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ORIGINAL ARTICLE

Study on outcome of fracture shaft of the humerus treated non-operatively with a functional brace

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Abstract
Background Non-operatively treated fractures of the humeral diaphysis have a high rate of union with good functional results. The objective of this study is to find out the outcome of fractures of the humeral diaphysis treated with a functional brace that permits motion of shoulder and elbow joints and progressive use of the injured extremity.
Materials and methods This was a descriptive analytical study in patients of 16 years and above with closed fracture shaft of humerus treated with a functional brace that permits the motion of shoulder and elbow joints. The fracture arms were initially stabilized with U slab or hanging cast for an average of 11 days before application of brace. Radiographs were made at each follow-up visit until the fracture union occured. Angulation at fracture site, motion at shoulder and elbow joint were measured at the time of removal of brace.
Results One hundred and five out of 108 fractures (97.2 %) were united with mean duration of 12.16 weeks (range, 7.5–19.3 weeks). Radial nerve injury was present in 6 cases (5.5 %). Varus angulation of ≤15° was present in 90.9 % out of 99 patients, while no angulation was present in 6 cases (5.7 %) out of 105 patients. Apex anterior angulation of ≤10° was present in 100 % out of 48 patients, whereas apex posterior angulation of ≤10° was present in 94.1 % out of 51 patients.
Conclusion Functional bracing for the treatment of fractures of the humeral diaphysis is associated with a high rate of union with nearly normal elbow motion and some restriction of shoulder motion.

Keywords Fracture shaft of humerus · Functional brace · Radial nerve palsy

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Introduction

Fractures of the humeral shaft account for roughly 3 % of all fractures; most can be treated non-operatively [1, 2]. Most humeral shaft fractures can be treated non-operatively with a greater than 90 % rate of union [3–5]. Application of surgery is accepted in general for fractures with vascular and nerve injury, patients with multiple fractures, bilateral humeral shaft fractures, pathological fractures, comminuted segmental fractures and open fractures [1]. Functional bracing has essentially replaced all other methods of conservative treatment and has become the "gold standard" for non-operative treatment because of its ease of application, adjustability, allowance of shoulder and elbow motion, relatively low cost and reproducible results [1]. The humeral functional brace works on the principles of the hydraulic effect of the brace by compressing the soft tissues circumferentially to produce fracture alignment, active contraction of the muscles and beneficial effect of the gravity, and it has been shown to be very effective for treating closed humeral shaft fractures [3–7]. Union rates of 96–100 % have been reported with this technique [3]. A maximum of 3 cm of shortening, 20° anterior or posterior angulation and 30° of varus is acceptable [8]. United fractures with up to this

much deformity still allow full functional use of the upper extremity [9]. Most of the studies state that the average time to union of these fractures is 8–12 weeks. Healing in humeral fractures occurs within the first 3 months in general (average time for union is 8–12 weeks) [4, 8, 10]. Although facilities for operative treatment are easily accessible in developed countries, these facilities are not available in most of peripheral areas in our country. Patients should wait for long time for surgery even in the centres that provide operative facilities because of overload of patients. So there is a prime importance of conservative treatment of humeral shaft fracture in the developing countries. Besides, the cost of operative treatment is quite high as compared to conservative treatment. Patients should undergo operation second time for the removal of implant in case of operative method. There is chance of infection and neurovascular injury in operative treatment [23]. Patients are free of stress of surgery in conservative treatment. Union in conservative treatment is comparable to that of operative treatment.

Primary objective of this study is to evaluate the effectiveness of functional brace in fracture shaft of humerus in adult in terms of radiological and clinical union of fractures.

Patients and methods

It is a descriptive analytical study conducted in TUTH, Kathmandu, from August 2005 to May 2011. Closed fracture shaft of humerus of patients age 16 years and above was included in the study and those associated with Compound fracture, polytrauma, multiple injuries, bilateral humeral fractures, pathological fracture, vascular injury, nerve injury during the period of conservative management, intra-articular extension to shoulder and elbow joint, brachial plexus injury, poor patient compliance like mental retardation and those with neurological disorders like parkinsonism or epilepsy, head injury were excluded from the study (Fig. 1).

After receiving permission from the department of orthopaedics and clearance from the ethical committee, consent was obtained from all eligible candidates after fully explaining the nature of study. Those having any exclusion criteria were excluded from the study. Initially, the injured extremity was stabilized in U slab or hanging cast that held the elbow in 90° of flexion. None of the fractures was manipulated. Patients were evaluated in the outpatient department approximately 1 week after the injury. If the acute symptoms subsided and the injured extremity was not swollen, a functional brace was applied and the patient was given a collar-and-cuff sling to wear. After application of brace, patients were followed on an outpatient basis on 2nd week and then once a month until clinical and radiological

Fig. 1 Patients with fracture shaft of humerus wearing functional brace

union occurs. At each visit, radiographic and clinical observations were made. After seeing clinical and roentgenographic signs of good callus formation and healing, the brace was removed. The criterion for clinical healing is no pain and lack of abnormal movement at the fracture site, and the criterion for roentgenographic healing is the formation of sufficient external bridging callus on both anteroposterior and lateral radiograms (bridging callus in at least three quadrants). Patients were shown how to adjust the brace and tighten the Velcro straps several times of a day to accommodate the changes in the girth of extremity that occured as the swelling subsided and muscle atrophy developed. The brace was worn at all times. Patients were instructed in the performance of pendulum exercises immediately after the application of the initial cast or splint, and exercises were continued after the application of brace (Fig. 2).

Functional evaluation of the patients was made with respect to the range of shoulder and elbow movements, and

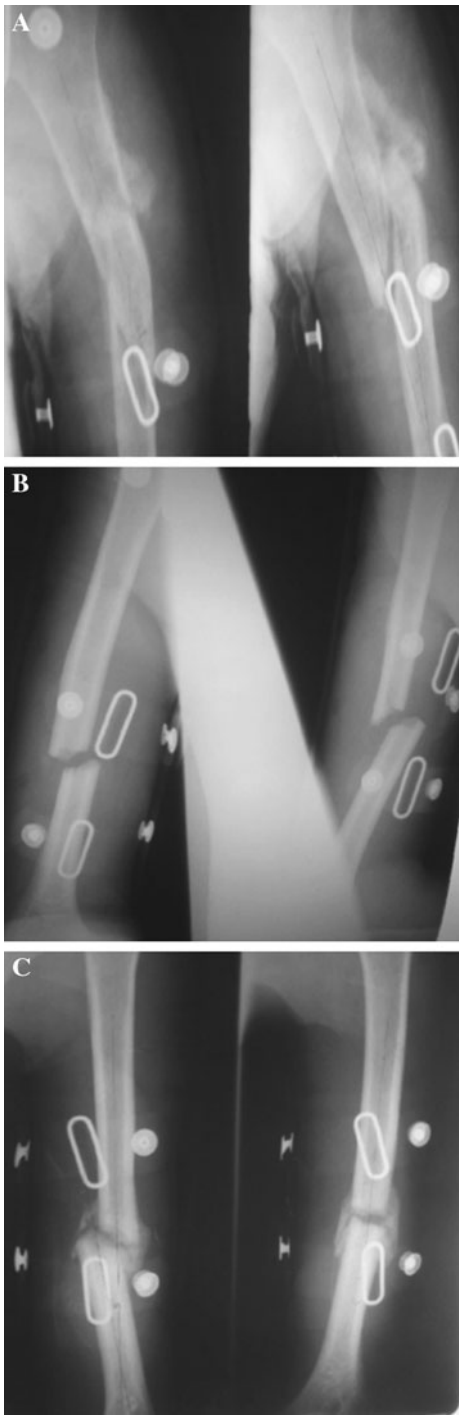

Fig. 2 **a** AP and lateral radiograph 14 weeks after application of brace. **b** Anteroposterior and lateral radiograph of another patient with application of functional brace. **c** AP and lateral radiograph of same patient 10 weeks after application of brace

final varus-valgus angulation on anteroposterior radiograph, anteroposterior angulation on lateral radiograph, limb length discrepancy and muscle wasting at mid-arm level were recorded at the time of brace removal. Cases where pain and mobility persisted at fracture and no signs

Fig. 3 **a** Teaching how to do the shoulder mobilization exercise. **b** Showing range of movement of shoulder joint at the time of removal of brace

of callus formation in radiograph at 12 weeks after fracture were treated with surgery. Protocol of treatment of radial nerve palsy included splintage and observation, if there was no improvement at 12 weeks, electromyography was performed. During analysis of data, if the number of patients in each group was more than five, chi-square test was applied. If the number of cases in each group was less than five, Fisher's Exact test was applied (Fig. 3).

Observations and results

There were altogether 123 patients who were found to be eligible for the study after initial assessment of the patients, out of which 4 patients did not give the consent and excluded from the study. Again 11 patients were lost during the follow-up. So, 108 patients were finally included in the study, and results were obtained. Average age of patients was 38.61 years with minimum age of 17 years and

maximum age of 77 years. There were 63 males (58.3 %) and 45 females (41.7 %). There were 33 students (30.6 %), 39 farmers (36.1 %), 15 housewives (13.9 %), 21 servicemen (19.4 %). Thirty-nine (36.1 %) patients sustained fractures because of fall from height, 15 (13.9 %) from fall on the ground while walking, 24 (22.2 %) from motor bike accident, 15 (13.9 %) from vehicular accident and another 15 (13.9 %) from miscellaneous injuries, for example direct heat by lathi, throwing objects and sports injuries. Sixty-six (61.1 %) patients sustained fractures because of high energy trauma and 42 (38.9 %) patients sustained fracture because of low energy trauma. There were 45 (41.7 %) fractures in right arm, 63 (58.3 %) in left arm. There were 15 (13.9 %) fractures in proximal third, 69 (63.9 %) in middle third and 24 (22.2 %) in distal third of shaft of humerus. There were 57 (52.8 %) transverse fractures, 42 (38.9 %) oblique, 6 (5.6 %) comminuted and 3 (2.8 %) spiral types. Eighty-one (75 %) fractures were stabilized with U slab, and 27 (25 %) were stabilized with hanging cast before application of brace. Brace was applied as early as 7 days and as late as 16 days after fracture with an average of 11.33 days. At the time of application of brace, there was varus angulation in 102 cases with mean angulation of 8.65°, minimum 3 and maximum 22°, while no angulation in 6 cases in AP view. Similarly, there was apex anterior angulation in 51 cases with mean of 5.24°, minimum 2 and maximum 13°. Apex posterior angulation was present in 51 cases with mean of 5.35°, minimum 2 and maximum 13°, and no angulation in 6 cases in lateral view.

In 105 out of 108 patients, fracture united at an average of 12.16 weeks with minimum of 7.5 weeks and maximum of 19.3 weeks. At the time of removal of brace, there was varus angulation in 99 patients out of 105 patients whose fracture united, with mean angulation of 7.88°, minimum 4 and maximum 24°, and no angulation in 6 patients in AP view. Similarly, there was apex anterior angulation in 48 patients with mean angulation of 4.75°, minimum 3 and maximum 10°, and apex posterior angulation in 51 patients with mean of 4.71°, minimum 2 and maximum 11°, no angulation in 6 patients in lateral view. Varus angulation of ≤15° was present in 90.9 % out of 99 patients. Apex anterior angulation of ≤5° was present in 39 (81.2 %) patients and 6–10° angulation in 9 (18.8 %) out of 48 patients. There was apex posterior angulation of ≤10° in 94.1 % out of 51 patients. There was normal or ≤25° restriction of abduction was present in 60 % of patients, normal or ≤25° of restriction of adduction was present in 88.6 % patients, ≤25° restriction of shoulder flexion in 65.7 % patients, normal or ≤25° restriction of extension in 91.4 % patients, normal or ≤25° restriction of external rotation in 80 % patients, and normal or ≤25° restriction of internal rotation in 85.7 % patients. Extension of elbow joint as compared to uninjured side was normal in 93 (88.6 %) patients and <10° restriction of motion in 12 (11.4 %) patients. Fracture union was obtained in 105 (97.2 %) out of 108 patients in our study.

Discussion

Increased incidence of male patients 58.3 % as compared to the female patients 41.3 % in this study may be due to more involvement of male patients in outdoor activities like going to field for working, climbing the tree for foliage, going to steep and hilly areas for cutting grasses for their cattle in villages. Similarly, more use of motor bike, driving under the influence of alcohol and aggressive nature of male made them prone to accident in male patients in town. In this study, there were 45 (41.7 %) fractures in right arm, 63 (58.3 %) in left arm. All of right arm fracture patients were right-sided dominant hand and left arm fractures were non-dominant hand. According to various studies, left extremity has been found to be more injured than right, and non-dominant extremity has been found to be more involved than dominant extremity. It has been suggested that right upper extremity is in use and the left assumes the protective function during injury. The less mature neuromuscular coordination of the non-dominant limb may also be responsible [11, 12]. Most of other studies including our studies showed that middle third of humerus is common site for fracture. The reason for common site of middle third fracture of humerus may be due to the angulatory forces, which cause the transverse fractures mostly occurs at middle third of humerus.

In this study, there were 57 (52.8 %) transverse fractures, 42 (38.9 %) oblique, 6 (5.6 %) comminuted and 3 (2.8 %) spiral types. Fracture pattern in our study is not comparable to the study of Sarmiento et al. [13] because they included the open fractures with bullet injuries where chance of comminution is high instead of transverse fracture. Most of other studies including our study showed that fall from the height and road traffic accident are the leading causes of mode of injuries for fracture shaft of humerus. Angulation at fracture site in our study is comparable with different other studies. In our study, there is no single case of valgus angular deformity in X-ray. In the study of Sarmiento and Horowitch et al. [15], there was 3 % of valgus deformities in 69 united fractures. Varus deformity was significantly more common and more severe than any other angulatory deformity [5]. This may be due to abduction of proximal fragment by deltoid muscle if fracture is distal to the insertion of deltoid muscle, tendency of varus deformity when the patients lean over the chair or bed and tendency of varus angulation while abducting the arm on brace. Less than 15° of varus angulation was clinically undetectable and 15°–20° could be demonstrated only by positioning the

arm in such a way as to accentuate the deformity, especially in individuals with thin arms. These degrees of angulation are considered by most to be aesthetically acceptable [4, 5, 15–19].

In this study, out of 105 patients whose fracture were united, shortening was present in 93 cases with mean shortening of 4.06 mm and ranges from 2 to 10 mm. Lengthening was present in 12 cases with mean of 2.50 mm and ranges from 2 to 3 mm. Shortening is mainly due to overlap of fracture fragments and angulation at fracture site, while lengthening is due to distraction at fracture. Distraction at fracture site up to 3 mm does not hamper for the union of bone. Shortening of as much as 5 cm is clinically insignificant [13]. In our study, fractures in 105 out of 108 patients were united at an average of 12.16 weeks with minimum of 7.5 weeks and maximum of 19.3 weeks. Time to unite the fracture in this study is comparable to other studies. According to different studies, healing in humeral fractures occurs within the first 3 months in general (average time for union is 8–12 weeks) [4, 8–10].

Motion of shoulder and elbow joint in our study is comparable to other studies. The shoulder flare of the functional brace allows the patient sufficient motion of the shoulder at the time of brace wearing. Mobilization exercises of shoulder joint after the early signs of callus formation in X-ray prevent the restriction of shoulder motion at the time of removal of brace. Brace acts by compressing the soft tissue, creating a tube that lends some stability to the fracture. This stability is adequate to permit early joint motion above and below the fracture site [4, 13]. Near normal motion of elbow at the time of removal of brace is due to elbow joint is completely free to movement during brace wearing. In our study, 105 out of 108 fractures were united with union rate of 97.2 %. High prevalence of fracture union in functional brace gives credence to long-held hypothesis that motion at the fracture site is an important factor in osteogenesis. They suspect that pain and the subsequent irritation created by motion between the fragments result in a cascade of favourable events, such as increased vascularity, piezoelectric potentials and local chemical and thermal changes [20].

In this study, radial nerve palsy was present in 6 (5.5 %) out of 108 cases. Function was recovered in all cases, 3 cases in 3 week and another 3 cases in 7 week after the injury. Although there are differences in the order of rates and approaches in the literature, commonly held opinions are (a) nerve damage in a closed fracture is usually related to contusion, (b) nerve damage usually occurs in distal third humeral shaft fractures and (c) early nerve exploration is not indicated except for open fractures, because initial radial nerve damage resolves spontaneously in most instances [14, 15, 17, 21]. Associated radial nerve palsy is a common complication of fractures of the humeral diaphysis. Spontaneous recovery is likely to occur in virtually all instances if the fracture is closed and the palsy develops at the time of the injury [4, 5, 15, 16, 18, 19, 22].

Conclusion

Functional bracing for the treatment of fractures of the humeral diaphysis is associated with a high rate of union with nearly normal elbow motion, and some restriction of shoulder motion at the time of removal of brace as well as resulting residual angular deformities are usually functionally and aesthetically acceptable.

Conflict of interest No conflict of interest was present regarding this study.

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