[Reprinted from THE JOURNAL OF BONE AND JOINT SURGERY Vol. 70-A, No. 4. PP. 607-610. April 1988]
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Diaphyseal Fractures of the Humerus

Treatment With Prefabricated Braces

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Abstract

Using a prefabricated brace, we treated 233 patients who had a fracture of the humeral shaft. One hundred and seventy patients were available for follow-up, which ranged from five weeks to forty-eight months. In these patients (43 open and 127 closed fractures), the average time to union was 10.6 weeks; the average varus-valgus angulation, 5 degrees; the average anterior-posterior angulation, 3 degrees; and the average shortening, as measured radiographically, four millimeters. All but three of the patients had an excellent or a good functional result with a nearly full range of motion of the extremity. There were a minimum of complications, including three non-unions. Because of the low morbidity and high rate of success, we concluded that the treatment of choice for diaphyseal fractures of the humerus is the prefabricated brace.

Most diaphyseal fractures of the humerus heal uneventfully,[2,4-7,10,15,17,18,23,24,26,27-29,30] in acceptable position and with satisfactory function, and non-operative treatment is therefore almost always indicated. The most common fixation devices have been coaptation splints, hanging casts, and Velpeau bandages, but with each of these methods of treatment, the end result may include adhesive capsulitis of the shoulder or stiffness of the elbow as well as transient inferior subluxation of the shoulder. A lengthy period of rehabilitation may also be necessary.

Sarmiento demonstrated that in fractures of the tibia that were treated with a custom-made brace, early motion and early function eliminated many of the problems that have been associated with plaster-cast immobilization[19,20]. He and his associates applied these two principles to fractures of the humerus [23], but, despite rewarding results, it became obvious that the custom-fitted device had major disadvantages. Their manufacture was time-consuming and expensive and required the services of an experienced orthotist, and the materials were limited both in durability and in potential for adjustment [30,31]. A standardized, prefabricated orthosis has been devised, by us [30-33] and by others [1,21], for easy application, low cost, and comfort. In this type of brace, the extremity is accessible for hygiene, and early function can be instituted.

In this report, we describe our experience with a prefabricated brace that we developed at the Special Fracture Clinic, University of Miami/Jackson Memorial Hospital. We used the brace in a large series of patients who had a fracture of the diaphysis of the humerus.

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Materials and Methods

From July 1980 through December 1984, at the University of Miami/Jackson Memorial Hospital, we used a prefabricated brace to treat 233 patients who had a diaphyseal fracture of the humerus. One hundred and seventy of these patients were available for follow-up. There were ninety-eight male and seventy-two female patients, and the average age was thirty-six years (range, fourteen to ninety years). The average length of follow-up was twenty-eight weeks (range, five weeks to forty-eight months).

Eighty-eight of the fractures were in the right extremity and eighty-two were in the left. One hundred and twenty-seven of the fractures were closed and forty-three were open. The two most common mechanisms of injury were a fall (fifty-one patients) and a motor-vehicle accident (sixty patients). Thirty-five of the forty-three open fractures were secondary to a gunshot wound. Thirty-three fractures were in the proximal third of the humeral diaphysis, ninety-three were in the middle third, and forty-four were in the distal third. There were two segmental fractures.

In determining whether to use the brace as the treatment for a given fracture, there were three contraindications: massive injury to soft tissue, or loss of bone; a presumed lack of reliability or cooperation on the part of the patient; and the impossibility of obtaining or maintaining acceptable alignment.

We used the MPF humeral brace (Maramed Precision, Hialeah, Florida), developed at the Special Fracture Clinic, University of Miami/Jackson Memorial Hospital, in all patients. The brace consists of two components: an anterior shell and a posterior interlocking shell, which are held together by two Velcro belts. Our initial use of the humeral brace, from 1980 through 1983, was as secondary treatment, as described by Sarmiento et al. [23]. This early treatment involved the application of a plaster coaptation splint and a sling.

In 1983, we began to apply the brace on the initial day of treatment for most patients[33]. The majority of these patients easily tolerated immediate application of the prefabricated brace over cast-padding. They were seen on the next day for a neurovascular re-evaluation, and again approximately one week after injury. At the third visit, the cast-padding was removed, and a double layer of cotton stockinette was applied to the extremity. The brace was fitted, and a radiograph was made to check for alignment. Whether treatment with the brace was primary or secondary, at the one-week check-up the patient was instructed by the occupational therapist to begin pendulum exercises of the shoulder, passive forward flexion of the upper extremity, and active function of the hand, wrist, elbow, and shoulder in the brace. At this time, removal of the brace was allowed for hygienic purposes, and the patient was supplied with extra cotton stockinette for cleaning and changing. At the next examination, in the second week after injury, the radiographic alignment in the brace was checked, and active function of the entire extremity was encouraged.

Range of Angulation *(Degrees)*	Level of Fracture*			
	Prox. Third (N = 33)	Middle Third (N = 93)	Distal Third (N = 44)	All Levels (N = 170)
0	55	31	39	38
1-5 varus**	15	26	4	21
1-5 valgus	3	0	0	0.5
6-8 varus**	15	20	30	22
6-8 valgus	0	1	0	0.5
9-12 varus**	6	11	11	10
9-12 valgus	0	0	0	0
>12 varus**	6	11	4	8
>12 valgus	0	0	2	0.5

Table 1. Angulation of the humerus in the medial-lateral plane as measured radiographically.

*Percentage of patients in each group within each range.
**The percentage of fractures that had varus angulation was significantly greater than that of those that had valgus angulation at all levels and for all ranges (chi-square test, $p < 0.0005$).

Thereafter, re-examination took place at intervals of three to four weeks, and at each visit the radiographic and clinical assessments were repeated. Function and range of motion were continually stressed and evaluated. When

radiographic evidence of union was confirmed clinically, use of the brace was discontinued. Subsequent evaluations occuffed on a long-term basis.

Open and closed fractures were treated in the same manner, except that patients who had an open fracture initially were admitted to the hospital for operative exploration, irrigation and debridement, intravenous antibiotic therapy, and immobilization using a plaster (coaptation) splint. All wounds were left open to heal by secondary intention. Bracing was begun at the time of the first change of dressing (at two to three days).

Results

The average time to union was 9.5 weeks for the closed injuries and 13.6 weeks for the open fractures. The overall average time to healing was 10.6 weeks (range, five to twenty weeks). Fractures in the middle third of the humeral diaphysis were the slowest to heal (11.4 weeks, compared with 9.2 and 9.4 weeks for the proximal and distal thirds).

The mean varus-valgus angulation at follow-up was 5 degrees (Table 1) and the mean anterior-posterior angulation was 3 degrees (Table 2). About 90 percent of the patients had 8 degrees of varus or valgus angulation, or less, and approximately 85 percent had 8 degrees of anterior or posterior angulation, or less. Varus deformity was significantly more common and more severe than any other angulatory deformity (p 7lt; 0.0005 by the chi-square test) (Table 1). Proximal third fractures had significantly less residual angulation in all planes than did fractures at any other level of the humerus ($p < 0.03$ by the chi-square test). No clinically significant rotational deformities were detected. Shortening, as evaluated radiographically, was a mean of four millimeters (range, zero to fifteen millimeters). Distraction of a few millimeters in abundant periosteal callus is very difficult to measure radiographically. Thus, minor amounts of distraction were recorded as no shortening. Shortening of as much as five centimeters is clinically insignificant[3]. In this series, no patient who had humeral shortening demonstrated any functional or cosmetic problems.

Function was evaluated with respect to range of motion of the shoulder and elbow and to function of the extremity in the activities of daily living. Approximately 95 percent of the patients (all but twelve) had an excellent functional result and an essentially full range of motion of the shoulder and elbow. Eight patients (5 percent) had a good functional result but lacked 15 degrees of forward flexion of the shoulder, or less, or 5 degrees of extension of the elbow, or less (or both). Three patients (2 percent) had a poor initial result secondary to instability that was due to non-union of the fracture. The majority of the patients required formal physical or occupational therapy only for the first few weeks after injury while they wore the brace. Only seven patients (approximately 5 percent) required rehabilitation of the extremity after union of the fracture was evident.

The complications were minimal. In three patients, a non-union developed. Two of these fractures were closed and one was open; all three subsequently had open reduction and internal fixation with bone-grafting. All healed, and the patients had a good functional result. In the first year of the study, only two patients had major maceration of the skin. These patients did not remove the brace during treatment and had poor hygienic habits. The maceration resolved promptly with cleaning of the extremity, application of a drying lotion, and changing of the stockinette.

Two patients had a refracture that was attributable to removal of the brace less than eight weeks after the original injury. Both patients had sustained additional trauma to the limb. The fractures healed after the brace was worn for several more weeks.

Three patients had varus angulation of more than 25 degrees at follow-up. All three patients were obese women, in whom the breast on the involved side apparently acted as a fulcrum at the site of the fracture. None of these patients

had a functional deficit, and the involved arm was cosmetically acceptable.

A radial-nerve palsy that was due to the injury was initially seen in seven patients who had a closed injury. The palsy was not associated with any specific type of fracture, as described by Holstein and Lewistt, but rather, with a fracture of the middle or distal third of the humerus. All seven palsies resolved spontaneously in one week to six months without surgical intervention.

Discussion

The use of bracing in the management of humeral shaft fractures requires the same meticulous attention to detail as does operative reduction and internal fixation. Because the humerus is an unpaired bone and is surrounded by a thick layer of soft tissue, humeral fractures are inherently unstable. It is not uncommon for internal rotation and varus angulation deformities to occur in a patient whose fracture was initially treated with a hanging cast. Bracing is designed to take advantage of the early instability by using extension of the elbow and early functional activity; this treatment allows gravity to correct the alignment of the fracture fragments naturally [21].

A primary objective in the application of the brace is to achieve early active motion of the shoulder, elbow, wrist, and hand, and, particularly, to activate the muscles surrounding the site of the fracture. Local activation of the muscles in the area of the fracture is important for maintaining the milieu for optimum healing of lesions in which motion of the fracture fragments is to be expected [16,21,22,32]. While the custom-designed brace accomplished these mechanical goals, development of the proper clinical protocol was also necessary [21,23]. The earliest prefabricated device, developed by Sarmiento et al. [23], consisted of a one-piece, wrap-around polypropylene sleeve. Although polypropylene is rigid and durable, the properties of the material are not critical to the function of the brace. This was demonstrated in the laboratory, where the measured change in the rigidity of the limb was affected more dramatically by soft-tissue compression than by the rigidity of the cast or brace [32]. Thus, we chose low-density polyethylene, which provides satisfactory durability and more compliance for comfort without sacrificing structural rigidity.

Our previous experience with earlier designs of braces [30-32] led to the conclusion that braces that have suspension straps are awkward and unnecessary. Designs that have an over-the-shoulder extension prohibit a full range of motion and frequently result in considerable limitation of motion after removal of the brace. The wrap-around design of brace results in more severe angulatory deformities. Devices that do not entirely encompass the soft tissues of the extremity violate a basic principle of soft-tissue encasement [21,32] and do not provide adequate compression and stability.

Range of Angulation *(Degrees)*	Level of Fracture*			
	Prox. Third (N = 33)	Middle Third (N = 93)	Distal Third** (N = 44)	All Levels (N = 170)
0	72	53	42	54
1-5 anterior	9	8	27	13
1-5 posterior	6	13	2	9
6-8 anterior	3	5	4	5
6-8 posterior	6	10	7	8
9-12 anterior	0	3	2	2
9-12 posterior	0	2	9	3
>12 anterior	0	2	7	3
>12 posterior	3	4	0	3

Table 2. Angulation of the humerus in the anterior-posterior plane as measured radiographically.

An orthosis that has separate anterior and posterior interlocking shells provides the best range of adjustability without altering the contour of the brace. This design also gives the best suspension on the limb.

*Percentage of patients in each group within each range.
**Anterior bowing was significanly more frequent than posterior bowing in distal third fractures for all ranges combined (chi-square test, $p < 0.0005$). For all other levels, there was no significant difference.

Minor anatomical deformities were found at follow-up in the majority of the patients in this series. These results are consistent with those that were reported for other series of patients who had closed treatment of fractures of the humeral shaft [2,4-7,12,15,17,18,23,24,26,27,29,30]. The consensus was that these minor angulatory deformities were clinically insignificant;[5,12,23,26,30]however, excessive angulation (25 degrees or more) is potentially a cosmetic problem'4. Although three patients in this series, all obese women, had excessive angulation, it was precisely in these patients thatthe angulatory deformity was not cosmetically obvious because of the large girth of the arm, and in no patient was the result unacceptable.

Primary bracing of a fracture is often associated with moderate edema distal to the brace. Ten patients in our series had severe distal edema; it resolved within three weeks, after continued function, exercises for the hand, elevation of the forearm on a pillow with the sling applied, and intermittent recumbency.

Transient inferior subluxation of the shoulder developed in eight of our patients. Initially, the radiographs of these patients demonstrated only the fracture, but the subluxation was evident at the first follow-up visit, within one week after injury. There was no clinical neurological deficit in any of these patients, and with routine physical therapy the subluxation resolved spontaneously, within eight to ten weeks after injury. We have not been able to arrive at a satisfactory objective explanation of the etiology of the subluxation in these patients.

A radial-nerve palsy is commonly associated with a fracture in the distal third of the humerus [11]. In our opinion, the majority of radial-nerve injuries that occur at the time of the fracture will resolve spontaneously. Splinting of the wrist may be performed in conjunction with bracing of the fracture. Physical or occupational therapy should be continued during the course of treatment. A radial-nerve injury that develops after the initial injury is usually identified after a manipulation or during the course of treatment. If resolution does not occur by the time of union of the fracture, surgical intervention may be considered [8,9,13,25,28]. No such palsy was evident in this series.

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