

# Functional Bracing for the Treatment of Fractures of the Humeral Diaphysis\*

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## Abstract

**Background:** Nonoperatively treated fractures of the humeral diaphysis have a high rate of union with good functional results. However, there are clinical situations in which operative treatment is more appropriate, and, though interest in plate osteosynthesis has decreased, intramedullary nailing has gained popularity in recent years. We report the results of treating fractures of the humeral diaphysis with a prefabricated brace that permits full motion of all joints and progressive use of the injured extremity.

**Methods:** Between 1978 and 1990, 922 patients who had a fracture of the humeral diaphysis were treated with a prefabricated brace that permitted motion of adjacent joints. The injured extremities were initially stabilized in an above-the-elbow cast or a coaptation splint for an average of nine days (range, zero to thirty-five days) prior to the application of the prefabricated brace. Orthopaedic residents, supervised by teaching staff, provided follow-up care in a special outpatient clinic. Radiographs were made at each follow-up visit until the fracture healed.

**Results:** We were able to follow 620 (67 percent) of the 922 patients. Four hundred and sixty-five (75 percent) of the fractures were closed, and 155 (25 percent) were open. Nine patients (6 percent) who had an open fracture and seven (less than 2 percent) who had a closed fracture had a nonunion after bracing. In 87 percent of the 565 patients for whom anteroposterior radiographs were available, the fracture healed in less than 16 degrees of varus angulation, and in 81 percent of the 546 for whom lateral radiographs were available, it healed in less than 16 degrees of anterior angulation. At the time of brace removal, 98 percent of the patients had limitation of shoulder motion of 25 degrees or less.

**We were unable to follow most of the patients long-**

**term, as they did not return to the clinic once the fracture had united and use of the brace had been discontinued.**

**Conclusions:** Functional bracing for the treatment of fractures of the humeral diaphysis is associated with a high rate of union, particularly when used for closed fractures. The residual angular deformities are usually functionally and aesthetically acceptable. The present study illustrates the difficulties encountered in carrying out long-term follow-up of indigent patients treated in charity hospitals that are affiliated with teaching institutions. These difficulties are also becoming common with patients insured under managed-care organizations and are frequent in our peripatetic population.

To our knowledge, the senior one of us (A. S.) and his colleagues<sup>11</sup> were the first to report the successful use of functional bracing for the treatment of fractures of the humeral diaphysis. The new method permitted freedom of motion of all joints in the injured extremity<sup>4</sup>. The initial report on fifty-one patients showed nonunion in one patient who had a pathological fracture. Subsequent reports have shown a high rate of union and few complications<sup>3,5,14,16,17</sup>. In recent years, improved operative techniques have made other methods of treatment available, particularly intramedullary nailing. The initial intramedullary nailing procedures were followed by a high rate of complications. Robinson et al.<sup>8</sup> reported a 23 percent rate of delayed union and nonunion (seven of thirty patients).

Since our study population consisted primarily of indigent patients seen at teaching institutions, a large number of the patients failed to return for additional follow-up once the acute symptoms had subsided. This deprived us of the opportunity to perform an outcomes study.

## Materials and Methods

Between 1978 and 1990, we treated 922 patients who had a fracture of the humeral diaphysis with a prefabricated brace that permitted functional motion of the shoulder and elbow. We were able to follow 620 (67 percent) of these patients.

The average age of the patients was thirty-six years (range, sixteen to eighty-three years) at the time of injury. There were 391 male patients (63 percent) and 229 female patients (37 percent). Three hundred and three

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FIG. 1

Photograph showing a prefabricated brace, held in place with Velcro straps, that compresses the soft tissues and permits unlimited motion of the shoulder and elbow joints.

(49 percent) of the fractures were in the right humerus, and 317 (51 percent) were in the left humerus; 465 (75 percent) were closed, and 155 (25 percent) were open. One hundred and eighteen (76 percent) of the open fractures were gunshot injuries, and the remaining thirty-seven (24 percent) resulted from motor-vehicle accidents. One hundred and ninety-two patients (31 percent) sustained the fracture in a fall to the ground; 118 (19 percent), from a gunshot; 211 (34 percent), in a motor-vehicle accident; and ninety-nine (16 percent), from various other causes, such as a bicycle accident, a direct blow to the arm, or a twisting force.

Ninety-two fractures (15 percent) were in the proximal third of the humeral diaphysis, 303 (49 percent) were in the middle third, 219 (35 percent) were in the distal third, and six (1 percent) were segmental. One hundred and one fractures (16 percent) were transverse, 149 (24 percent) were oblique, 364 (59 percent) were comminuted, and six (1 percent) were segmental. Twelve (2 percent) of the fractures had an associated inferior glenohumeral subluxation.

Sixty-seven patients (11 percent) had an associated radial nerve palsy. Fifty-two (78 percent) of the palsies were associated with a closed fracture and fifteen (22 percent), with an open fracture. Twenty-eight (42 percent) of the sixty-seven fractures were transverse, fourteen (21 percent) were oblique, and twenty-five (37



FIG. 2-A

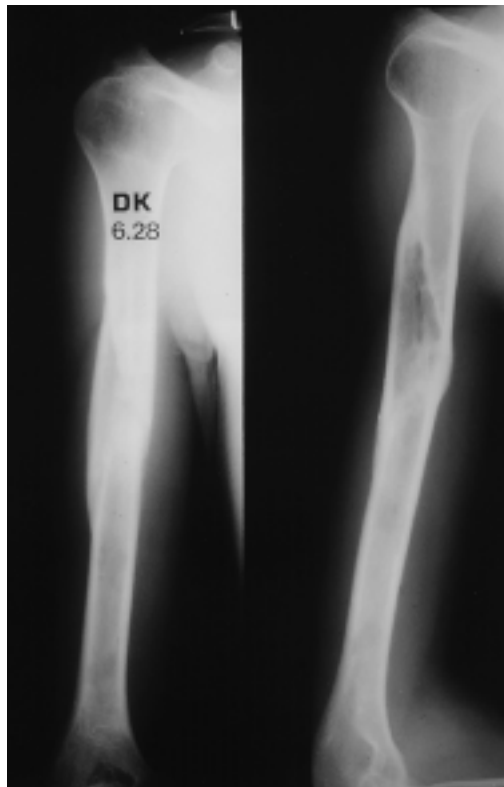


FIG. 2-B

Figs. 2-A and 2-B: Radiographs of a comminuted fracture of the proximal third of the humerus due to an automobile accident.

Fig. 2-A: Anteroposterior radiograph, made one week after the initial injury, showing subluxation of the glenohumeral joint (arrows).

Fig. 2-B: Anteroposterior and lateral radiographs, made six months after the initial injury, showing spontaneous reduction of the glenohumeral subluxation.

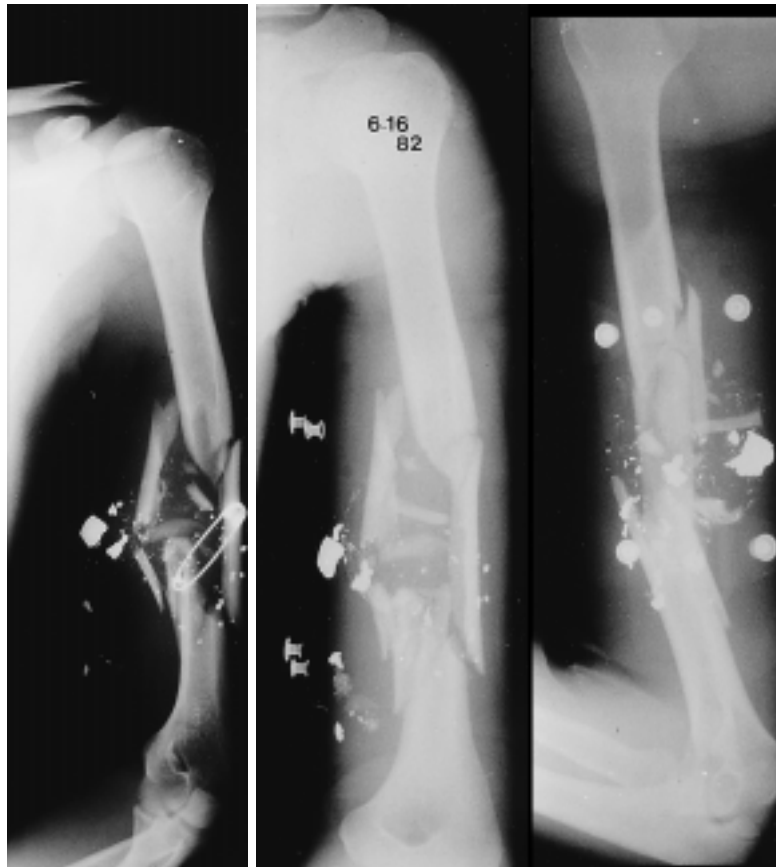


FIG. 3-A

FIG. 3-B

Figs. 3-A, 3-B, and 3-C: Radiographs of a comminuted fracture of the middle third of the humeral diaphysis due to a low-velocity gunshot.

Fig. 3-A: Anteroposterior radiograph made after the initial injury.

Fig. 3-B: Anteroposterior and lateral radiographs, made two weeks after the application of the functional brace, showing the alignment and reduction.

percent) were comminuted. The mechanism of injury was a fall for sixteen patients (24 percent), a motor-vehicle accident for twenty-four (36 percent), a low-velocity gunshot for twenty-three (34 percent), and unknown for four (6 percent).

In the instances in which a nerve injury was due to a penetrating injury or a high-velocity gunshot wound, operative exploration was performed and, if necessary, the nerve was repaired. We were unable to determine the exact number of patients in this category. The fractures in these patients were stabilized by other orthopaedic surgeons within the department, and we were unable to follow them. Only patients who had an open fracture or an associated injury were admitted to the hospital. The humeral fractures of an unknown number of patients who had multiple injuries were treated by operative or nonoperative methods, and these patients were not included in our study.

Initially, the injured extremity was stabilized in an above-the-elbow cast or a coaptation splint that held the elbow in 90 degrees of flexion, for an average of nine days (range, zero to thirty-five days). None of the fractures were manipulated. Patients were evaluated in the outpatient department approximately one week (range,

three days to five weeks) after the initial injury. If the acute symptoms had subsided and the injured extremity was not swollen, a brace was applied and the patient was given a collar-and-cuff sling to wear. The brace consisted of two plastic sleeves that encircled the arm with two adjustable Velcro straps to hold the sleeves together. The brace extended from approximately two inches (five centimeters) distal to the axilla to two inches proximal to the olecranon. Patients were shown how to adjust the brace and tighten the Velcro straps several times a day to accommodate the changes in the girth of the extremity that occurred as the swelling subsided and muscle atrophy developed (Fig. 1). The brace was worn at all times, except during bathing.

Patients were instructed in the performance of pendulum exercises immediately after the application of the initial cast or splint, and the exercises were continued after the application of the brace. The collar-and-cuff sling was taken off for a few minutes several times a day to permit combined active and passive exercises of the elbow and to regain full extension of this joint as soon as possible. Active elevation and abduction of the shoulder were not allowed, since such exercises could lead to angular deformity. The patients also were in-

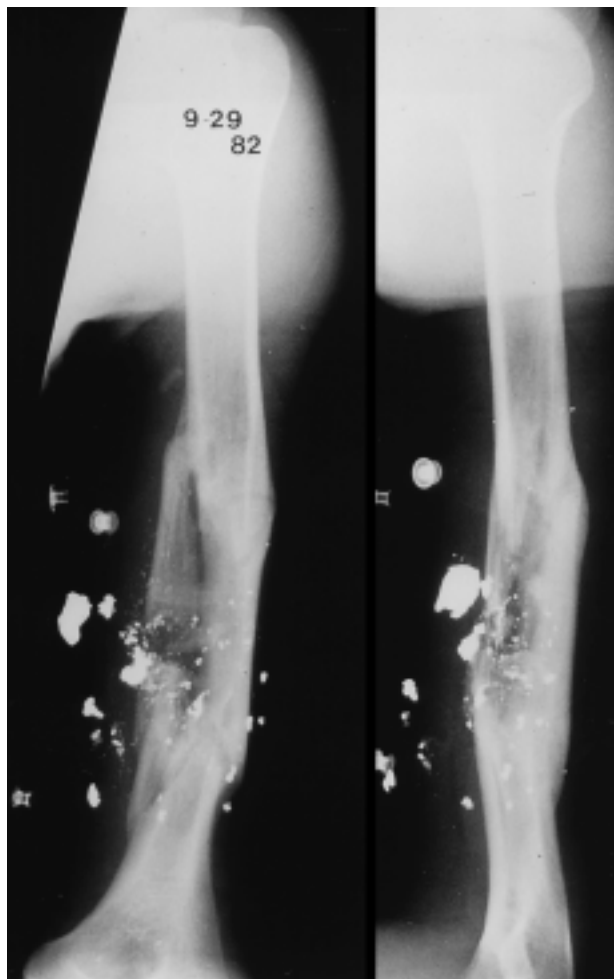


FIG. 3-C

Anteroposterior and lateral radiographs, made four months after the initial injury, showing healing and consolidation of the fracture with good alignment of the humeral diaphysis.

structed not to lean the elbow on the arm of a chair, a table, or their lap, as leaning on the elbow of a fractured extremity during the early stages of healing may cause varus angulation. Such angulation is more likely to occur in association with transverse fractures, particularly when the bone fragments contact each other; it is less likely to occur in association with oblique fractures, where elastic pistoning of the fragments takes place.

Patients were seen one week after the application of the brace, and radiographs were made to evaluate the position of the fracture. Once full extension of the elbow had been achieved, use of the collar-and-cuff sling was discontinued during walking but its use was encouraged during recumbency. During the next four weeks, patients increased the frequency and intensity of exercises involving passive flexion of the shoulder and active flexion and extension of the elbow.

Fracture treatment was the same for the sixty-seven patients (11 percent) who had an associated radial nerve palsy at the time of the injury. A cock-up wrist splint was not used in the anticipation that, once the elbow reached full extension, the wrist would spontaneously extend to

neutral, precluding the development of a permanent flexion contracture of the wrist and fingers. Patients were instructed to perform active and passive extension of the wrist and fingers several times a day.

No attempt was made to document a history of smoking, drinking, or recreational drug use, since the patients, with few exceptions, belonged to a population in which habitual use of these substances is common. Questions related to these habits probably would not have been answered accurately. We believed that, under those circumstances, it would have been very difficult to obtain reliable data. We have no information on the amount of time away from work, since many of our patients either were unemployed or did not hold a permanent working position.

### Results

We were able to follow 620 (67 percent) of the 922 patients who had a fracture of the humeral diaphysis to the point of complete healing. A large number of patients discontinued their visits to the outpatient clinics as soon as the injured extremity became painless and functional. Despite numerous attempts, we could not obtain long-term follow-up for these patients.

The functional brace was removed upon confirmation of clinical and radiographic union of the fracture, which occurred at an average of 11.5 weeks (range, five to twenty-two weeks) (Figs. 2-A through 3-C). Union was arbitrarily defined as being present when osseous bridging between the main fragments was observed on at least one radiograph and there was no pain at the fracture site.

The 465 closed fractures healed at a median of 9.5 weeks (range, five to nineteen weeks) and the 155 open fractures, at a median of fourteen weeks (range, eight to twenty-two weeks). The median healing time was twelve weeks (range, eight to twenty-two weeks) for the 101 transverse fractures, ten weeks (range, five to seventeen weeks) for the 149 oblique fractures, eleven weeks (range, five to eighteen weeks) for the 364 comminuted fractures, and twelve weeks (range, eight to twenty-one weeks) for the six segmental fractures. The median healing time was ten weeks (range, five to fourteen weeks) for the ninety-two fractures located in the proximal third of the humeral diaphysis, ten weeks (range, six to twenty-two weeks) for the 303 fractures located in the middle third, nine weeks (range, six to twenty-two weeks) for the 219 fractures located in the distal third, and twelve weeks (range, eight to twenty-one weeks) for the six segmental fractures.

Sixteen patients (3 percent) required operative intervention because of a nonunion. The mechanism of injury was a fall to the ground for four of these patients, a motor-vehicle accident for nine, and a low-velocity gunshot for three. Nine open fractures and seven closed fractures did not unite. Of the nine nonunions of open fractures, four (two transverse and two comminuted)

### FINAL ANGULATION HUMERAL SHAFT FRACTURES

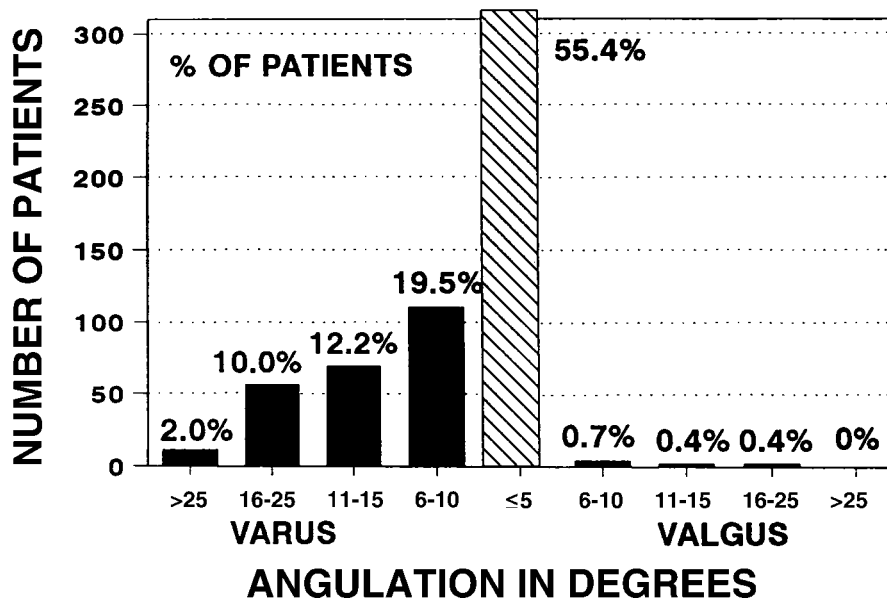


FIG. 4

Bar graph showing the degree of varus-valgus angulation at the time of the most recent follow-up in the 565 patients for whom anteroposterior radiographs were available.

were in the middle third of the humerus and five (two transverse and three comminuted) were in the distal third of the humerus. Of the seven nonunions of closed fractures, four (three transverse and one comminuted) were in the middle third of the humerus and three (two

transverse and one comminuted) were in the distal third. Distraction between the fragments in the nonunion was observed in seven patients on radiographs made with the patient standing.

Four (less than 1 percent) of the patients had a re-

### FINAL ANGULATION HUMERAL SHAFT FRACTURES

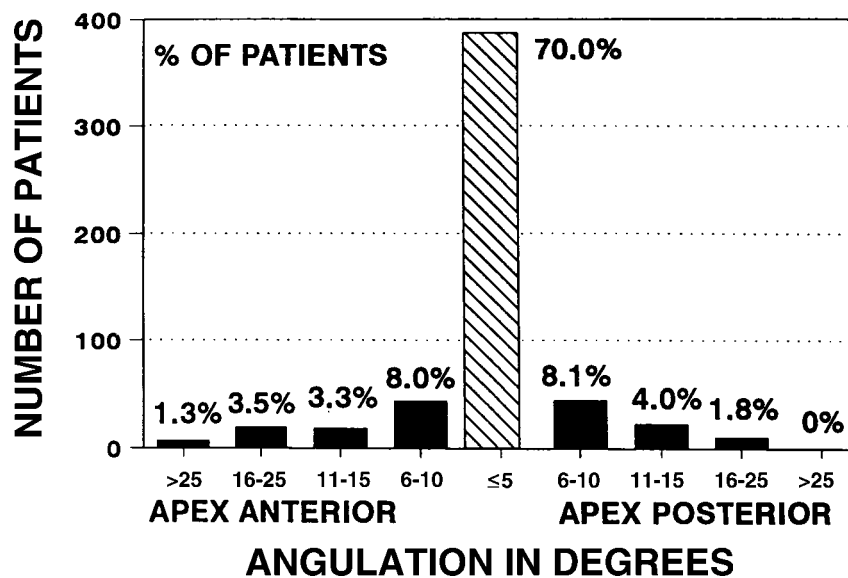


FIG. 5

Bar graph showing the degree of anterior and posterior angulation at the time of the most recent follow-up in the 546 patients for whom lateral radiographs were available.

## FINAL SHOULDER MOTION HUMERAL SHAFT FRACTURES

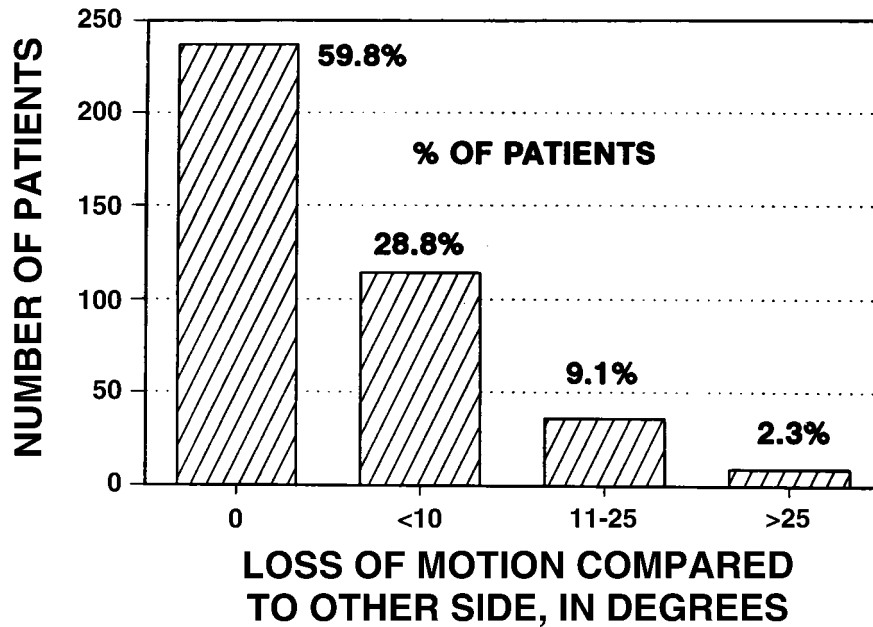


FIG. 6

Bar graph showing the degree of loss of motion of the affected shoulder as compared with the contralateral side at the time of the most recent follow-up.

fracture between the second and the eighth week after removal of the brace. Two of the refractures occurred after a fall; one, during sports activities; and one, from

an unknown mechanism. The four refractures healed following reapplication of the brace.

The most recent anteroposterior radiographs were

## FINAL ELBOW MOTION HUMERAL SHAFT FRACTURES

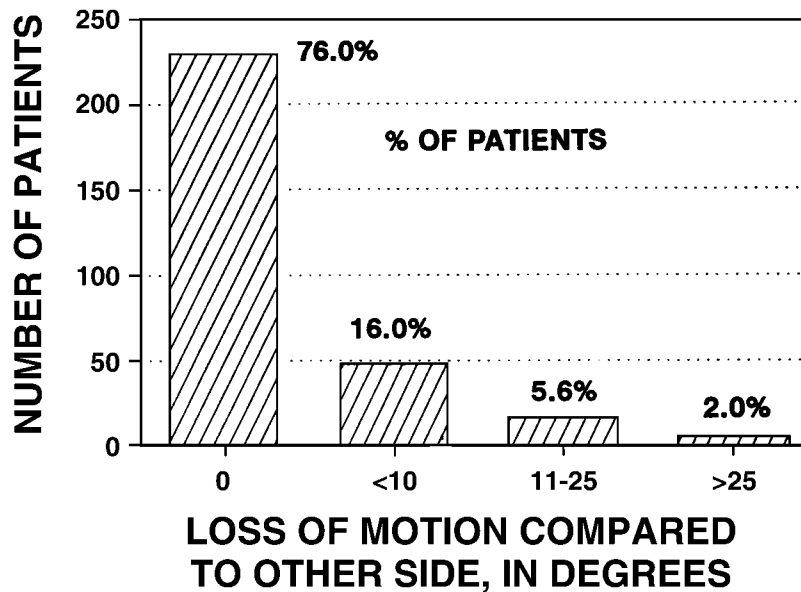


FIG. 7

Bar graph showing the degree of loss of motion of the affected elbow as compared with the contralateral side at the time of the most recent follow-up.

available for measurement of the humeral angulation in 565 patients (91 percent) (Fig. 4), and the most recent lateral radiographs were available for measurement of angulation in 546 patients (88 percent) (Fig. 5). The 101 transverse fractures healed in an average of 9 degrees of varus angulation; the 149 oblique fractures, in an average of 4 degrees; and the 364 comminuted fractures, in an average of 8 degrees.

Nerve function did not return in one of the sixty-seven patients who had a radial nerve palsy. Because of the relatively short duration of follow-up of many of the patients, we are not in a position to state the ultimate degree of recovery that might have taken place. As we stated, an unknown number of patients who had a repair of the lacerated nerve were followed at other services and were not seen in our clinic.

The twelve patients who had an inferior subluxation of the shoulder demonstrated spontaneous correction of the subluxation, but no accurate data was kept concerning the speed of recovery.

Once the fracture was clinically stable and there were radiographic signs of healing, the patients were asked by the examining resident to flex, abduct, and rotate the shoulders. The range of motion was recorded on specially designed forms, and the final recording reflected the motion measured at the time of the last contact with the patient (Fig. 6). Elbow motion was recorded for 301 (49 percent) of the patients (Fig. 7).

We have no information on the number of deep infections that may have occurred in the patients who were admitted to the hospital and never transferred to our clinic, since they were treated by a different service. None of the patients who had an open fracture that was treated by us had an infection at the time of transfer to our clinic.

### Discussion

Nonoperative management still remains the treatment of choice for most fractures of the humeral diaphysis<sup>5,12</sup>. A high rate of union and satisfactory functional results have given credence to this method<sup>3,5,8,11,14,16,17</sup>. Ostermann et al.<sup>5</sup> reported nonunion of four (2 percent) of 191 fractures. Zagorski et al.<sup>17</sup> reported that three (2 percent) of 170 patients had a nonunion, and the average varus-valgus angulation in their series was 5 degrees. Sharma et al.<sup>16</sup> found a residual varus angulation of less than 5 degrees in more than 50 percent of forty patients who were treated with a functional brace. In another, comparable group of twenty-five patients treated with a coaptation splint, only four (16 percent) had a final varus angulation of less than 5 degrees.

Rüedi et al.<sup>10</sup> reported nonunion, infection, and other complications after the treatment of fractures of the humeral diaphysis, particularly after operative treatment. Habernek and Orthner<sup>1</sup> found no instance of nonunion, infection, or secondary radial nerve palsy in a group of nineteen patients treated operatively. In a

study of thirty-nine patients treated with the use of a retrograde nail, Rommens et al.<sup>9</sup> reported that 95 percent (thirty-seven) had union and 92 percent (thirty-six) had excellent shoulder function. However, Robinson et al.<sup>8</sup> reported a postoperative complication rate of 87 percent (twenty-six patients), a reoperation rate of 70 percent (twenty-one patients), and a rate of delayed union or nonunion of 23 percent (seven patients) in a group of thirty patients. Postoperative shoulder function was poor in seven of the eighteen patients for whom functional assessments had been performed. Riemer et al.<sup>7</sup> found complications in seven of twelve patients in whom a fracture had been treated with nine-millimeter-diameter nails. Hems and Bhullar<sup>2</sup> reported a 33 percent rate of nonunion (seven of twenty-one patients) and a 16 percent rate of shoulder pain (four of twenty-five patients) related to use of an interlocking nail through an antegrade approach.

In our study of functional bracing for the treatment of fractures of the humeral diaphysis, we found a rate of nonunion of less than 2 percent in the 465 patients who had a closed fracture and of 6 percent in the 155 patients who had an open fracture. The final angular deformities were cosmetically acceptable in most instances: 87 percent of the 565 fractures for which anteroposterior radiographs were available healed in less than 16 degrees of varus angulation, and only 2 percent had a permanent varus angular deformity of more than 25 degrees (Fig. 4). These degrees of angulation are considered by most to be aesthetically acceptable<sup>3,5,8,14,16,17</sup>. We believe that the low prevalence of refracture of less than 1 percent (four patients) is related to the fact that fractures treated without rigid immobilization heal with abundant and stronger periosteal callus<sup>13</sup>.

The brace was removed at an average of 11.5 weeks (range, four to twenty-two weeks) after the initial injury. Since the functional brace does not immobilize any of the joints in the injured extremity for more than one week, permanent limitation of function is unlikely and many patients are able to perform most functional activities of daily living before the fracture is healed and the brace is removed.

Sixty percent of the patients had a full range of shoulder motion upon discontinuing use of the functional brace. At the time of brace removal, 98 percent of the patients had limitation of shoulder motion of 25 degrees or less (Fig. 6). The patients did not receive supervised physical or occupational therapy throughout the treatment period. They were instructed by the residents or attending surgeons in the exercises during the weeks preceding the development of intrinsic fracture stability, and this was followed by active and passive exercises consisting of flexion, extension, abduction, and adduction of the shoulder. We found that, on examination of the patients who were seen several months after completion of healing, there was an increase in the range of motion with continued use of the extremity. Pa-

tients were instructed not to actively abduct or elevate the extremity against gravity until early bridging callus was seen on radiographs; otherwise, an angular deformity could develop.

Of the 301 patients for whom the range of elbow motion was recorded, 230 (76 percent) had a full range of motion upon removal of the brace and the remaining seventy-one (24 percent) had limitation of flexion and extension at that time (16 percent had less than 10 degrees of limitation; 5.6 percent, 11 to 25 degrees; and 2 percent, more than 25 degrees) (Fig. 7). We assumed that, as in the case of the shoulder, continued use of the extremity would result in an improved range of motion.

Functional bracing does not restore anatomical alignment of a fracture of the humeral diaphysis, but the final angular deviations were cosmetically and physiologically acceptable<sup>3,5,8,14,16,17</sup> and should not be considered complications but simply minor deviations from the normal. Permanent loss of the carrying angle of the elbow does not result in a functional loss and is cosmetically well tolerated. This is particularly true for patients with large muscular or flabby arms<sup>3,5,8,14,16,17</sup>. Malrotation of the fragments can be kept within functional and aesthetically acceptable parameters with early active contraction of the flexors and extensors of the elbow joint. We believe that the triceps, brachialis, and biceps muscles experience a coiling of their fibers as the bone fragments rotate after the injury but recoil as the muscles contract during activity. This recoiling appears to align the fragments in a parallel direction, correcting the malrotation<sup>15</sup>.

Manipulation of fractures of the humeral diaphysis is not necessary with functional bracing since, in most instances, the gravity-dependent position of the extremity and compression of the soft tissues about the humerus restore adequate alignment to the fragments. This concept is substantiated by the fact that only 2 percent of the fractures healed with angular deformities of more than 25 degrees (Figs. 4 and 5).

Associated radial nerve palsy is a common complication of fractures of the humeral diaphysis. In our series, the prevalence was 11 percent (sixty-seven patients).

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<sup>3,5,8,14,16,17</sup>. Only one of our patients who had a radial nerve palsy failed to demonstrate improvement of nerve function. However, since the duration of follow-up was not long, we do not know the maximum extent of recovery. We do not consider routine exploration of the radial nerve to be necessary in patients who have a closed fracture or a fracture produced by a low-velocity gunshot. Operative exploration of the radial nerve is indicated when a patient has a sharp, penetrating injury; a high-velocity gunshot wound; or an open fracture associated with severe soft-tissue injury.

Associated inferior subluxation of the glenohumeral joint is rarely seen, but it appears to be more common in association with fractures located in the proximal third of the diaphysis. We identified inferior subluxation in twelve patients (2 percent). Early voluntary contractions of the biceps and triceps muscles rapidly restore congruity of the glenohumeral joint. The active contraction of the two muscles, which attach proximally on the scapula and distally on the humeral diaphysis, restores the normal relationship between the humeral head and the glenoid fossa (Figs. 2-A and 2-B).

The high prevalence of union (97 percent) in this combined group of closed and open fractures of the humeral diaphysis gives credence to our long-held hypothesis that motion at the fracture site is an important factor in osteogenesis<sup>13,15</sup>. We do not know the exact mechanism through which motion encourages fracture-healing. Nonetheless, we suspect that pain and the subsequent irritation created by motion between the fragments results in a cascade of favorable events, such as increased vascularity, piezoelectric potentials, and local chemical and thermal changes<sup>13</sup>.

The cost of care of fractures of the humeral diaphysis with nonoperative functional bracing is lower than that of operative treatment, since hospitalization is not required, the rate of nonunion is low, and recovery occurs within a short period. These factors need to be considered when treating such fractures, particularly in view of the rising cost of health care.

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