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Diaphyseal Fractures of the Humerus Treated with a Ready-Made Fracture Brace

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ABSTRACT: A method of treatment of diaphyseal fractures of the humerus with a polyethylene brace was developed. In our series of patients, more-rapid fracture union was obtained than with other methods of treatment as was early restoration of joint mobility and increased comfort for the patient.

Fractures of the shaft of the humerus represent approximately 1 per cent of all fractures². Even the most ardent advocates of internal fixation recommend initial conservative treatment of these fractures, because early surgical treatment has been associated with a non-union rate twice that with commonly used closed methods^{7,11}. Most non-operative treatments such as hanging casts, sling and swathe, and plaster splints are generally successful in obtaining union^{4,6,10,11}. Sarmiento et al.¹⁰ reported on the use of a brace consisting of a circumferential plastic sleeve. We initially used a similar brace, but because of difficulties with achieving a proper fit, swelling of the forearm, and discomfort to the patient, we devised the brace reported in this paper, which minimizes these difficulties.

The Orthosis

The initial fracture braces were hand-made in the research prosthetic laboratory of the Rancho Los Amigos Hospital. After the first year, our brace became commercially available and we used the manufactured version. The brace consists of two 4.8-millimeter-thick (0.19-inch) polyethylene splints, a 1.6-millimeter-thick (0.06-inch) polyethylene hinge, and three elastic webbing straps. The medial splint is flat, and when properly trimmed it extends from 12.7 millimeters (0.5 inch) inferior to the axilla to the medial epicondyle. The lateral splint is molded over the deltoid; distally it extends to the lateral epicondyle. It is 12.7 centimeters (five inches) wide and is slightly curved to conform to the circumference of the arm.

The lengths of the splints are individualized for each patient by appropriate trimming. The polyethylene can be

cut easily with ordinary scissors and has the additional advantages of being radiolucent and washable.

The hinge is a polyethylene strip, measuring 127 by 38.1 by 1.6 millimeters (five by 1.5 by 0.06 inches), which is fastened to each splint.

For applying the splints to the arm, we use two circumferential 2.5-centimeter (one-inch) elastic webbing straps, each riveted to the lateral splint. This heavy elastic material provides continuous compression of the soft tissues and permits the brace to be tightened as the swelling recedes.

A shoulder strap of the same elastic webbing is used for suspension of the brace. It is riveted to the proximal posterior corner of the shoulder flare. We bring the strap forward over the ipsilateral shoulder, across the chest, through the opposite axilla, and across the back, and we attach it to the brace through a buckle at the anterior corner of the shoulder flare. Where the strap crosses over itself, over the ipsilateral shoulder, it is fastened to itself with a large safety pin.

We use a double thickness of stockinette as a liner under the brace. Initially, every patient has a collar and cuff to support the wrist but the elbow hangs free.

Treatment Method

In the series described in this paper, the time when use of the brace was initiated depended on the availability of the researcher. It usually was applied within the first week after injury. Initially, we tried to apply the brace as early as possible; later we chose to allow some of the initial swelling to resolve before using the brace. Patients who had the brace applied four to seven days after the injury were appreciative of this treatment method after they had been exposed to other types of treatment. In most patients the initial treatment was a sling and swathe. The time of application of the brace ranged from the day of injury (two patients) to twenty-two days after injury; the mean was 6.7 days and the median, 6.0 days.

We initially used the brace on any patient with a diaphyseal humeral fracture, and the population included several alcoholics, one schizophrenic, one patient with a severe head injury, and two with multiple fractures. One of our patients was a twenty-two-year-old man who was in skeletal traction for an acetabular fracture and had a con-

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tralateral Malgaigne fracture. The humeral fracture in this patient, treated in a brace, healed in 25 degrees of varus angulation. We no longer use braces on bedridden patients, and we wish to stress that the brace treatment requires the influence of gravity on the dependent arm of an ambulatory patient.

Our brace treatment has to be accompanied by an exercise program. We have borrowed freely from Sarmiento's regimen⁹. Every one of our patients initially wore a collar and cuff along with the brace, and was encouraged to move the elbow passively as well as to do active pendulum exercises. Two or three weeks after fracture, most patients tolerated the brace without the collar and cuff. Sarmiento⁹ suggested that allowing the arm to hang fully extended will correct some of the fragments' tendency to angulation.

The fractures under discussion have a tendency to go into varus angulation, and the brace by itself does nothing to prevent that. Late in the study we attempted to reduce varus deformity, when it seemed to be excessive, by placing a pad inside the brace over the apex of the fracture, or by holding the hand in forced pronation with a small splint and an eccentrically attached collar and cuff.

The deltoid flare of the brace never limited the full use of pendulum exercises but no patient could achieve more than 45 degrees of abduction until the fracture was clinically united. We used active abduction to 90 degrees (which can be achieved in the brace) as an end point indicating firm union of the fracture, at which point the brace was removed. This end point usually corresponded to the appearance of radiographic signs of union. We defined union as full abduction of the shoulder against gravity and complete absence of tenderness.

Clinical Material

Over a period of three and one-half years, seventy-four patients were treated with the brace. Of those, only forty-two could be followed until union was documented (or, in one patient, non-union). Of the thirty-two patients who could not be included in the study, one had an operation elsewhere at seven weeks after injury, and another had motion at the fracture site at eight weeks but never returned after that examination. Four of the thirty-two patients achieved union, but wore the brace so little that we decided not to include them in the study. Twenty-six patients who had a brace applied did not return for periodic follow-up.

Of the forty-two patients included in the study, all were seen by one of us (G. W. B.), predominantly at the Martin Luther King, Jr. General Hospital. Except for seven fractures in patients with gunshot wounds, all of the fractures were closed.

Twenty-eight of the patients were male and fourteen were female. They ranged in age from eleven to seventy-eight years: eleven to fifteen years, four patients; sixteen to twenty years, seven patients; twenty-one to thirty years, eleven patients; thirty-one to forty years, seven patients;

forty-one to fifty years, four patients; fifty-one to sixty years, three patients; sixty-one to seventy years, five patients; and seventy-eight years, one patient. Three patients were skeletally immature.

The right humerus was involved in twenty patients and the left, in twenty-two. There were ten proximal fractures, twenty in the middle third, and twelve in the distal third of the humerus. Transverse fractures occurred in twenty-one patients and spiral or oblique fractures, in twenty-one patients. Falls and assaults accounted for the injury in twelve patients; automobile accidents, in twenty; motorcycle accidents, in three; and gunshot wounds, in seven.

We had five patients with nerve palsy: one of the suprascapular nerve, one (in a patient with a gunshot wound) of the radial and median nerves, and three of the radial nerve. All resolved by eight weeks, except in the patient with the gunshot wound. In this patient, the median-nerve palsy resolved rapidly but the radial-nerve palsy was still improving at final follow-up.

Of the forty-two patients, forty-one had union of the fracture. One had a non-union and that patient, a forty-two-year-old man, had persistent motion at four months and was then treated by internal fixation and bone-grafting. (Two years later he was seen with a stasis ulcer on the foot that had eroded into the bone, and he required a partial amputation of the foot.) There were three re-fractures; two patients had a re-fracture in a fight and the third, in a fall off a brick wall.

The time to union averaged fifty-four days, with a median of seven weeks and a mean of seven and one-half weeks. The shortest time to union was thirty days (four weeks) and the longest, 105 days (fifteen weeks). Follow-up ranged from six weeks to three years; twenty-three patients had more than three months' follow-up. Early in the study we followed patients for as long as possible. Later we stopped following patients when they had achieved clinical and radiographic union, as well as when full shoulder and elbow motion had been regained.

The varus deformity in our patients averaged 9 degrees. Five patients had 20 degrees of varus deformity or more. Two patients, bedridden because of other injuries, had 25 degrees and 20 degrees of varus angulation, and three ambulatory patients had 20-degree deformities. Less than 15 degrees of varus angulation was clinically undetectable and 15 to 20 degrees could be demonstrated only by positioning the arm in such a way as to accentuate the deformity, especially in individuals with thin arms.

Bowing of the fracture fragment in the anterior-posterior plane could be controlled by changing the length of the collar and cuff, as with a hanging cast. Our patients averaged 6.2 degrees of anteroposterior bowing, but half of them showed no anteroposterior deformity on the lateral radiograph.

Almost as important as union and deformity in estimating the benefit of the brace as treatment is residual joint stiffness. Most of our patients regained a normal

range of motion of the elbow at the time of brace removal, and all but four had full motion four months after the fracture. In three of those four, the deficits were 10 degrees of extension in the elbow or less. The fourth patient was one of those who had a re-fracture and he had a radial-nerve palsy as well; he had a 45-degree limitation of elbow extension.

The shoulder flare of the brace allows the patient sufficient motion of the shoulder so that twenty-one patients had a full range of motion at brace removal. Only four patients failed to achieve full shoulder motion rapidly. There were abduction deficits of 5, 10, and 20 degrees in those patients.

Discussion

Prior to the popularization of such conservative treatment as hanging casts, sling and swathe, or u-shaped plaster splints, fractures of the humeral shaft were commonly treated in extensive plaster casts (shoulder spicas and airplane splints)⁴. With all such non-operative treatment, a non-union rate of 2 to 20 per cent was the rule. Sarmiento et al., who first reported the use of a brace, had one non-union in fifty-one fractures¹⁰. We had one non-union in forty-two fractures. With one exception⁶, a retrospective study of patients treated in a sling and swathe that showed a 20 per cent failure rate (non-union or delayed union requiring operation), most studies have had roughly similar low rates of non-union.

The study of Mast et al. of the use of a sling and swathe provides good comparison data for evaluation of our method of treatment. Both their study and ours were done in teaching hospitals, and both institutions are owned and operated by the same government body and essentially serve the same population with regard to racial and socioeconomic factors. Although the study of Mast et al. was retrospective and ours was prospective, the percentage of their patients with adequate follow-up was the same as ours: they treated 240 fractures but had adequate data on only 111, and we saw seventy-four patients and had adequate data on forty-two. Our loss to follow-up of thirty-two patients is typical of studies done in this or similar institutions, mostly because of the mobility of an urban pa-

tient population. Excluding gunshot wounds, Mast et al. had 13.9 per cent open wounds; we had none. Their study, therefore, included essentially 100 fractures treated with sling and swathe. They had non-union (failure to unite at eight months) in five patients and delayed union (four to eight months) in fifteen. We had one non-union and one delayed union (fifteen weeks to union). Their rate of failure (non-union as well as delayed union) was 20 per cent; ours was 4 per cent.

Studies that provide data on joint motion have suggested that a common complication of treatment is significant stiffness requiring prolonged rehabilitation time. Caldwell, who is credited with introducing the hanging cast, noted that three of his fifty-nine patients ultimately had poor motion of the shoulder. He also noted that some of his patients had as much as 50 degrees' loss of elbow extension which took three months to resolve. Hosner reported that 11 per cent of his patients lacked 60 per cent of shoulder abduction and seven of seventy patients lacked 30 degrees of elbow motion. In comparison, our results (and those of Sarmiento et al.¹⁰) showed that in most patients there was complete restoration of shoulder and elbow motion at or soon after clinical evidence of union of the fracture.

We believe that the 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.

Little is mentioned in the literature of the discomfort experienced by patients who are treated with the sling and swathe. It has been our experience that patients treated with a brace are significantly more comfortable, can dress more normally, and can attend to their personal hygiene more easily.

With the brace, one must continually adjust the collar and cuff to control the position and alignment of the fracture fragments. This technical detail should be emphasized. The brace should not be used for the bedridden.

We believe that this brace, while it is a little harder to apply than Sarmiento's⁸⁻¹⁰, allows somewhat better support of the fracture fragments. We think that it is more comfortable and does not slip down the arm as much.

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