Current Concepts in Fracture Bracing Part I: Upper Extremity

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Since the early 1960s it has been recognized that certain long bone fractures could be treated successfully by functional methods. Dehne demonstrated the feasibility of maintaining a satisfactory reduction and achieving a high rate of fracture union in tibial fractures treated with early weight bearing.[1] Encouraged by these results, Sarmiento began experimenting with functional fracture treatment in the late sixties. Applying certain prosthetic principles to fracture management, he developed the patellar tendon bearing (PTB) cast[2] and later the PTB brace [3] for tibial fractures. The brace enabled free motion of both joints adjacent to the fracture. Realizing the limitations of plaster, Sarmiento developed custom fabricated braces using thermoplastic materials. Fractures of the tibia,[3]humerus,[4] ulna,[5] and distal radius[3,6] were treated with these fracture braces, yielding good clinical results.[7] These earlier braces were expensive and the custom application required significant time on the part of the surgeon as well as the services of an orthotist.

The disadvantages inherent in custom fabrication were overcome by the development of prefabricated fracture braces. Clinical studies at the University of Miami[8,9] and University of Southern California[1] using these braces have shown equal or better results when compared to the earlier custom devices. At the University of Miami Special Fracture Clinic, since 1980, over 2000 fractures in the upper and lower extremities have been treated utilizing prefabricated fracture braces.

This lesson will cover basic concepts of fracture bracing, general indications and contraindications, and protocols for specific fractures and complications in the upper extremity.

Biomechanical Considerations

Fracture site motion is the major conceptual difference between closed, functional treatment and modern internal fixation methods of fracture management.[13] Both methods encourage early muscle activity and joint motion. With closed, functional treatment, early function causes motion of the fragments before consolidation occurs.[14,15] Fracture site motion produces abundant periosteal callus.[16,17] If function is present during this formation, the callus will usually develop mechanical strength and stiffness before the radiographic image shows consolidation.[13] Therefore, clinical signs and symptoms play a major role in assessment of fracture healing. Radiographs are used primarily to assess fracture alignment and secondarily to assess fracture healing.

Fracture alignment is maintained by soft tissue compression while fracture site motion is present. Fracture site motion is elastic when controlled by soft tissue compression.[15] This means that the fragments displace with load and then return to their initial position after the load is relaxed.[7,15] Such motion will not cause malunion as long as the relaxed position of the fragments is maintained by soft tissue compression in an acceptable position.[7] Fracture braces will not obtain acceptable alignment; they can only maintain alignment.

Limb stiffness maintains bone alignment.[7] A circumferential sleeve or fracture brace can increase the stiffness of a limb with a fresh fracture by over 100 times through soft-tissue compression. It is soft-tissue compression, not the stiffness of the material in the brace or cast, which provides limb stiffness. Limb stiffness is required in three modes to prevent malalignment; (1) angulation, (2) rotation, and (3) length. Braces are most effective at maintaining angulatory alignment. Rotation and length alignment must be maintained intrinsically by soft tissue healing and by early callus in weight bearing bones and most intraarticular fractures. Diaphyseal fractures in the upper limb for which fracture bracing is indicated either have sufficient intrinsic stability or a natural tendency for self-alignment with early function in a fracture brace.[7] Therefore, fracture braces can often be applied where indicated in the upper limb very early postfracture.

Indications

In general, fracture bracing can be used for certain diaphyseal fractures of the humerus, ulna, and the distal radius. The exact limits for bracing will be defined in the individual sections for each bone. The patients must be cooperative and be able to follow this proper protocol.

Contraindications

Contraindications to fracture bracing may be divided into two groups: absolute and relative.

Absolute. Unreliable or uncooperative patients including young children, are unable to conform to the treatment protocol and should not be braced. Fractures with unacceptable reduction or position will have a tendency to worsen in the brace. If a satisfactory reduction cannot be achieved, fracture bracing is contraindicated. Braces cannot be used in patients with proven hypersensitivity to any of the component materials. Extremities with neurologic or vascular impairments should not be treated in this manner.

Relative. Fractures with severe soft-tissue damage. such as Grade III open fractures, should not be braced until some soft tissue stability is obtained. This may require an initial period of external fixation or skeletal traction prior to application of the fracture brace. The only exception to this, in our experience, has been in open fractures of the humerus.

Humerus Fractures

Diaphyseal fractures of the humerus are ideal for nonoperative management. Minor angulatory deformities do not affect functional activity and accurate anatomic reduction is not necessary for an excellent functional result. Sarmiento demonstrated successful results with custom braces for humeral shaft fractures in the early 1970s.[4] The clinical protocol and prefabricated braces developed at the University of Miami have provided predictable and satisfactory results in the management of over 150 fractures of the humeral shaft since 1980.[18]

Design. Humerus fractures are inherently unstable because the arm is bulky and often surrounded by thick, adipose tissue. Braces provide minimal support to stabilize the limb, but early function encourages gravity alignment of the bone fragments. This tends to correct varus and internal rotational malalignment which often develops in hanging casts or slings during acute care.[7] Fracture braces which are effective must allow adjustment to maintain circumferential soft-tissue compression. Overlapping shells with biceps contour and triceps molding are preferable to straps or extensions above the shoulder to maintain suspension (Figure 1).

Figure 1. Prefabricated humeral fracture brace used on over 150 fractures of the humeral diaphysis. Complete freedom of motion of the shoulder and elbow is allowed. Soft tissue compression is accomplished by tightening the straps on the overlapping shells.

Clinical Protocol. The nonoperative management of humeral shaft fractures requires the same meticulous attention to detail as open reduction and internal fixation. The use of an orthotic device will lead to excellent results provided the extremity is allowed to function early and joint motion is encouraged.

For many years, fracture bracing was used entirely as a secondary management technique, that is, braces were applied after initial cast immobilization. In the humerus, however, with advances in orthotic design, bracing may now be performed primarily in the emergency department for the acute injury. The suggested protocol consists of application of the fracture brace over a thin layer of cast padding and application of a sling. The patients are then seen within the first week, at which time the cast padding is removed, double layer cotton stockinette is applied, and the brace is reapplied. Routine follow-up visits are made at monthly intervals. Radiographs should be obtained at every visit to insure satisfactory alignment. The fracture brace can usually be removed by the ninth or tenth week postinjury. Most open fractures of the humerus may be treated identically, with the exception that they should have operative debridement, after which fracture bracing may be utilized. In our experience, the average time to brace removal in closed fractures treated with bracing is 9-1/2 weeks. The average time to brace removal in open fractures is 13-1/2 weeks.

Results. Anatomic results in diaphyseal fractures of the humerus treated by bracing rarely achieve normal bony contour. There are usually minor angular deformities, which are not clinically perceivable or consequential. In our first 107 cases with complete follow-up, 82% of the patients had 8° or less of varus/valgus and/or anterior/posterior angulation. In the few patients with greater than 80 of angulation, no obvious functional impairment has been noted and the cosmetic results have still been satisfactory.[8]

Functional results with fracture bracing are superior to most other techniques of fracture management. Ninety-three (93%) of our patients have achieved a full range of motion and normal function of the shoulder and elbow. The remainder lack less than 150 of terminal forward flexion of the shoulder. Most patients require physical therapy only during the first few weeks after injury, during the period of brace wear. In addition, only the occasional patient requires post-treatment rehabilitation.

Complications with the use of prefabricated fracture braces are uncommon. Problems with skin maceration are infrequent and occur only in the patient with poor hygiene who has not removed the brace for bathing. The overall nonunion rate is 2.0%. Unacceptable angulation (greater than 25°) is extremely uncommon (less than 3%). If angulation is considered a problem, open reduction and internal fixation can be performed, or any other method of management which the physician prefers may be utilized. Radial nerve palsies associated with humeral shaft fractures usually tend to resolve spontaneously provided the nerve injury was present at the time of the initial examination. Nerve injuries that occur after any manipulation of the extremity or those that are progressive may be observed for a short period of time (a few days) and should be explored surgically if no improvement occurs. Surgical exploration, in our experience, has rarely been required, as most radial nerve injuries are present at the time of initial trauma and represent only a neuropraxia, which will resolve spontaneously without surgical intervention. Splinting for wrist control is not usually necessary but, if required, may be utilized in conjunction with the humerus fracture brace.

Conclusions. Fracture bracing for humeral shaft fractures is clearly one of the simplest and most effective methods of management and almost universally leads to excellent anatomic and functional results, with a minimal amount of effort and few complications. We believe it is the current method of choice for the treatment of humeral shaft fractures.

Ulna Fractures

Isolated diaphyseal fractures of the ulna are ideal indications for nonoperative management. Minor degrees of angulatory deformity do not affect functional result, as long as joint motion and hand function are begun early. Sarmiento first demonstrated successful results with custom braces for isolated ulnar fractures in l976.[5]

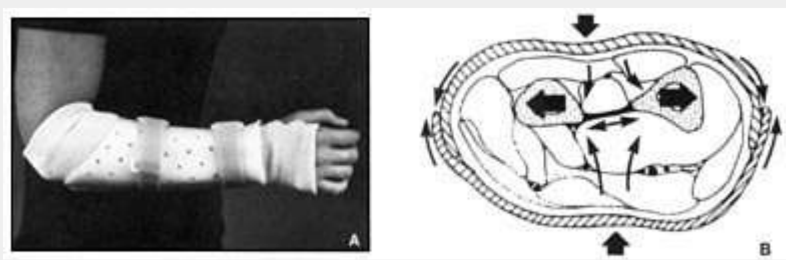

Figure 2. (A) Prefabricated fracture braced used in over 60 fractures of the ulnar diaphysis. Complete freedom of motion of the wrist and elbow and nearly complete rotation of the forearm is alowed. Soft tissue compression is accomplished by tightening straps on the overlapping shells. **(B)** A cross-section of the forearm to illustrate the molding of the soft tissues with the forearm fracture brace. Pressure applied into the interosseous space places lateral and medial forces on the radius and ukna to maintain seperation of the bones and tension on the interosseous membrane. An overlapping shall design is required to maintain the shape of the brace cross-section while adjusting the straps to compress the soft tissues.

Design. Isolated ulnar fractures are inherently stable (if the radioulnar joints are not disrupted) due to the intact radius and the intrinsic strength of the interosseous membrane. Soft-tissue compression directed into the interosseous space tends to separate the ulna from the radius and places tension on the interosseous membrane to enhance angular stability of the ulna.[7] To maintain interosseous soft tissue compression with circumferential brace adjustment, the brace should have overlapping shells with a molded interosseous groove (see Figure 2). In our experience, wrap-around designs have been inadequate in preventing, and may contribute to, radial deviation of ulnar fractures.

Indications and Contraindications. Isolated fractures of the ulna, usually caused by a direct blow, are suitable for fracture bracing if located within the distal one-half of the diaphysis. Angulation at the fracture site should be less than l0° in any plane. Shortening is common and usually averages only a few millimeters. Rotational deformity is rarely seen.

Unstable fractures of the ulna with dislocation of the radial head, (Monteggia injury) are absolute contraindications. Fractures located in the proximal one half of the diaphysis have a tendency to angulate toward the radius and should not be braced. Here, angulation greater than 10° may lead to clinically significant loss of forearm rotation.[18,19]

Treatment Protocol. Acutely, the fracture is reduced, if necessary, although the majority of these fractures have minimal initial displacement and require no reduction. The extremity is immobilized in a long arm cast with the elbow at 90° flexion and the forearm in neutral rotation. In our recent cases, the ulna fracture brace has been applied acutely, instead of the cast. Although results generally have been satisfactory, it is too early to recommend this procedure routinely. A neurovascular check is required within 48 hours. The next outpatient visit is scheduled for one to two weeks. At this visit, if the fracture position is acceptable, the cast is removed and the fracture brace applied. Active motion exercises of the hand, wrist, elbow, and shoulder are begun to tolerance. The patient is allowed to remove the brace daily for hygienic purposes only.

Follow-up visits are scheduled at monthly intervals until clinical fracture union is achieved. This is defined as absence of motion or tenderness at the fracture site and the presence of bridging callus on the radiograph. It should be noted that clinical union precedes complete radiographic union by several weeks, therefore, it is not necessary to continue the brace until the fracture callus is completely consolidated.

Results. Sarmiento et al reported on a series of 72 ulnar fractures treated with custom fracture braces. All fractures healed with an average time of 9.9 weeks. Loss of forearm rotation averaged 7°.[5]

In our series of 61 patients with 65 fractures treated with prefabricated braces, the average time to clinical union was 8.3 weeks with a range from 3.3 to 21.4 weeks. Average angulation was 40 in the lateral plane and 50 in the anteroposterior plane. Shortening averaged 2 millimeters. Results were evaluated according to pain, motion, and function. Excellent results were obtained in 89%, fair in 8%, and poor in 3%. The fair and poor results were due to complications as noted below.

Complications were encountered in 10 patients. Residual angulation greater than l0° was seen in 10 cases. The majority of these fractures were located in the middle third of the ulna and most had unacceptable or marginal fracture position initially. Two of these patients, both with closed head trauma, also had incomplete radioulnar synostosis and significant loss of forearm motion. There were no delayed or non-unions.

Conclusions. Fracture brace treatment of nondisplaced or minimally displaced isolated distal ulnar shaft fractures yields satisfactory functional results and a high rate of union. Fractures with more than 10° of angulation or those located in the proximal half of the diaphysis should not be braced.

Colles' Fractures

Despite the high frequency of Colles' fractures and the alleged satisfactory long-term result with most methods of treatment, the fact remains that a critical analysis of results from treatment of Colles' fractures is often lacking. Treatment by bracing has been associated with good functional results, even when anatomic results are less than ideal.[6,20]

Design Considerations. Forces which act upon the fracture site are related to three factors: muscular, anatomic, and mechanical. Each contributes individually to the problem of loss of reduction.

The muscular forces associated with deformity are the finger and wrist extensors and brachioradialis. These dorsal and radial deforming forces will contribute to collapse at the fracture site if a mechanical advantage exists. Positioning the forearm in supination helps to minimize forces on the dorsal side of the wrist, thereby assisting in maintenance of reduction.

Anatomic restoration with volar cortical apposition is essential if reduction is to be maintained. In the vast majority of Colles' fractures the volar cortex is the intact cortex and the dorsal cortex is comminuted. Forces should be minimized on the dorsal side and maximized on the volar side. Positioning the forearm in supination appears to accomplish this by giving mechanical advantage to the flexor forces while decreasing extensor forces.

Clinical results have demonstrated that Colles' fractures treated in supination have superior results to those treated in pronation.[2] Therefore, the fracture brace is designed to limit radial deviation, prevent extension of the wrist, and maintain the position of the forearm in supination. A supracondylar elbow extension prevents rotation of the forearm as well as aiding in suspension of the device (see Figure 3).

Figure 3. Prefabricated fracture brace used on over 300 Colle's fractures. Wrist dorsiflexion is limited, but the hand and fingers are free. Proximal extensions over the humeral condyles limit elbow extension in order to prevent full pronation of the forarm. Full supination and elbow flexion are allowed.

Indications. The indications for bracing of Colles' fractures are extremely broad. There are very few instances in which bracing cannot be applied to fractures of the distal radius. In those cases for which bracing techniques are not recommended, internal or external fixation should be used. The indications include all displaced fractures of the distal radius, with the following exceptions: (1) fractures in which there is significant impaction associated with volar cortical comminution and displacement; (2) fractures in which adequate reduction cannot be achieved or maintained; (3) fractures in which there is a large volar fragment within the carpal tunnel and an associated median nerve palsy; or (4) open fractures in which the carpal tunnel has been explored.

Management Protocol. The use of fracture braces for Colles' fractures may be classified as a secondary type of treatment, i.e., initial immobilization must be with some type of plaster. The patient should have a closed reduction performed in the emergency department, or in the operating room if necessary. Adequate anesthesia is essential if an accurate reduction is to be accomplished. In our experience, local infiltration of the fracture hematoma is usually unsatisfactory in complex, comminuted fractures. With anesthesia, longitudinal traction with Chinese finger traps is recommended with lO to 15 pounds of countertraction above the elbow for 15 to 20 minutes to facilitate reduction. A closed reduction can then be performed in the classic manner and the wrist positioned in 30° to 40° of volar flexion, maximum ulnar deviation, and relaxed supination with a sugar tong plaster or long arm cast. (Relaxed supination generally refers to a position a few degrees less than full supination.) Follow-ups are arranged for neurovascular checks for the following day and patients may then be seen within the first week to assess the status of the fracture within the plaster immobilization. Depending on the stability and the nature of the fracture, the plaster may be removed between 7 and 14 days for application of a prefabricated brace. Radiographs within the brace are obtained immediately after its application. Patients are then seen at one week for additional radiographs. During this period of time they are encouraged to see the occupational therapist for range of motion exercises of the fingers, wrist, elbow, and shoulder. (The early involvement of the occupational or physical therapist helps to minimize the complication of reflex sympathetic dystrophy). Patients are then seen at the end of the sixth week, at which time the brace may be removed and range of motion encouraged. Routine follow-up visits for range of motion checks are arranged after brace removal.

Results. Although the likelihood of an excellent functional result with an excellent anatomic result is increased by fracture bracing, excellent functional results may be obtainable even with unacceptable anatomic results. Anatomic results based on radial length, volar tilt, and radial deviation demonstrated satisfactory alignment in 86% of our patients treated in braces.[8]

Functional results of Colles' fractures treated with prefabricated bracing are generally very good. Early improvement in function is directly related to the amount of motion allowed during the fracture healing phase. Using bracing techniques, good to excellent results can be expected in nearly 90% of the patients treated. In addition, complications of finger stiffness, Sudeck's atrophy, and severe limitation of wrist motion are uncommon.

Complications with bracing for Colles' fractures are minimal when compared to other techniques. Loss of reduction is the most common complication, but this is usually related to the quality of the initial reduction. That is, if an anatomic reduction is achieved initially, usually the final result will be satisfactory. Reflex sympathetic dystrophy after Colles' fractures treated with bracing techniques is uncommon and is usually related to the amount of function obtained early in the course of treatment. If early therapy in the brace is instituted and early function of the entire extremity is encouraged, reflex sympathetic dystrophy will rarely be seen. Limitations of motion will occur with any technique, but with bracing are less likely to be of significance. Volar flexion is usually well preserved. There is usually some limitation of wrist extension and minor degrees of loss of forearm pronation. Skin problems may occur if hygiene is neglected. With frequent cleansing and stockinette changes begun within the first week of brace application, skin maceration or rashes are uncommon. Median nerve palsy has been associatedin the past with closed treatment of Colles' fractures. This complication is usually due to poor casting technique with excessive wrist flexion or is present at the time of initial injury. We have not seen progressive median nerve palsies which have developed within fracture braces.

Conclusions. The use of prefabricated fracture braces for Colles' fractures is a viable technique which, in the overall analysis, is cost effective, clinically efficacious, and generally predictable in the results achieved. Moreover, the technique is associated with a very low complication rate. The advent of prefabrication has helped to achieve standardization of brace design with reasonable cost and simplicity of application. Functional results are superior to most other methods, and the usual morbidity associated with other treatment techniques has been minimized with the use of fracture bracing.

Summary

Fracture bracing in the upper limb has proven to be an effective, reliable, and low-risk method of management for selected injuries. With the careful development of prefabricated fracture braces, the technique has become more practical and acceptable to the surgeon as well as the patient. The treatment protocol and patient selection criteria are critical to the consistency and quality of results. With proper patient management, fracture bracing is the method of choice in many upper limb fractures.

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