International Journal of Orthopaedics and Rheumatology
Online ISSN: 2664-9705, Print ISSN: 2664-9691
Received: 02-01-2019; Accepted: 03-02-2019; Published: 10-02-2019
www.orthopaedicsjournal.net
Volume 1; Issue 1; 2019; Page No. 03-08

Evaluation of the results of locking compression plate for the treatment of non-united humeral shaft fracture augmented with autogenous cancellous bone graft

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DOI: https://doi.org/10.33545/26649691.2019.v1.i1a.2

Abstract
A fracture bone usually heals by the formation of new bone at the fracture site. Occasionally, only fibrous tissue is formed, when this happens both surgeon & patient are disappointed. The bone is a specialized form of connective tissue may account for its ability to heal by the formation of new bone. The humerus is a long bone connecting two important joints of upper limb- which has wide range of movement having very little bony stability in shoulder joint and distal elbow joint which is a uni axial hinge joint. This prospective study of "treatment of nonunion of humeral shaft fracture by locking plate and screws augmented with autogenous cancellous bone grafting" was carried out during the period of 1st December 2011 to 31th May 2013 at National Institute of Traumatology and Orthopeadic Rehabilitation (NITOR) Dhaka, Bangladesh. Sample size will be calculated by using following statistics = 384. Purposive sampling (non-randomized) according to availability of the patients and strictly considering the inclusion and exclusion criteria. Data will be collected with a pre-tested structured questionnaire containing history, clinical examination, laboratory investigations, pre-operative, per-operative, postoperative follow up findings and complications. 16 Patients were selected by using non randomized sampling method. The age ranges from 28-60 years. The mean age of occurrence was 38.19 (+10.04) years. Motor vehicle accident was the commonest cause of fracture found in 81.25% cases. Second most common cause was fall from height (12.50%). Right side involvement was more (62.50%). Among the affected people ser\Tce holders and shopkeepers were commonest (25% each), next were businessmen and farmers (18.75% each). The mean union time was 16.38 (+2.78) weeks. Postoperative complications were noticed such as wound infection (6.25%) and shoulder pain (6.25%). There was no complication (81.25%). Functional outcome of this treatment was analyzed by Constant and Murley scoring (1999). Excellent functional outcome was found in 5 (31.25%) cases, good in 9 (56.25%) cases, fair in 1 (6.25%) case and poor in 1 (6.25%) case. Regarding the final outcome satisfactory result was found in 14 (87.50%) cases and unsatisfactory result in 2 (12.50%) cases. Based on the results shown above it is concluded that "treatment of nonunion of humeral shaft fracture by locking plate and screws augmented with autogenous cancellous bone grafting" is an effective modality of treatment for the nonunion of humeral shaft fracture and is especially recommended in osteoporotic bones and elderly patients with compromised bone quality.

Keywords: pre-operative, postoperative follow, outcome

1. Introduction
A fracture bone usually heals by the formation of new bone at the fracture site. Occasionally, only fibrous tissue is formed, when this happens both surgeon & patient are disappointed. The bone is a specialized form of connective tissue may account for its ability to heal by the formation of new bone (Boyd *et al*., 1961). The humerus is a long bone connecting two important joints of upper limb- which has wide range of movement having very little bony stability in shoulder joint and distal elbow joint which is a uni axial hinge joint. It is an unpaired bone, the shaft of which is totally covered by a thicker layer of soft tissue. Approximately 10% of all long bone fractures occur in the humerus. Fracture of the humeral shaft is commonly encountered by the orthopaedic surgeons, accounting for approximately 30% of all humeral fractures (Ward *et al*., 1998). Both younger and elder people suffer from these fractures. The mechanism of injury is mainly direct trauma, motor vehicle accident, fall from height, direct blow and penetrating injury like bullet or sharp object causing transverse or comminuted fractures. Indirect trauma due to fall on out stretched hand, twisting injuries or even violent muscle contraction results spiral or oblique fracture. Treatment of these injuries continue to evolve as advances are made in both non-operative & operative management (Cole *et al*., 2010 and Swanson & Gustilo, 1993) [32]. Most of the humeral shaft fracture heals with close Method without surgical intervention (Zuckerman and koval, 1996) [40], in certain circumstances when this fracture fails to unite in expected period of time (4-6 months after injury) and then it is called delayed union or non-union (Khan *et al*., 2004). The middle third of the bone is the most vulnerable in relation to delayed or non-union. This is because, the main nutrient artery enters the bone very constantly at the function of the middle & lower thirds or in the lower part of the middle third and the foramina of entry are concentrated in a small area of the distal half of the middle third of the shaft on the medial side of the bone. (Carroll, 1963 and Choudhury, 1988) [3]. Muller and Thomas (1979) [19] stated that operative treatment is usually indicated for non-union, poly trauma patients, bilateral humeral shaft fracture, floating elbow, fractures with neurovascular complications, segmented fractures, radial nerve palsy after manipulation, pathological fracture, failure to obtain or maintain acceptable alignment after close reduction, associated injury or patient conditions precluding close management, failure

to conservative treatment (Swanson & Gustilo 1993 and Crenshaw, 2008) [32, 5]. Unfortunately not all the fractures of the humeral shaft in the adults united in a specific time and if not given appropriate treatment the fracture can go on to state of established non-union. When this stage of indolence is reached with sclerosis of the bone ends & mature fibrous tissues laid down between the fragments, treatments become more difficult. It is then necessary not only to refresh the bone surfaces but also immobilize them as rigidly as possible, which cannot be done by simple plaster cast & not even by a shoulder Spica (Swanson & Gustilo, 1993) [32]. When fractures of the upper extremity are treated, the social and economic status of the patient must be considered. An operation may be justified in preference to the risks of prolonging convalescence, yet union may be possible without surgery if immobilization is continued for 6 to 8 months after injury (Crenshaw, 2008) [5]. Patient often find the hanging cast uncomfortable, tedious and frustrating; they can fell the fragments moving and that is sometimes quite distressing the temptation is to 'do something' and the something usually means an operation (Cole *et al*., 2010). Operative methods of treatment include open reduction and internal fixation by plate & screws (LCP, DCP), open or close reduction & internal fixation by intramedullary interlocking nail or semiflexible pins and external fixator (Andrew *et al*., 2008 and Cole *et al*., 2010). Banquet *et al*. (1989) reported successful union in 24 of 25(96%) aseptic non-union of the humerus. Rosen, 1990 [27] reported 97% healing rate with one surgical procedure in 32 humeral non unions treated with dynamic plate and screws. Two series have reported excellent results for treatment of humeral non-union with compression platting combined with cancellous bone grafting. A recent trend in internal fixation has been a more towards locking compression plating system. With locking compression plating system the locking screws are locked with plate which stabilizes the screws and gives better rigid fixation. The friction between the plate & bone is less that provide less disturbance of periosteal blood supply (Larson and Rizzo, 2007). Several new locked plate devices have been developed because researchers suggest plates with attached (locked) screws may provide improved fracture stability & healing (Perron, 2002). Locking the screws to the plate mechanically recreates a point of cortical bone contact (Kolodziej *et al*., 1998) which may be useful in poor cancellous bone of proximal humerus. Locking compression plates also a have preconfigured shape & screw direction which may reduce hardware complications. Early clinical results using the locking-humerus, plates have been promising (Fankhauser *et al*. 1005). Locking compression plates provide stable fixation of poor quality bone in patients with delayed union or non-union of the humerus; successful union & restoration of function are achieved in most patients (Ring *et al*., 2004) [25]. Both experimental & clinical studies with early locking compression plates have shown a lower rate of infection with locking system compared with the standard dynamic compression plate (Koval *et al*., 1997) [40]. The existing benefits of the new internal fixator principles are enhanced by the combination in the following respects over other modalities of treatment are- Improvement in angular stability due to locking head screws (even if unicortical), accurate plate contouring is not required, and more options & greater versatility in fracture management especially fracture with limited bone quality are present. However, these new techniques demand very careful pre-operative planning, especially in the sequence of applying different type of-screws since this process requires a clear understanding of the principles governing each technique. The versatility of the system may increase the risk of application error with disturbance to fracture healing- (Sommer *et al*., 2004) There are some drawbacks to locking compression plates, locking compression plates are more difficult to remove than standard compression plates, cold welding may occur in which the locking screws heads become affixed to the screws hole, & cannot be removed from the plate without great difficult. Although hard ware removal is not routinely done many practitioners recommend placing all locking screws by hand rather than on power to avoid cold wielding (Freeland and Lumber, 2005). In our hospitals, most of the patient of humeral shaft fractures admitted several weeks after injury after taking some form of conservative treatment but fail to unite, with the complained of abnormal mobility, stiff elbow and shoulder. These patients need stable internal fixation by either DCP or LCP for early mobilization of elbow and shoulder. LCP is the recent modification of DCP which can give more stable fixation especially in osteoporotic bone (Koval *et al*., 1997) [40]. The aim of treatment is to give a good functional limb as early as possible with sound bony union to achieve the best result in the humeral shaft fracture in adults and early return to work, much importance to be given to such factors as early accurate diagnosis, rigid internal fixation of the bone with open reduction & providing autogenous cancellous bone grafting & lastly cast immobilization in appropriate position. This study will be included those patients who reported to DMCH-Orthopaedic Department, Dhaka, 12-28 weeks old injuries to the arm with the complain of instability, abnormal mobility in arm, mild to severe pain to the fracture site, stiff shoulder and elbow & impaired function of the limb. The aim of this study will be to evaluate the result of the internal fixation of non-united humeral shaft fractures by locking compression plate & screws with autogenous cancellous bone-grafting.

2. Aims and objectives

1. General objective

a. To assess the evaluation of results of locking compression plate for the treatment of non-united humeral shaft fracture augmented with autogenous cancellous bone graft.

2. Specific objectives

a. To assess fracture union time and rate by follow up-both clinically & radio logically.
b. To evaluate post-operative complication.
c. To assess functional outcome of shoulder & elbow joints by-modified Constant and Murley score.

3. Materials & Methods

Study design: Prospective interventional study (quasi experimental type).
Study period: 01/ 12/2011 to 31/05 /2013 (18 Months)
Place of study: Department of Orthopaedics and Traumatology, DMCH and NITOR, Dhaka.
Study population: All patients with history, clinical examination and radiological evaluation suggesting non-united fracture of shaft of humerus attended in Dhaka

Medical College Hospital and NITOR for treatment.

Sample size: Sample size will be calculated by using following statistics = 384

Sampling technique: Purposive sampling (non-randomized) according to availability of the patients and strictly considering the inclusion and exclusion criteria.

Data collection procedure: Data will be collected with a pre-tested structured questionnaire containing history, clinical examination, laboratory investigations, pre-operative, per-operative, postoperative follow up findings and complications.

Inclusion criteria

a. Established non-union of shaft of the humerus.
b. Age (18 to 60 years)
c. Sex- Both sexes.
d. Site- Diaphyseal fractures of humeral shaft between 3 cm distal to surgical neck and 5 cm proximal to the olecranon fossa.
e. Any side affected.
f. Failure of conservative treatment.

Exclusion criteria

a. Recent fracture.
b. Infected non-union.
c. Pathological fracture.
d. Fracture in children.
e. Persistence of wound.
f. Unstable medical illness.

Study procedure: A questionnaire will be prepared by the researcher considering the key variables like age, sex, presenting symptoms, clinical findings, associated medical conditions, investigations, preoperative findings, outcome of surgery which wil be verified by the guide. The data will be collected by the researcher himself. Aims & objectives, procedures risks and benefits of this treatment were explained to the selected patients. The patients will be encouraged for voluntary participation. They will also be assured about the secrecy of information and records. Then written informed consent will be taken from each patient.

Pre-Operative preparation: Patient will be counseled regarding the treatment procedure with emphasis on the available treatment options along with merits and demerits of each. He/she will be informed about the possible post-operative sequele. Informed written consent will be obtained from each case included in the study. All issues regarding the patient's welfare will be approved by the local ethical committee.

Pre anaesthetic check-up will be done.

Patient will be asked to abstain from oral feeding from 6 hours before operation.

Appropriate size of LCP and screws will be selected.

Antibiotics: All patients will be received prophylactic antibiotic, a third generation cephalosporin (ceftriaxone), one gram i.v. and flucloxacillin 500 mg i.v. at the time of induction of anaesthesia. Post operatively parenteral ceftriaxone will be given 12 hourly and flucloxacillin 500 mg 6 hourly for 3 days. After 3 days oral cephalosporin (cefixime 200gm 12 hourly) and flucloxacillin 500 mg will be given for a further weeks or till wound healed.

Positioning of patient: During operation patient will be placed in the supine position and sometimes lateral position after GA. Preparation of the skin: Preparation of the skin will be done by soap washing and using an antiseptic on the skin, such as povidone iodine solution.

Draping was done.

Surgical procedure: With all aseptic precautions open reduction and internal fixation will be achieved with a standard LCP by anterior Henry approach or posterior approach (for distal third)

Follow-up: At the beginning patients will be followed up at three weeks interval. Thereafter at monthly interval till the fracture union will be achieved. Evaluation of the functional outcome will be achieved at 6 months visit. Six months will be chosen as by that time healing of the fracture would normally have taken place & functional improvement would have reached to a satisfactory level. This protocol will be changed a little in some particular cases due to failure of attending the schedule or other causes. The patients will be also advised to attend the OPD or contact personally if any problem regarding the treatment occurred. Pendulum shoulder exercise will be started after 2 weeks. Long arm back slab will be removed after 3 weeks and were allowed to move the elbow joint.

4. Observations and results

This prospective study of treatment of nonunion of humeral shaft fracture by locking plate and screws augmented with autogenous cancellous bone grafting was carried out in 16 patients to find out the common cause of fracture, age and sex incidence and to propose a protocol for treating such cases. Sixteen patients were included in the study group and they were divided into 4-groups. The mean age was 38.19 with a standard deviation mean (±SD) 0.04 years. The age ranged from 28 to 60 years and the maximum number was found in the age group of 30 - 39 years. The age distribution is shown in [Table I].

Table 1: Age distribution of the patients (n=16)

Age in years	Number	Percentage
<30	1	6.25
30-39	8	50.00
40-49	4	25.00
>50	3	18.75
Mean ^SD		38.19 ±10.04
Range		(28-60)

Table 2: Occupational distribution of patients (n=16)

Occupation	Number	Percentage
Serviceman	4	25.00
Businessman	3	18.75
Farmer	3	18.75
Shopkeeper	4	25.00
Housewife	2	12.50

Most (25.0%) of the patients were service holder and shopkeeper (25.0%), 18.75°o were businessman, 18.75% were farmer and 12.5% were house wife. "He results are shown in [Table 2].

Table 3: Mean duration of injury of the patients (n=16)

Duration of injury (months)	Months
Mean =SD	15.38±3.91
Range	(9-20)

The following table shows the mean duration of injury of

the patients was 15.38 months with a SD of ±3.91 months and the minimum injury duration was 9 months and maximum was 20 months [Table 3].

Table 4: Post-operative hospital stay (n=16)

Hospital stay (days)	Days
Mean±SD	4.81±1.22
Range	(3-6)

The following table shows the average hospital stay of the patients postoperatively. The mean duration of hospital stay was 4.81 days with a SD of 11 days. The maximum and minimum hospital stay were 6 and 3 days respectively [Table 4].

Table 5: Time of union by radiological evaluation (n=16)

Radiological evaluation Time of union	Weeks
Mean±SD	16.38±2.78
Range	(13-24)

Radiologically all cases were found to be united and the mean time of presence of union was 16.38±2.78 weeks and the maximum and minimum time needed for union were 24 to 13 weeks respectively [Table 5].

Table 6: Distribution of patients by post-operative complications (n=16).

Post-operative complications	Number	Percentage
Infection	1	6.25
Loosening of the screw	0	0.00
Shoulder pain	1	6.25
No complication	13	81.25

Most (81.25%) of the cases did not have any complication. One patient developed infection and one patient had shoulder pain [Table 6].

5. Discussion

When a humerus fracture fails to unite in 3 to 4 months, it is termed as delayed and if union is delayed and arrested beyond 6 to 8 months, it is nonunion Rosen (1990) [28]. Nonunion is established when minimum of 9 months has elapsed since injury and the fracture shows no visible progressive signs of healing for 3 months (La Velle, 1998) [16]. Though a number of treatment methods have been documented none of the method seems to be superior to others. Orthopaedic surgeons in several countries contributed to the foundations mat led to the concepts, techniques and instruments used today. Various methods of surgical treatment are known, such as, fixation by plate and screws and bone grafts, intramedullary nails, intramedullary interlocking nails with bone grafts, inlay and onlay tibial grafts with bone pegs or. Bone screws, dual ribial onlay grafts dual fibular onlay grafts, cerclage wire, external fixators, llizarov technique. A recent trend in internal fixation has been a more toward locking plating system. Specific advantage of locking plating system includes 1. Stable rigid fixation, 2. Direct reduction, 3. Less periosteal vascular disturbance. Modabber and Jupiter (1998) [18] reviewed twenty-one cases of humeral nonunion after the failure of locked humeral nails. The study revealed mat open reduction and internal fixation with plating and bone grafting was successful in nine of nine cases and exchange nailing was successful in four often cases. Ramchander siwach, Roop singh (2008) published their studies of treating displaced proximal humeral fracture in elderly patients with osteoporosis by locking plate & screws of 25 patients (12 males & 13 females) with 28%, excellent outcome, 64% good functional outcome & *8%* had moderate outcome. All fractures united with an; union time of 18 weeks. The humenis is often osteoporotic when nonunion occurs. It becomes difficult to ngid fixation in terms of loosening of screws. There is always tendency to bowing of humerus in its fracture at middle third. Hence there is always 2 feilure of union. By using locking plate & screws in nonunion of humeral shaft osteoporotic bone it gives better rigid fixation & chance of loosening. At DMCH and NITOR the treatment of humeral shaft nonunion by locking plate & screws with autogenous cancellous bone grafting has gained acceptance in the recent years. This prospective study was carried out during the period from July 2011 to June 2013 at Dhaka medical college hospital and the National Institute of Traumatology and Orthopaedic Rehabilitation(NITOR),Dhaka, Bangladesh, to find out the result of locking plate and screws with ; cancellous bone grafting in the non-union of fracture shaft of humerus. A total number of 16 patients were included in this study. All the patients were iy locking plate & screws augmented with autogenous cancellous bone grafting. Follow up time was 6 months & maximum 18 months. In this study, age ranges from 28 to 60 years. Hie mean age incidence was 38.19 years. The high incidence in young adult age group points to higher rate of mobility as well as social violence in this age group. Male population in this study constitutes 14 cases (87.5%) while the female's p remaining 2 cases (12.5%). Christensen (1976) [4] observed a male predominance 19^ \vhile Wright, Miller and Vander Griend (1993) and Pandey (2003) [22] showed males to made up 55.55% and Ring *et al*. (2000) [26] 60%. Malesr Vig'the majojAorking force of our society and are thus more consistently exposed to external environment which probably accounts for this predominance. Motor vehicle accidents were found to be the most common causative factor in this study 81.25%. Christensen (1976) [4], Ring *et al*. (2000) [30] observed motor vehicle accidents as the major reason for humeral shaft fractures occupying 50% and 40% respectively (Swanson and Gustilo, 1993) [32]. Second common cause was fall from a height counting 12.50%. In this study right side was affected more (62.5%) than left side (37.5%). Ring (2000) [25] found 66.76% of the cases with left humeral fractures in his series. In 4 cases, there were associated injuries, 2 had soft tissue injuries, one had ipsilateral fracture shaft of femur, and one had radial nerve injury. Among the 16 cases, 2 of them were treated by open reduction and internal fixation with *DCP*, one treated initially with external fixator, the rest of them were treated conservatively with U slab, long arm back slab. Post-operative hospital stay is one of the important parts of this study. In this series minimum 3 days and maximum 6 days. Mean post-operative stay 4.8 (+1.22) days. Longer hospital stay was required for patients having postoperative infection and other complication. Union time of fracture in this series was minimum 13 weeks and maximum 24 weeks. Mean 16.38 (+2.78) weeks. In the study of Robinson *et al*. (1992) [29] men time of union 18 weeks (8-96 weeks) but 7 patients required treatment for delayed union. In the study of Habernek and Orthner (1991) [10], average union time was 2 months. In this series

postoperative infection (Superficial wound infection) developed in 1 patient (6.25%) which was controlled by regular dressing and sensitive antibiotic. Shoulder pain in 1 (6.25%) case. In the study of Habernek and Orthner (1991) [10], there was no infection in 19 cases and no rotator cuff lesion, in my study infection rate was 6.25%. In this study 5 cases (31.25%) had excellent functional outcome according to Constant and Murley scoring, 9 cases (56.25%) had good, 1 case (6.25%) had fair outcome and 1 case (6.25%) had poor outcome. In this series there was excellent result in 5 cases (31.25%), good in 9 cases (56.25%), fair in 1 case (6.25%) and poor in 1 case (6.25%). In this study overall a satisfactory result was found in 14 (87.50%) cases and unsatisfactory in (12.50%) cases.

6. Conclusion

Based on the results shown above it is concluded that "treatment of nonunion of humeral shaft fracture by locking plate and screws augmented with autogenous cancellous bone grafting" is an effective modality of treatment for the nonunion of humeral shaft fracture and is especially recommended in osteoporotic bones and elderly patients with compromised bone quality.

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