Volar Fixation for Dorsally Displaced Fractures of the Distal Radius: A Preliminary Report

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Using a volar approach to avoid the soft tissue problems associated with dorsal plating, we treated a consecutive series of 29 patients with 31 dorsally displaced, unstable distal radial fractures with a new fixed-angle internal fixation device. At a minimal follow-up time of 12 months the fractures had healed with highly satisfactory radiographic and functional results. The final volar tilt averaged 5°; radial inclination, 21°; radial shortening, 1 mm; and articular incongruity, 0 mm. Wrist motion at final follow-up examination averaged 59° extension, 57° flexion, 27° ulnar deviation, 17° radial deviation, 80° pronation, and 78° supination. Grip strength was 79% of the contralateral side. The overall outcome according to the Gartland and Werley scales showed 19 excellent and 12 good results. Our experience indicates that most dorsally displaced distal radius fractures can be anatomically reduced and fixed through a volar approach. The combination of stable internal fixation with the preservation of the dorsal soft tissues resulted in rapid fracture healing, reduced need for bone grafting, and low incidence of tendon problems in our study. (J Hand Surg 2002;27A:205–215. Copyright © 2002 by the American Society for Surgery of the Hand.)

Key words: Distal radius fracture, volar plate, subchondral peg fixation.

Open reduction and internal fixation with plates is a valid alternative treatment of displaced extra-articular and intra-articular distal radial fractures.[1–4] As opposed to bridging external fixation[5] or percutaneous pinning and casting,[6] stable internal fixation permits early motion of the neighboring joints and optimizes functional rehabilitation of the wrist and hand.[1,7] Although the results of dorsal plating systems have shown satisfactory overall outcomes, the incidence of extensor tendon complications including irritation tendinitis, attrition, and ruptures secondary to direct contact of these structures with dorsal plates is not negligible.[4,8–11] The use of volar buttress plating for volar displaced distal radius fractures has seldom been associated with flexor tendon problems because the anatomy of the volar aspect of the wrist offers more cross-sectional area and the implant is separated from the flexor tendons by the pronator quadratus (Fig. 1).[12]

After comparing dorsal versus volar plate fixation with regard to interference with the surrounding soft tissue envelope, we developed the following working hypothesis: If dorsally displaced unstable fractures could be anatomically reduced through a volar approach and if secondary displacement of the fractures could be prevented by a fixed-angle internal fixation device, the danger of attritional tendinitis and the need for bone grafting of dorsal metaphyseal defects would be greatly reduced. The use of a volar approach would avoid the need for dorsal dissection and maintain anatomic continuity of extensor tendon

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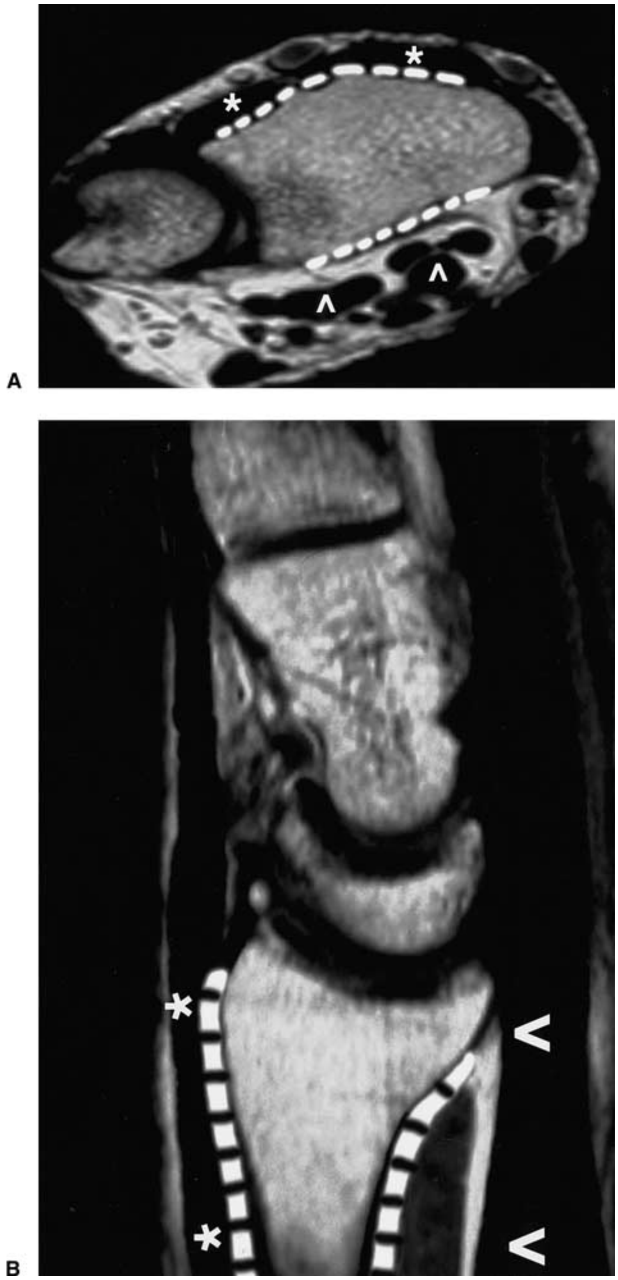

Figure 1. Interrupted lines represent plate application sites on these magnetic resonance images. (A) Dorsal tendons (*) directly contact the dorsal plate. (B) Volar tendons (^) are well separated from the volar plate by the pronator quadratus.

sheaths, periosteum, dorsal retinaculum, and vascular supply to dorsal metaphyseal fragments. These dorsal fragments would be reduced indirectly by traction on the soft tissues, and rapid fracture healing would follow. The application of a strong fixed-angle implant, acting as an internal fixator, would control fracture collapse. We describe the surgical approach, technique of reduction and fixation, and preliminary results obtained with this method.

Materials and Methods

From January 1, 1998, to December 31, 1998, we undertook a prospective study to evaluate the effectiveness of volar fixed-angle plate fixation of dorsally displaced unstable distal radial fractures in 2 institutions (Miami Hand Center, Miami, FL, and Lindenhof Hospital, Berne, Switzerland). The study was approved by corresponding institutional review boards, and informed consent was obtained from all patients. Criteria for study inclusion were a dorsally displaced fracture of the distal radius that after an initial attempt at closed reduction had radiographic evidence of a persisting deformity of >15° of angulation in any plane, >2 mm of articular displacement, or >2 mm of radial shortening. Patients were not excluded on the basis of age or bone quality. Exclusion criteria were fractures of the immature skeleton, a dorsal Barton fracture, fractures with massive comminution of the joint surface or fractures with ≥5 articular fragments, and distal radial fractures extending into the distal third of the radial shaft.

A consecutive series of 12 patients with 14 fractures who met the inclusion criteria after failure of our initial attempts at closed reduction and casting were included. Another 17 patients were referred by other physicians after unacceptable reduction or increasing secondary displacement after closed reduction and cast treatment (n = 14) or failed fracture reduction after initial external fixation (n = 3). In total 29 patients with 31 dorsally displaced distal radius fractures comprised the study. Three of the fractures had a grade 1 open wound on the volar-ulnar side of the wrist, and the remaining 28 were closed fractures. None of the injured wrists had static intercarpal instability or unstable lesions of the distal radioulnar joint. The fractures (14 intra-articular and 17 extra-articular) were classified according to Müller et al.[13] There were 5 A2, 12 A3, 4 C1, 7 C2, and 3 C3 fracture types. There were 12 men and 17 women with an average age of 54 years (range, 25–86 years). Seventeen patients were >60 years old. The causes of injury were simple falls on the outstretched hand (n = 16), work-related accidents (n = 8), motor vehicle accidents (n = 5), and sports injuries (n = 2). Before receiving study treatment, 9 patients had developed median nerve symptoms that persisted for >4 days despite anti-inflammatory medication and elevation, and 5 had developed severe soft tissue swelling and pain with limitation of finger mobility as a result of constricting circumferential casting. Preoperative radiographic evaluation showed an average dorsal angulation of 30° (range, 0° to 65°), average radial inclination of 10° (range, −10° to 50°), and average radial shortening of 3 mm (range, 0–8 mm). Residual intra-articular incongruity in the 14 fractures with articular involvement had a step-off or gap of the articular surface averaging 3 mm (range, 1–5 mm). Of 29 patients, 2 had bilateral fractures (one right dominant and the other left dominant). Of the remaining 27 with unilateral fractures, 18 affected the right wrist (15 dominant and 3 nondominant) and 9 affected the left wrist (2 dominant and 7 nondominant). The time interval between the injury and plate fixation averaged 9 days (range, 0–26 days). Twenty-one patients had regional anesthesia and 8 had general anesthesia.

At the time of last follow-up visit we reviewed the final radiographic and functional results. Standard plain radiographs were obtained and the following parameters, according to Castaing,[14] were measured: volar tilt, radial inclination, radial length, and articular congruency. These films were compared with preoperative films and with previous follow-up films to assess the correction of the original deformity and to recognize any postoperative loss of reduction. The surgeons measured wrist and forearm motion with a goniometer. Digital motion was assessed by measuring the distance from the fingertips to the distal palmar crease. Grip strength was measured with a Jamar dynamometer (Asimov Engineering Corp, Santa Monica, CA) on the second position and, when possible, compared with the contralateral side. Residual pain was graded as mild, moderate, or severe. For clinical assessment the Stewart scale[15] and Gartland and Werley method[16] were used.

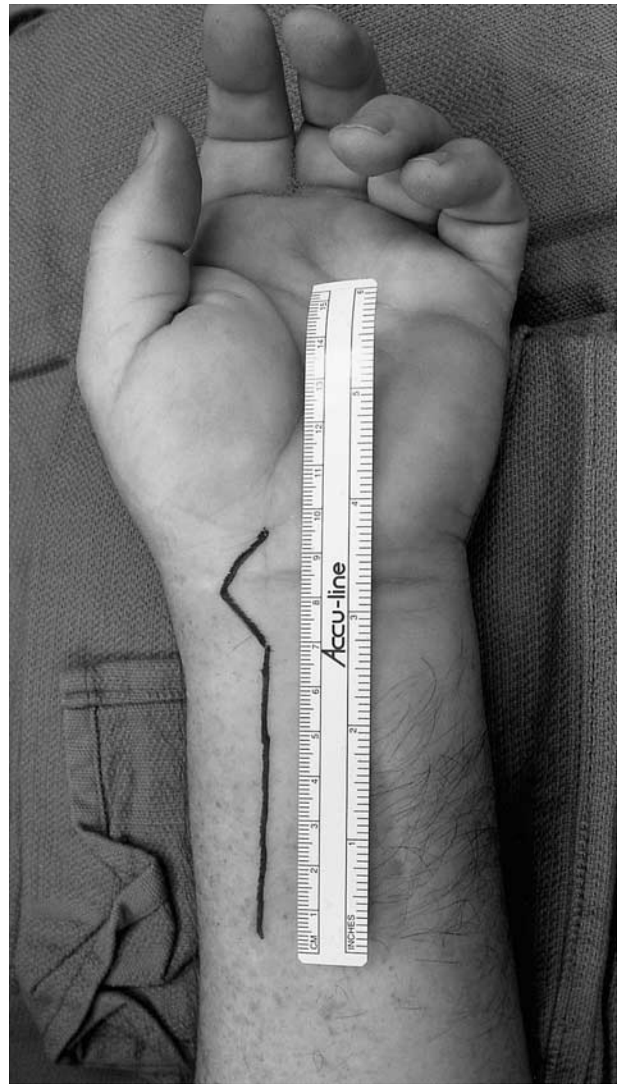

Figure 2. The skin incision is made directly over the course of the FCR tendon, zigzags across the wrist flexion creases, and is 8 to 10 cm long.

Surgical Technique

All procedures were done with fluoroscopic assistance. Surgical approach was through an 8- to 10-cm longitudinal incision located directly over the distal course of the flexor carpi radialis (FCR) tendon (FCR approach) (Fig. 2). When necessary this approach was extended (see later). Distal dissection was carried down through the sheath of the FCR tendon, and proximal dissection was carried down between the FCR tendon and radial artery. The virtual space underneath the flexor tendons (Parona's space) was developed, and the FCR tendon, the median nerve, and the remaining flexor tendons all were retracted ulnarly. The radial artery was protected and retracted radially. The distal and radial borders of the pronator quadratus were lifted with an L-shaped incision, and the muscle was retracted ulnarly. In severely displaced fractures it frequently was found torn and interposed in the fracture site, necessitating release or partial debridement. The standard FCR approach was used in 12 extra-articular and 4 intra-articular fractures. In these 16 cases longitudinal traction combined with restoration of the anatomic continuity of the volar cortex automatically restored the radial length, volar tilt, ulnar inclination, and articular congruency of the joint surface. These were mostly

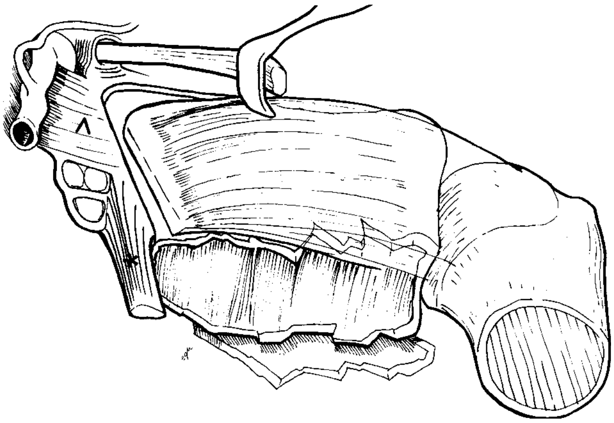

Figure 3. At the level of the distal radial metaphysis the radial septum is a complex fascial structure consisting of the intermuscular membrane, insertion of the brachioradialis (∗), and first extensor compartment (ʌ). It is necessary to release this structure when treating more difficult injuries.

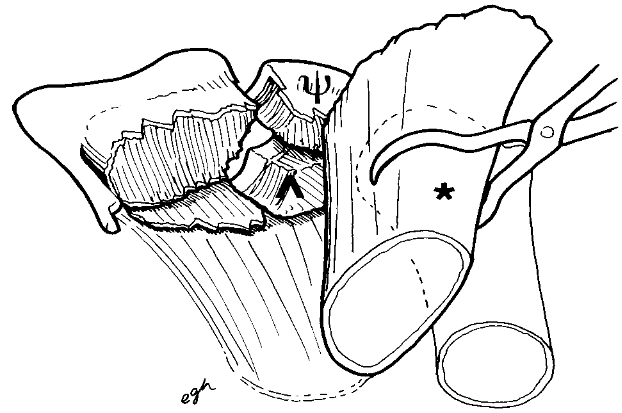

Figure 4. The extended form of the FCR approach allows the volar management of partially healed or difficult-to-reduce intra-articular fractures. The pronated proximal radius fragment (∗), dorsal die-punch fragment (ʌ), and volar dye-punch fragment (ψ) are shown.

recent fractures (<2 weeks) with unorganized fracture hematomas and were reduced closed easily under fluoroscopy.

In the remaining 5 extra-articular and 10 intra-articular fractures a more comprehensive debridement of organized fracture callus or direct manipulation of difficult-to-reduce intra-articular fragments or both were necessary to achieve anatomic reduction. An extended form of the FCR approach, which uses the fracture plane for exposure and allows the joint surface to be reduced from within the fracture, was used. This extended approach was performed in 3 steps. First, the radial septum was released (this is a complex fascial structure formed by the intermuscular membrane, the first extensor compartment, and the insertion of the brachioradialis) (Fig. 3). Second, the proximal radial fragment was mobilized by its subperiosteal release, a safe maneuver because this fragment is provided with a dependable endosteal blood supply. Third, the proximal fragment was rotated out of the way and into pronation with the help of a bone clamp (Fig. 4). This rotation exposed the fracture site and permitted the debridement of callus and the manipulation of articular fragments (Fig. 5). When adequate reduction was obtained the proximal radial fragment was supinated back into position, “closing the book,” and fixation finally was applied.

We released the brachioradialis, which forms the floor of the proximal aspect of the first extensor compartment, by dividing its bony insertion after opening the proximal aspect of the tendon sheath. Incomplete release of the sheath prevented tendon subluxation. Releasing the brachioradialis exposed the radial styloid fragment, eliminated a major deforming force, and greatly facilitated reduction. Maintaining the dissection on the subperiosteal plane prevented injury to the radial sensory branches, and the radial artery was protected in its course underneath the first compartment. Soft tissue attachments to the dorsal aspect of the distal fragments always were preserved carefully to ensure their blood sup-

Figure 5. Direct manipulation of articular fragments against the carpus, which acts as a template, achieves reduction.

ply. The most distal fibers of the flexor pollicis longus origin on the proximal radial fragment frequently were released to provide better proximal exposure. Bone graft was applied through this approach when necessary.

Reduction of dorsally displaced extra-articular fractures was obtained by disimpacting the volar cortex of the distal fragment with traction, hyperextension of the wrist, debridement of fracture callus, and use of a small periosteal elevator as a lever. The distal fragment was flexed to obtain an anatomic reduction of the volar cortex, and the reduction was easily maintained because there usually was cortical contact, which was maintained by support from a rolled towel or by temporary fixation of the fracture with a percutaneous K-wire. The reduction of difficult intra-articular fractures was done through the extended FCR approach by first placing the distal fragments in hyperextension and the proximal shaft fragment in pronation. This placement allowed manipulation of the radial styloid, dorsal die-punch, volar die-punch, and central impacted articular fragments against the scaphoid and lunate surfaces from within the distal fracture surface. Temporary fine K-wires could be used to maintain the articular reduction. In the case of severe segmental metaphyseal comminution (A3 or C3 fractures), intercalary fracture fragments first were reduced and fixed with small lag screws to the proximal radial fragment. The restored proximal radius was supinated back on to the radial epiphysis to complete the reconstruction. Reduction was maintained with wrist flexion and a rolled towel support or 1 or 2 K-wires driven from the radial styloid into the proximal radius. Three fractures that had a marked metaphyseal defect with combined dorsal and volar comminution were repaired with bone grafting. Bone grafting was done through the same approach using crushed cancellous allograft bone.

A volar plate specially designed to meet the objectives of this project provided final fixation for all fractures in this series (DVR Plate; Hand Innovations, Miami, FL) (Fig. 6). Because a volar plate stabilizing a dorsally displaced distal radial fracture is unable to act as a dorsal buttress, screw fixation of the distal fragments is likely to fail, and the implant is subject to higher axial and bending forces. To overcome these difficulties this implant provides distal fixed-angle fixation through 2.0-mm subchondral support pegs and obtains proximal fixation through 3.5-mm cortical screws, and the plate is reinforced to withstand the expected higher loads. Mechanical testing was done at the University of Miami/Mount Sinai Orthopedics Biomechanical Laboratory, and the implant was found to be 3 times as strong as other commercially available devices when loaded in a distal radius fracture model with a segmental dorsal defect.

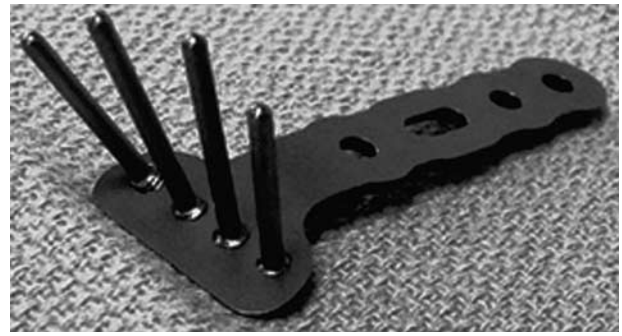

Figure 6. The DVR plate is a strong fixed-angle device designed specifically for volar fixation of unstable distal radius fractures. Distal fixation is through 2.0-mm subchondral support pegs. Proximal fixation is through 3.5-mm cortical screws.

After obtaining proper fracture reduction the plate was applied to the volar aspect of the radius. A cortical screw first was applied to the oval plate hole, fixing the plate to the proximal fragment but allowing proximal or distal adjustment. Next after accurate predrilling with a special threaded drill guide, a peg was inserted into the distal fragment. One peg and one screw offered enough fixation to stabilize most fractures temporarily and allow fluoroscopic inspection; afterward the remaining 3 pegs were applied. Placement of the subchondral support pegs 2 to 3 mm below the subchondral bone is essential for optimal fixation, especially in cases with osteoporotic bone. The design of the implant, provided that anatomic fracture reduction is present, ensures the peg's optimal position. In fractures with intra-articular disruption the radial styloid fragment was fixed by the radial-most peg, which is angled for this purpose. The ulnar-most pegs effectively fixed dorsal die-punch fragments, whereas the 2 central pegs supported centrally impacted fragments. Sizable volar die-punch fragments were buttressed by the distal expansion of the plate. In 2 patients a small volar marginal fragment needed complementary K-wire fixation. These were applied as volar buttress wires. The final steps of the procedure were the insertion of the rest of the shaft screws, suturing the pronator quadratus back in place, and wound closure. Drains

Figure 7. (A) Posteroanterior and (B) lateral views of a dorsally displaced distal radius fracture caused by a fall from a height.

were used in our study at the discretion of the operating surgeon. In 9 patients with persistent median nerve symptoms and in 5 patients with severe swelling and increasing preoperative pain, the median nerve was decompressed through a separate incision. The release was performed according to the surgeon's preference and instrument availability by a formal open technique along the axis of the fourth ray in 6 wrists and an endoscopic technique (Agee) in 8 wrists.

Six patients with severe soft tissue swelling, including the 2 with bilateral fractures requiring elevation and edema control, were hospitalized for an average of 3 days. The remaining 23 were treated as outpatients. Postoperative management included active finger motion and forearm rotation encouraged immediately after surgery and short arm postoperative dressing for an average of 7 days. After the first postoperative visit a removable short arm splint or cast was used for an average of 4 weeks. Rehabilitation was adjusted to the patient's clinical course. Generally patients with substantial wrist swelling and pain recovered digital motion faster if their wrist was immobilized; these patients usually were given a short arm cast. Patients with little wrist swelling and early recovery of finger motion progressed faster if allowed to move the wrist early and were given a removable plastic splint. Functional use of the hand for light daily activities was allowed in patients with good bone quality, as judged by the purchase of the implants in bone during surgery. Patients were referred to formal physiotherapy if they had not recovered full digital motion at the first postoperative visit, had not recovered full forearm rotation at the second visit, or had disproportionate pain and swelling at any time after surgery. Radiographs were taken at every visit. These were scheduled the week after surgery, 4 to 6 weeks after surgery, at monthly intervals as needed, and at late follow-up evaluation.

Figure 8. (A) Posteroanterior and (B) lateral views after fracture healing. Dorsal cortical comminution is still apparent (*). The soft tissue attachments and blood supply to these fragments have been preserved by the volar approach, facilitating fracture healing and avoiding the need for bone grafting.

Results

All cases were accounted for and had an average follow-up time of 12.5 months (range, 53–98 weeks). The average time to radiographic healing was 5.6 weeks (range, 5–8.2 weeks). Seventeen patients who were employed at the time of injury all were able to return to work within 16 weeks of injury. The remaining 12 patients, including 10 elderly patients (>65 years old) and 2 students, returned to their preinjury everyday activities. Nineteen patients attended physical therapy and 10 did rehabilitation by themselves under supervision of the attending surgeon. At final follow-up visit the average volar tilt was 5° (range, 5° dorsal tilt to 12° volar tilt), radial inclination averaged 21° (range, 15° to 26°), radial shortening averaged 1 mm (range, 0–2 mm), and articular congruity averaged 0 mm (range, 0–1 mm) (Figs. 7, 8). Comparison of the first postoperative radiographs with films taken at final evaluation (average, 66 weeks; range, 53–98 weeks) revealed complete maintenance of reduction in all except 2 cases. These 2 cases had slight settling (1 mm of loss of radial length) but no angular displacement and were severely osteopenic cases in which the fixation pegs had been applied >3 mm proximal to the subchondral plate.

At final evaluation all patients had achieved full finger range of motion, that is, they were able to touch the distal palmar flexion crease with finger tips and fully extended fingers. Wrist range of motion assessed by the physician with a goniometer averaged 59° wrist extension (range, 45° to 85°), 57° wrist flexion (range, 40° to 80°), 27° ulnar deviation (range, 15° to 40°), 17° radial deviation (range, 10° to 25°), 80° pronation (range, 65° to 90°), and 78° supination (range, 70° to 90°). Grip strength measured with a Jamar dynamometer in the second po-

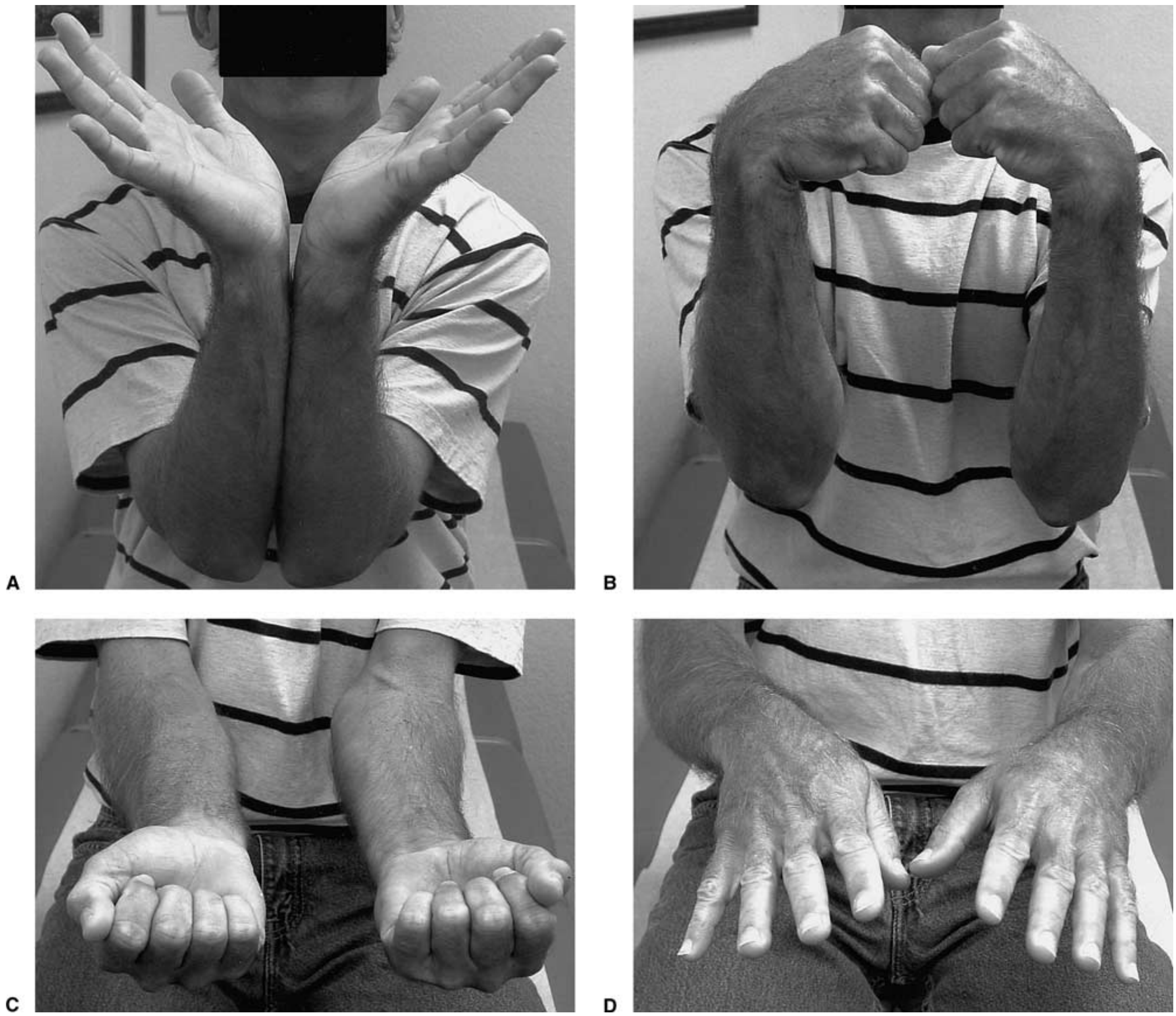

Figure 9. At 12 weeks this patient returned to work with almost symmetric range of motion, (A) extension, (B) flexion, (C) supination, and (D) pronation. (*Figure continues*)

sition averaged 79% of the contralateral side at final evaluation (range, 60% to 110%) (Fig. 9).

Residual pain in the wrist was graded as mild, moderate, or severe. Mild pain was present only at the extremes of the active range of motion of the wrist, and the patient was neither physically nor psychologically disturbed by the pain. Moderate pain occurred during heavy manual labor and caused the patient to be disturbed physically or psychologically or both. Severe pain occurred during activities of daily living and at rest. At final evaluation, 26 patients were free of pain, 1 had mild pain, and 2 had moderate pain. The 3 patients with residual pain had C3 intra-articular fractures. Despite anatomic or almost anatomic reduction of the joint surface (0–1 mm) and normal carpal alignment, additional chondral damage or partial nonrecognized carpal ligament injuries may explain the persistence of discomfort. According to the Stewart scale there were 21 excellent and 10 good results, and according to the Gartland and Werley scale there were 19 excellent and 12 good results.

Complications consisted of 1 case of dorsal tendon irritation from an excessively long peg, which was treated with hardware removal. Of the 9 patients with preoperative median nerve symptoms who had carpal tunnel release, the final neurologic examination (2-point discrimination test, median nerve motor func-

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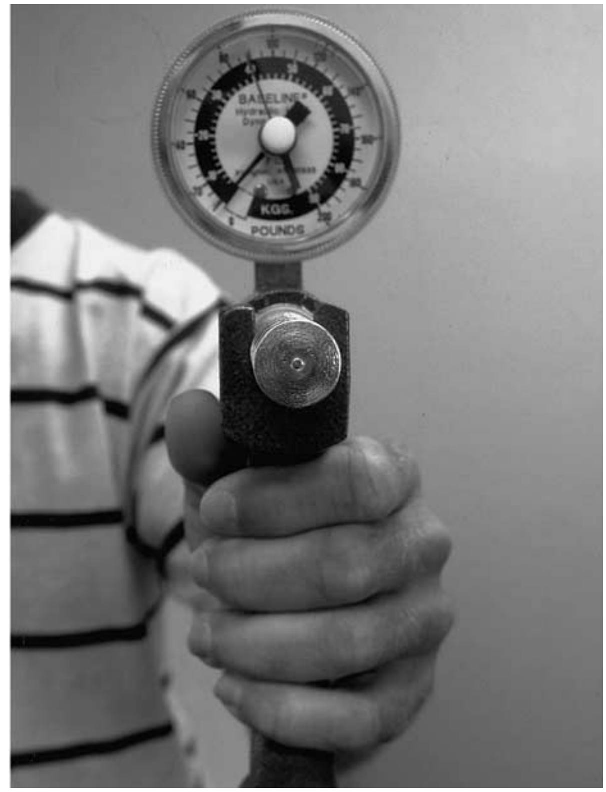

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Figure 9. (*Continued*) At 12 weeks this patient returned to work with 90% of grip strength (E) right and (F) left.

tion) showed complete resolution at the time of late follow-up. The K-wires used in 2 fractures for additional fixation of volar marginal articular fragments were removed 7 and 8 weeks after surgery. Except for the case with the excessively long peg, all DVR plates were left in place. There were no cases of infection, reflex sympathetic dystrophy, or implant failure.

Discussion

The primary goal in treatment of unstable fractures of the distal radius is to achieve optimal restoration of the disrupted anatomy and allow quick return of hand function, while preventing secondary fracture displacement. If the fracture has a displaced intra-articular component, additional efforts to secure and maintain anatomic reduction of the joint surface should be undertaken. If these goals are achieved, better final functional results are to be expected. Early wrist motion has been shown to enhance hand and finger function.[17] Advances to achieve these goals have been sought with modern refinements of internal and external fixation techniques. The major drawback of conventional dorsal plating systems has been irritation, adhesion formation, and ruptures of the extensor tendons as a result of the limited space between the extensor tendons and the dorsal cortex. Investigators using dorsal plating systems have modified the implants to provide low-profile smoother plates or have used double plating systems with smaller implants to diminish tendon irritation.[3,8,9,18] Refinements of fragment-specific limited open reduction of intra-articular fractures[19] with the development of low-profile stable implants that would allow early functional aftertreatment have been undertaken.[20] Direct fixation of the distal radius fragment with nonbridging wrist fixators currently is advocated.[21]

Encouraged by the ease of application of volar plates for volarly displaced fractures and the absence of tendon irritation reported with these techniques, we decided to investigate the possibilities and limitations of open reduction and internal fixation of dorsally displaced distal radius fractures through a volar approach. The volar anatomy of the wrist presents an obvious advantage over the dorsal aspect because there is more space between the volar cortex and the flexor tendons. The pronator quadratus separates these structures, preventing soft tissue complications and allowing application of larger implants. Under some circumstances a volar plate fixing a dorsally displaced fracture is subject to higher loads than a dorsal plate. The bending strength of our plate was therefore augmented by increasing its cross-sectional area. Secondary displacement with loosening and toggling of the distal screws had been observed frequently with the use of conventional T-plates, particularly in osteopenic bone. We selected a device based on the fixed-angle principle and one with subchondral support pegs. These do not depend on the buttress effect, carry all the loads across the fracture site, and effectively fix weak metaphyseal bone.[22] The distal pegs were introduced as closely as possible to the subchondral plate to prevent loss of reduction of the distal fragments as a result of the axial loads generated by early function.

Our preliminary results show that open reduction and internal fixation with a volar fixed-angle device is effective for the treatment of dorsally displaced unstable distal radius fractures. Except for 1 case that was reduced and fixed in 5° dorsal tilt, all other patients had a satisfactory restoration of the volar tilt averaging 5°. Restoration of ulnar inclination and radial length also was highly satisfactory. Absence of settling, secondary angular displacement, and shortening seems to correlate with accurate placement of the distal pins in the immediate subchondral position, especially in patients with osteopenic bone. The function of this implant as an internal fixator in combination with the preservation of the vascularity to the dorsal comminuted area accounts for the rapid restoration of the anatomic continuity of the dorsal cortex, despite the infrequent use of bone graft. Similarly subchondral buttressing of anatomically reduced intra-articular fragments with the fixed-angle principle accounts for the absence of secondary displacement of articular fracture components.

The functional outcomes of our patients are comparable with other reports of open reduction and internal fixation and functional aftercare of dorsally displaced distal radial fractures.[3,8,11] The excellent degree of pain relief we observed correlates with the restoration of extra-articular and intra-articular wrist anatomy, restoration of radial length and the distal radioulnar joint, absence of associated intercarpal ligament injuries and radioulnar joint instability, and avoidance of extensor tendinitis. Except for the one patient with extensor tendon irritation caused by a long protruding peg, the result of faulty technique, there were no tendon-related complications, and all other implants have remained in place. Articular fragments of adequate size involving the radial styloid, the central portion of the articular surface, and dorsal and palmar die-punch fragments could be adequately reduced and fixed. This reduction was done when necessary with the extended FCR approach and intrafocal manipulation of the fragments through the metaphyseal fracture area. Small but crucial volar lunate fossa fragments that required separate fixation could be addressed with the use of volar buttress K-wires. A possible difficulty of this volar technique could be the fixation of a small dorsal marginal fragment of the sigmoid notch that might prove essential for distal radioulnar joint stability, a situation that may require a small separate dorsal incision. Although this implant could be used alternatively for the fixation of volar Barton fractures and extra-articular Smith fractures, it is contraindicated for the less common massively comminuted fractures of the joint surface and in cases with important comminution extending into the distal third of the radius shaft.

This method represents a valuable treatment modality for the most frequent types of unstable fractures of the distal radius in young and elderly patients. The surgical approach is simple and can be extended depending on the complexity of the fracture. The biomechanical features of the DVR plate in combination with preservation of the vascularity of the dorsal comminuted area rendered additional bone grafting rarely necessary except for unusual cases of important dorsal and volar comminution seen with high-energy injuries.

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