

Original Research Article

Functional outcome in adults treated for both bone forearm fractures with intramedullary square nails

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ABSTRACT

Background: The forearm fractures are considered intraarticular due to functional characteristics and spatial orientation. These fractures require anatomic reduction to maintain axial and rotational stability and preserve bone length with absolute stability for adequate healing to restore function. Open reduction and internal fixation is accepted as the treatment of choice for both bone forearm fractures according to many studies. However, it can result in complications like extensive soft tissue damage, evacuation of fracture hematoma, periosteal damage, radioulnar synostosis, neurovascular injury, compartment syndrome, delayed union, non-union, infection, refracture after implant removal. Intramedullary nailing is an alternative technique to avoid the above problems, with the advantages of minimal incision, no periosteal stripping, faster healing and biologic fixation. This study evaluates the functional outcome in adults treated for both bone forearm fractures with intramedullary square nail fixation at our institute.

Methods: 113 patients with closed both bone forearm fractures were treated with Intramedullary square nail fixation between January 2014 to December 2023. There were 54 (22A) type fractures, 44 (22B) type fractures, 15 (22C) type fractures. Functional outcome was assessed based on Anderson's criteria.

Results: 105 patients had excellent to satisfactory results while fixation in 8 patients resulted in failures based on Anderson's criteria.

Conclusions: Intramedullary nailing is a simple, safe and effective method of alternative fixation of both bone forearm fractures that is associated with closed reduction, early union, biologic fixation, low infection rate, small cosmetic scars, less blood loss, shorter operating time, and less risk of compartment syndrome.

Keywords: Both bone forearm fractures, Intramedullary square nails, Anderson's criteria

INTRODUCTION

Both bone forearm fractures in adults are most encountered fractures in day-to-day practice accounting for almost 31% of all upper limb fractures. The forearm consists of radius, ulna, interosseous membrane with proximal and distal radioulnar joints and helps in supination and pronation movements. Radius and ulna articulate with one another at proximal and distal radioulnar joints and their stability is an essential requirement for long term functional outcome after injury.¹

Forearm fractures are regarded as intraarticular fractures as slight deviation in the spatial orientation of the radius and ulna significantly decreases the forearm's rotational amplitude and thereby impairs the positioning and function of the hand. Thus, the management of these fractures and their associated injuries is not the same as the treatment of other diaphyseal fractures. Imperfect treatment of fractures of the radius and ulna diaphysis leads to a loss of motion as well as muscle imbalance and poor hand function impeding the function of the upper limb and activities of daily living. Most of the fractures of

both bones of the forearm in adults are treated operatively and various modes of internal fixations are available that are used depending on the choice of the treating surgeon.^{2,3}

Restoring alignment to <10 degrees of angulation is crucial for adequate recovery and patient function.⁴ The goal of treatment for forearm fracture is to ensure maintenance of optimal length and radioulnar joint relationship with full pronosupination.⁵ Open reduction and internal fixation is accepted as the treatment of choice for both bone forearm fractures according to many studies. However, open reduction and internal fixation can result in complications like extensive soft tissue damage, evacuation of fracture hematoma, periosteal damage, radioulnar synostosis, neurovascular injury, compartment syndrome, delayed union, non-union, infection, refracture after implant removal, restriction of forearm rotation due to non-anatomic reduction.¹⁻²⁰

Determining factors in the stability and reduction of the fracture are the muscle strength exerting the deforming force and depends on the presence or absence of injury to the interosseous membrane.⁶ The preservation of interosseous space becomes necessary for successful pronation and supination to take place while treating fractures of the radius and ulna.

Intramedullary nailing is an alternative technique to avoid the above problems, with the advantages of minimal incision, no periosteal stripping, faster healing and biologic fixation. Closed intramedullary nailing respects the soft tissues and vascular supply compared to open reduction.⁷ However, the intramedullary nailing technique is also associated with high rate of non-union, entry point related skin and tendon irritation and the need for additional immobilization.⁸ Intramedullary nailing has been the predominant method of fixation in the paediatric population due to the nature of paediatric bone healing in growth and remodelling potential.⁹ Early reports of intramedullary nailing treatment of forearm fractures with Kirschner wires (K-wires), Steinmann pins, or Rush rods resulted in high non-union rates due to unsatisfactory rotational stability, therefore, nailing was not a preferred method.¹⁰ Street used square nail to overcome the rotational instability of previous nails. The main drawback of this nail was the distraction of the fracture with increased risk of non-union (7%) and the need for cast immobilization.^{11,21} The fracture healing occurs on the principles of relative stability and additional protection to the fracture can be provided by long arm cast or splint.¹²

In 1959, Dr. Sage used prebent triangular nails for the fixation of radius fractures with good results.²² In 1959, Dr. Talwarkar designed and performed fixation of both bones of forearm fractures with flexible square nails.²³ Square nails have revolutionised the concept of internal fixation allowing a four-point fixation with an adequate functional outcome. Intramedullary nailing comes with its own sets of advantages and disadvantages. The chances of infection are significantly decreased, as it is a closed procedure and uses the least amount of periosteal

stripping. It also has lower refracture rates after implant removal.^{13,14} The advantages of intramedullary nail fixation over plating include small incisions, shorter duration of anesthesia, limited soft tissue dissection, rapid union, and excellent recovery of range of motion. However, open reduction and plating allow a more anatomic repair for most fractures forearm rotation.¹⁵ This study evaluates the radiological union, functional outcome to assess forearm rotation in comparison with opposite forearm at follow up and any functional restriction after intramedullary square nail fixation at our institute.

METHODS

Our retrospective study included 113 patients with both bone forearm fractures that were treated with intramedullary square nail fixation from January 2014 to December 2023 at Post Graduate Institute of Swasthiyog Pratishthan, Miraj. Ethical approval for the study was taken from the ethics committee. There were 54 (22 A) type fractures, 44 (22 B) type fractures, 15 (22 C) type fractures. Patients with shaft fractures of both bones of forearm, closed fractures, Gustilo type 1 open fracture, segmental fractures, length stable fractures, pathological fractures, and fit for surgery were included in the study. Patients below 18 years of age, Gustilo type 2 and 3 open fractures, Monteggia and Galeazzi fractures, comminuted fractures, unstable length fractures, isolated radius or ulna oblique fractures or very proximal/distal fractures, medically unfit patients were excluded from the study. Patients were posted after they were declared fit for surgery following their pre-operative workup.

Surgical technique: intramedullary square nail fixation

Patient was placed supine on the operating table. Although tourniquet is not required for nailing, it was tied over the arm but not inflated. The arm was positioned with the forearm in supination and the elbow straight on an arm board. Patients were induced under regional block. Forearm was painted and draped.

A 2 to 3 cm longitudinal skin incision was taken over the radial styloid. Care was taken to protect the superficial radial nerve, abductor pollicis longus (APL) and extensor pollicis brevis (EPB) muscles. The incision was gradually deepened by spreading the forceps and moving the retractors layer by layer until the bone was reached. Incising a section of the extensor retinaculum maybe required. Entry for nail was taken from radial styloid using awl in central position in lateral view. A square nail was slightly curved by hammering the nail to accommodate the radial curve. Fracture was reduced and the nail attached to T-handle was then hammered under C-arm image guidance past the fracture site. The nail was cut flush at the radial styloid end under C-arm image guidance. Wash was given followed by suturing and sterile dressing.

A straight, longitudinal incision was taken above the tip of the olecranon that was about 1 cm long while the patient was supine and their arm was pronated on an arm board.

Entry for nail was taken using awl that was slightly distal to the tip and slightly lateral to prevent backing out of nail & nail protuberance as it could be buried under anconeus. Radius square nail was usually used for ulna and it was slightly contoured. Fracture was reduced and the nail attached to T-handle was then hammered under C-arm image guidance past the fracture site. The nail was cut flush at the olecranon end under C-arm image guidance. Wash was given followed by suturing and sterile dressing.

Postoperative care

The limb was given a posterior above elbow splint in supination and kept elevated for 48 hours, and the patient was instructed to move their fingers. Wound and swelling was inspected after daily dressing. The patient was given above elbow plaster cast in supination on discharge for 4 weeks and encouraged to move their fingers. The patient received analgesics and antibiotics until suture removal. When the patient returned for the plaster cast removal, the sutures were taken out. Anteroposterior and lateral images of the check X-ray were acquired.

Physiotherapy

For two to three days, a posterior splint was used as comfort measure. The patient was urged to move their fingers actively. Elbow range of motion, wrist range of motion, supination and pronation exercises were begun after removal of plaster cast after 4 weeks. Exercises that are isotonic are crucial for the best results because physiotherapy increases blood flow, tethers muscles to the bone, and prevents soft tissue contracture, and it aids with fracture union. As a result, physical treatment under strict fixation produces fantastic outcomes.

Follow-up

All the patients were followed up initially after 2-3 weeks for physiotherapy and thereafter every 6-8 weeks and evaluation was done based on "Anderson's criteria".^{16,17} Elbow, wrist movements, forearm supination and pronation were observed, and a radiological evaluation of the union was conducted. The fracture was classified as united when trabeculation stretched across the fracture line and periosteal callus bridged the fracture site.

Statistical analysis

IBM statistical package for the social sciences (SPSS) for Windows, Version 22.0. Released 2013. Armonk, NY: IBM Corp., was used to perform statistical analysis.

RESULTS

In our study, we included 113 patients aged 18-84 years with both bone forearm fractures. 77 patients were males and 36 were females, 67 cases were right and 46 cases were left both bone forearm fractures, mode of injury in 76 cases resulted from road traffic accidents (RTAs) and 37

cases occurred due to self-fall. There were 54 (22 A) type fractures, 44 (22 B) type fractures, 15 (22 C) type fractures.

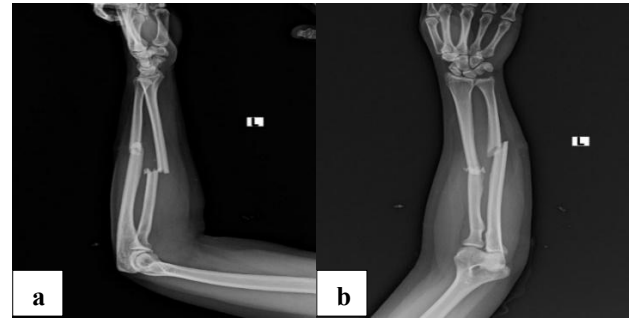


Figure 1 (a and b): Preoperative X-ray of a 38-year-old female patient with AO type 22 A3.2 left both bone forearm fracture.

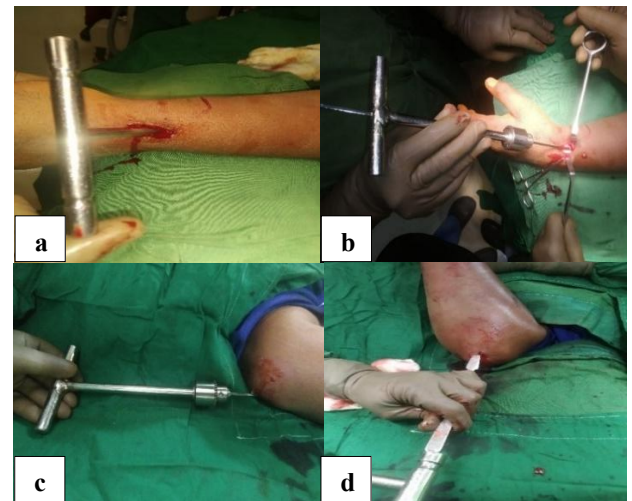


Figure 2 (a-d): Intraoperative clinical images of square nail fixation.

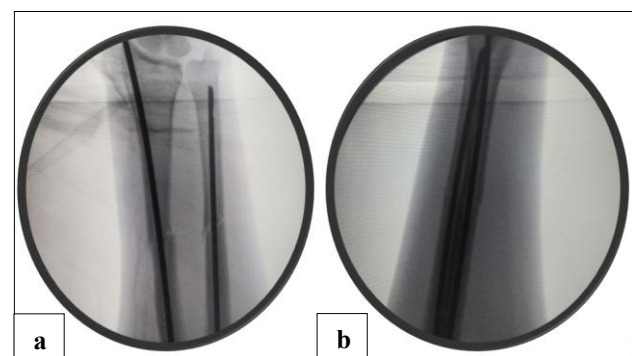


Figure 3 (a and b): Intraoperative C-arm images of square nail fixation in AP and lateral views.

105 cases have united successfully. There were 8 cases of non-union probably due to the oblique, spiral, segmental pattern of fractures that had no compression at the fracture site. Both bone forearm fractures took an average of 28 weeks (24-32 weeks) for the radiological union.



Figure 4 (a and b): Post-operative X-ray of a 38-year-old female patient with AO type 22 A3.2 left both bone forearm fracture.

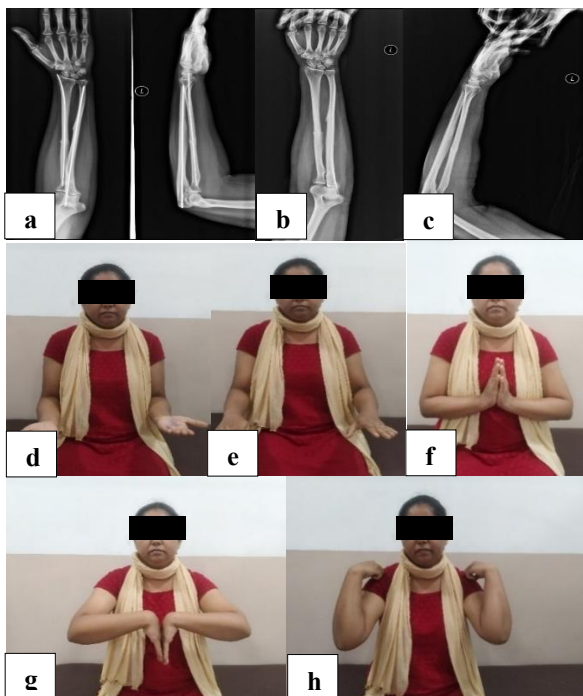


Figure 5: (a) 1.5 years follow up X-ray, (b and c) post implant removal X-ray of a 38-year-old female patient operated with square nail fixation for AO type 22 A3.2 left both bone forearm fracture, and (d-h): clinical images of 1.5 years follow up of a 38-year-old female patient operated with square nail fixation for AO type 22 A3.2 left both bone forearm fracture showing full range of forearm supination/pronation, elbow and wrist flexion/extension.

Table 1: Data with various parameters with respect to both bone forearm fracture fixation.

Parameters	No. of cases (n=113)	Percentage (%)
No. of patients		
Male	77	68.14
Female	36	31.86
Age group (18-84 years), mean age: 35.5 years		
18-30	52	46.02
31-50	45	39.82
51-84	16	14.16

Continued.

Three patients with both bone forearm non-union, two patients with ulna non-union, one patient with radius non-union were revised with plating. One patient with radius non-union was revised with iliac crest bone graft at non-union site. One patient required square nail exchange for radius as smaller diameter nail that was put during primary surgery backed out. 16 patients requested the removal of their implants that was done after 1 year following surgery. Functional results were assessed using Anderson et al criteria which was based on the state of union, loss of flexion and extension at the wrist joint and loss of forearm supination and pronation as compared to that of the uninjured forearm.^{16,17} According to our findings, excellent results were seen in 100 patients (88.50%), satisfactory results in 5 patients (04.42%), and failures in 8 patients (07.08%). All the various parameters of our study are presented in Table 1 with respect to both bone forearm fracture fixation.

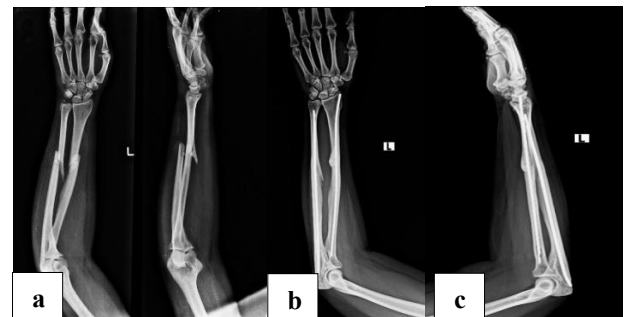


Figure 6: (a) Preoperative, and (b) and (c) 6 years follow-up X-ray of a 35-year-old female patient with AO type 22 B3.1 left both bone forearm fracture.



Figure 7: (a) Preoperative, and (b) 3 years follow-up X-ray of a 30-year-old male patient with AO type 22 A3.2 right both bone forearm fracture.

Parameters	No. of cases (n=113)	Percentage (%)
Mode of injury		
Road traffic accident	76	67.26
Fall	37	32.74
Both bone forearm fracture		
Right	67	59.30
Left	46	40.70
AO classification		
22 A3.1	1	00.89
22 A3.2	53	46.90
22 B3.1	21	18.58
22 B3.2	16	14.16
22 B3.3	7	06.20
22 C1.2	6	05.31
22 C2.2	5	04.42
22 C2.3	1	00.89
22 C3.1	3	02.65
Anderson's criteria		
Excellent	100	88.50
Satisfactory	5	04.42
Unsatisfactory	0	0
Failure	8	07.08
Complications		
Ulna non-union	2	01.77
Radius non-union	2	01.77
Both bone non-union	3	02.65
Nail backout	1	00.89
Revision surgery		
Both bone LCP	3	02.65
Ulna LCP	2	01.77
Radius LCP	1	00.89
Nail exchange	1	00.89
Bone graft	1	00.89
Implant removal	16	14.16

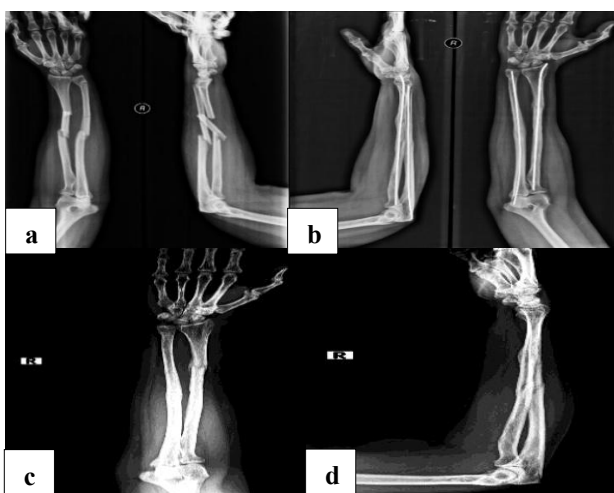


Figure 8: (a) Preoperative X-rays, (b) 1.5 years follow up X-rays, (c), and (d) post-implant removal X-rays of a 44-year-old female patient with AO type 22 C3.1 right segmental both bone forearm fracture.

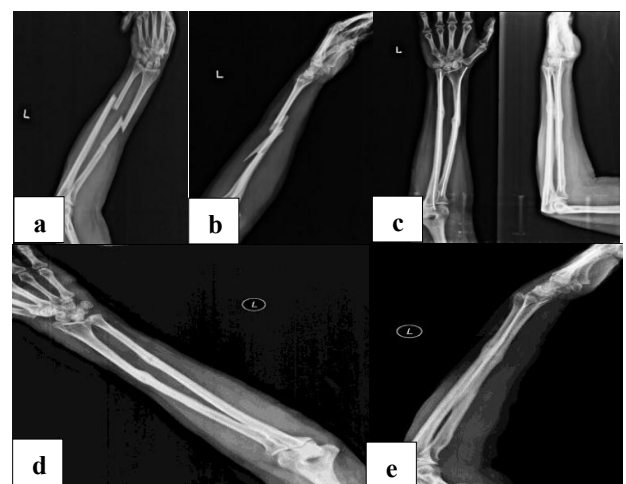


Figure 9: (a) and (b) Preoperative X-rays, (c) 1.5 years follow-up X-rays, (d), and (e) post-implant removal X-rays of a 44-year-old female patient with AO type 22 C2.2 left segmental both bone forearm fracture.

DISCUSSION

Forearm fractures are common in the general population and are usually fixed. They can be managed conservatively with cast application but can result in complications, such as malunion, bayonet apposition, and compartment syndrome leading to decreased rotation of the forearm and poor outcomes. The loss of rotation affects daily activities and hampers upper limb function. The forearm anatomy must be restored for optimal outcomes.

Open reduction and internal fixation with a plate gives functional outcomes, but it also comes with challenges such as disruption of the fracture hematoma and increased chances of infection. Although the use of plates for fracture fixation aligns with the osteosynthesis principles, a straight plate is unable to support and maintain the radial bow essential for the normal rotational movements of the forearm. An intramedullary nail serves as a central load-sharing device based on the principle of three-point fixation preserving the radial bow and helps to resolve distal radioulnar joint (DRUJ) issues. The Rush brothers proposed the concept of three-point fixation to provide stability maintaining the curvature of the radius using the flexible rush pins, however, a thin pin does not adequately ensure rotational stability and its end can cause skin irritation.²⁴ The square shape of the nail significantly enhances stability and promotes fracture healing, leading to reduced rates of non-union for these injuries, however, the possibility of implant migration continues to be a major concern with these nails.

The application of intramedullary nailing for forearm fractures shows promise, however, it remains relatively new for most surgeons. Pre-contoured nails may require bending and further adjustment to align with the radial bow of patients. Nails are less likely to restore and maintain the anatomical bow following closed reduction compared to plating. However, a residual angulation of under 10° in any direction is unlikely to cause functional issues. Forearm rotation may reduce by 20° if there is an angulation of 10° in either the radius or ulna. When angulation reaches 20°, it can lead to significant limitations in passive forearm movement.¹⁶ In the studies by Köse et al and Lee et al, alterations in the radial bow were found to have no association with changes in pronosupination, which aligns with earlier findings from intramedullary nailing research.^{25,26} Therefore, while intramedullary nailing may have reduced accuracy in restoring the radial bow, alterations in the radial bow do not necessarily result in notable differences in clinical outcomes.⁴ Importantly, the idea of utilizing nails for treating forearm fractures allows for "relative stability," challenging the conventional belief that compression and precise anatomical alignment are essential for managing these injuries.⁹

Talwalkar et al treated 80 cases of both bone forearm fractures achieving a 100% union rate using a square nail design.²³ The implementation of Talwalkar's square nail design has led to consistently positive outcomes. The

incidence of complications is lower compared to plate fixation and even locked intramedullary nails, although there is one additional requirement of an above elbow cast after nailing.^{14,15} Intramedullary nails offer several mechanical advantages over the plate and screw fixation. Intramedullary nails are subjected to smaller bending loads than plates and are unlikely to fail by fatigue as they are closer to the mechanical axis than usual plate position on the external surface of the bone. Closed intramedullary nailing is a minimally invasive procedure requiring shorter operating time without disturbing the biology of fracture healing with no requirement of bone graft usually. There is minimal risk of infection. Intramedullary nails serve as a load sharing device in fractures with cortical contact. Intramedullary nails decrease the stress shielding effect with resultant osteopenia that is usually seen with plate and screws. Stress shielding properties of the implant lead to secondary periosteal callus formation. Stabilization in the form of above elbow slab or cast must be provided for at least for one month and sometimes, in comminuted fracture, until callus formation seen on subsequent X-rays. This may result in slight stiffness in wrist and elbow joints that can be improved after physiotherapy.^{2,6-8,16,18}

The most useful aids for maintaining anatomic alignment is to ensure that cortical thickness is the same at the proximal and distal ends of the fracture.¹⁰ Pronation and supination of the forearm and flexion and extension of the wrist were specifically assessed for their relationship to the maximal radial bow and its location.¹⁹ Nail fixation can be an alternative choice in patients with poor skin that may result in infection or wound gape requiring coverage. Further, it is suggested that they may be of particular use in addressing highly comminuted or segmental fractures that are unlikely to be reduced anatomically with open reduction and internal fixation. Some studies suggest that intramedullary nailing is a less invasive, rotationally stable construct that carries high union rates and reduces the chances of infection. A significant finding after intramedullary nail removal is the lack of refractures. Refracture rates following plate removal have been reported in previous studies to range between 5% and 20%. Removal of a nail does not require repeat surgical dissection and does not leave bone voids like in plates after screw removal.

Surgeons should be aware of the problems that might be encountered during the intramedullary forearm nailing. In our study, main complications of nailing were found to be due to improper nail size. The use of nails with a larger diameter can cause iatrogenic fracture while nails with a smaller diameter can cause rotational instability.¹¹

There is risk of damage to the extensor pollicis longus tendon and the superficial branch of radial nerve at the point of entry of the nail. Preoperative planning and a cautious approach during surgery reduces the rate of complications caused by inappropriate nail selection and incorrect surgical technique.¹⁶

Limitations

The limitations of the study were: retrospective design, and absence of a control group.

CONCLUSION

Intramedullary nailing though a simple method is associated with superior results and less complications. Several benefits come with intramedullary nailing: it can be used for temporary fixation in compound fractures till adequate healing of soft tissues, segmental fractures, polytrauma, early union, biologic fixation, low infection rate, small cosmetic scars, less blood loss, shorter operating time, and less risk of compartment syndrome. Best indications for intramedullary nailing in adult diaphyseal forearm fractures include incomplete soft tissue covers, segmental fractures, multiple injuries, severe osteoporosis, non-union in plate fixation, pathological fractures. Stress fractures are not caused by removing an implant. Intramedullary implants also have the essential benefit of stress-sharing behaviour, which makes revision procedures easier if necessary and promotes the production of secondary periosteal calluses. Thus, intramedullary nailing, if done properly in selected patients can give excellent outcomes with proper technique and adequate reduction. The square nail is an ideal and affordable intramedullary implant for the fixation of forearm shaft fractures considering its complications rates, cost and acceptable results.

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Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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