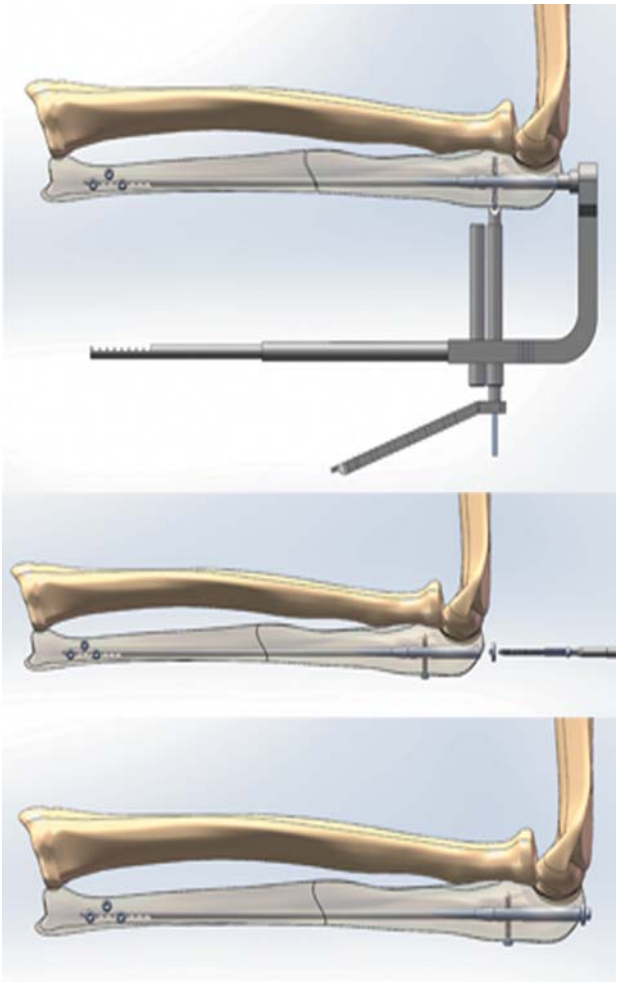

Fig. 7. The proximal end of the ulna nail allows static or dynamic locking. With the oval hole, transverse lateromedial or posteroanterior locking can be done. If necessary, dynamic locking can be done for the compression of the fracture line. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

assessed using the Mann-Whitney U test. P values of less than 0.05 were considered significant, and all tests were two-tailed.

Results

Standard radiographs taken at the final follow-up showed no patients with nonunion. In all cases, callus tissue was clearly apparent on radiographs about 6 weeks after surgery. Average healing time was 13 (range: 10 to 14) weeks (Table 2). The overall average range of motion was 80° of pronation and 82° of supination (Table 2).

Two patients with open fractures had superficial infections which were resolved with antibiotics. Radioulnar synostosis or deep infection was not observed. Compartment syndrome, early or late fixation failure, implant breakage (nail or locking screw) and mechanical irritation or refracture were also not observed. Nails did not have to be removed from any patient,

Mean postoperative grip strength (13.71±11.60) differed significantly between the fractured and uninjured forearms ($p<0.01$) (Table 2). However, functional results did not differ significantly between the fractured and uninjured forearms.

The relationship between supination and pronation of the injured forearm according to AO classification was not statistically significant ($p>0.05$) (Table 3). Mean wrist extension and flexion of the injured forearms did not differ from those of the uninjured forearms (Table 2). The relationship between DASH scores and grip strength, pronation, and supination in the fractured forearms were not statistically significant ($p>0.05$) (Table 4).

Table 2. Outcomes of 18 patients with 20 isolated ulna fractures treated with the new intramedullary nail.

Variables	Ulna fractures (n=20)
Mean time to union in weeks (range)	13 (10 to 14)
Mean healing time in weeks (range)	13 (10 to 14)
Range of motion at last follow-up in degrees (range)	
Supination	82 (80 to 90)
Pronation	80 (70 to 90)
Grace and Eversmann rating (n)	
Excellent	15
Good	2
Poor	1
Mean DASH score (range)	8.08 (0 to 17.5)
Mean difference in grip strength	
Fractured forearm (±SD)	82.2 (20.1)
Uninjured forearm (±SD)	95.9 (18.1)
Mean wrist extension in degrees (range)	82 (65 to 90)
Mean wrist flexion in degrees (range)	84 (70 to 90)

Grace and Eversmann scores revealed 15 excellent results, 2 good results and one poor result (Fig. 8). The patient with the poor result experienced delayed union which appeared related to intraoperative technical error. Revision with a suitable length and diameter IM ulna nail was applied at the 4th postoperative

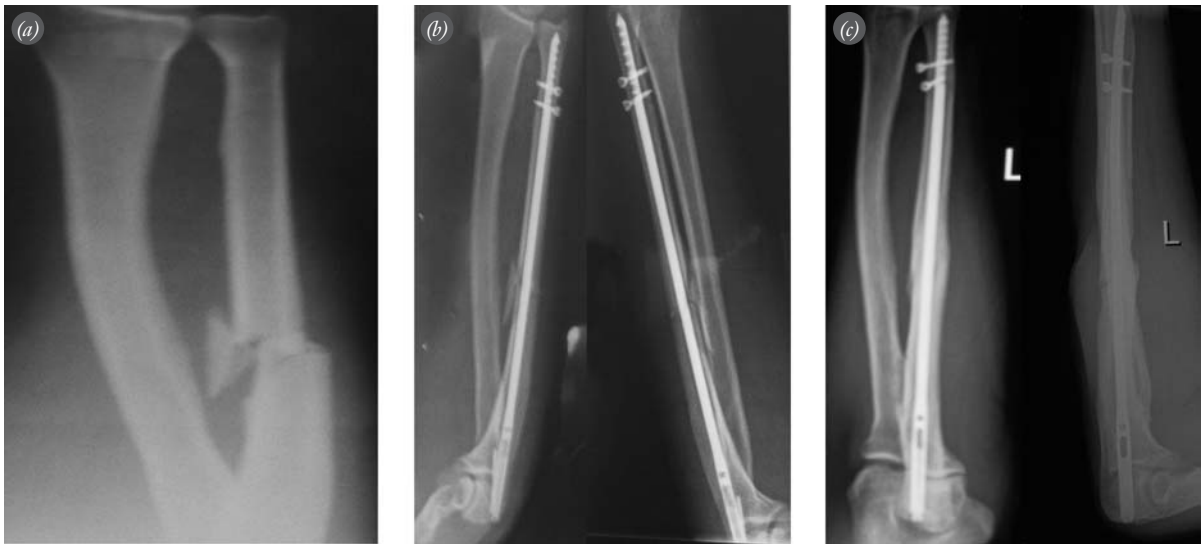

Fig. 8. A 40-year-old man with an isolated ulnar diaphyseal fracture. **(a)** Preoperative radiographs of the ulna fracture. **(b)** The fracture was reduced and fixed with the new intramedullary nails using closed technique. **(c)** At 14 months postoperatively, healing and alignment were satisfactory. Grace and Eversmann grade was excellent, and DASH score was 2.5.

Table 3. Relationship between fracture classification and forearm supination and pronation in forearms with fractures treated with the new intramedullary ulna nail.

	AO Classification*		
Postoperative action	Type A (Simple) (n=12)	Type B (Wedge) (n=7)	p
Mean pronation (±SD)	82.5 (12.3)	90 (0)	0.36
Mean supination (±SD)	89.5 (1.51)	89.2 (2.04)	0.80

AO: Association for Osteosynthesis/Association for the Study of Internal Fixation fracture classification system.
*One patient with a Type C fracture was excluded from the analysis.

Table 4. Relationship between DASH scores and grip strength, pronation, and supination in the fractured forearms.

	DASH scores	
Postoperative values	r	p
Grip strength in pounds	-0.38	0.14
Pronation in degrees	-0.34	0.21
Supination in degrees	-0.5	0.04

r=Pearson's correlation coefficient; p<0.05.

month. Union was gained following the second operation after 6 weeks. Overall mean DASH scores were 8.08 (Table 2).

Discussion

The goal in the treatment of ulna fractures with IM nails is the restoration of length, axial and rotational alignment without anatomic reduction of all fracture fragments. Optimal management for ulnar diaphyseal fractures remains debatable. The choice of treatment is influenced by the injury mechanism, fracture pattern, degree of displacement, angulation, location, associated injuries, and patient preferences.[15]

Some authors recommend open reduction and fixation with a dynamic compression plate[16] or IM nail[17] for all fractures. Others advocate below elbow[18] or above elbow[19] plaster casts. Functional bracing[20] or early mobilization in a simple compressive bandage[21] is also recommended.

In addition, fracture stability is very important for treatment. Isolated ulnar shaft fractures may be classified as stabile and unstable. Unstable fractures are defined as those with more than 50% displacement and 10° angulation, involve the proximal third or have associated instability at the proximal radioulnar joint (PRUJ) or the distal radioulnar joint (DRUJ). Operative treatment is recommended in the literature for displacement of over 50%.[22-24] For displacement of less than 50%, both surgical and conservative treatments have been recommended by different authors, both with good results.[22-24] We concluded that fractures displaced by more than half the diameter of the bone or angulated by more than 10° are potentially unstable.

Biological internal fixation has gained widespread acceptance among orthopedic surgeons for the treatment of long bone fractures. Intramedullary nails provide more biological fixation than classical plate-screw fixation. Therefore, interlocking IM nail systems have expanded the use of forearm nails in managing forearm diaphyseal fractures.[7-9]

Surgical treatment is indicated in fractures with greater than 10 to 15 degrees of angulation and greater than 50% translation. Additional indications include open fractures, high-energy injuries, neurovascular injuries, and patients with weight-bearing upper extremities.[25] Interlocking IM nailing is strongly indicated for segmental or comminuted forearm fractures and closed fractures with poor overlying skin.[8,26-28] However, IM fixation is contraindicated by active infection, a medullary canal diameter of less than 3 mm, and open physes.[4,8,27] In our study, IM fixation was planned for open fracture cases, especially Grade 3A, to prevent additional periosteal and soft tissue damage, provide wound care, ensure skin capping as soon as possible and avoid osteosynthesis material on the bone.

Schöne was the first to use silver nails for radial and ulnar medullary fixation in 1913, and subsequently various nails were developed to stabilize forearm fractures.[7,29] Recently, good results were reported for the treatment of forearm fractures in adults with the ForeSight nail system (Smith & Nephew, Memphis, TN, USA).[26] However, in each patient, the nail required intraoperative bending to create the anatomic bow of the radius and the serpentine shape of the ulna.[4,8] A fluoroscope was also required to apply the distal interlocking screw in the ulna nail as a result of its relatively small diameter.[4,8] Good or excellent results with locked IM nails in the forearm have been reported as 92% by Lee et al.,[7] 100% by Gao et al.,[8] 88.6% by Visńa et al.,[9] and 100% by De Pedro at al.[30]

Brakenbury et al.[31] reported 21 nonunions in a series of 254 isolated ulnar fractures. Displacement of greater than 50% of the ulnar diameter was present in 13 of the nonunions and associated with an increased incidence of nonunion. High-energy injuries and those with indirect mechanisms were also said to be more likely to result in nonunion. Corea et al.[18] reported, in

a series of 245 fractures, a nonunion rate of 10%. In this series, nonunions occurred in 1.4% of the undisplaced fractures, 8% of fractures displaced by 1/4 of the shaft width and 20% of fractures displaced by 1/2 of the shaft width.[18] In our series, there was no incidence of nonunion.

Although isolated ulnar shaft fractures are comparatively rare, they are often associated with a high rate of complications and serious limitations in function.[15] The most commonly reported complications include compartment syndrome, nonunion, radioulnar synostosis, and refracture after hardware removal.[15] In adults, these fractures are known as problematic, necessitating a long time to union and causing possible functional disability in the forearm. However, an angulation of less than 10 degrees in any plane has been shown not to interfere with any limitation in forearm range of motion.[32] None of the angulation in our patients was more than 10 degrees.

The addition of a bone graft to comminuted diaphyseal forearm fractures treated with plate osteosynthesis remains controversial.[4,33,34] However, bone grafting is not necessary when comminuted fractures are treated with IM nails using a closed technique.[8] If open reduction is necessary before nailing, grafting can be performed by obtaining a bone graft from the iliac crest.[25] We did not perform grafting in any of our patients.

In conclusion, the use of the new interlocking IM nails in the treatment of isolated adult ulnar diaphyseal fractures appear to have many benefits and is a good alternative to plate-screw osteosynthesis and classical IM nails. This technique results in a union rate comparable with that following plate fixation, requires no periosteal stripping and uses smaller incisions than those required for plate fixation. Additionally, functional results are extremely good and hopeful as immediate free movement is permitted without using additional fixation.

Conflicts of Interest: No conflicts declared.

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