A NEW ARTICULATED ELBOW EXTERNAL FIXATION TECHNIQUE FOR DIFFICULT ELBOW TRAUMA

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ABSTRACT

Articulated external fixation of the elbow allows aggressive elbow range of motion while protecting the joint and periarticular structures from excessive forces. A technique for aligning a monolateral-hinged fixator to the rotational axis of the elbow without the use of an invasive axis pin has been developed. Thirteen patients with acute and chronic post-traumatic elbow problems were treated over a four year period with this technique. An average arc of motion of 84 degrees was achieved in the frame. Frames were removed at an average of 7.6 weeks. Complications were confined to pin tract infections. In 11 patients followed for an average of 35 weeks the average arc of motion was 81 degrees. Further experience is required to determine the role of this device and to identify which elbows achieve the most benefit compared to conventional techniques.

INTRODUCTION

Articulated external fixation with a uniaxial hinge is well suited to the elbow since the normal elbow moves around axes that closely approximate a single hinge axis (Figure 1).[1] Skeletal fixation to the humerus and the ulna combined with a hinge aligned with the axis of rotation permits elbow movement through a near full arc with minimal resistance[2]. Unstable fracture dislocations, comminuted periarticular fractures and instability after elbow reconstruction are clinical problems for which articulated external fixation has become an important adjunct to treatment.[3,4,5,6,7]

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Figure 1. The centers of rotation of the elbow during a flexion/extension arc all lie within this tight axode.[1]

The Mayo device[3] and the Compass elbow hinge[5] are commonly used articulated elbow fixators. These devices have either bilateral (Mayo) or circumferential (Compass) designs with fixator components on the medial side of the elbow. In addition, they require the use of an invasive axis pin to align the hinge. We have used a monolateral articulated fixator applied to the lateral side of the elbow and arm and have developed a new technique to align the hinge with the axis of rotation using radiographic landmarks without physically implementing an invasive axis pin.[1,8] This report describes the application technique and our initial clinical experience with this device.

TECHNIQUE OF APPLICATION

The patient is positioned supine with the arm extended on a radiolucent arm board or hand table. A critical portion of the procedure is to align the flouroscopic beam precisely with the axis of the elbow so checking C-arm positioning prior to prepping and draping is recommended. The C-arm should come from the superior part of the arm board or table parallel to the operating table. With the arm abducted, the elbow extended and the forearm pronated, the C-arm will usually need to

Figure 2. The patient is positioned with the arm abducted and elbow extended on a radiolucent hand table. The C-arm is positioned above the arm table and is rotated approximately 60 degrees from the vertical.

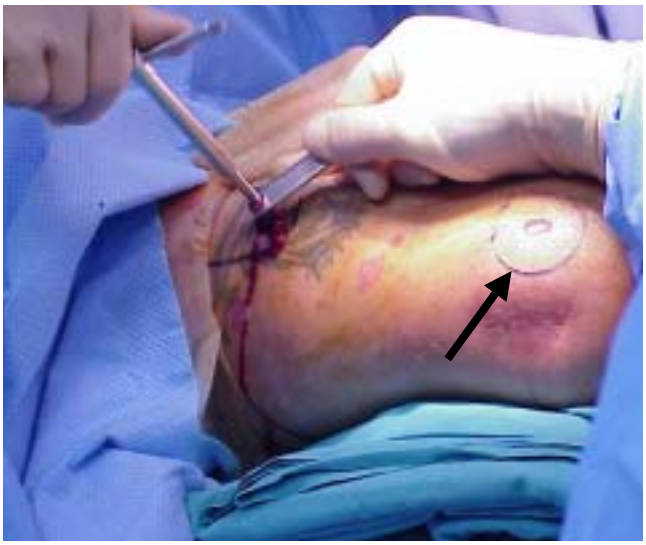


Figure 3. The first humeral pin is inserted free hand. Note that the position of the lateral epicondyle and eventual hinge location (arrow) was marked to help locate the correct position for the humeral pins.

Figure 4. A fluoroscopic view along the axis of rotation of the elbow. The medial supracondylar ridge (white arrows) is 27% from the posterior humeral border. The periphery of the capitellum (black arrows) is concentric with the trochlea over a 90 degree anterior and distal arc. The center of rotation is the center of these arcs (x).

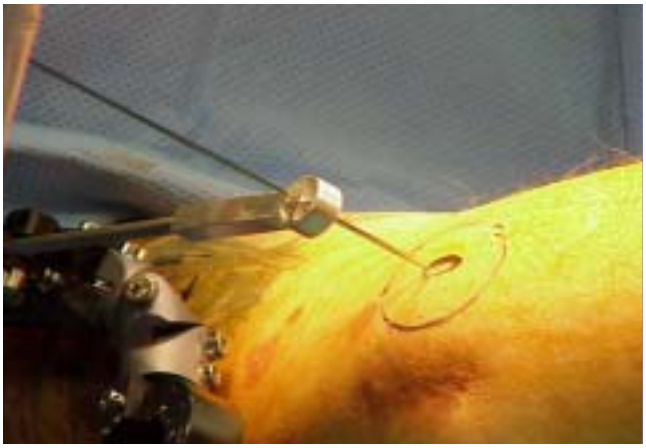


Figure 5. The axis wand is attached to a humeral pin and a long free pin is used to help orient the wand to the rotation axis. This pin is not drilled into the bone.

be rotated approximately 60 degrees from the vertical towards a lateral position (Figure 2).

Planning for the location of the humeral pins is based off the lateral humeral epicondyle, which is near the eventual location of the hinge center. When the circular hinge is roughly centered over the lateral epicondyle and the humeral side of the frame is aligned along the lateral side of the humerus, the position of the humeral clamp is marked. This provides a reference for the first humeral pin position, which we prefer to insert free hand without the encumbering clamp (Figure 3). A second parallel 6/5 mm tapered pin is inserted through the humeral clamp and the clamp is securely locked to these two pins. We use a percutaneous technique for humeral pin insertion when we are confident that the clamp lies proximal to the middle of the humerus. Otherwise, an open technique is recommended to minimize

Figure 6. An intra-operative fluoroscopic view of an unstable elbow shows the typical radiographic appearance of the axis landmarks of the distal humerus and the positioning of the axis wand.

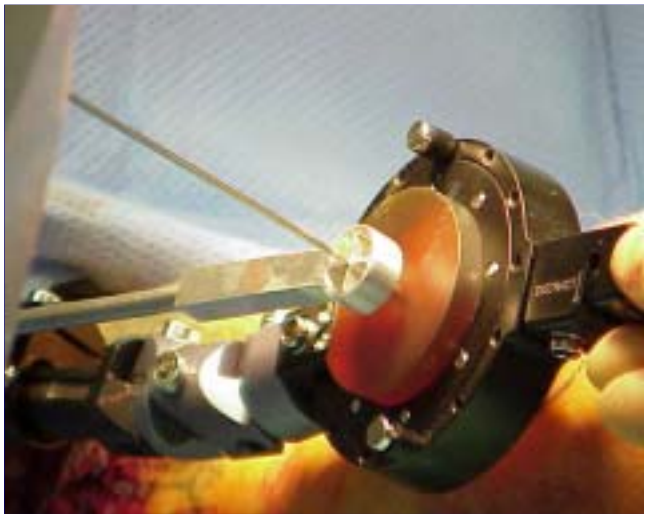


Figure 7. The wand has been locked in position and the circular hinge is precisely oriented to the wand by a pin which drops through the wand and through a hole in the center of the hinge.

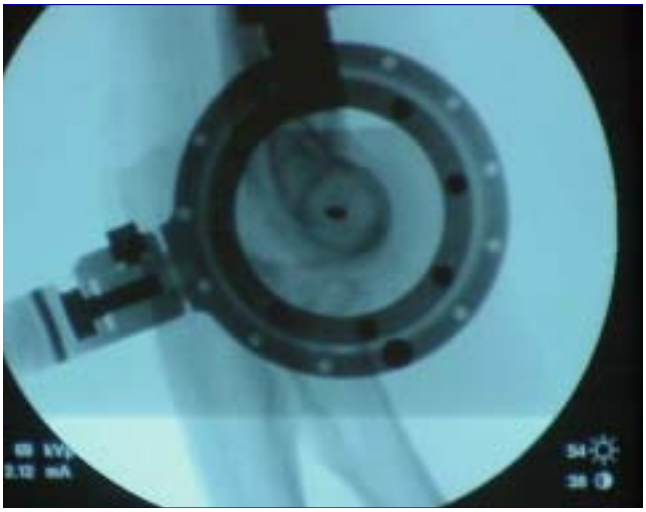


Figure 8. The wand has been removed and the pin in the center of the hinge is seen as a dot in the center of the axis of rotation. Note that the landmarks are still aligned.

Figure 9. Pins are applied to the subcutaneous border of the ulna.

the risk to the radial nerve. The fixator is then mounted on the humeral clamp.

Precise alignment of the flouroscopic beam and the elbow rotation axis is achieved in two steps (Figure 4). First adjust the medial supracondylar ridge to be 27% of the way from the posterior to the anterior border of the humerus in the lateral view. Second align the capitellum and the trochlear ridge so that there are two symmetrical uniform arcs on the humeral side of the elbow joint along a 90 degree arc from anterior to distal. Check that the first landmark (the medial supracondylar ridge) is still appropriately positioned. The flouroscopic beam is then aligned along the rotation axis of the elbow. The C-arm and the arm and elbow should not be moved until the hinge is aligned and locked.

An axis wand mounted on the humeral pins above the humeral clamp is now aligned and positioned within the flouroscopic beam (Figures 5 and 6). The center of rotation is directly in the center of the two arcs of the

Figures 10 A and B. The flexion and extension range of motion is tested intra-operatively.

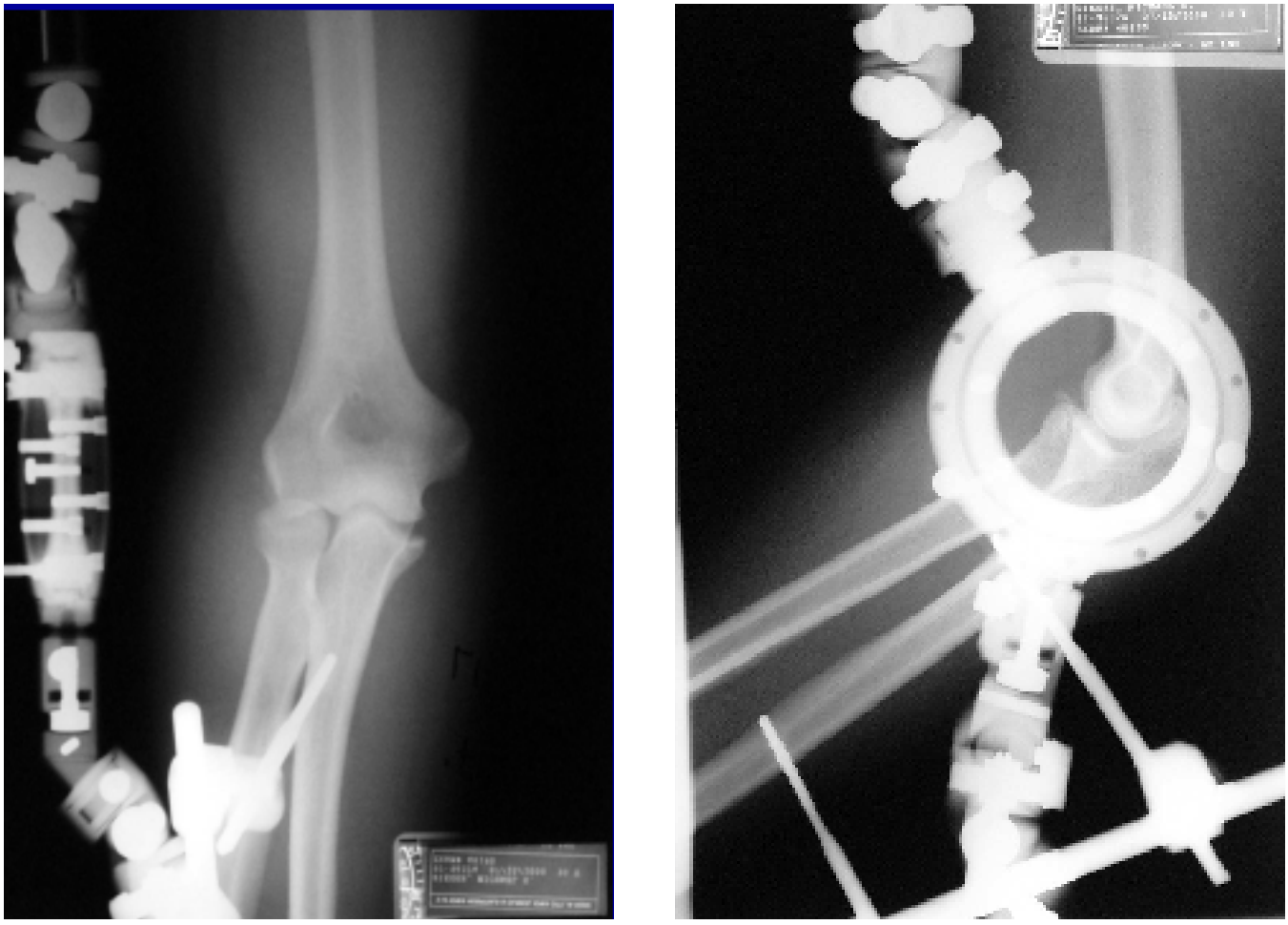
capitellum and trochlea. Dropping a pin through the center of the wand and adjusting the wand position until the pin is a dot in the center of the wand and over the center of rotation of the joint, facilitates achieving a precise position and alignment of the wand. After locking the wand, the same pin is then used to align the hinge with the wand (Figure 7). When the pin drops smoothly through the locked and aligned wand and through the hole in the center of the hinge, locking the hinge completes the hinge alignment. The radiographic landmarks should again be checked to confirm hinge position (Figure 8).

The ulnar side of the frame mounting is completed after the hinge is securely locked. The pin to bar design allows flexibility in pin position and number (Figure 9). We usually use two 4.5/3.5 mm pins spread along the bar and inserted into the subcutaneous border of the ulna. Once the pins are inserted, the elbow joint is checked for concentric reduction. If the elbow is subluxated it should be reduced prior to locking the ulnar side of the frame. After securely locking the ulnar side, the range of movement of the elbow should be tested clinically and observed radiographically on a lateral flouroscopic view through the circular hinge (Figure 10). The surgeon should not notice a significant difference in the resistance to movement after the frame is applied compared to the non-articulated elbow. If there is unexpected resistance the position and alignment of the hinge should again be checked flouroscopically in the steps previously described and if necessary readjusted without changing any pins.

MATERIALS AND METHODS

Between August of 1996 and July of 2000, thirteen patients with complicated elbow joint problems had a lateral monolateral elbow fixator applied and a hinge aligned without the use of an invasive axis pin. The average patient age was 40 (range 24-67). There were eight males and five females. The diagnosis was acute elbow trauma in nine patients [unstable dislocation - 1, fracture dislocation - 4, distal humerus fracture - 3 , radial head fracture - 1] and reconstruction for chronic post-traumatic elbow problems in four patients [joint stiffness/contracture - 2, heterotopic ossification - 1, nonunion distal humerus fracture -1]. The fixator was applied as an isolated procedure in two of these elbows, and in conjunction with other procedures in eleven. The procedures included open reduction and internal fixation in seven [distal humeral fracture - 3, coronoid fracture - 1, radial head fracture 2], soft tissue release in three, ligament repair in two, and radial head excision in two. Some patients had more than one of these additional procedures.

Postoperatively, all elbow hinges were released and patients were encouraged to perform gentle active and active assisted range of motion. Postoperative continuous passive motion machines were not used routinely. The amount of physical therapy varied between dedicated supervised motion programs for up to four months post injury to only a postoperative in hospital consult. All patients were allowed to lock their fixator for comfort, but encouraged to perform range of motion exercises at least three times per day. All patients were fol-



Figures 11 A and B. AP and lateral radiographs demonstrate the typical appearances of the fixator post-operatively.

lowed frequently in the outpatient clinic to monitor their pin sites, their fracture site, the reduction of the joint and the range of motion of the elbow. Elbow radiographs were obtained at least once a month during the first three months (Figure 11). All fixators were removed in the outpatient clinic without supplementary analgesia. After fixator removal all patients were counseled to continue to work on range of motion exercises.

RESULTS

The average duration of external fixation was 7.6 weeks with a range of 3 to 18 weeks. The average maximal arc of movement while in the frame was 84 degrees (range, 20-125) with an average range of flexion of 99 degrees (range, 35-130) and an average range of extension of 15 degrees (range, 5-60) (Figure 12).

Complications related to the fixator were confined to pin tract infection in five patients, which was treated with oral antibiotics and resolved without further treatment. There were no broken pins and no instabilities secondary to the frame. There were no iatrogenic nerve injuries. All open wounds and surgical wounds healed. There were no superficial or deep infections. Subsequent procedures have not been required for any patients.

Eleven patients were followed for an average of 35 weeks (range of 9 to 133). Two patients were lost to follow-up immediately after frame removal. At the final examination the average maximal arc of movement for these eleven elbows was 81 degrees (range, 50-125) with an average range of flexion of 104 degrees (range, 71-130) and an average range of extension of 23 degrees (range, 5-40).

DISCUSSION

Optimal management of complex injuries of the elbow joint should restore stability while still permitting motion. Absolute stability can be difficult to achieve surgically, and permanent loss of motion is a common outcome of severe elbow injury. Articulated external

Figures 12 A and B. A patient with an unstable coronoid fracture-dislocation of the elbow demonstrates active range of motion three weeks post injury.

fixation potentially provides stability while permitting movement and this technique could potentially have frequent indications. Unfortunately, until now available devices have required the surgeon to apply an axis pin through the capitellum and trochlea of the distal humerus, which is technically demanding and difficult to achieve. Reported complications of these devices have included pin loosening and breakage, nerve injury, and recurrent elbow instability.[5,9] Using a radiographic technique of hinge alignment we did not have any of these complications in the current series.

We believe that some of these complications are related to the complexity of applying the fixator leading to inaccurate axis pin placement and consequently inaccurate alignment of the hinge with the elbow axis. Accurate alignment of the hinge to the rotation axis of the elbow is critically important to minimize abnormal stress at the elbow joint and the bone-pin interface. Hinges placed off the elbow axis by as little as five degrees or five millimeters significantly increase the force of elbow movement and those placed 10 degrees or 10 millimeters off-axis result in dramatic increases.[2]

A monolateral design with flexible component construction facilitates an easier technique of applying the fixator. The surgeon can then direct more attention to accurately aligning the hinge. When the hinge is positioned using radiographic markers, the monolateral frame can be adjusted until the desired alignment is achieved independent of the skeletal fixation in the humerus and the ulna. This is a significant advantage over techniques where the fixator is built around an initially applied axis pin leading to potential errors and stresses in the frame-pin-bone system.

When the hinge is aligned using flouroscopy, the radiographic landmarks of the elbow rotation axis must be known. These are well defined and easily visualized fluoroscopically.[2,8] In a previous laboratory model, three investigators radiographically achieved alignment within an average of 2.5 degrees of the true axis of rotation.[8] Although this was not compared to the accuracy achieved with an invasive axis pin, we believe that it is potentially more accurate and certainly more forgiving than multiple passes of a pin through dense bone in a narrow corridor of the distal humerus.

The radiographic technique of hinge alignment is applicable to severe distal humerus fractures with plates and screws in place. In this series three distal humerus fractures had adjunctive treatment with the fixator by aligning the hinge using the radiographic technique. The fracture hardware will interfere with the placement of an axis pin. Hall et al.[10] reported a case of a distal humerus fracture treated with the Compass elbow hinge. They were unable to apply the required axis pin and had to drill medial and lateral pins.

The reason for an articulation is to facilitate movement of the elbow. Despite this the final range of movement achieved in this series was not uniformly excellent. We feel this result is due to the fact that during the four years of this study only the most severe elbow problems were treated with this device. Further study and experience is required to determine if the outcomes of these patients were improved by the use of the fixator compared to static external fixation or to non-skeletally fixed bracing. It is possible that further refinements in technique will allow even more accurate hinge alignment leading to easier early mobility. We also plan to pursue the use of motorized passive motion connected directly to the frame, which may lead to further improvements in elbow motion.

In summary this series demonstrates that applying a monolateral articulated elbow fixator without the use of an invasive axis pin is feasible and has potential advantages over axis-pin dependent techniques. The technique was used for patents with severe traumatic and posttraumatic elbow problems. There were few complications and the laterally based frame was well tolerated. However, as with other articulated fixators, further experience is required to determine the role of this device and to determine which elbows achieve the most benefit compared to conventional techniques.

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