FUNCTIONAL OUTCOME OF OPEN REDUCTION AND INTERNAL FIXATION OF SEGMENTAL (BIFOCAL) FOREARM FRACTURES

Abstract:

Background- Segmental fractures of the forearm bones are rare and occasionally seen by trauma surgeons. These are often seen in high velocity injuries, and hence are accompanied by high degree of comminution and compounding of fracture fragments. Proper preoperative planning is required for optimal restoration of forearm function. Although Segmental fractures of forearm bones have been classified by AO group, it does not provide a treatment algorithm. Aim of our study is to analyze the functional outcome of segmental forearm fractures treated by various modalities, and to classify these fractures based on management modalities.

Materials and methods- Between January 2009 to December 2015 19 patients with segmental forearm fractures who underwent operative management were included. Patients less than 18 years and group III-b and group III -c open fractures (Gustilo and Anderson) were excluded. For the study purpose the segmental fractures of (radius or ulna) were classified in to five groups and operative procedure was defined for each group based on fracture location and pattern.

Results - A total of 19 patients were included in the study. 16 were male and 3 female patients. According to the Grace and Eversmann rating system 9 patients (47%) had an excellent result, 7 patients (36%) had good result, and 3 patients (15%) had acceptable result.

Conclusions- Although segmental fracture pattern can be classified by AO classification, guide lines for management of these fractures have not been defined. Based on our classification and treatment algorithm for segmental forearm fractures in 19 patients we had good to excellent results in 16 (84%). Average union time in our series was 30 weeks. An Attempt has been made to classify segmental forearm fractures based on treatment modalities which can be adapted for most segmental fractures. Our study has limitations in that it involves a small number of patients and further long term randomized control studies are needed.

Keywords: Segmental (bifocal fracture), forearm fractures, fracture surgery
Introduction

Forearm fractures in adults are commonly encountered in orthopedic practice and are treated accordingly by plating or nailing as per current standard practices. Anatomical restoration of length of both ulna and radius is of critical importance, as a small amount of mismatch will produce restriction of supination and pronation, this is the reason why the forearm is also called as a “functional joint”\(^1\). So this restoration of functional joint still becomes critical in segmental forearm fractures. Segmental forearm fractures are relatively rare with reported incidence of 0.1% of all fractures\(^2\). Segmental forearm fractures occur as a result of high energy injury, and are usually complicated by associated soft tissue injury, comminution at fracture site and open fractures. So in these fractures it is of critical importance to reestablish the function of the forearm. Although the classification of segmental both bones forearm fractures has been included in the Ota Classification, Its usefulness in management strategy is limited and its use is largely restricted for research methodology\(^3\). Proper preoperative planning is required in terms of choice of implant, surgical approach and sequence of fracture fixation to achieve stable fixation and to avoid soft tissue complications. There are various case reports of segmental both bones forearm fractures reported, however there is no attempt made to classify these fractures from a management point of view. So with this background we have made an attempt to study and classify these fractures based on fracture anatomy and pattern, and also propose an operative algorithm for these fractures.

Materials And Methods

Between January 2009 to December 2014, 19 patients with segmental (bifocal) forearm fractures who were treated in our institution were included in the study. Patients who were less than 18 years and group III-b and group III -c open fractures (according to the criteria defined by Gustilo and Anderson\(^4,5\)) were excluded from the study. Life threatening and associated surgical injuries were treated first and the patient hemodynamically stabilized before preparing for orthopaedic investigations and interventions. The radiological investigations of segmental fractures of forearm where once again reviewed and studied preoperatively for any missed fractures around the elbow and wrist. Any additional radiographs required were obtained and assessed.

For the study purpose the segmental fractures of either bones (radius or ulna) were classified in to five groups,
GROUP IV
Segmental fracture involving upper 2/3rd of radius
Unifocal ulna fracture

GROUP V
Segmental fracture of radius
Segmental fracture of ulna

Surgical Technique

Majority of patients operated under brachial block or general anesthesia depending on anesthetist and associated injury. Tourniquet was used in all patients. Thorough debridment in consultation with plastic surgery team for open segmental fractures was done. Unifocal fractures depending upon the groups to which the fractures belonged were fixed first by open reduction and plating to gain the length of the forearm. Radius fracture was approached by volar Henry’s approach and ulna fractures were approached by direct incision over the palpable border of ulna. Standard 3.5mm DCP was used to fix these fractures and standard plating principles followed. Segmental fractures of the radius or ulna which required square nailing was done under C-ARM guidance by closed methods whenever possible, mini incisions over the fracture site was taken if closed nailing failed. Final reduction was checked under C ARM guidance and also the elbow and wrist for any instability.

Post-operative protocol

Following surgery operated forearm was immobilized with above elbow slab for 6 weeks and after 6 weeks mobilization of elbow and wrist joint started. Patients were allowed to lift weight with operated limb after radiological union of fracture. Patients were followed up at 1, 3, and 6 months and at one year and evaluated for functional and radiological outcome at one year follow up.

All patients were evaluated at minimum one year follow up for radiological union and range of movement of elbow, forearm and wrist joint movements. Results were assessed depending on the time to union, functional recovery, physical activity and complications.

Functional recovery assessed using Grace and Eversmann’s rating system, which is based on fracture union and forearm rotation. The patient-rated outcome was assessed with use of the Disabilities of the Arm, Shoulder and Hand questionnaire (DASH). Results

A total number of 19 patients were available for follow up, All patients were evaluated at minimum one year follow up for radiological union and range of movement at elbow, forearm and wrist joint. Results were assessed depending on the time to union, functional recovery, physical activity and complications. There were 16(84%) male and 3(16%) female patients. The right forearm was involved in majority of the patients 13(68%) as compared to left forearm 6(32%). The mode of injury in majority of the patients was 17(89%) RTA( road traffic accidents) and in the remaining 2(11%) patients the injury was due to fall from height.

The distribution of patients based on classification of segmental forearm fractures was as follows.

Group I- 2 patients
Group 2-4 patients
Group 3-6 patients
Group 4-4 patients
Group 5-3 patients

Fractures Based On Compounding At Fracture Site

Closed -7
Grade I-7
Grade II-2
Grade IIIA-3
Average time for radiological union in our study was 30 weeks (range 23 weeks to 42 weeks). One patient with
grade III-A open segmental fracture of ulna required bone grafting at 8 months for the signs of delayed union. One patient with type III-A open fracture of lower third ulna went into pseudoarthrosis as the comminuted small fragments with no soft tissue attachments were removed at the time of surgery primarily. No patient in our study had radio-ulnar synostosis.

Three patients had restriction of pronation and one patient had restricted supination and pronation. Mean supination was 82° (range 72° to 90°). Mean pronation was 70° (range 60° to 90°).

Functional recovery was assessed using Grace and Eversmann\(^3\) rating system, which is based on fracture union and forearm rotation. The patient-rated outcome was assessed with use of the Disabilities of the Arm, Shoulder and Hand questionnaire (DASH)\(^5\).

According to the Grace and Eversmann rating system, 9 patients (47.3%) had an excellent result, 7 patients (36.8%) had good result, and 3 patients (15.7%) had acceptable result. Two patients with acceptable result in our study had open fracture and other patient with acceptable result is attributed to delayed union. Average DASH score in our study is 18 points with range from 6 to 54 points. 13 (70%) patients had very good result with DASH score less than 19 points.

Discussion

Open reduction and internal fixation as an effective treatment modality in the treatment of acute diaphyseal forearm fractures has been well established\(^8,9,10,11,12,13\). Although forearm fractures do not involve the wrist or elbow joint and hence can’t be considered as intraarticular fractures, the concept of the intreosseous space to be acting as a functional joint and its normal restoration, has been well recognized to gain full pronation and supination in the management of these fractures\(^1,10\).

So with the above background it’s very essential to restore the forearm to its optimal function even in case of segmental (bifocal) forearm fractures as compared to simple forearm fractures. Segmental (bifocal) forearm fractures although are seen now occasionally by orthopedic surgeons, their Incidence is set to increase in the near future due to increased incidence of high velocity RTA (road traffic accidents). This increase in high velocity (RTA) injuries can result in fractures with increased comminution and configuration which sometimes cannot fit into traditional classification systems. In this scenario the treating orthopedic surgeon must have a protocol or a management based classification which he can rely on to plan and execute a treatment protocol which will restore the forearm to its optimal function.

The OTA classification is comprehensive and has classified segmental (bifocal) forearm fractures extensively and its usefulness is unquestioned and most useful for documentation and research purpose. The OTA classification however does not propose or provide a guideline or protocol to treat segmental forearm fractures. In order to have a better understanding of these fracture, and to classify these fractures from a management point of view this study was undertaken. The outcome was to provide a rough guideline to the treating surgeon when such fractures are encountered.

Epidemiologically the incidence of forearm fractures is more in males compared to females and in the present study also there were 84% males as compared to females 16% in segmental (bifocal) forearm fractures. In our study the right side was predominantly involved (68%) and in majority of the patients the mode of injury was RTA (road traffic accidents) indicating that these fractures are a result of high velocity injuries. The initial assessment of segmental forearm fractures who are involved in such high velocity injuries become difficult as there are more serious and life threatening injuries which have to be dealt immediately. However a quick assessment of soft tissue and neurovascular integrity has to be done during the initial assessment, once the X rays are available then the operative plan can be made.

The rationale of classifying these fractures into 5 groups was based on management strategies depending upon the fractures site and fixation biomechanics. When we study the biomechanical principles of various fixation modalities used in the treatment of forearm fractures, mainly plating and nailing, numerous authors have demonstrated their usefulness\(^10,11,12\).

Anderson LD et al\(^13\) have shown good to excellent results in 96 to 98% of patients treated with open reduction and plating of diaphyseal fracture of radius and ulna. Hadden WA et al\(^14\) also have shown 98% union rate in their study where AO plate fixation used for forearm shaft fractures in adults. These results no doubt are apt in management of closed diaphyseal fractures of forearm, but in the scenario of segmental (bifocal) forearm fractures in which there is some soft tissue compromise also present, can these principles of plating be applied is debatable. This is due to the extensive soft tissue stripping involved in plating.
of segmental (bifocal) fractures with compromised soft tissue envelope. The intramedullary devices used for treatment of forearm fractures were introduced to overcome drawbacks of plating. Earlier designs like k wire and rush nail had high incidence of nonunion (20%) and are associated with poor results. This is attributed to poor rotational instability due to thin nail and circular cross section of implant design. Street came up with square nail which improved the rotational stability and shown satisfactory result in diaphyseal fractures of forearm. Platz A et al also recommended dorsal plating in comminuted proximal ulnar fracture due to wide medullary canal which also holds good for other fractures in upper limb bones with wide medullary cavity.

The decision of plating and nailing in compound fractures is debatable and depends upon the treating surgeon’s assessment and acumen. In our series we have performed thorough debridement and primary internal fixation for compound fractures with either DCP or intramedullary nailing; this we believe stabilizes the bone, restores stability and eliminates dead space promoting wound healing. The decision of intramedullary nailing in compound fractures has to be taken carefully considering the feasibility of primary skin cover and fracture pattern. Intramedullary nailing is more favorable in areas with narrow medullary cavity (for example in lower third of ulna and upper third of radius).

Bone grafting at primary surgery is not preferred and can be done later if the situation demands. In our series 1 patient with grade 3A compound ulnar fracture with bifocal radius fracture developed nonunion at ulnar fracture site which united with bone grafting. In our series we encountered a case of pseudoarthrosis of distal ulna in whom there was primary bone loss at the distal compound ulna fracture and she also had a trifocal segmental radius fractures. The radius fractures healed uneventfully. Reconstructive surgery for pseudoarthrosis of distal ulna was refused by her due to financial constraints. (figure 3)

Majority of patients in our study had functional recovery of elbow and wrist joint movements. Three patients had restriction of pronation and one patient had restricted supination and pronation. Mean supination was 82° (range 72° to 90°). Mean pronation was 70° (range 60° to 90°) table 3. Functional recovery assessed using the Disabilities of the Arm, Shoulder and Hand questionnaire (DASH).

According to the Grace and Eversmann rating system, 9 patients (47.3%) had an excellent result, 7 patients (36.8%) had good result, and 3 patients (15.7%) had acceptable result. Average DASH score in our study is 18 points with range from 6 to 54 points. 13 (70%) patients had very good result with DASH score less than 19 points. These functional results are compared to forearm fractures rather than segmental (bifocal) forearm fractures due to paucity of literature. We feel segmental (bifocal) forearm fractures are serious injuries in which union of fractures with optimal soft tissue healing are the primary goals with an aim to restore maximal (functional) movements of forearm.

Rationale For Classification Into 5 Groups

Our classification of segmental forearm fractures into 5 groups and the treatment methods formulated was based on these studies.

-For fractures that involve radius shaft, these require anatomical restoration of the radial bow to restore Pronation and supination and this is best accomplished by plating if the soft tissue envelope permits.

-For segmental fractures that involve the upper ulna shaft, these fractures involve areas which have broad medullary cavity and hence stable fixation can be achieved by plating rather than nailing as the rotational stability is compromised with nailing if fractures in these areas are further associated with comminution.

-For fractures that involve the lower one third radius, these fractures are best treated by buttress plating volarily if the fracture pattern allows.

-For fractures that involve the lower two third of ulna or upper two third of radius, these fractures involve areas which have narrow medullary canal, and hence can be treated by closed or mini open intramedullary nailing (square nail) to achieve adequate stability for fracture healing.

-For fractures that involve the segmental (bifocal) forearm fractures in which there are segmental fractures of both radius and ulna, depending upon the soft tissue integrity the surgeon can choose to do plating of one bone and nailing for the other depending upon the contamination and local soft tissue environment.

We have not used locked intramedullary nails for any of the segmental forearm fractures in our
series, these locked intramedullary nails for the forearm may have a significant role to play in as they can be inserted in a closed manner and the newer locking systems in these nails may provide more rotational stability then the traditional square nails. The locking mechanisms in these nails can further increase the stability and provide more biomechanical advantages to intramedullary nails when compared to plating. To conclude segmental (bifocal) fractures of the forearm bones are rare and usually result from high velocity injuries. Fracture comminution and compromised soft tissue envelope pose serious challenges in planning and managing these injuries. Our classification involving 5 groups can be used to classify most of these injury patterns, and also outlines management guidelines which are based on fracture location and biomechanical fracture fixation principles which can be adapted in operative management of these injuries. We also feel that in spite of classifying segmental (bifocal) fractures into these groups there may still be some fracture patterns which may still not be possible to include in any of these groups. This may be due to increased high speed collisions in road traffic accidents which may produce bizarre fracture patterns which may not fit into any of the classification patterns. However for comprehensive classification of segmental (bifocal) fractures the AO (OTA classification) is still useful. Our study has got limitations in that although our study has made an attempt to classify segmental (bifocal) forearm fractures into groups so as to describe a management based protocol, it involves a small group of patients (19). Further large studies involving more patients can give a clear insight regarding these challenging injuries.

**Figure 1---Group II**

**Figure 2---group III fracture pattern showing pre-operative, immediate post-operative and final X ray appearance after fracture union**

**Figure 3---Group IV**

**Figure 4 Group V**
Figure 4—group V fracture pattern showing pre-operative, immediate post-operative and final X ray appearance after fracture union

References

3. Rockwood and Greens fractures in adults -Charles M. Court-Brown, James D. Heckman, Margaret M. McQueen, Paul Tornetta (III), William M. Ricci, Michael D. McKee-Wolters Kluwer Health 8th edition page-1134-1136
20. Kenneth a. egol, Kenneth j. koval, joseph D. Zuckerman in HAND-BOOK OF FRACTURES 5TH EDITION Page number 559-571