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ORIGINAL ARTICLE

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Functional treatment of the distal third humeral shaft fractures

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Abstract *Objective:* The objective of the present study was to determine the effectiveness of functional treatment for distal third humeral shaft fractures in young adults. *Patients and methods:* A custom-made prefabricated brace was applied for the functional treatment of 21 isolated, closed, distal third humeral shaft fractures of 21 patients (17 male and 4 female). Their average age was 25 years (range 18–37 years). The mean follow-up period was 39 weeks. *Results:* All of the fractures united. The average time to union was 12 weeks. The average varus angulation was 7.8 deg in 8 patients, and the average shortening of the fractured limb was 10 mm in 4 patients. Minimal motion restrictions mostly occurred in shoulder abduction and lateral rotation. No patient showed a lack of elbow motion. Angulatory deformities and shortening had no effect on the functional outcome. None of the patients suffered radial nerve palsy during the course of treatment or due to entrapment in the callus of the healed fracture. *Conclusions:* Young adults who have isolated, closed, distal third humeral shaft fractures are good candidates for functional bracing.

Keywords Functional treatment · Humeral shaft fracture

Introduction

Functional treatment of isolated, closed, humeral shaft fractures has been widely accepted because of its high and early union rate with good functional results [1, 14, 17, 19]. Despite the agreement concerning fractures of the middle and proximal thirds of the humeral shaft, there has been controversy about the distal third fractures [6, 15, 18]. Difficulty in controlling angular deformity, close relationship with the radial nerve, and elbow stiffness after fracture healing have been the main reasons for this. In this prospective study, we aimed to determine the effectiveness of functional bracing for isolated, closed, distal third humeral shaft fractures.

A brace creates a circular compression effect on soft tissues around the fracture site, so that the fracture fragments are stabilized. With the effect of gravity and stabilization, spontaneous reduction takes place. This stabilization of the fracture fragments allows active shoulder and elbow movements adjacent to the fracture. With the active contraction of the muscles around the fracture, physiologically controlled micromovement takes place, and blood flow and mineral deposition increase at the fracture site. These two factors together stimulate osteogenesis, and fracture healing occurs with external bridging callus [5, 9, 10, 13, 16] (Fig. 1).

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Patients and methods

From August 1997 to December 2000, a prefabricated functional brace was applied on 25 isolated, closed, distal third humeral shaft fractures in 25 patients Twenty-one patients (84%) were included in the study because the remaining 4 patients (16%) were lost to follow-up.

Since most of our patients are military personnel, our patient population consists mainly of young male adults. There were 17 male (81%) and 4 female (19%) patients. Their average age was 25 years (range 18–37 years). The right humerus was involved in 13 patients (62%) and the left in 8 (38%). The site of the fractures was below the junction of the middle and lower thirds of the humerus, thus below the insertion of the deltoid muscle. All of the fractures were closed and extra-articular. Fracture classification according to the shape of the fracture line was: 9 simple two-part spiral (43%) and 12 comminuted three-part with butterfly fragment (57%); AO/ASIF A1 and B1, respectively. The mechanisms of injury were: 7 motor-vehicle accidents (33%), 8 falls (38%), and 6 failed attempts to throw a hand grenade in military training (29%). None of the patients suffered concomitant or neurovascular injury.

A functional brace was used for the treatment of 21 patients. Primary stabilization of the fractures was achieved by the application of a long-arm plaster splint in one patient (5%), a long-arm plaster cast in 4 patients (19%), a 'U' splint in 1 patient (5%), and a hanging cast in 15 patients (71%). After the acute pain and

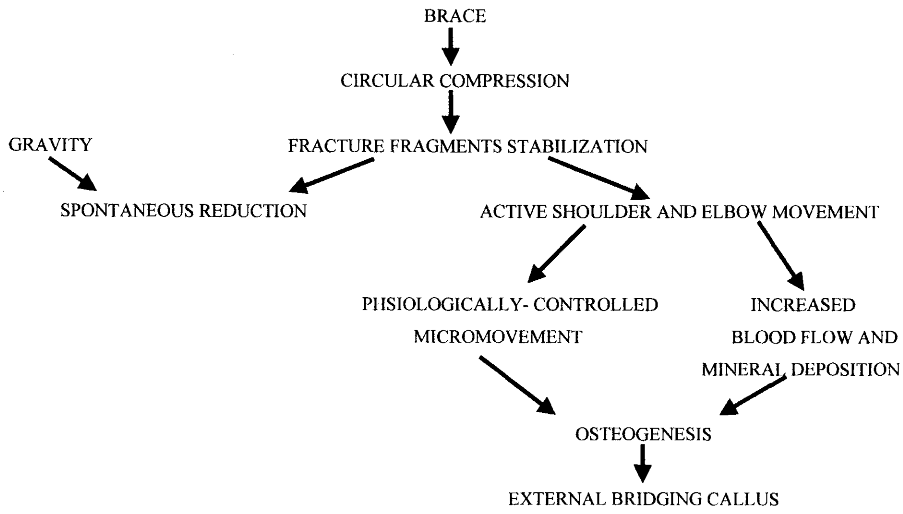

Fig. 1 Diagram showing the steps and mechanism of healing at the fracture site with functional brace

swelling had subsided, the primary stabilization device was removed, and a custom-made prefabricated functional brace was applied. The time from injury to the application of functional brace ranged from 2 to 15 days, average 8 days. This interval decreased as our experience with the technique increased (Table 1).

All of the braces that we applied in our study were made for each patient individually from thermoplastic polyethylene sheets which were perforated and 4 mm in thickness. We followed Sarmiento's measurements when we made braces: medially from 2.5 cm below the axilla to 1.3 cm above the medial epicondyle, laterally from just below the acromion to slightly above the lateral epicondyle [14]. We took care not to limit shoulder and elbow joint movements. The brace was held on the arm with three adjustable Velcro straps (Fig. 2). Because of the Velcro straps, the brace could be removed for personal hygiene, and adjustment of the soft-tissue compression was possible. In some cases, excessive tightening of the straps caused swelling of the forearm, and loosening of the straps was required.

After the application of the brace, the patients were taught and encouraged to do pendulum motion exercise of the shoulder and flexion/extension exercises of elbow. An arm sling was applied to hold the elbow in 90 deg of flexion. For the 1st week, the patients were asked to remove the arm sling at least five times a day and to do passive motion exercises for adjacent joints. At the end of 1st week, the arm sling was prohibited except during bedtime, and the patients were asked to do active shoulder and elbow motion exercises as much as possible. In order to avoid angulatory deformities, especially varus angulation at the fracture site, resting the elbow on a surface and shoulder flexion/abduction were forbidden until clinical and roentgenographic signs had demonstrated external

Table 1 Data after initial trauma

Case	Sex (male-female)	Age (years)	Mechanism of injury	Involved side	Shape of fracture line	Initial treatment	Time to application of brace after injury (days)
1	M	21	Fall	Left	Spiral	Long-arm plaster cast	12
2	M	34	Fall	Right	Comminuted	Hanging cast	15
3	M	24	Motor-vehicle accident	Right	Comminuted	Hanging cast	15
4	M	20	Motor-vehicle accident	Left	Comminuted	'U' splint	12
5	M	33	Motor-vehicle accident	Left	Comminuted	Hanging cast	12
6	F	18	Motor-vehicle accident	Right	Spiral	Hanging cast	10
7	M	22	Throwing	Right	Comminuted	Hanging cast	10
8	M	21	Motor-vehicle accident	Right	Comminuted	Long-arm plaster cast	15
9	F	30	Fall	Left	Spiral	Hanging cast	2
10	M	27	Throwing	Right	Comminuted	Hanging cast	7
11	M	22	Throwing	Right	Comminuted	Hanging cast	2
12	F	37	Fall	Left	Spiral	Long-arm plaster cast	5
13	F	35	Motor-vehicle accident	Right	Comminuted	Hanging cast	3
14	M	21	Throwing	Right	Spiral	Hanging cast	7
15	M	28	Fall	Right	Spiral	Hanging cast	7
16	M	23	Motor-vehicle accident	Left	Spiral	Long-arm plaster cast	5
17	M	23	Throwing	Right	Comminuted	Hanging cast	7
18	M	30	Fall	Right	Comminuted	Hanging cast	2
19	M	21	Fall	Left	Spiral	Hanging cast	7
20	M	21	Throwing	Right	Spiral	Hanging cast	5
21	M	21	Fall	Left	Comminuted	Long-arm plaster splint	2

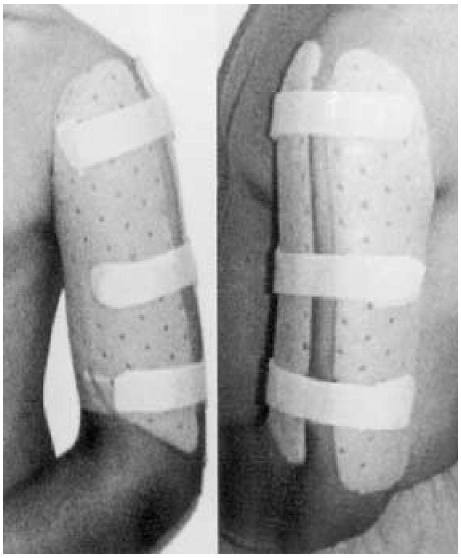

Fig. 2 Prefabricated functional brace made for each patient without limiting shoulder and elbow movements; soft-tissue compression is adjustable with Velcro straps

bridging callus formation between fracture fragments. The brace was always kept on the arm except for personal hygiene.

Patients were followed on an outpatient basis once a week for the 1st month, and subsequent visits were made once a month. At each visit, radiographic and clinical obsevations were made, and the range of joint movements was recorded. After seeing clinical and roentgenographic signs of good callus formation and healing, the brace was removed. The criterion for clinical healing was lack of pathological movement at the fracture site, and the criterion for roentgenographic healing was the formation of sufficient external bridging callus on both anteroposterior and lateral radiograms. Persistence of a fracture line between the fracture fragments does not necessarily mean lack of healing [13].

The mean follow-up time for 21 isolated, closed, distal third humeral shaft fractures of 21 patients was 39 weeks (range 29–70 weeks). We assessed the results according to radiographic, functional and clinical findings. The results were evaluated according to the modified Hannover Shoulder Score System [17] (Table 2). We also recorded the complications that we met (Table 3).

Results

All of the fractures united. The time to union was 8 weeks as the shortest time and 30 weeks as the longest time, for an average of 11.8 weeks. We evaluated both mediolateral and anteroposterior plane angulations at the fracture site at the time of brace removal and at the last follow-up visit. We observed that there was no change between the two measurements. In the mediolateral plane, 8 patients (38%) had varus angulation, on average 7.8 deg (range 2–10 deg). Thirteen patients (62%) had no deformity in the mediolateral plane. In the anteroposterior plane, one patient (5%) had an apex-posterior angulation of 4 deg. Twenty patients (95%) had no deformity in the anteroposterior plane. In general, varus angulation was the predominant deformity. There was no radiologically important rotational deformity.

Functional evaluation of the patients was made with respect to the range of shoulder and elbow movements at the time of brace removal. Six patients (29%) had lost less than 10 deg of abduction, and 4 patients (19%) had lost less than 10 deg of external rotation of the shoulder joint. These minimal losses of shoulder joint movements did not affect the patients' daily activities and improved with use of the extremity. There was no elbow flexion/extension limitation in any of the patients. No patient required formal physical therapy following removal of the brace.

We performed a clinical evaluation at the end of the follow-up period. We measured the arm length from the acromion to the lateral epicondyle of humerus, and limb length discrepancy of more than 4 mm was recorded. Shortening on the fracture side averaged 10 mm (range

Table 2 Modified Hannover shoulder score (maximum score that can be achieved is 100 points: excellent 90–100, good 80–89, moderate 70–79, poor <69)

Pain	Never	35
	During/after much use	30
	During/after little use	20
	At rest/at night	10
	Always	0
Function	Without limitation	35
	Minimal limitation	30
	Neck or backside cannot be reached	20
	Face or backside cannot be reached	10
	Stiffness	0
Instability	None	15
	Possible luxation of shoulder joint	5
	Frequent luxation	0
Activity	Without limitation	10
	Restrictions during work/sports	5
	Incapable of work/sports	0
Working level above head	Without limitations	5
	With complaints	2
	Unable	0

Table 3 Data after brace treatment

Case	Time to union (weeks)	Duration of follow-up (weeks)	Varus/valgus angulation (deg)	Ant./post. angulation (deg)	Limb length discrepancy	Complication during treatment
1	12	65	–	–	–	–
2	30	56	Varus 2.0	Posterior 4.0	–	Delayed union
3	10	29	Varus 10.0	–	Shortening 5.0 mm	–
4	10	29	–	–	–	–
5	20	45	Varus 5.0	–	–	Delayed union
6	10	29	–	–	–	–
7	10	29	Varus 10.0	–	Shortening 5.0 mm	–
8	22	44	–	–	–	Delayed union
9	10	34	Varus 10.0	–	Shortening 10.0 mm	–
10	10	39	Varus 10.0	–	Shortening 20.0 mm	Maceration of skin
11	9	35	Varus 5.0	–	–	–
12	10	42	–	–	–	–
13	8	38	–	–	–	–
14	10	32	–	–	–	–
15	11	40	Varus 10.0	–	–	–
16	8	39	–	–	–	–
17	10	29	–	–	–	–
18	8	70	–	–	–	–
19	10	29	–	–	–	–
20	10	29	–	–	–	–
21	10	32	–	–	–	–

Fig. 3 Initial radiographs of a typical distal third humeral shaft fracture with the application of a functional brace, 7 days after the initial injury

Fig. 4 Radiographs at the time of brace removal with good signs of callus formation and healing, 10 weeks after the initial injury

5–20 mm) in 4 patients (19%). We observed that varus angulation up to 10 deg and shortening up to 20 mm did not affect the functional outcome or cosmetic appearance. There was no rotational deformity of clinical importance. Figures 3, 4, 5 and 6 show the course of treatment for a typical closed distal third humeral shaft fracture from the inital injury to the end of follow-up.

We did not see any complication involving nonunion. Three patients (14%) who did not exhibit good callus formation and healing at the fracture site on both clinical and roentgenographic evaluations within 16 weeks were con-

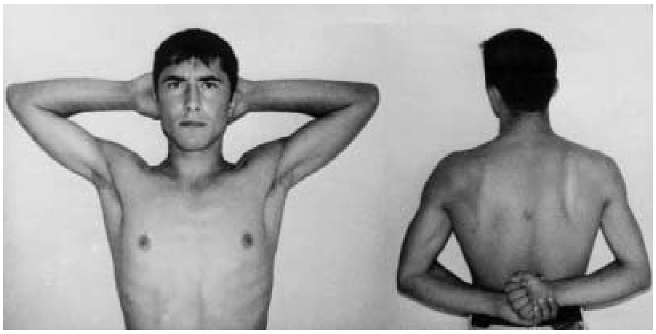

Fig. 5 Photographs of the functional results at the time of brace removal

Fig. 6 Radiographs at the end of the follow-up period, 32 weeks after the initial injury

sidered as delayed union. Brace treatment continued for these patients until union was achieved. Because of poor hygiene, one patient (5%) suffered skin maceration during brace treatment. Without interrupting the treatment, this problem was solved by skin care and dermatologic ointments. None of the patients experienced radial nerve palsy during the course of treatment due to entrapment in the callus of the healed fracture.

According to the score system results, 18 patients were classified as excellent (86%) and 3 as good (14%).

Discussion

It is now widely accepted that the primary choice of treatment for isolated, closed, humeral shaft fractures is conservative. With closed methods, a high rate of union can be obtained with good functional results without the risks of surgery (infection, nerve injury, rotator-cuff damage, implant loosening, etc.) [2, 3, 6, 8, 18]. However, some orthopedic surgeons have advocated surgery for closed distal third fractures of the humeral shaft because of the difficulty in controlling the fracture fragments and elbow joint stiffness after fracture healing with conservative methods [4, 6, 15, 17]. We intended to avoid these disadvantages by using a functional brace which makes active shoulder and elbow motion possible during the course of treatment of the humeral shaft fracture.

Successful results have been reported after the application of a functional brace for isolated, closed, distal third humeral shaft fractures with high rates of union and a satisfactory range of shoulder and elbow motion [1, 14, 15, 19]. In our study, we obtained a 100% union rate with no elbow stiffness. When the brace was removed, minimal motion restrictions mostly occurred in external rotation and abduction of shoulder. These restrictions did not affect the patients' daily activities and improved with use of the limb without the need for formal physical therapy. With the other popular conservative methods such as the 'U' splint and hanging cast, despite the high rates of union, loss of elbow and shoulder movement range is the main problem after fracture healing is complete, and formal physical therapy is required for most patients [1, 7, 17, 19].

The most common problems of conservative treatment of distal third humeral shaft fractures involve difficulty in reduction and the risk of axial deviations at the fracture site. By applying a functional brace, spontaneous reduction can be achieved by letting the arm respond to the effect of gravity as soon as the patient tolerates the pain. This leads to a decrease in Rrtational deformities at the fracture site due to contraction of the flexors and extensors.

Axial deviations mostly tend to develop in varus angulation [1, 14, 15, 19]. In our patient group, 8 patients (38%) had varus angulation at the fracture site. We found that varus angulation up to 10 deg did not affect either the functional outcome or the cosmetic appearance. It is accepted that angulatory deformities of the humeral shaft of up to 25 deg can be tolerated both functionally and cosmetically because of the large soft-tissue mass around the humerus and the large range of movement of the adjacent joints [14, 17, 19]. In order to minimize axial deviations, especially varus angulation, resting the elbow on a surface and flexion/abduction of the shoulder must be strictly forbidden until external bridging callus can be seen on radiographs.

On clinical observations, we found that shortening of the humerus by up to 20 mm did not affect the functional outcome and was hard to detect cosmetically. It is accepted that shortening of the humerus up to 5 cm is not of clinical importance [17, 19].

Humeral shaft fractures are expected to unite within 4 months. If a fracture does not unite within 4 months but there are clinical and radiographic signs of healing, it is defined as delayed union [12]. It must be kept in mind that when a fracture has radiographic signs of good callus formation and healing with the persistence of a fracture line, it should not be defined as delayed union [13]. In our study, 3 patients (14%) had delayed union, and brace treatment was maintained until there were clinical and radiographic signs of good callus formation.

No patient suffered initial radial nerve palsy in our study. The rate of initial radial nerve damage in humeral shaft fractures is 4%–22%. Altough 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, (c) early nerve exploration is not indicated except for open fractures, because initial radial nerve damage resolves spontaneously in most instances [2, 11, 15].

With our clinical experience, we have concluded that young adults with isolated, closed, distal third humeral shaft fractures are good candidates for functional bracing. Bracing offers good functional results, patient comfort, and cost reduction with a high rate of union. Since bracing requires patient compliance, patients who cannot cooperate are not candidates for bracing. Pathologic fractures, fractures with multiple injuries, or bedridden patients are also candidates for surgical treatment [2, 6, 17].

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