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Treatment of Isolated Ulnar Shaft Fractures with Prefabricated Functional Fracture Braces

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In a prospective study, from September 1980 to December 1984, 146 isolated ulnar shaft fractures were treated with prefabricated fracture braces. Clinical and roentgenographic follow-up data were available for 73 fractures. Functional results were rated excellent in 64 fractures (88%), good in seven (9%), and poor in two (3%). All fractures healed in an average time of 57 days. The mean angulation measured 6° in the mediolateral plane and 4° in the anteroposterior plane. The complication rate was 18%, relating mostly to residual angulation. Most isolated fractures of the distal one-half of the ulnar shaft can be treated successfully with prefabricated fracture braces.

Figure 1. The prefabricated ulnar fracture brace consists of overlapping dorsal and ulnar shells. It is adjustable and allows free motion of the elbow and wrist.

The treatment of isolated ulnar shaft fractures has included plaster immobilization, open reduction and internal fixation,[2-4,6] fracture bracing,[11,12] and no immobilization.[10] Nonunion rates, however, have ranged from 14% in Grace and Witmer's study[5] to 0.6% in the series of Tarr *et al*. [15] Although most authors report satisfactory functional results in the majority of patients, the methods that stress early extremity function yield the best results. This article reports the results, indications, contraindications, and treatment protocol for isolated ulnar shaft fractures using prefabricated functional fracture braces.

Materials and Methods

From September 1980 to December 1984, 146 isolated fractures of ulnar shaft were treated with a prefabricated ulnar functional fracture brace in a special fracture clinic. Because the clinic was a major urban trauma center and the patient population was culturally diverse, sufficient clinical and roentgenographic data were available for follow-up examination of 73 fractures in 69 patients. The remainder of the cases (73 fractures) either had incomplete data or were lost to follow-up examination and are addressed later in the article.

There were 50 men and 19 women in the study. The mean age was 36 years (range, 21—62 years). Forty-three fractures were on the left side and 30 on the right. The most common mechanism of injury was a direct blow to the forearm, and the remainder of cases were due to a fall from a standing position or a gunshot. There were open fractures, either Grade I or Grade II, in seven cases. The fractures were divided according to location within the extraarticular portion of the ulnar shaft. Forty-six fractures were in the distal one-third, 25 in the middle one-third, and two in the proximal one-third.

Fracture patterns were classified as oblique in 37 fractures, transverse in 19 and comminuted in 17. Displacement greater than or equal to one-half the shaft diameter was present in 53 fractures (73%).

To be included in this prospective study, patients had to have isolated extraarticular fractures of the ulnar shaft, either closed or open. Fracture angulation, in any plane, up to 10° was considered acceptable. This amount of angulation does not produce significant limitation of forearm rotation. [7]Monteggia fracture dislocations were excluded. Also, patients with general contraindications for fracture bracing, such as unreliability, inability to cooperate, and significant neurologic and vascular deficits, were excluded.

A prospective treatment protocol was followed. For closed fractures, the injured extremity was placed in longitudinal traction via finger traps with gravity countertraction on the day of the injury. A long arm cast was applied with the elbow at 90° of flexion and the forearm in neutral rotation, with emphasis placed on molding of the forearm portion along the interosseous groove. There was no specific manipulative reduction in any of the cases. Generally, the patient was seen for a cast check within 48 hours.

All gunshot fractures were the low-velocity type and were not surgically debrided, but the patients received intravenous cephalosporin antibiotic for 72 hours. Other open fractures were treated with operative debridement, the wounds were left open, and an intravenous cephalosporin antibiotic was administered for 72 hours. Upon hospital discharge, the usual protocol for closed fractures was followed.

Within three weeks, the long arm cast was removed and the prefabricated ulnar fracture brace applied. This low-density polyethylene short arm brace is inexpensive, lightweight, and removable and allows almost full motion of the extremity (Fig. 1). The adjustable straps allow for volume changes in the forearm. Roentgenograms in the brace were obtained, and the patient was instructed to maintain proper brace tightness and not to remove the brace. Active motion exercises of the hand, wrist, elbow, and shoulder were begun. Patients were seen in one week; if the roentgenograms showed acceptable fracture position, the patient was permitted to remove the brace daily for hygienic purposes.

The patient was examined at monthly intervals until clinical fracture union was achieved, at which time the brace was discontinued. Clinical fracture union was defined as absence of fracture tenderness or ease of motion, and roentgenographically, indicating bridging callus. Patients were followed to ensure that complete fracture consolidation occurred. The final results were evaluated according to a modification of the criteria of Altner and Hartman.[1] (Table 1). Roentgenographic analysis included measurement of fracture angulation, displacement, shortening, and status of fracture union.

Results

The mean time from day of injury to brace application was 22 days (range, 1—66 days).

Excellent	No pain 90% or more of normal forearm rotation and motion of elbow, wrist, hand
Good	Mild pain, usually with heavy activity 70%–90% of normal forearm rotation and motion of elbow, wrist, hand
Poor	Moderate or severe pain Less than 70% of normal forearm rotation and motion of elbow, wrist, hand

Table 1. Functional classification as modified from Altner and Hartman[1] to include evaluation of residual pain in the extremity.

Twenty-six fractures were braced within two weeks of the injury; nine of these patients had the brace applied within the first week of injury. Two patients had acute application of the fracture brace on the day of injury and were not placed initially in a long arm cast. The 26 patients were braced relatively early.

Their initial outpatient visit was less than two weeks after injury, and the treating physicians believed these fractures had sufficient stability for bracing. Another group of 15 fractures were braced more than 30 days after injury. These fractures were braced late for a variety of reasons. Some of the patients did not present for their initial outpatient visit until more than one month after injury. The mean length of time to clinical union and discontinuance of the brace was 57 days (range, 23—150 days).

Final fracture angulation averaged 6° (range, 0°-20° in the mediolateral plane and 4° (range, 0°-18° in the anteroposterior plane. Shortening at the fracture site averaged 2mm (range, 0—5 mm). All fractures were healed completely. Two patients had an incomplete radioulnar synostosis.

Functional results, using the modified criteria of Altner and Hartman,[1] were excellent in 65 fractures (89%), good in six fractures, (8%) and poor in two fractures (3%). Residual angulation greater than 10° occurred in 11 fractures (15%), and synostosis occurred in two fractures (3%), for a total of 13 complications (18%). Five fractures had unsatisfactory angulation at the time of initial cast application. An additional four fractures lost an acceptable reduction while in the cast. Therefore, at the time of brace application, nine fractures had unacceptable angulation. These patients were braced, despite the prospective study indications, for one of two reasons: the treating physician did not recognize the amount of angulation as unacceptable, or a satisfactory functional result could be obtained with limited goals. Four of these nine patients with unacceptable angulation at the time of brace application had increased angulation while in the brace. Of the angulated fractures overall, five were oblique, four were comminuted, and two were transverse. Six were in the middle one-third of the shaft, four in the distal one-third, and one in the proximal one-third. All four fractures in the distal one-third had excellent functional results. Of the remaining seven fractures in the proximal two-thirds of the shaft, only one was rated as having excellent results. The results for the other six fractures were rated as good.

Two patients developed incomplete radioulnar synostosis at the level of the ulnar fracture. Both of these were multiply injured, with closed head trauma, and were unable to initiate active motion exercises in the brace until several weeks after the injury. Roengenographically both of these patients developed exuberant callus formation from the ulnar fracture site, which extended across the interosseous space but did not unite with the radius. There was no evidence of occult radial shaft fracture in either case. At the final follow-up examination, both patients had significant loss of forearm rotation and had results graded as poor.

Discussion

In 1976, Sarmiento *et al*.[12] first reported on their experience in 72 isolated ulnar shaft fractures with a custom fabricated fracture brace. All fractures were healed at an average of 9.9 weeks. The maximum fracture angulation was 10°. The functional results were excellent. In a follow-up study, Tarr *et al*. [15] presented a series of 159 ulnar fractures treated with a prefabricated fracture brace. The mean time to brace application was 14 days and mean time to healing was 9.4 weeks. Non-union occurred in one fracture (0.6%). Excellent and good results were observed in 99% of the fractures.

Recently, Pollock *et al*.[10] reported their results with two different methods of treatment. Only 54 of 71 patients were followed to fracture union. With long arm cast immobilization, the average fracture healing time was 10.5 weeks, with a nonunion rate of 8%. Patients treated with minimal or no immobilization healed in an average of 6.7 weeks, with no non-unions. Minimal loss of forearm and wrist motion was observed in the majority of cases. Two patients, however, had significant loss of forearm rotation, due to exuberant callus formation.

A study of 102 isolated ulnar shaft fractures was described by Milliner and Nunley. [8] Short arm cast immobilization was used for an average of 24 days. Adequate follow-up data were available for only 40 patients, and functional results were not described in detail. All fractures were said to have healed.

This study differs from those previously reported in several aspects.[2,8,10,14] Sarmiento *et al*.[12] stated that the nightstick fracture of the ulna is characteristically not or minimally displaced, with insignificant angulation. However, 53 of 73 fractures (73%) in this study had fracture displacement greater than or equal to one-half of the shaft diameter, and 16 of 73 fractures had angulation of 10° or more on the injury roentgenograms. Because the most common injury in the patients was a direct blow, these data suggest that the typical nightstick fracture may have significant displacement, and consequently more soft tissue damage than usually realized. At follow-up examination, no patient had either clinical or roentgenographic evidence of injury to the radial head, excluding an undiagnosed Monteggia injury.

Isolated ulnar fractures are inherently stable (if the radioulnar joints are not disrupted) because of the intact radius and the intrinsic strength of the interosseous membrane. Soft tissue compression into the interosseous space separates the ulna from the radius and places tension on the interosseous membrane to enhance angular stability of the ulna.” In the clinical development of the ulnar brace in this study, wrap-around designs contributed to radial deviation of the ulnar fracture. Therefore, the overlapping shell design was chosen, with molded groove to maintain interosseous soft tissue compression with circumferential brace adjustment.

The fracture brace used in this study was prefabricated in three sizes, with right and left models, and could fit all patients without any major modification. The plastic brace was sufficiently durable to be used throughout the treatment period and well tolerated by the patients.

In our experience in the 1 970s regarding the application of custom ulna fracture braces, it was our impression that the optimum protocol for the bracing of ulnar fractures was to accept no more than 10° angulation at the time of bracing and to apply braces as soon as the acute symptoms had

subsided. With such a protocol, it could be anticipated that the final angulation would be less than 10° at the time of healing in approximately 95% of the fractures and excellent functional results in approximately 90% of the patients. [13] Of the 73 patients treated in this study with complete follow-up examination (Table 2), 64 followed this protocol. The results in these 64 patients are summarized in Tables 2—5. As anticipated, 94% of these patients had excellent functional results and 95% had no more than 10° angulation in any plane at the time of healing. Using a graded scale of 4, 3, 2, and 1 points for excellent, good, fair, and poor functional results, respectively, an average and standard deviation of functional results were calculated for each group. There was a significant difference ($p < 0.05$) in these functional grades (Student's t-test), comparing patients with greater than 10° with those with less than or equal to 10° angulation in any plane at the final follow-up examination. This difference applied to all 73 patients and the 64 who followed the protocol (Table 2).

Statistical analysis was used to evaluate parameters that predisposed to an end result of greater than 10° angulation in any plane. Fractures that had greater than 10° angulation in any plane at the time of initial bracing, regardless of the level of fracture, had a significantly higher incidence of final angulation greater than 10°. Fractures in the proximal two-thirds of the ulna that were braced with greater than 5° but less than or equal to l0° of angulation in any plane had, by chi-square test, a significantly greater probability of progressing to final angulation greater than 100, compared with the distal one-third fractures under the same circumstances (Tables 3 and 4). Fractures in the proximal two-thirds of the ulna with greater than 10° angulation in any plane at bracing had a significantly higher rate of progression of angulation than the distal one-third fractures and fractures at any level braced with less than 10° angulation in all planes. There was no significant difference in the rate or degree of progression of angulation in the fracture brace for patients that had angulation of less than or equal to 50 but greater than 10° at the time of bracing, regardless of fracture level (Table 5). However, there was a significant increase in the degree of progression and number of patients ending up with greater than 10° angulation in any plane in this same group if the fracture was located in the proximal two-thirds of the ulna.

	Angulation at Final Follow-up Examination					
	Whole Group		*<10° in all Planes*		*>10° in any Plane*	
*Group**	*No. (% of all FXs)*	*Function (Mean ± S.D.)*	*No. (% of Group)*	*Function (Mean ± S.D.)*	*No. (% of Group)*	*Function (Mean ± S.D.)*
A	73 (100%)	3.84 ± 0.55	62 (85%)	3.90 ± 0.52	11 (15%)	3.45 ± 0.52
B	9 (12%)	3.67 ± 0.50	1 (11%)	4.0 ± 0	8 (89%)	3.63 ± 0.52
C	64 (88%)	3.81 ± 0.59	61 (95%)	3.90 ± 0.54	3 (5%)	3.33 ± 0.58
D	30 (41%)	3.80 ± 0.61	27 (90%)	3.89 ± 0.58	3 (10%)	3.00 ± 0
E	34 (47%)	3.91 ± 0.51	34 (100%)	3.91 ± 0.51	0 (0%)	—

Table 2. Results for all fractures.
* See caption in Table 4.

	Angulation at Final Follow-up Examination					
	Whole Group		<10% in all Planes		>10% in any Plane	
Group*	No. (% of all FXs)	Function (Mean ± S.D.)	No. (% of Group)	Function (Mean ± S.D.)	No. (% of Group)	Function (Mean ± S.D.)
A	27 (37%)	3.78 ± 0.42	20 (74%)	4.00 ± 0	7 (26%)	3.14 ± 0.38
B	4 (5%)	3.25 ± 0.50	0	—	4 (100%)	3.25 ± 0.50
C	23 (32%)	3.87 ± 0.34	20 (87%)	4.00 ± 0	3 (13%)	3.00 ± 0
D	10 (14%)	3.70 ± 0.98	7 (70%)	4.00 ± 0	3 (30%)	3.00 ± 0
E	13 (18%)	4.00 ± 0	13 (100%)	4.00 ± 0	0	—

Table 3. Fractures in the proximal two-thirds of the ulna.
*See caption in Table 4.

	Angulation at Final Follow-up Examination					
	Whole Group		≤10° in all Planes		>10° in any Planes	
Group*	No. (% of all FXS)	Function (Mean ± S.D.)	No. (% of Group)	Function (Mean ± S.D.)	No. (% of Group)	Function (Mean ± S.D.)
A	46 (63%)	3.87 ± 0.62	42 (91%)	3.85 ± 0.64	4 (9%)	4.00 ± 0
B	5 (7%)	4.00 ± 0	1 (20%)	4.00 ± 0	4 (80%)	4.00 ± 0
C	41 (56%)	3.85 ± 0.65	4 (100%)	3.85 ± 0.61	0	—
D	20 (27%)	3.85 ± 0.67	20 (100%)	3.85 ± 67	0	—
E	21 (29%)	3.85 ± 0.65	21 (100%)	3.85 ± 0.65	0	—

Table 4. Fractures in the distal one-third of the ulna.
* Group A, all patients; Group B, patients with >10° angulation in any plane at the time of brace application; Group C, patients with less than or equal to 10° angulation in all planes at the time of brace angulation; Group D, patients with less than or equal to 10° angulation in all planes but >5° in any plane at the time of brace application; Group E, patients with less than or equal to 5° angulation in all planes at the time of brace application.

	Angulation at Final Follow-up Examination		
Group*	Whole Group No. (% of all FXS;	≤10° in all Planes: No. (% of Group)	>10° in any Plane: No. (% of Group)
B Proximal ⅔	3 (4%)	0	3 (75%)
B Distal ⅓	1 (1%)	0	1 (25%)
C Proximal ⅔	6 (8%)	3 (30%)	3 (30%)
C Distal ⅓	4 (5%)	4 (40%)	0

Table 5. Angulation that progressed in the brace.
* Key to Groups: Group B, patients with >10° angulation in any plane at the time of brace application; Group C, patients with less than or equal to 10° angulation in all planes at the time of brace application.

Therefore, there is statistical support for the original hypothesis that fractures with greater than 10° of angulation at the time of bracing will have worse anatomic and functional results than those with less than 100 of angulation. New information gained from this study includes the significant increase in rate of progression of angulation in fractures in the proximal two-thirds of the ulna that are braced with greater than 10° of angulation. Also, it seems apparent that the criteria for reduction of mid one-

third and proximal one-third fractures should be more strict than for distal one-third fractures. Fractures of the proximal two-thirds of the ulna have a significantly greater probability of achieving an excellent anatomic and functional result if the angulation at the time of bracing is less than 5° in any plane, whereas the same results were obtained in distal onethird fractures with less than or equal to 100 angulation in any plane at bracing.

Some authors have suggested that ulnar shaft fractures may be treated without immobilization.[10] We disagree for two reasons. First, fracture tenderness does not always subside rapidly, and wearing the brace protects the fracture from minor local trauma, encouraging the patient to use the extremity. Second, soft tissue compression provided by the brace may encourage functional activities by reducing the amount of antagonist muscle force required to control function for a given task. Estimates of muscle force from electromyographic recordings indicate that a statistically significant decrease in muscle force is required to accomplish a given torque about a joint when soft tissue compression is present. In early phases of fracture repair, this may relate to the observed increase of functional activity because of the reduction of forces at the fracture site. This encouragement of functional activity is important in the stimulation of fracture healing, as well as in the recovery of joint motion during the fracture healing process. It is difficult to speculate at this time how long and how much such effects may be operative or required in these cases.

Of 146 fractures treated initially with the ulnar brace, 73 had incomplete data or were lost to follow-up examination early in treatment. The typical patient with this fracture was in a lower socioeconomic level, and the usual mechanism of injury was a direct blow sustained during some altercation. A review of all available data on these patients showed that at their last follow-up examination, they were similar in all respects to those with adequate data. Because the authors' clinic is essentially the only county facility that treats indigent patients, most patients with complications or poor results would probably be seen by the authors. However, some patients may have sought follow-up examination with other physicians or may have relocated. Other authors have previously noted the difficulty of completing follow-up examination in such a county hospital patient population.[9]

The results of this study indicate that isolated fractures of the ulnar shaft with angulation of 10° or less can be treated with a prefabricated fracture brace and can achieve satisfactory functional and radiographic results. With this method, the rate of union is predictably high and the complication rate acceptable.

References

1. Altuer, P. C., and Hartman, J. I.: Isolated fractures of the ulnar shaft in the adult. Surg. Clin. North Am. 52(l):l55, 1972.
2. Anderson, L. D.: Fractures of the shafts of the radius and ulna. In Rockwood, C., and Green, D. (eds.):Fractures, ed. 2, vol. 1. Philadelphia, J. B. Lippincott, 1984, pp. 541—592.
3. Anderson, L. D., Sisk, T. D., Tooms, R. E., and Park, W. I. III: Compression plate fixation in acute diaphyseal fractures of the radius and ulna. J. Bone Joint Surg. 57A(3):287, 1975.
4. DeBuren, N.: Causes and treatment of non-union in fractures of the radius and ulna. J. Bone Joint Surg. 44B(3):6l4, 1962.
5. Grace, I. G., and Witmer, B. J.: Isolated fractures of the ulnar shaft. Orthop. Trans. 4(3):299, 1980.

6. Hooper, G.: Isolated fractures of the shaft of the ulna. Injury 6(2):180, 1974.
7. Matthews, L. S., Kaufer, H., Garver, D. F., and Sonstegard, D. A.: The effect of supination—pronation of angular malalignment of fractures of both bones of the forearm. J. Bone Joint Surg. 64A(1):l4, 1982.
8. Milliner, S., and Nunley, J. A.: Treatment of isolated fractures of the shaft of the ulna. Orthopedics 5(12): 1604, 1982.
9. Phillips, W. A., Schwartz, H. S., Keller, C. S., Woodward, H. R., Rudd, W. S., Spiegel, P. G., and Laros, G. S.: A prospective randomized study of the management of severe ankle fractures. J. Bone Joint Surg. 67A(1):67, 1985.
10. Pollock, F. H., Pankovich, A. M., Prieto, J. J., and Lorenz, M.: The isolated fracture of the ulnar shaft. J. Bone Joint Surg. 65A(3):339, 1983.
11. Sarmiento, A., Cooper, J. S., and Sinclair, W. F.: Forearm fractures. J. Bone Joint Surg. 57A(3):297, 1975.
12. Sarmiento, A., Kinman, P. B., Murphy, R. B., and Phillips, J. G.: Treatment of ulnar fractures by functional bracing. J. Bone Joint Surg. 58A(8): 1104, 1976.
13. Sarmiento, A., and Latta, L.: Closed Treatment of Fractures. Berlin, Springer-Verlag, 1980, p. 495.
14. Tarr, R. T., Garfinkle, A. I., and Sarmiento, A.: The effects of angular and rotational deformities of both bones of the forearm. J. Bone Joint Surg. 66A(1):65, 1984.
15. Tarr, R. T., Sew Hoy, A. L., Racette, W. L., and Sarmiento, A.: Evolution and current status of functional fracture bracing. Orthop. Rev. 13(l):25, 1984.