Fractures of the distal radius: controversies in treatment, rehabilitation and management of complications
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DISTAL RADIUS OSTEOTOMY IN THE ELDERLY PATIENT USING ANGULAR STABLE IMPLANTS AND NORIAN BONE CEMENT
ABSTRACT

Purpose
Corrective osteotomy of malunited distal radius fractures is a well-recognized and effective surgical procedure. However, it has potential technical challenges especially with the fixation of osteopenic bone and iliac crest donor site morbidity. Two technology advances have facilitated this procedure, eliminating the donor site morbidity and expanding its application to osteoporotic bone. The first is the development of angular-stable locked implants, and the second bone cement.

Methods
Our series include 8 patients, 6 females and 2 males with an average age of 56 years. Three patients had corrections through a dorsal approach, 1 through a volar and 4 through a combined approach. Two corrections included an intrarticular osteotomy. 2.4 mm volar T plates were used in patients approached volarily and 2.4 mm L and T plates for those approached dorsally; the osseous defect was filled with bone cement (Norian SRS®). Range of motion and grip strength were measured at a 17 months average follow-up. Standard wrist radiographies were taken to evaluate alignment and determine improvement. Patients filled at follow-up evaluation the Modified Mayo Wrist score, the Modified Garland and Werley score and the DASH questionnaire.

Results
There were no perioperative complications. All corrective osteotomies healed. One patient required a Darrach procedure at 6 months. The average wrist and forearm motion was 78% of the opposite side and grip strength 88% of opposite side. The average correction in the sagittal plane was 19 degrees with all patients returning to neutral or better alignment. The average ulnar variance improvement was 2.4 mm. Average postoperative DASH was 21.5 points; average Modified Mayo Wrist score, 71; and the Modified Garland and Werley score averaged 7.8 points.

Conclusion
We believe this operative technique to be safe and predictable, even with underlying osteoporosis, eliminating donor site morbidity. Patient rated outcome measures demonstrated acceptable daily living function return.
Level of Evidence
Level 4, therapeutic study

INTRODUCTION

Union with deformity is the most common complication following a distal radial fracture (1). This deformity can be intra-articular, affecting either the radiocarpal or radioulnar joints; extra-articular, characterized by metaphyseal angulation and loss of length; or it may be a combination of both (1). Corrective osteotomies have been proven to be an effective treatment for symptomatic malunion (1, 2). A variety of techniques have been used, however there has remained concern regarding the indications for surgical intervention in the presence of underlying osteoporosis, as well as the recognized morbidity associated with autogenous iliac crest bone grafting (3-5).

Technical advances including the use of precontoured internal fixation devices with angular stable fixation, as well as the use of osteointegration biomaterials have offered some advantages.

The contoured implants facilitate osteosynthesis by providing higher stability even in osteopenic bone (6-12). These implants afford osseous fixation that allows early motion and rehabilitation(13). Also their precontoured shape maintains desirable patterns of alignment, congruency and inclination of the distal radius after corrective osteotomy (13-15). These properties reduce the probabilities of screw loosening and consequent loss of reduction. [4, 20]

Following osteotomy and achievement of proper angulation and alignment, there will exist a three-dimensional defect that must be filled in order to adequately support the bone fragments (16-20). Autogenous bone grafts have been widely used for this purpose. They have a recognized potential for donor site morbidity, in particular those involving corticocancellous variants (3, 5, 21). Materials such as polymethylmethacrylate (PMMA) and osteoconductive biomaterials such as Norian Skeletal Repair System (Norian SRS) offer structural support eliminating effects of donor site morbidity (16-20). Experience with polymethylmethacrylate (PMMA) has shown lack of osseous integration(19, 20) In contrast, prospective randomized trials demonstrated good clinical and radiological results with osteoconductive synthetic materials such as Norian SRS ® (16-20).

The purpose of this study is to present our experience with eight patients that received a combined approach using both technologies. We believe this operative technique to be
safe and predictable. Additional benefits such as the use in osteoporotic patients and the elimination of donor site morbidity also support the practice of this technique.

**MATERIALS AND METHODS**

Between 2002 and 2004, 11 patients, 7 female and 4 male with an average age of 56 years (range: 44 to 74 years), were treated at our Orthopaedic Hand Surgery Service by a single orthopaedic hand surgeon. Of them 8 (6 females and 2 males) accepted to participate in the IRB approved study to evaluate the functional outcomes of this technique for distal radius osteotomy. Their initial fracture according to the AO classification system(22) was classified as type A.3.2 in three patients, A.3.3 in one, one as C.3.1, two as C.3.2 and one as C.3.3. According to the Fernandez classification(23), four patients were type 1 (Bending mechanism) and 4 type 3 (Compression mechanism). All of them were right handed. All patients defined their occupation as a desk-based work. Six dominant hands were involved. The mechanism of trauma was a fall from standing height in two patients, sport related injury in one, higher-height fall in two patients and lastly, one fracture occurred after an assault and one after a motor-vehicle collision. (Table 1)

<table>
<thead>
<tr>
<th>Case</th>
<th>Gender</th>
<th>Age</th>
<th>Occupation</th>
<th>Hand Dominance</th>
<th>Involved Hand</th>
<th>Mechanism of Injury</th>
<th>Interval between malunion and surgical correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>51</td>
<td>Disabled</td>
<td>R</td>
<td>R</td>
<td>Self height fall</td>
<td>7/15/2004 - 11/10/2004</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>44</td>
<td>Nurse Manager</td>
<td>R</td>
<td>R</td>
<td>Fall while skating</td>
<td>9/5/2002 - 10/9/2002</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>46</td>
<td>Jeweler</td>
<td>R</td>
<td>L</td>
<td>MVC Polytrauma</td>
<td>1/22/04 - 1/26/04</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>60</td>
<td>Real State Developer</td>
<td>R</td>
<td>R</td>
<td>Fall walking on ice</td>
<td>9/24/2002 - 3/3/2004</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>55</td>
<td>Legal Assistant</td>
<td>R</td>
<td>R</td>
<td>High height fall</td>
<td>11/4/2003 - 12/31/2008</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>74</td>
<td>Supervisor department store</td>
<td>R</td>
<td>R</td>
<td>High height fall</td>
<td>6/20/2002 - 9/4/2002</td>
</tr>
</tbody>
</table>
The patients presented at 8 months post trauma (range: 1 to 14 months) with symptomatic distal radius malunions. Preoperative clinical and radiological evaluations were done to assess range of motion, grip and pinch strength and characterize radiologically the malunion. Three patients were classified as “Dorsal” malunions. This pattern was typified as severe dorsal tilt of the radius in the lateral plane. (Fig 1) The physical exam of these patients consistently presented excessive wrist extension and lack or impairment of wrist flexion.

![Figure 1. A. Pre operative Dorsal deformity of a patient with distal radius malunion. B. Post operative status showing the correction of the dorsal deformity with stable angle implants and Norian cement.](image)

Seven patients were classified as “Volar” malunions. These were characterized as deformities with marked volar tilt of the distal radius on the pre-operative radiography lateral view. (Fig 2) In contrast, these patients had a lack of wrist extension and greater wrist flexion when compared to their control (same patient opposite upper limb).

The osteotomy was performed through dorsal approach in three patients and via volar approach in one; four had a combined approach due to excision of previously placed internal fixation (two cases) as well as the need for median nerve decompression (two cases). Two combined corrections included an intraarticular osteotomy.
Figure 2. A. Pre operative Volar deformity of a patient with distal radius malunion. B. Post operative status showing the correction of the Volar deformity with stable angle implants and Norian cement.

All cases were performed under regional block anesthesia. For internal fixation five patients were treated with volar locking 2.4 mm T plates and three with dorsal 2.4 mm. T, L and/or radial column locking plates. Following the osteotomy and internal fixation, the created defect was filled with Norian SRS cement. X rays were taken to evaluate quality of reduction and fixation after the osteotomy. At 10 to 14 days of postoperative immobilization, all patients started active motion exercises.

SURGICAL TECHNIQUE

Volar approach

A standard volar radial side approach described by Henry was used. (24). A specially designed 2.4-mm AO locking volar plate was then specially contoured and one screw was placed in the distal limb. This was confirmed on x-ray. Using an osteotome through the original fracture site, an osteotomy was created in all cases. It was slowly lengthened with a lamina spreader and this was confirmed under fluoroscopy. Additional locking 2.4 mm screws were placed proximally and distally once an acceptable position in the frontal and sagittal planes was obtained. (Figure 3)
Figure 3. Distal radius malunion treated through volar approach. Please note the stable fixation of fragments after the distal radius osteotomy leaving the defect to be filled with Norian cement.

The defect was then filled with Norian paste; complete filling of the defect was confirmed on X-rays. Following this, the tourniquet was released. Hemostasis was obtained and the wound was closed in layers after placing a drain. A sterile dressing and splint were applied in all patients. Immobilization was used from 10 to 14 days before starting rehabilitation movement protocol.

Dorsal Approach

Dorsal approach consisted in a dorsal incision through the skin over the third compartment. Dissection of subcutaneous tissue until the Extensor Pollicis Longus (EPL) visualization took place. The EPL tendon was released from the third dorsal compartment and transposed radially and dorsally into the subcutaneous tissues where it was left at the end of the procedure. The second and fourth compartments were elevated subperiosteally. In the majority of cases, two Schantz screws were placed in the radius, one in the proximal diaphyseal area and another distal in the metaphyseal fragment. Distraction forces were applied with a small skeletal distractor or a lamina spreader to facilitate and stabilize transiently the realignment. (Figure 4)
The osteotomy was performed on a parallel plane to the articular surface with an osteotome at the previous fractured site. Realignment was monitored and evaluated under fluoroscopy. In two cases of intra-articular involvement, a dorsal capsulotomy was performed after which the intraarticular osteotomy was created. Fixation was accomplished with 2.4 mm T, L and/or radial column locking plates LCP (Synthes, USA). (Figure 5) After fixation, injection of osteoconductive biomaterial (Norian SRS®) was done after distractor removal to fill the defect recreated after performing the osteotomy. Filling with Norian was verified under fluoroscopy. (Figure 6 and 7) After haemostasis we proceeded with wound closure. All patients were immobilized with a splint from 10 to 14 days before starting rehabilitation protocol.
Figure 6. Defect filling through Norian injection in a patient who was treated through a dorsal approach.

Figure 7. Final result after stable angle implants fixation and defect filling with Norian cement.

Pre and postoperative range of motion and grip strength were measured by an independent observer. Wrist and forearm mobility were objectively quantified with a goniometer (Orthofix, USA). Excellent range of motion was defined as 100% of wrist and forearm motion of the contralateral limb. Good results as between 75%
and 99%; fair between 50% and 74% and bad when achieved motion was less than 50% of the uninvolved limb. Grip strength was tested also pre and postoperatively, using a hydraulic hand dynamometer (Baseline (FEI, Irvington, N.Y. 10533, USA) with the elbow set at the third station (elbow at ninety degrees of flexion and the wrist and forearm in neutral). All patients received postoperatively the Modified Mayo wrist score (25) and the modified Gartland and Werley (26) score to evaluate outcomes in terms of pain, ability to return to work, mobility, grip strength, residual deformities and complications. DASH questionnaire was also applied at the postoperative visit.

Ulnar inclination, volar tilt, radial length and ulnar variance were measured in pre and postoperative radiographies according to the standard technique for radiographic measurement in the radius. Percentage quantification of improvement and averages were calculated per each patient.

**RESULTS**

The patients had their corrective osteotomies performed 8 months on average after the initial injury (range: 1 - 14 months). There were no perioperative complications. All osteotomies healed. At an average follow up of 17 months (range: 6 to 22) an average wrist and forearm motion of 78% of the opposite side was achieved. Average achieved wrist and forearm motion was 47 degrees of flexion, 43° of extension, 75° of supination, 86° of pronation, 20° of radial deviation and 35° of ulnar deviation.

In terms of grip strength, the Modified Mayo wrist score scale was used. All patients were rated as good strength (strength between 75% and 99%). The grip strength on average was 88% when compared to the uninvolved hand. (Table 2) The average grip was 69.8 pounds.

According to the Modified Mayo Wrist Score, two patients rated as good result (75-89pts) and six as a fair outcome (50-74pts). There were no patients scoring as a bad result (less than 50pts). The average modified Mayo Wrist Score was 71 points of a hundred (range: 65-85).

When using the Modified Gartland and Werley Score, one patient rated as excellent outcome (0-2pts.); four as good results (3-8pts); and three as a fair result (9-20pts). There were no poor results (more than 21 pts). The average Gartland and Werley score was 7.8 points, ranging from 1 to 18 points. The average DASH score was 21.5 points, ranging from 0 to 41. (Table 2)
Table 2. Functional Series Outcome after Corrective Osteotomy with Angle Fixed Implants and Norian Cement.

<table>
<thead>
<tr>
<th>Case</th>
<th>Date Of Follow Up</th>
<th>Complications</th>
<th>Mayo</th>
<th>Mayo</th>
<th>G/W</th>
<th>G/W Score</th>
<th>DASH</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>12/4/2003</td>
<td>None</td>
<td>85.00</td>
<td>Good</td>
<td>1.0</td>
<td>Excellent</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>11/4/2004</td>
<td>None</td>
<td>75.00</td>
<td>Fair</td>
<td>4.0</td>
<td>Good</td>
<td>5.83</td>
</tr>
<tr>
<td>5</td>
<td>8/5/2004</td>
<td>None</td>
<td>65.00</td>
<td>Fair</td>
<td>15.0</td>
<td>Fair</td>
<td>29.10</td>
</tr>
<tr>
<td>6</td>
<td>11/9/2004</td>
<td>None</td>
<td>65.00</td>
<td>Fair</td>
<td>9.0</td>
<td>Fair</td>
<td>41.00</td>
</tr>
<tr>
<td>7</td>
<td>6/13/2003</td>
<td>None</td>
<td>65.00</td>
<td>Fair</td>
<td>18.0</td>
<td>Fair</td>
<td>25.92</td>
</tr>
<tr>
<td>8</td>
<td>12/30/2004</td>
<td>None</td>
<td>65.00</td>
<td>Fair</td>
<td>8.0</td>
<td>Good</td>
<td>38.00</td>
</tr>
<tr>
<td>10</td>
<td>2/2/2006</td>
<td>None</td>
<td>70.00</td>
<td>Fair</td>
<td>5.0</td>
<td>Good</td>
<td>17.00</td>
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<tr>
<td>11</td>
<td>2/14/2006</td>
<td>None</td>
<td>80.00</td>
<td>Good</td>
<td>3.0</td>
<td>Good</td>
<td>15.30</td>
</tr>
</tbody>
</table>

One patient required a Darrach’s procedure at 6 months to increase motion and management of pain at the distal radio ulnar joint. Two patients required plate removal due to pain and limitation in movement.

In terms of x-ray evaluation the average preoperative volar tilt was 19.4° in extension in the dorsal deformity group and 25° in flexion in the volar deformity group. Postoperatively, the average palmar tilt was 12.9° in the former and 12.5° in the latter. The average improvement after surgery was 24.6 degrees in patients with dorsal deformity and 14.1° in those with volar deformity. Pre operative ulnar variance was on average 4.1 mm, after surgery it corrected to 2.54 mm (50%). Ulnar inclination averaged 14.5° preoperatively, after treatment it averaged 22° presenting an improvement of 7.5°. Lastly, with the exception of one patient, restoration after surgery achieved acceptable clinical outcomes and radiologic parameters. Assessment for posttraumatic arthritis was negative in every case at the time of follow-up.

**DISCUSSION**

A corrective osteotomy in the older patient is more difficult because of the associated osteopenia as well as the limited autogenous bone graft to be obtained from the iliac crest. Several technological advances have made this procedure more predictable. The first is the development of low profile implants with angular stable screw fixation. This osteosynthesis system device has shown good results in maxillofacial and spine surgery, where stability is required without bicortical screw purchase (8, 11, 12). The locking compression system offers a similar mechanism of action with the mechanical advantage of multiple points of screw fixation when compared to fixed...
angle devices. It is a point of crucial importance in fractures with long working lengths, short periarticular fragments and the absence of osseous support on the contralateral side where the plate is placed (8). The angle fixed constructs do not affect the blood supply to the bone and do not require good bone quality to proportionate stability. In this system, threads on the screw heads lock into the corresponding threads on the screw hole of the plate, eliminating therefore toggling. Forces are transmitted then from the bone to the plate across the threaded connection converting compression unnecessary to get stability. This lack of compression preserves the blood supply to the bone, improving conditions for healing. Disadvantages of this system include no tactile feedback to the surgeon while tightening the screws. Previous reduction is needed before application of the device, once the locked screw is placed below or above of the fracture site no further reduction is possible unless the construct is totally removed (27-29). Clinical trials have verified the efficacy of fixed angled plates for the treatment of distal radius fractures (27-29). Functional outcomes are promising and the rate of complications low, making this implant desirable also for the stabilization of osteotomies for the treatment of distal radius malunion.

The second technical advance is the use of cement and biomaterials that can support and put together fragments of bone, and that can fill defects after severe comminution or osteotomies. The role of this material is particularly important in osteoporotic bone that cannot tolerate adequately constructs and that needs support while consolidation process takes place. Norian SRS Cement offers biocompatibility and osteointegration; high compressive strength, even higher than cancellous bone; fast-setting that cures in vivo at physiological pH and temperature, avoiding local damage tissue characteristic of PMMC use; and lastly injectable consistency that allows percutaneous as open techniques usage. (19) Additionally, advantages in imaging under fluoroscopy and X rays have been proved (4,30). Some studies have demonstrated better clinical outcomes when compared to standard protocols of treatment; however, controversies exist in terms of radiologic outcomes after both types of treatment, conventional open reduction and internal fixation vs. percutaneous fixation and Norian cement use. (16, 19) Two prospective randomized studies (Sanchez-Sotelo et al and Cassidy et al) evaluating this technique showed good results (16, 19). Clinical outcomes were significantly better than the standard care; however, none of them defined what type of fractures gets benefit from this particular approach with cement and percutaneous fixation. Recent research has demonstrated comparable results between percutaneous fixation and open reduction and internal fixation for extra articular and non-complex intraarticular fractures(31),
therefore, the role of Norian cement in distal radius fractures in previous studies must be related with bone quality, in other words, osteoporosis and osteopenia.

According to the mechanism of action and previous description of these two surgical advances, we consider them extremely useful for the treatment of malunions in osteopenic patients that suffered a distal radius fracture concluding in malunion or mal-alignment. According to the clinical and radiological outcomes, we find this technique useful and safe to treat malunions.

This series reports the results of treatment of distal radius malunion with osteotomy plus internal fixation with locking compression plates and Norian SRS® in 8 patients. Our purpose is to present this technique as an alternative in these complex cases where we have to face the elderly patient with osteoporotic bone. We are aware of the statistical limitations of this study but we consider it is valuable as a new proposal of a surgical technique that will develop a new research field in orthopaedic surgery.

REFERENCES


