Comparative study between hybrid fixation and dual plating in the management of both bone forearm fractures involving proximal half of radial shaft in adult patients

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Abstract

Background: Both bone forearm fractures in adults are conventionally managed with plate fixation for both radius and ulna. The fractures involving proximal half of radial shaft need extensive muscle dissection, periosteal stripping and carry a risk of posterior interosseous nerve injury. Hybrid fixation for such fractures with titanium elastic nail system (TENs) for radial fixation and standard plating for ulnar fracture is a potentially safer alternative for these fractures. The purpose of this study is to compare the outcomes of the aforementioned hybrid fixation to conventional dual plating for adult both bone forearm fractures involving proximal half of the radial shaft.

Methods: Adult patients with both bone forearm fractures involving proximal half of the radial shaft were randomly divided into a hybrid fixation(A) and dual plating(B) groups over a two-year period. The patients were followed for a minimum of six months and radiological and functional outcomes were compared.

Results: Radiological and functional outcomes between the two groups were comparable with the exception of wrist dorsiflexion which was significantly reduced in the hybrid fixation group. The surgical duration was significantly shorter in hybrid fixation group. Loss of reduction and nail entry point pain were major complications in the hybrid fixation group. Hypertrophic radial scar and transient posterior interosseous nerve palsy were major complications in the dual plating group.

Conclusion: Hybrid fixation using plate osteosynthesis for ulnar fracture and TENs for radial fracture is a valid option for treatment of adult both bone forearm fractures involving the proximal half of radial shaft with a shorter surgical duration and less soft tissue complications when compared to open reduction and plate osteosynthesis for both the fractures.

Keywords: Adult fractures; hybrid fixation; forearm fractures; plate fixation; proximal radius

Introduction

Forearm shaft fractures are among the most commonly observed fractures in orthopedic practice[1]. While multiple treatment options have been advocated for these fractures in pediatric patients with surgical treatment being preferred in older children, the treatment of most of the adult forearm fractures is surgical[2]. A variety of surgical options have been explored for the treatment of these injuries in older children and adults. Intramedullary elastic nailing and plate osteosynthesis have been the commonly used modalities for the treatment of forearm fractures in older children and adults, respectively[3,4,13,14]. The least explored option of hybrid fixation with one of the two fractured bones being treated with plate osteosynthesis and other with an intramedullary device in adult patients has been analyzed in very few studies[5,6,7]. These few studies have reported good radiological and functional outcomes with hybrid fixation. However, a larger volume of evidence is still needed to establish the equivalence between hybrid fixation and standard plating methods for the treatment of both bone forearm fractures in adults.

For forearm fractures with involvement of proximal half of the radial shaft, the plating methods require careful dissection around the posterior interosseous nerve and can potentially injure the same because of its variable location[8]. Moreover, the muscular bulk in the proximal forearm requires extensive exposure and periosteal stripping which may lead to muscle necrosis, soft tissue injury and even compartment syndrome[4-7]. The closed elastic intramedullary nailing for these fractures has been successfully used in young and older children with functional outcomes comparable to plating methods[9]. These are associated with reduced periosteal and soft tissue damage and do not hinder the process of natural fracture healing. The fracture healing occurs on the principles of relative stability and additional protection to the fracture can be provided by a long-arm cast or splint. However, there is paucity in literature regarding the use of hybrid fixation in adult both bone forearm fractures[10]. We attempted to explore the outcomes of hybrid fixation with titanium elastic nail system (TENs) for radial shaft fractures and standard plating (compression or bridge mode) for ulnar fractures in adult both bone forearm fractures involving proximal half of...
the radial shaft and compared the radiological and functional outcomes with a control group that was treated with standard plating for both the fractures.

Materials and methods
The study was conducted in a tertiary care center after obtaining the clearance from the institutional ethical committee. The study was a prospective one conducted over a two year period between June 2017 to June 2019 and the enrolled and patients were followed for a minimum period of 6 months after surgery. Adults with both bone forearm fractures with involvement of proximal half of the radial shaft were included. Only those cases that were planned for definitive internal fixation were enrolled. Open fractures, delayed presentation of more than 3 weeks, fractures with neurovascular injuries, pathological fractures, cases with signs of old bony injury on the affected forearm, associated wrist or elbow joint injuries and patients with a known history of smoking or tobacco consumption and metabolic disorders were excluded. The enrolled patients were randomized (permuted block randomization method) into two groups, group A that underwent hybrid fixation with an intramedullary fixation using titanium elastic nail system (TENs) for radial shaft fracture and standard plating for ulnar shaft fracture. The ulna was approached using the standard subcutaneous approach with a plane between Flexor Carpi Ulnaris and Extensor Carpi Ulnaris. The TENs for the radial shaft fracture was inserted in a retrograde manner through an entry point over the lister tubercle using a small 1-2 cm incision for exposure. The diameter of the nail was kept approximately half to two-thirds of the diameter medullary.

### Surgical procedure:
All surgeries were performed under tourniquet control, either in general or regional anesthesia or both. In Group A, the ulnar shaft fracture was fixed using a 3.5mm locking compression plate (LCP) or dynamic compression plate (DCP) and intramedullary TENs were used for fixation of radial shaft fracture. The ulna was approached using the standard subcutaneous approach with a plane between Flexor Carpi Ulnaris and Extensor Carpi Ulnaris. The TENs for the radial shaft fracture was inserted in a retrograde manner through an entry point over the lister tubercle using a small 1-2 cm incision for exposure. The diameter of the nail was kept approximately half to two-thirds of the diameter medullary.
canal at the isthmus of the radius. The nail was inserted up to the terminal extent of the medullary canal under fluoroscopic control. The near end of the nail was bent and buried inside the wound. All attempts were made to perform closed intramedullary nailing of the radial fracture. In cases with failed attempts of closed intramedullary nailing, a small incision, sufficient enough to expose the fracture was made over the fracture site in the plane of either Henry’s anterior approach or Thompson’s posterior approach to the radial shaft and an open reduction was performed. In Group B, the radius shaft fracture was approached using either Thompson’s posterior approach or Henry’s anterior approach and the ulnar shaft fracture was exposed using a standard subcutaneous approach. Plating methods depending upon the fracture pattern for fixation of both radial and ulnar shaft fractures. In both the groups, the simpler fracture was stabilized first. In both ulnar and radial comminuted fractures, the less comminuted one was fixed first. The surgical duration was recorded in all cases.

Postoperative care:
All fractures in group A were kept in an above elbow plaster splint or cast for a period of four weeks postoperatively, while in group B the fractures were supported by an arm pouch for two weeks. The patients were discharged on the 2nd or 3rd postoperative day after wound inspection with the exception of cases with clinical suspicion of wound infection. Sutures were removed at two weeks postoperatively. Range of motion exercises around elbow, forearm, and wrist were started in group B as early as from 1st post-operative day, while in group A, supervised followed by independent elbow flexion-extension and wrist range of motion exercises were started after four weeks and the limb was kept supported in a removable above elbow posterior splint during the rest of the time until the signs of radiological union were evident. Supination and pronation exercises were started only after the radiological union of both the bones was evident on follow-up radiographs.

Followup:
All patients were followed at two weeks postoperatively for suture removal and to look for early complications. Second follow up was at four weeks for group A to document radial shaft fracture displacement and for initiation of exercises, and at six weeks postoperatively for group B for radiological and functional evaluation. Thereafter, the patients in each group were followed at every six-week interval for radiological and functional assessment for the next six months and every three months after that. However, only six months follow up assessments for each patient were charted to maintain uniformity in results.

**Table 3: Patients profile and functional outcomes**

| Variable                              | Group A (Hybrid fixation) | Group B (Dual plating) | Remarks           |
|---------------------------------------|---------------------------|------------------------|-------------------|
| Number                                | 29                        | 27                     | Comparable numbers |
| Male:female ratio                     | 20:9                      | 20:1                   | Similar sex ratio  |
| Mean age (in years)                  | 30.05                     | 31.33                  | Non-significant   |
| SD                                    | 30.40                     | 30.37                  |                   |
| Mean surgical duration (in minutes)   | 5.65                      | 7.17                   | p = 0.035         |
| SD                                    | 3.97                      | 5.2                    | Significant       |
| Mean forearm supination (in degrees)  | 60.48                     | 64.97                  | Non-significant   |
| SD                                    | 5.69                      | 4.97                   |                   |
| Mean forearm pronation (in degrees)   | 77.09                     | 80.70                  | p = 0.060         |
| SD                                    | 5.86                      | 4.99                   | Non-significant   |
| Mean loss of supination pronation arc (in degrees) | 12.43 | 11.44 | p = 0.305 |
| SD                                    | 3.00                      | 4.11                   | Non-significant   |
| Mean elbow flexion (in degrees)       | 3.88                      | 4.11                   | Non-significant   |
| SD                                    | 5.89                      | 4.98                   |                   |
| Mean elbow extension (in degrees)     | 3.73                      | 6.62                   | p = 0.717         |
| SD                                    | 9.99                      | 5.90                   | Non-significant   |
| Mean loss of elbow flexion-extension arc (in degrees) | 2.80 | 3.73 | p = 0.531 |
| SD                                    | 5.06                      | 5.22                   | Non-significant   |
| Mean wrist dorsiflexion (in degrees)  | 32.13                     | 77.81                  | p = 0.005         |
| SD                                    | 3.48                      | 4.11                   | Non-significant   |
| Mean wrist palmar flexion (in degrees)| 75.68                     | 75.44                  | p = 0.973         |
| SD                                    | 4.21                      | 4.22                   | Non-significant   |
| Mean Mayo elbow performance score (out of 100) | 92.24 | 90.55 | p = 0.409 |
| SD                                    | 8.13                      | 10.33                  | Non-significant   |

**Table 4: Radiological assessment, performance scores, and complications**

| Variable                              | Group A (Hybrid fixation) | Group B (Dual plating) | Remarks |
|---------------------------------------|---------------------------|------------------------|---------|
| Cases with delayed union              | 5                         | 2                      |         |
| Cases with non-union                  | 0                         | 0                      |         |
| Functional score according to Anderson criteria | Excellent - 26 | Excellent - 22 |         |
| Unsatisfactory                        | 0                         | 0                      | Non-united based on radiographs. A fracture was considered as united when bridging bone was formed around the fracture site with appreciable trabecular or cortical continuity within four months follow up. Delayed union was present when radiological signs of bridging bone appeared after four months of follow up. Nonunion was defined as the absence of radiological signs of unions for up to a period of six months.

**Radionical assessment**
Standard radiographs were obtained at second follow up and six weekly thereafter until the fracture was deemed united or not united based on radiographs. A fracture was considered as united when bridging bone was formed around the fracture site with appreciable trabecular or cortical continuity within four months follow up. Delayed union was present when radiological signs of bridging bone appeared after four months of follow up. Nonunion was defined as the absence of radiological signs of unions for up to a period of six months.

| Variable                              | Group A (Hybrid fixation) | Group B (Dual plating) | Remarks |
|---------------------------------------|---------------------------|------------------------|---------|
| Complications                         |                           |                        |         |
| Wound infection                       | 0                         | 4                      |         |
| Fracture displacement                 | 5                         | 0                      |         |
| Transient posterior interosseous nerve pathology | 0 | 3 |         |
| Entry point pain                      | 5                         | 0                      |         |
| Hypertrophic scar                     | 0                         | 5                      |         |
| Radial fracture site pain             | 0                         | 3                      |         |
| Total complications                   | 10                        | 15                     |         |
Functional assessment-
To maintain uniformity in the assessment of functional outcomes, the functional assessment was made using the criteria of Anderson et al.[11]( Table 1) and Mayo elbow performance score[12]( Table 2) at six months follow up which was also the cut-off limit for marking a fracture as united or non-united.

Statistical analysis was performed using IBM ® SPSS 22 software (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.). The parameters related to radiological and functional outcomes were compared among the two groups and differences with a p-value < .05 were considered significant.

Results
A total of 61 patients were enrolled in the study, out of which 56 patients ( group A = 29, group B = 27) were available for assessment at a minimum of six months follow up period. Male to female ratio was 20:9 in group A and 2:1 in group B. The mean age was 30.8 years in group A and 31.3 years in group B. Among the various parameters studied, statistically significant differences were noted in relation to two parameters, first, the surgical duration which was less for hybrid fixation as compared to the dual plating group, and second the wrist dorsiflexion which was reduced for hybrid fixation group at six months follow up. Detailed results are presented in Table 3. Union was evident in all the cases by the end of six months (Figures 1 and 2).

Complications
Delayed union was observed in 5 cases in group A and 2 cases in group B. As far as the functional outcomes were concerned, the results were comparable. The complication rate was slightly higher in group B (dual plating group) (Table 4). However, the types of complications in the two groups were different with posterior interosseous nerve palsy, wound infection and a hypertrophic scar on radial incision site being noted in group B only. The hypertrophic scar did not affect the functional capacity of the affected limb. The posterior interosseous nerve palsy was transient and recovered in all the affected cases without any intervention. None of the patients developed any deep infection. All wound infection cases had a superficial infection which responded well to oral antibiotics without any surgical intervention. Fracture site pain was mild to moderate in intensity and was managed symptomatically with analgesics when required. The elastic nail entry point pain was probably related to a prominent nail tip and got improved in cases that underwent nail removal following the union.

Discussion
Fractures of forearm shaft have classically been treated with open reduction and internal fixation using plate osteosynthesis. Forearm fractures being considered equivalent to articular fractures need anatomical reduction and stable fixation to permit early mobilization. However, the problem occurs when the proximal third of the radial shaft is involved. The muscle bulk in this region is more voluminous. When anterior Henry’s approach is used there is damage to pronator teres and supinator muscles which are usually stripped off to gain exposure. This can affect the functional strength of the forearm. And when posterior Thompson’s approach is used, it carries a risk of injury to the posterior interosseous nerve. Moreover, frequently, these fractures have been associated with excessive swelling and performing open procedures for both the fractures results in increased soft tissue damage and aggravating the swelling. The wound closure in such cases can be under increased tension and carries a risk of compartment syndrome and wound dehiscence. An open procedure for ulnar fracture and a closed one for the proximal radius shaft fracture can effectively reduce these risks. Closed methods of radius shaft fixation include intramedullary solid nail insertion, rush nail insertion, interlocking nail fixation, and titanium elastic nail insertion. The problem associated with nonlocking intramedullary nails, especially the square nails is their non-elastic nature which leads to mismatch with normal radial bowing and thus leading to loss of reduction[15]. The rush nail is a flexible nail and can take the shape of the radial bow when inserted but does not carry any inherent stability and function like an intramedullary spacer. There is a need for prolonged cast immobilization and the additional risk of non-union[16]. Interlocking nails need insertion of locking bolts proximally and distally which again carries the risk of injuring posterior interosseous nerve proximally and Extensor Pollicis Longus and superficial radial nerve distally[17]. TENs had been successfully used for pediatric and adolescent forearm fractures and helps avoiding the shortcomings related to open procedures[13,14]. The titanium elastic nail has its own inherent stability with three-point pressure stabilization inside the intramedullary cavity which provides relative stability at the fracture site. The stability gets further augmented when one of the two bones of the forearm is fixed with plate osteosynthesis. The usual period of immobilization in such fixation is up to four weeks and functional outcomes do not vary much with fracture displacement[10,18]. The application of TENs for fixation of proximal radial shaft fractures has been shown to have favorable functional outcomes in the past few studies[5,6,7]. Our results support...
these results and indicate several advantages of TENs nailing over open fixation with plates. The procedure is soft tissue friendly, avoids the risk of muscle and nerve damage and significantly reduces surgical time. The only functional limitation observed in our results is related to the limited dorsiflexion of the wrist because of the protruding end of the nail. The same can be corrected after removal of the implant once a consolidated union at fracture has been obtained. The complications related to TENs nailing were very few and far simple compared to the dual plating group. Five patients had entry site pain which was probably related to the prominent end of the nail and five patients had fracture site displacement. Although the union was delayed in 5 cases in the hybrid fixation group, none of the patients developed non-union. The complications related to wound infection, hypertrophic scar and posterior interosseous nerve palsy were observed in the dual plating group. These complications might not affect the long term outcomes but can pose major functional limitations and psychological burdens to the patient for the short period of their affection.

The complication of dorsal tendon rupture or irritation, especially the extensor pollicis longus tendon, has not been observed in our study. The entry point of titanium elastic nail was created over lister tubercle under direct vision, thus avoiding injury to surrounding tendons. However, the risk of delayed tendon rupture could not be assessed owing to the limited follow up of 6 months. A long term followup would be needed to comment on the same.

**Conclusion**

Hybrid fixation using plate osteosynthesis for ulnar fracture and TENs for radial fracture is a valid option for treatment of adult both bone forearm fractures involving the proximal half of radial shaft with a shorter surgical duration and less soft tissue complications when compared to open reduction and plate osteosynthesis for both the fractures.

**Clinical relevance**

Hybrid fixation of adult both bone forearm fractures involving proximal half of radial shaft, using plate fixation for ulnar shaft fracture and TENs for radial shaft fracture, is a potential alternative to conventional plating with comparable functional and radiological outcomes and a lesser risk of complications.

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