Treatment of Extra-Articular Distal Radial Malunions With an Intramedullary Implant

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Purpose Malunited distal radius fractures pose considerable problems, especially for young, active individuals. Surgical correction with osteotomy, bone grafting, and internal fixation with plates and screws has been the treatment of choice. Locked intramedullary fixation is an alternative technique to provide bony stability while minimizing soft tissue irritation in the management of acute distal radius fractures, with acceptable clinical results. The purpose of this study was to describe our experience with the use of an intramedullary device combined with grafting to repair distal radial malunions. This fixation device is inserted through the radial styloid and obtains distal fixation with 3 fixed-angle locking screws.

Methods Thirteen patients underwent distal radius malunion repair with an intramedullary implant and grafting. There were 6 male and 7 female participants with an average age of 51 years (range, 18–72 y). Patients were evaluated at an average follow-up of 24 months (range, 13–38 mo). Clinical outcome was measured by range of motion of the wrist and forearm, and grip strength, and by using the Disabilities of the Arm, Shoulder, and Hand questionnaire. We analyzed radiographs to determine time to union and adequacy of correction.

Results All of the malunions healed, with an average time to healing of 11 weeks. Patients' average range of motion at follow-up was 56° of flexion, 66° extension, 85° pronation, and 84° supination. Mean grip strength was 83% of the unaffected side, and the average Disabilities of the Arm, Shoulder, and Hand score was 21. Radiographs taken on the latest follow-up showed correction to the following average parameters: 20.6° radial inclination, 11.0 mm radial height, +1.0 mm ulnar variance, and 2.1° volar tilt.

Conclusions The technique presented in this report demonstrates the effectiveness of an intramedullary nail combined with bone graft or graft substitute in repairing malunited fractures of the distal radius. The results show reliable correction of the deformity and good functional outcomes. *(J Hand Surg 2010;35A:892–899. © 2010 Published by Elsevier Inc. on behalf of the American Society for Surgery of the Hand.)*

Type of study/level of evidence Therapeutic IV.

Key words Distal radius, malunion, osteotomy, intramedullary, fracture.

Distal radius fractures are one of the most common extremity injuries, accounting for about 8% to 15% of all skeletal injuries.[1] There are many accepted options available for treatment, but as many as 23.5% of these fractures can result in malunion.[2–4] This typically results in a volarly angulated, dorsally displaced malalignment of the distal radial metaphysis. Although generally tolerated in low-de-

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mand, elderly patients, this deformity can lead to considerable problems in young, active individuals. These symptoms may be due to resulting arthritis, ulnar-carpal impaction, or midcarpal instability. Thus, correction of a distal radial malunion is generally recommended in active patients to avoid these complications.[5]

Closing wedge osteotomy, proposed by Posner and Ambrose, proved to be useful in certain types of malunion.[6] However, the combination of opening wedge osteotomy, bone grafting, and internal fixation is typically used for most distal radial malunions because it allows multiplanar deformity correction and stable fixation for early motion. This technique has proven to result in improvement of wrist and forearm function after fixation.[5,7] Although the options for fixation are similar to those for acute fractures, different variations of plates and screws are the most commonly used technique for internal fixation.[8] Dorsal plating has the advantage of a direct approach to the deformity and easy insertion of structural grafts.[7] This method, however, carries a risk to the soft tissues adjacent to the implant. The presence of the hardware just deep to the extensor retinaculum can result in hardware prominence and tendon problems, at times requiring plate removal.[9,10] Alternatives to this technique are smooth pins and external fixation. These options may be less irritating to tendons but they provide decreased rigidity and are prone to peri-implant infection. Volar locked plating has recently been used,[11,12] but the volar approach does not allow visualization of the dorsal cortex of the distal fragment, which may allow more direct reduction of the malunion. In addition, volar plate application can cause tendon irritation, as has been reported in its use for acute fractures.[19–21]

An intramedullary implant theoretically would provide adequate stability with minimal impingement on the soft tissues. This principle has shown considerable success in the diaphyseal portion of long bones of the body. The use of a locked intramedullary device for distal radius fractures is relatively new and has been limited mainly to simple acute fractures.[13–15] The purposes of this report were to describe our experience with osteotomy, grafting, and stabilization with the use of the same intramedullary device (Micronail Distal Radial System; Wright Medical Technology, Arlington, TN) for treatment of distal radius malunions, and to evaluate the clinical, radiographic, and functional outcomes. The fixation device used in this study is inserted through the radial styloid and obtains distal fixation with 3 fixed-angle locking screws and proximal fixation with 2 nonlocking bolts (Fig. 1).

FIGURE 1: Photograph of Micronail intramedullary nail implant. The 3 distal screws are in place and are locked in the nail. The 2 larger holes in the proximal nail are for the nonlocking shaft screws and the smaller hole is for placement of a temporary holding K-wire.

MATERIALS AND METHODS

Between 2004 and 2007, 3 surgeons at 2 institutions treated 21 patients with malunited distal radius fractures with dorsal osteotomy, bone grafting, and fixation using a locking intramedullary nail system. Radiographic measurements that were graded as unacceptable and were used as the entrance criteria for the study were: radial shortening greater than 5 mm, less than 15^o radial inclination, and sagittal tilt in excess of 10^o dorsal or 20^o volar. Only one of these criteria was necessary to be entered into the study, but most cases met several of the inclusion criteria. All of the nonunions were extra-articular and did not involve the radiocarpal or distal radioulnar joint. The patients underwent corrective surgery at an average of 26 weeks (range, 4–174 wk) after the original fracture. Four of the patients had nascent malunions with less than 6 weeks between original fracture and the malunion correction. These nascent malunions could not be reduced with manipulation alone and typically required an osteotome but not a saw for re-establishment of the fracture plane. The fracture malunion callus was mobilized, morselized, and then inserted into the resulting gap from the osteotomy.

Of the original 21 patients, 2 had incomplete data, 5 were lost to follow-up, and one died of an unrelated disease process, leaving 13 patients for evaluation. Regarding the patients lost to follow-up, there were no known complications or adverse sequelae. The records were retrospectively reviewed for details surrounding injury and surgery. These patients had sustained distal radius fractures and were initially treated for their acute fracture with closed reduction and casting, which eventually healed in an unacceptable position. One patient had previously undergone a corrective osteotomy with structural bone grafting and pin fixation alone. Patients were seen at 2, 4, and 6 weeks, 3, 6, and 12 months, and then yearly thereafter. Only patients with at least 12 months of follow-up were included in this study. The group consisted of 6 men and 7 women, with an average age of 51 years (range, 18–72 y). We evaluated functional outcome using the Disabilities of the Arm, Shoulder, and Hand (DASH) scoring questionnaire, a 30-item, self-reported questionnaire designed to measure physical function and symptoms in people with musculoskeletal disorders of the upper limb. A lower score is a better functional outcome. Radiographs were taken immediately after surgery and several times postoperatively until radiographic union was achieved.

An unbiased research coordinator assessed final clinical results in 5 patients, and individual operating surgeons in 8 patients. Wrist and forearm motion were measured with a hand-held goniometer and grip strength was measured with a Jamar dynamometer (Lafayette Instruments, Lafayette, IN) set at position 2. Final grip strength was compared with the normal, contralateral side. Plain radiographs were used to judge the time to osteotomy union. The distal radial malunions were graded as healed when there was bony bridging on both the anteroposterior and lateral views. An independent examiner not involved with the surgery measured alignment of the distal radius from a digital Picture Archiving and Communication System using the automated software tools. The values measured were volar tilt, radial inclination, radial height, and ulnar variance.

Statistical methods

We performed statistical analysis using the software program Minitab 15 (Minitab, Inc., State College, PA). The analysis employed was a 2-sample *t*-test to determine significance between preoperative and postoperative radiographic results from patients. Significant difference was defined as a p value less than .05.

Surgical technique

The patients are positioned supine with the arm abducted on a radiolucent hand table. Using an image intensifier, the location of the malunion and radial styloid is located and marked. The incision for the nail insertion portal is made first, to aid in easier insertion of the nail after the fracture is exposed and the osteotomy is made. This incision, which is used for placement of the nail, is longitudinal, approximately 2.5 cm, and is centered over the radial styloid (Fig. 2). The subcutaneous tissue is carefully dissected and superficial radial nerve branches are identified, mobilized, and retracted from the surgical field. The radial styloid and the first and second extensor compartments are identified.

FIGURE 2: Intraoperative photograph showing approach to radial styloid. The interval is between the first and second compartments. A dorsal K-wire is seen provisionally holding reduction of the distal radius.

Next, the malunion site is approached dorsally through the third dorsal compartment. The second and fourth dorsal compartments are elevated off of the distal radius. The fracture is cut at the metaphysis and the correction is done under guidance of an image intensifier (Fig. 3). If the deformity is a nascent malunion, often some portion of the original fracture line can be found with a blunt elevator or osteotome. The radius is corrected and K-wires are placed along the distal dorsal-ulnar corner proximally into the shaft, spanning the defect, to temporarily maintain the alignment (Fig. 4). An additional wire may be placed dorsally from the radial styloid into the proximal shaft for added stability. Anteroposterior and lateral fluoroscopic views are used to confirm proper correction of the distal radius. Preoperative films of the contralateral side are used as a guide to determine normal distal radial alignment for each individual patient.

Through the radial-sided exposure, the styloid is visualized and entered with a guide pin. The styloid is

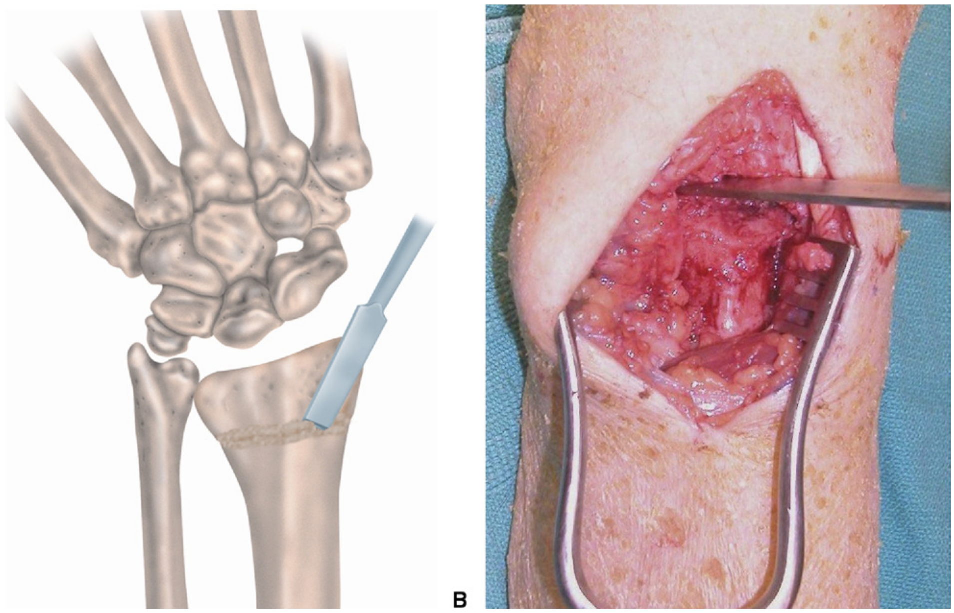

FIGURE 3: Schematic drawing and intraoperative photograph of a patient showing the creation of a dorsal wedge osteotomy of the distal radius. **A** The deformity is entered with an osteotome at the level of exhuberant dorsal callus. **B** The osteotomy is created with an osteotome and levered open to correct the distal radial alignment. A trapezoidal defect is created.

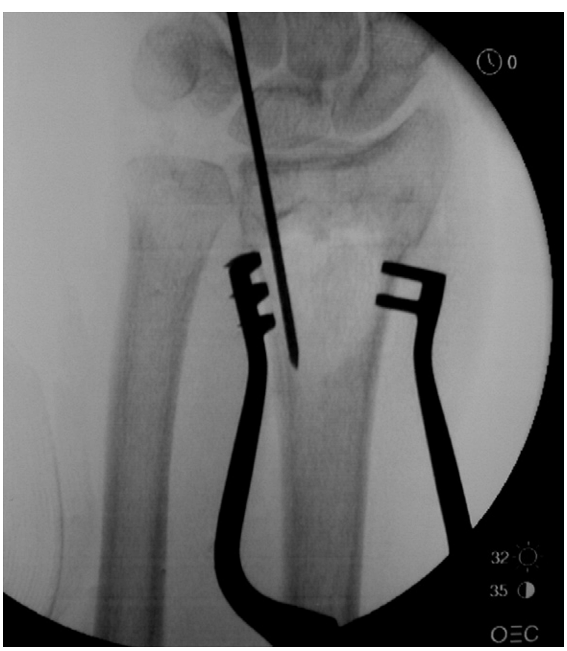

FIGURE 4: Fluoroscopic view showing intraoperative placement of provisional K-wires stabilizing the opened osteotomy site. The K-wire is inserted along the ulnar cortex of the radius to avoid impingement from the broaches or nail.

approached between the first and second dorsal compartments. The guide pin is placed approximately 5 to 7 mm from the articular surface and at a 45° angle from the longitudinal axis of the radius. A 6.1-mm cannulated drill is placed over the guidewire and inserted to a depth of 15 mm. This portal into the metaphysis and intramedullary space is then opened further with sequential broaches. The broaches are contained within the set and range in 4 progressively enlarging sizes that correspond to the nail implant size. They are inserted by hand and with only light tapping with a mallet to avoid displacing the distal fragment. The nail is then placed on the insertion jig and the implant is inserted into the intramedullary canal of the radius (Fig. 5). The jig acts as a handle that assists in appropriate placement of the implant. Once proper nail positioning and alignment of the distal radius are noted on fluoroscopy, the nail is fixed to the distal segment with the 3 distal locking screws and to the shaft with 2 bicortical screws through the attached guide (Fig. 6).

At this point, the appropriate bone graft is placed around the nail. If the injury is a nascent malunion, local cancellous graft from the surrounding dorsal malunion callus created by deformity may be used. For larger gaps, a structural corticocancellous graft from the iliac crest is used. The graft is notched or split into 2 pieces and inserted around the nail and impacted into place (Fig. 7). In this study group, 5 patients had structural corticocancellous graft from the iliac crest inserted after correction, 6 had local cancellous graft with the addition of demineralized bone matrix (Graft-On Gel; Osteotech, Eatontown, NJ), and 2 had a bone calcium sulfate graft substitute

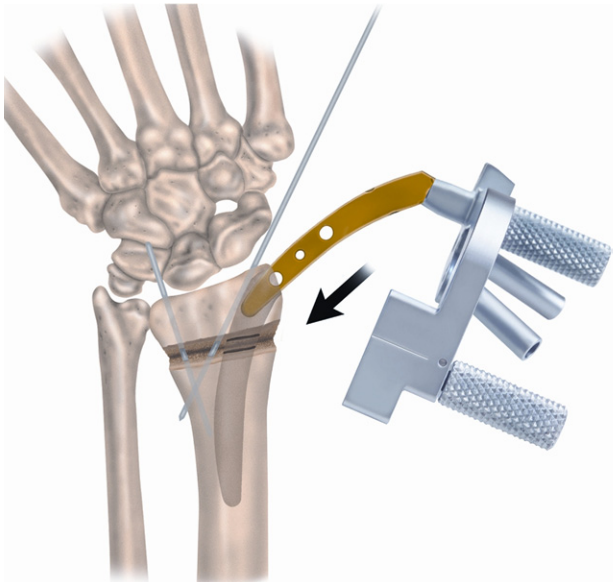

FIGURE 5: The nail is attached to the threaded insertion guide and placed into the intramedullary canal of the radius through the radial styloid. The provisional K-wires have been inserted to avoid the path of the intramedullary device.

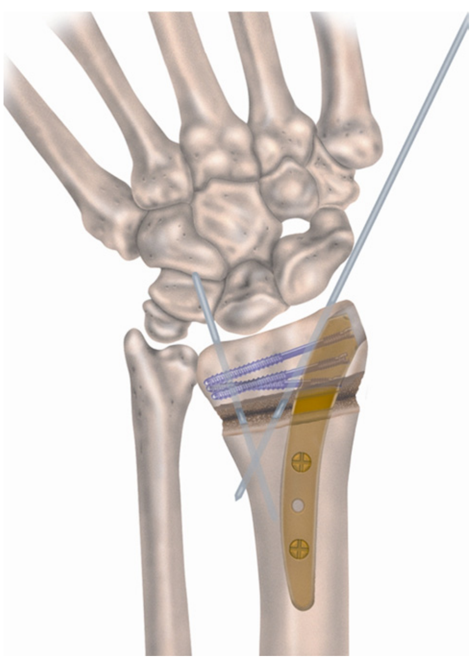

FIGURE 6: Drawing demonstrating placement of the nail across the distal radial defect and stabilization distally with 3 locking screws and proximally with 2 cross-bolts. The provisional K-wires are still in place.

(Wright Medical Technology, Arlington, TN). The nature of the graft used was based on the size of the defect created and the chronicity of the malunion, with larger gaps in more established nonunions requiring structural grafts (Fig. 8). The more chronic malunions did not have surrounding callous or hypertrophic bone to use as graft.

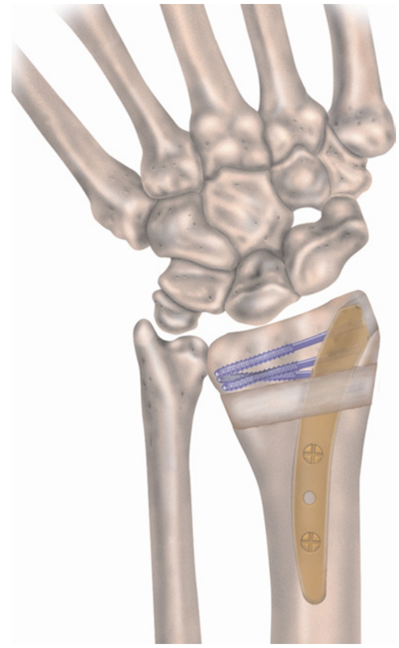

FIGURE 7: The iliac crest bone graft has been inserted into the defect and impacted into place around the nail. All provisional K-wires are removed and the nail insertion point is below the cortical level of the radial styloid.

The temporary K-wires are then removed, the retinaculum is closed, and the extensor pollicis longus tendon is left transposed. The skin is closed over the dorsal and radial wounds with nylon sutures. The wound is dressed in the standard fashion and the patient is placed in a short arm splint. Finger range of motion and gentle forearm rotation is encouraged immediately. The patient is seen after 10 to 14 days for removal of the splint and sutures, and gentle wrist range of motion is initiated. Patients used a removable volar wrist splint until full healing of the osteotomy and bone graft occurred.

RESULTS

We evaluated 13 patients at an average of 24 months (range, 13–38 mo) after osteotomy surgery. All patients originally had volarly angulated and dorsally displaced distal radial malunions. Table 1 lists the average radiographic measurements for radial inclination, radial height, ulnar variance, and volar tilt preoperatively, immediately postoperatively, and at final follow-up. There were statistically significant differences ($p < .05$) in all radiographic parameters between preoperative and postoperative values. All of the malunions healed at

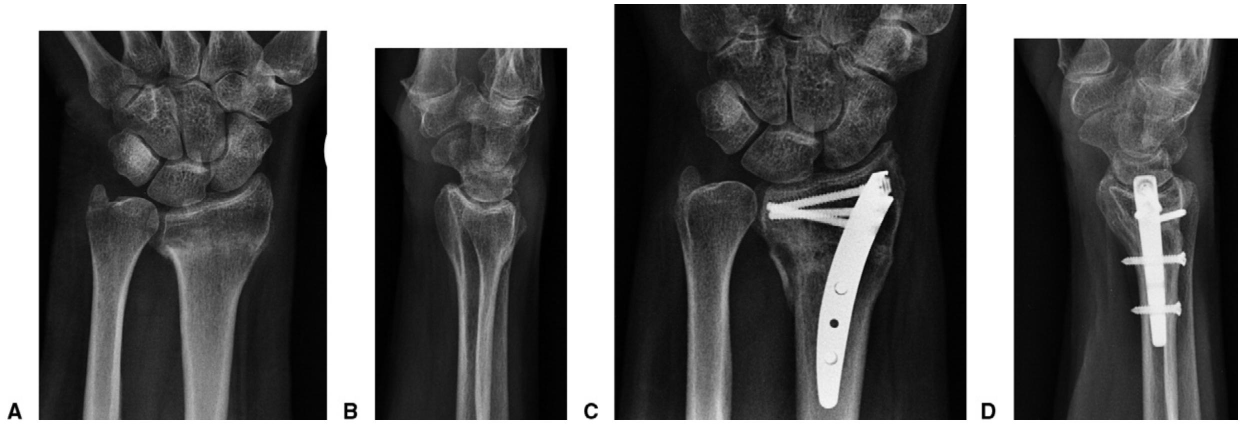

FIGURE 8: **A** Posteroanterior and **B** lateral view of an established malunion. Dorsal tilt malalignment is measured at 22° on the lateral view. Postoperative films demonstrating restored alignment in the **C** posteroanterior and **D** lateral radiographic views with complete consolidation of the bone graft.

TABLE 1. Preoperative and Postoperative Radiographic Parameters After Distal Radial Osteotomy Stabilized With an Intramedullary Nail

Radiographic Parameter	Preoperative	Immediate Postoperative	Final Postoperative
Volar tilt	–18.4°	+2.6°	+2.1°
Ulnar variance	+3.3 mm	+1.4 mm	+1.0 mm
Radial inclination	16.4°	19.9°	20.6°
Radial height	8.7 mm	11.2 mm	11.0 mm

an average time of 11 weeks (range, 5 to 24 wk) after surgery. The case that required 24 weeks to heal first underwent initial osteotomy and structural bone grafting that was stabilized with pins alone, and then had a subsequent procedure with an intramedullary nail and an additional calcium sulfate graft for failure of fixation. This case had a delayed union and required repeat structural grafting and eventually healed 24 weeks after placement of the intramedullary nail. One patient had backout of one of the proximal nail screws that required removal. The osteotomy healed in this patient. There was one case of temporary superficial radial nerve irritation that lasted 3 weeks and then completely resolved.

Clinical examination demonstrated the following average values for range of motion at the latest follow-up: wrist flexion 56°, wrist extension 66°, forearm pronation 85°, and forearm supination 84°. Average grip strength was 58 1b (26.3 kg), which was 83% of the uninjured side. Functional outcome score using the DASH averaged 21, with a range of 8 to 75. The patient with a DASH of 75 was a workers' compensation case who healed her malunion at 10 weeks in neutral lateral alignment. There were no cases of permanent nerve injury, tendon irritation, infection, or wound complications. No screws were placed into or were found to enter the radiocarpal or distal radioulnar joint on intraoperative or final follow-up films.

DISCUSSION

Several authors have shown excellent outcomes for corrective osteotomy for distal radial malunions using various techniques.[5–10] Variations of opening wedge osteotomy with bone grafting and internal fixation, presented in several case series, have been shown to be successful in terms of radiographic and functional outcome.[5] Fernandez in 1982 reported on 20 patients who underwent opening wedge osteotomy with volar or dorsal buttress plating and structural bone grafting from the iliac crest.[9] This report demonstrated good to excellent results in 75% of patients. The patients who showed the best postoperative outcome had greater preoperative motion and no existing degenerative changes. However, 17 of 20 patients underwent subsequent procedures for hardware removal. It is not clear whether these plates were removed for hardware prominence or as a routine procedure in that time period. There were also 2 cases of tendonitis of the extensor pollicis longus but no reports of tendon rupture.[9]

Bone grafting has an important role in the management of malunited distal radius fractures. Our study used different sources for bone grafting of the malunion site. Grafting is usually required because correction consistently leads to a metaphyseal gap on the opening side of the osteotomy. Graft sources have included iliac crest, parts of the distal radius, olecranon, and the resected ulna.[8] Autografts have certain advantages including biocompatibility and increased potential for incorporation.[16] Jupiter and Ring reported the technique of using resected exuberant callus from the fracture site for correction of nascent malunions.[17] In addition, the role of structural grafts has been challenged, as a recent study showed no advantage between cortical and cancellous autograft in terms of radiographic and functional outcome as long as stable fixation is achieved.[18] At present, a wide variety of bone graft substitutes are readily available, ranging from allograft-based to completely synthetic products.[16]

One of the weaknesses of our study is that the bone graft used was not consistent; however, our goal was to use the type of bone graft that was appropriate for the deformity present. Typically, if the malunion is nascent, being of short duration (less than 3 months), the path of the fracture line can be found and elevated, and the local callus can be morselized and used as a graft. This is usually combined with a demineralized bone matrix to increase the graft volume and aid in healing. If the malunion is more established and the defect is large, we still feel that a structural corticocancellous autograft is necessary.

With the recent popularity of volar plate application for fixation of distal radius fractures, this technique is now being used for malunions. However, the published studies are limited to case reports and small case series. Yasuda et al.[11] reported a case of a dorsal angulated malunion treated at 6 weeks after injury with volar plating and insertion of a calcium phosphate cement. The exact time to union is not stated, but the patient had functional range of motion and healing of his malunion at 16 months after the surgery. Malone et al.[12] reported their series of 4 patients with "dorsally angulated," apex volar malunions treated with corrective osteotomy, bone grafting, and volar plate stabilization through a volar approach. The average preoperative dorsal tilt of these patients was 26°. The resulting gaps were filled with cancellous grafts. The source was autogenous iliac crest in 2, the patient's resected distal ulna in 1, and allograft in 1. Results showed maintenance of acceptable reduction on follow-up and improved function measured by DASH scores. Grip strength and range of motion approached that of the uninjured side. In this small case series, there were no reports of tendon irritation or finger or wrist stiffness. All fractures healed with average graft incorporation at 12 weeks, with a range of 6 to 22 weeks.

Even with the proposed advantages of volar plating, there are still reports of hardware irritation and flexor pollicis longus tendon ruptures volarly, and extensor tendon ruptures from screw and drill bit penetration of the dorsal cortex.[19–21] However, with use of the extended flexor carpi radialis approach, the deformity may be adequately corrected and a suitable graft inserted. Also, if after the malunion is cut and corrected and the resulting gap is not large, a bone graft may be unnecessary with volar plate application.

Intramedullary nailing is an evolving technique created to lessen common problems encountered with extramedullary implants. The nail minimizes contact of the implant to the surrounding tendons with only the proximal screw heads lying outside the distal radius bone. Intramedullary nails have been used for forearm shaft fractures, with reasonable results.[22] Brooks et al.[13] reported early results of intramedullary fixation of acute distal radius fractures in a series of 23 patients. They noted encouraging clinical and radiographic results. There was minor irritation of the superficial radial sensory nerve in 3 patients, which eventually resolved within 2 months after surgery. There were no cases of hardware prominence or tendon irritation. In a recent report, Ilysas and Thoder[14] reported 10 patients treated with an intramedullary nail for acute distal radius fractures. They had an average DASH score of 8.1, with 8 excellent, 1 good, and 1 fair clinical result. They did have 3 cases in which screws were placed into the distal radioulnar joint. One of these 3 patients had resulting distal radioulnar joint arthritis at final follow-up and pain with rotation. This is a potentially serious complication that needs to be avoided and can be minimized by selecting screws shorter than the apparent border of the ulnar side of the radius owing to the concavity of the sigmoid notch. These studies on acute fractures give us a basis for use of intramedullary nailing of distal radial malunions. This same group of authors has also more recently published a technique article on the use of intramedullary nailing for distal radial malunions.[22] No clinical results were provided in that manuscript.

Use of an intramedullary nail for correction of distal radial malunions also requires proper case selection. The nail device used in this study has only 3 distal locking screws and thus may not be appropriate for malunions with a resulting small distal fragment. These cases would be more appropriately treated with a volar locking plate with which multiple locking screws can be placed into the distal subchondral bone. Also, a nail device would not be appropriate for volar angulated or intra-articular malunions. When the dorsal approach is used and an osteotomy defect created, there is a clear need for a bone graft. These reconstructive cases may be performed with a volar plate and possibly obviate the need for a structural bone graft. This fact is a disadvantage of the technique described here using an intramedullary device. Another weakness of the study is that we do not have preoperative wrist and forearm range of motion data for comparison; consequently, it is not clear whether the postoperative range of motion is better or worse than preoperative range of motion.

Since the beginning of our original series, we have modified the technique only in minor ways. A new set of instruments has been developed from the manufacturer that is largely radiolucent. This aids in visualization of the articular alignment and makes it easier to determine the osteotomy correction. If possible in nascent malunions, a percutaneous osteoclasis at the fracture site can be performed and elevation of the distal fragment with elevators and hemostats can re-establish the alignment. With adequate local callus present, no bone graft is needed. If there is a resulting metaphyseal void, this gap may be filled with a viscous bone graft replacement using a percutaneous technique.

One of the main differences between fractures and malunions is that the use of an intramedullary implant for treatment of distal radial malunions does require a formal open approach at the osteotomy site. However, soft tissue dissection can be limited to just the metaphyseal exposure needed for bony correction as a plate is not being placed. For nascent malunions and with the use of some of the new viscous bone graft substitutes, this may eventually become more of a percutaneous procedure. The results of this report demonstrate that the use of an intramedullary implant is an effective way of obtaining correction and fixation of malunited fractures of the distal radius.

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