A CLINICAL STUDY ON INTERNAL FIXATION OF DIAPHYSEAL FRACTURES OF BOTH BONES FOREARM WITH DYNAMIC COMPRESSION PLATE
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ABSTRACT

BACKGROUND
With mechanized farming in India and industrialization, both bone forearm fractures have become common. If the fractures are treated inadequately, it may result in severe loss of function. So, in order to restore function, anatomical reduction and internal fixation is necessary. Union may be achieved with any of the methods available; however, severe loss of function may be the end result unless adequately treated with proper technique and implants. With the development of compression plate osteosynthesis which provides a good treatment option and predictable outcome, there is an important change in the treatment of forearm fractures. This method helps in perfect reduction of fracture fragments in anatomical position by rigid fixation and early mobilization, the normal functions of the hand can be achieved at the earliest.

MATERIALS AND METHODS
In this study, 30 patients with forearm fractures, were treated by open reduction and internal fixation with 3.5 mm dynamic compression plate (DCP) and screws in patients with displaced fractures of the shaft of forearm bones. This study was conducted from February 2017 to January 2019 at Government General Hospital, Kurnool (attached to Kurnool Medical College, Kurnool).

RESULTS
On an average, follow up period of these patients was 12 months. The results were correlated under Anderson et al, scoring system. There were 23 (76.66%) patients with excellent results, 5 (16.66%) patients with satisfactory results and 1 (3.33%) patient with unsatisfactory result and 1 (3.33%) patient had failure. Unsatisfactory result was due to comminution of fracture (prolonged immobilisation) and patient non-cooperation for instructions.

CONCLUSION
Post operatively, with DCP fixation, additional supportive measures may not be required after soft tissue healing and shoulder elbow and wrist movements can be started early. This helps prevent muscle atrophy and joint stiffness. It is very much possible in intelligent and cooperative patients. However, all patients should be curtailed from lifting heavy weights till union of fracture. Almost all fractures in our study united by 4-6 months. The AO principles of internal fixation namely (1) anatomical fixation, (2) preservation of vascularity, (3) mechanically stable fixation, (4) rapid mobilization of joints in proximity, can be achieved with compression plating system. With rigid/anatomical internal fixation, dynamic compression plate is a good fixation for displaced diaphyseal fractures of the forearm bones. Adherence to AO principles, strict asepsis, proper post-operative rehabilitation and patient education are more important to obtain excellent results. Also, external immobilization was not necessary in intelligent and co-operative patients. Therefore, internal fixation with dynamic compression plate appears to be the gold standard for fractures of forearm.

KEYWORDS
Diaphyseal Fractures, Both Bones, Forearm, Dynamic Compression Plate.

HOW TO CITE THIS ARTICLE: Babu APK, Kumar MR, Reddy BS, et al. A clinical study on internal fixation of diaphyseal fractures of both bones forearm with dynamic compression plate. J. Evid. Based Med. Healthc. 2019; 6(11), 842-847. DOI: 10.18410/jebmh/2019/177

BACKGROUND
The forearm, being a component of upper limb, serves important movements that are important in activities of daily living. The forearm, in combination with the proximal and distal radioulnar joints, allows pronation and supination which in turn helps hand, to perform multi axial movements. With mechanized farming in India and industrialization, fractures of forearm bones have become more common. If the fractures are treated inadequately it may result in severe loss of function. Hence good anatomical reduction and internal fixation of these fractures is necessary to restore function. Closed reduction which was employed in earlier days yielded unsatisfactory results from either non-union or loss of motion. Also, there are complex forces acting on the
forearm bone that makes reduction and its maintenance of displaced fracture fragments difficult. Union may be achieved with any of the methods available however severe loss of function may be the end result unless adequately treated with proper technique and implants. Undisplaced single bone fractures can be treated in a long-arm cast until there is roentgenographic evidence of union or definitive evidence of delayed-union.

With the development of compression plate osteosynthesis which provides a good treatment option and predictable outcome, there is an important change in the treatment of forearm fractures. This method helps in perfect reduction of fracture fragments in anatomical position by rigid fixation and early mobilization, the normal functions of the hand can be re-achieved at the earliest.

The present study is to find out the clinical outcome in patients with forearm bone fractures surgically treated with dynamic compression plate.

**Aims and Objectives**
1. To assess and study the functional and radiological outcome of both bone forearm fractures after open reduction and internal fixation with DCP and screws.
2. To study fracture healing and union rate.
3. To prevent angulations and rotational deformity.
4. To mobilize the patient as early as possible.
5. To study complications of surgery.

**MATERIALS AND METHODS**
In this study 30 patients with forearm fractures, were treated by open reduction and internal fixation with 3.5 mm dynamic compression plate (DCP) and screws, in patients with displaced fractures of the shaft of forearm bones. This study was conducted from February 2017 to January 2019 at Government General Hospital, Kurnool (attached to Kurnool Medical College, Kurnool.)

**Inclusion Criteria**
1. Adults both males and female.
2. Fractures involving the diaphysis of both bones forearm.
3. Clean grade I, Gustilo Anderson compound fractures.
4. Segmental and comminuted fractures of both bones forearm.

**Exclusion Criteria**
1. Non-union.
2. Malunion.
3. Pathological fractures.
4. Grade II&III Gustilo Anderson compound fractures.

**Sample Size**
30 Cases.

**Sample Procedure**
A prospective study and all the patients are postoperatively assessed using Anderson et al, Scoring System. The variables taken into consideration were-

1. Union of the fracture.
2. Range of elbow and wrist movements.
3. Extent of functional capacity reached.

**Methodology**
All patients admitted with acute diaphyseal fractures of the radius and ulna, a careful history was elicited from the patient and/or attendants to reveal the mechanism of injury and the severity of trauma. Thorough clinical examination was to patients to evaluate their general condition. It was done in accordance to Acute Trauma Life Support protocol. Vital parameters were recorded. Local examination of injured forearm and hand such as attitude and position of the affected upper limb compared with normal counterpart, any abnormal swelling and deformity, their level and direction, vascularity and neurological examination were done followed by imaging.

**Preoperative Planning**
- Consent of the patient or relative.
- Appropriate length of the plate to be used was assessed with the help of radiographs.
- A dose of tetanus toxoid and antibiotic were given preoperatively.
- If evidence of compartment syndrome, surgery has to be done as soon as possible.
- Part Prepared.

**Operative Procedure**

**Type of Anaesthesia**
General anaesthesia was used in 14 cases and brachial block in 16 cases.

**Position**
- Patient supine on the operating table
- Henry’s approach-the arm is placed on an arm board with elbow straight and forearm in supination.
- Thompson approach-the arm is on the arm board, Elbow flexed and forearm in mid pronation.
- Painting and draping of the part done.

**Incision**
- Ulnar shaft: Parallel and slightly volar to the subcutaneous crest of the ulna.
- Radial shaft: Dorsal Thompson approach and Volar Henry’s approach.

**Procedure**
Usually radius was fixed first, however the bone which was less comminuted and more stable was fixed first and later the other bone was fixed.

After identifying the fracture ends, periosteum was not elevated, and fracture ends were cleaned. Fracture was reduced. The contoured plate is applied to the bone with middle portion placed over the fracture, and held with reduction forceps for short oblique, of transverse fracture.
A plate hole is left vacant for angled lag screw through the plate in case of oblique fractures. This hole is used for interfragmentary compression of a lag screw.

A plate of at least 6 holes was chosen and longer plates were used in spiral, segmental and comminuted fractures. The plate was fixed dorsally for the upper third fractures of the radius. For middle third, the plate was fixed dorsolateral and for distal radial fractures the plate was fixed on the volar aspect.

In case of transverse and short oblique fractures plate hole adjacent to fracture is drilled first using neutral drill guide.

In case of oblique fractures, the first screw is applied to the fragment, which forms an obtuse angle with the fracture near the plate. The resulting space between the fracture plane and plate under surface guides the opposite fragment towards the plate. The arrow of the neutral drill guide points towards the fracture. For drilling hole through both cortices, 2.5 mm drill bit is used, and appropriate 3.5 mm screw length is determined using a depth gauge. The tap of 3.5 mm is used to cut the thread. The chosen 3.5 mm cortex screw is inserted, but not fully tightened. The plate is pulled towards the fracture to place first eccentric screw.

The second screw hole for axial compression is drilled in the fragment which forms an acute angle near the plate.

The load guide (yellow) is used with the arrow pointing towards the fracture line to be compressed. At this position, a lag screw will be inserted. Tightening of the two screws produces axial compression.

The position of the oblique lag screw through the plate is determined. The angulation of the screw should not exceed ± 25 degrees longitudinally and ± 7 degrees transversely. The lag screw is applied by subsequently over drilling (3.5 mm) the near cortex to create a gliding hole. If compression is sufficient the remaining screws are applied one by one, alternating from one side to the other. Long screws and/ or larger plates were used for the fractures of osteoporotic, comminuted and / or small bones.

Finally, all the screws are tightened. Hemostasis is maintained, the wound is closed in layers over a suction drain and sterile dressing is applied.

**Post-Operative Treatment**
Crepe bandage was applied over the affected forearm and either pre op posterior slab was continued or arm pouch was given depending upon the requirement.

Limb is elevated and active movement of the fingers and elbow joint is encouraged. Suction drain was removed after 48 hours and Wound was inspected. Check X-ray AP and Lateral view was taken at that time.

Antibiotics and analgesics were continued till the time of suture removal which was done on 10-12 postoperative day.

On discharge patient was advised physiotherapy of shoulder, elbow, wrist and finger movements. They were told not to lift heavy weight or exert the affected forearm.

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**Follow-Up**
The patients were followed regularly at monthly interval for first three months then every three months depending upon the outcome. "Anderson" et al scoring system is used for evaluating the patients.

<table>
<thead>
<tr>
<th>Results</th>
<th>Union</th>
<th>Flexion/Extension at Elbow Joint and Wrist</th>
<th>Supination and Pronation of Forearm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>Present</td>
<td>&lt;10 0 loss</td>
<td>&lt;25% loss</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>Present</td>
<td>&lt;20 0 loss</td>
<td>&lt;50% loss</td>
</tr>
<tr>
<td>Unsatisfactory</td>
<td>Present</td>
<td>&gt;20 0 loss</td>
<td>&gt;50% loss</td>
</tr>
<tr>
<td>Failure</td>
<td>Non-Union With or Without Loss of Motion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Elbow movements and wrist movements were noted, and the union was assessed radiologically.

The fracture is said to be united when there was presence of periosteal callus bridging the fracture site and trabeculation extending across the fracture line.

**RESULTS**

**Age Distribution**
The age of these patients ranged from 18-60 years and an average age of 32.7 years.

<table>
<thead>
<tr>
<th>Age</th>
<th>Number of Patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-20</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>21-30</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>31-40</td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>41-50</td>
<td>4</td>
<td>13.33</td>
</tr>
<tr>
<td>51-60</td>
<td>2</td>
<td>6.66</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>100</td>
</tr>
</tbody>
</table>

**Sex Distribution**
Out of 30 patients, 25 patients (83.33%) were males and 6 patients (16.66%) were females showing male preponderance because of working in fields, travelling, factories, and sports.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Number of Patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>25</td>
<td>83.33</td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td>16.66</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>100</td>
</tr>
</tbody>
</table>

**Side Affected**
There were 19 (63.33%) patients with right forearm fracture and 11 patients (36.66%) with left forearm fracture.

<table>
<thead>
<tr>
<th>Side Affected</th>
<th>Number of Patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right forearm</td>
<td>19</td>
<td>63.33</td>
</tr>
<tr>
<td>Left forearm</td>
<td>11</td>
<td>36.66</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>100.00</td>
</tr>
</tbody>
</table>
Mode of Injury
In our study, there were 14(46.66%) patients with road traffic accidents, 11(36.66%) patients with fall, 4(13.33%) patients with assault and only 1(3.33%) patient with fall of heavy object over fore arm.

<table>
<thead>
<tr>
<th>Mode of Injury</th>
<th>Number of Patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTA</td>
<td>14</td>
<td>46.66</td>
</tr>
<tr>
<td>Fall on Out-Stretched Hand</td>
<td>11</td>
<td>36.66</td>
</tr>
<tr>
<td>Assault</td>
<td>4</td>
<td>13.33</td>
</tr>
<tr>
<td>Fall of Heavy Object Over Forearm</td>
<td>1</td>
<td>3.33</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table 5. Mode of Injury

Level of Fracture
Majority of the fractures were seen in the mid diaphysis of both bones of forearm. 22(73.33%) patients had mid diaphyseal fractures, 3(10%) had proximal third fractures and 5(16.66%) patients had lower third fracture of both bones of forearm.

<table>
<thead>
<tr>
<th>Level of Fracture</th>
<th>Number of Patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal Third</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Middle Third</td>
<td>22</td>
<td>73.33</td>
</tr>
<tr>
<td>Distal Third</td>
<td>5</td>
<td>16.66</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table 6. Level of Fracture

Type of Fracture
As we had included diaphyseal fractures of both bones. Among 30 radius fractures, 20(66.66%) were Transverse/short oblique type and 10(33.33%) were comminuted variety. Among 30 ulna fractures, 23(76.66%) were Transverse/short oblique type and 7(23.33%) were comminuted variety. In total 60 fractures 43(71.66%) were Transverse/short oblique type and 17(28.33%) were comminuted variety.

<table>
<thead>
<tr>
<th>Type of Fracture</th>
<th>Radius</th>
<th>Percentage</th>
<th>Ulna</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse/Short Oblique</td>
<td>20</td>
<td>66.66</td>
<td>23</td>
<td>76.66</td>
</tr>
<tr>
<td>Comminuted</td>
<td>10</td>
<td>33.33</td>
<td>7</td>
<td>23.33</td>
</tr>
<tr>
<td>Segmental</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30</strong></td>
<td><strong>100</strong></td>
<td><strong>30</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table 7. Type of the Fracture

Associated Injuries
5 (16.66%) of the patients had associated injuries.

<table>
<thead>
<tr>
<th>Associated Injuries</th>
<th>Number of Cases</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ipsilateral Humerus Shaft and Scapula Fracture</td>
<td>1</td>
<td>3.33</td>
</tr>
<tr>
<td>Fracture of The Shaft of Femur</td>
<td>1</td>
<td>3.33</td>
</tr>
</tbody>
</table>

Statistics of Surgery
16 of the 30 cases were operated under general anesthesia and in other 14 patients brachial block was used. Of 30 radius shaft fractures, Dorsal Thompson approach for radius was used in 10 patients and volar Henrys approach for radius was used in 20 patients. Ulna was approached subcutaneously. Follow-up ranged from 6 months to 22 months.

Duration of Radiological Union
The fracture was considered as united when there were no subjective complaints, radiologically when the fracture line was not visible.

<table>
<thead>
<tr>
<th>Duration of Fracture Union</th>
<th>Number of Patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;6 Months</td>
<td>27</td>
<td>90</td>
</tr>
<tr>
<td>6 Months-1 Year</td>
<td>2</td>
<td>6.66</td>
</tr>
<tr>
<td>Non-Union</td>
<td>1</td>
<td>3.33</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table 9. Duration of Radiological Union

Complications
We had complications in about 4(13.33%) patients with the following type.

<table>
<thead>
<tr>
<th>Complications</th>
<th>Number of Cases</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial Infection</td>
<td>2</td>
<td>6.66</td>
</tr>
<tr>
<td>Deep Infection</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Radio Ulnar Synostosis</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Non-Union</td>
<td>1</td>
<td>3.33</td>
</tr>
<tr>
<td>Nerve Injury-Posterior Interosseous Nerve Injury</td>
<td>1</td>
<td>3.33</td>
</tr>
<tr>
<td>Bone Shortening</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4</strong></td>
<td><strong>13.33</strong></td>
</tr>
</tbody>
</table>

Table 10. Complications

DISCUSSION
This study was conducted to at our hospital with the aim to know the importance of rigid anatomical reduction and fixation of forearm diaphyseal fractures with 3.5 mm DCP. This in turn was reciprocated on the functional results obtained. Initially our study had patient number of 20, however as the availability of patients were plenty and to obtain a statistically significant result the number of patients was raised to 30.

Age Distribution
In our study, the age of these patients ranged from 18-58 years and an average age of 32.7 years.
Sex Distribution
Our series had male preponderance with (83.33%) male patients and (16.66%) female patients which were comparable to previous studies.
H. Dodge in his study noted about 89% males and 11% females.
William in his series had 67% of males and 33% of females.
Talwalkar in his series had 80% males and 20% females.

Mode of Injury
In our series 46.66% of cases had road traffic accidents, 36.66% had fall, 13.33% with history of assault and only 3.33% with fall of heavy object over forearm.
Smith noted about 45% of his cases was due to RTA, 36% were due to fall and 19% were due to industrial accidents.
Thomas Grace et al. noted about 29 (45%) patients with automobile or motorcycle accident, 14 (22%), in falls 2(3%), had gunshot wounds and remainder had other miscellaneous types of injuries.

Extremity Affected
We had about 63.33% incidence of forearm fractures in right extremity, which is also comparable to the previous studies.
M. W. Chapman reported about 55% incidence of fractures in right extremity.

Type of Fracture
In a series conducted by M.W. Chapman et al, 53% of fractures were comminuted and 47% were transverse / short oblique.
As we had included diaphyseal fractures of both bones. Among 30 radii, 20 (66.66%) were Transverse/short oblique type and 10(33.33%) were comminuted variety. Among 30 ulnae, 23(76.66%) were Transverse/short oblique type and 7(23.33%) were comminuted variety. In total 60 fractures 43(71.66%) were Transverse/short oblique type and 17(28.33%) were comminuted variety. Ours were not comparable to any of the studies available.

Level of Fracture
H.S. Dodge and G.W. Cady documented 71.5% fracture both bones n middle third, 21.5% in distal third and 7% in proximal third.
A. Sarmiento et al, noted about 84.6% of fracture both bones were in middle third and 15.4% of cases had lower third fracture of both bones.
Our series had 73.33% of fractures in middle third, 10% in proximal third and 16.66% in lower third, comparable to previous studies.

Duration of Follow Up
Anderson et al had a follow up from 4 month to 9 years with an average of 3 years.
Moed in his series followed patients from 12 months to 9 years with an average of 3 years.
Chapman series had follow-up which ranged from 6 months to 48 months with average of 12 months.
We had a follow up which ranged from 6 months to 22 months with an average mean of 12 months, which is comparable to Chapman series, but other series had longer follow up.

Time of Union
For evaluation of union Anderson’s criteria was applied. In our study we had an average union time of 11.5 weeks.
Chapman in a study had 98% union with range of 6 to 14 weeks union the average union time was 12 weeks.
Mc Knee study had average union time of 10.7 weeks with range of 5 to 18 weeks. He had 97.3% union rate.
The present series had average union time of 11.5 weeks with a range of 8 to 16 weeks. In all the cases radius was united and ulna was united in 96.6% cases.

Functional Results
For measuring the functional outcome Anderson scoring system was applied.
Chapman et al reported 36 (86%) cases as excellent, 3 (7%) satisfactory, 1 (2%) unsatisfactory and 2 (5%) failure.
A study by Anderson et al reported that 50.9% cases were excellent in functional outcome whereas 34.9% cases were satisfactory, 11.3% unsatisfactory and 2.9% were failure.
In our series we had 23 (76.66%) cases with excellent results, 5 (16.66%) satisfactory and 1 (3.33%) case of unsatisfactory result and 1 (3.33%) case of failure due to ulnar non-union.

CONCLUSION
Diaphyseal fractures of forearm are seen most commonly in middle aged subjects.
With the use of AO/ASIF 3.5 mm DCP for acute diaphyseal fractures of forearm, rigid and anatomical fixation can be achieved.
With use of DCP, distraction forces leading to separation of fracture fragments like those seen in interlocking nail for upper limb is not possible.
Radial bowing is very important for normal supination and pronation. This can be maintained very well with compression plates.
A minimum of 6 cortices should engage in each fracture fragment. It is better to use longer plates like a bridge plate in case of comminuted oblique fractures.
Radius and Ulna are approached separately to avoid extensive soft tissue dissection and resulting complication.
Almost all fractures in our study united by 4-6 months.
The AO principles of internal fixation, namely (1) anatomical fixation, (2) preservation of vascularity, (3) mechanically stable fixation, (4) rapid mobilization of joints.
in proximity, can be achieved with compression plating system.

Dynamic compression plate is implant of choice most of the times for internal fixation of displaced diaphyseal fractures of the forearm bones. Adherence to AO principles, strict asepsis, proper post-operative rehabilitation and patient education are more important to obtain excellent results.

REFERENCES