Locked Intramedullary Total Wrist Arthrodesis

Jorge L. Orbay, MD¹ Eric Feliciano, BS¹ Carolina Orbay, BS¹

¹ The Miami Hand and Upper Extremity Institute, Miami, Florida

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Address for correspondence and reprint requests Jorge L. Orbay, MD, 8905 SW 87th Avenue Suite #100, Miami, FL, 33176 (e-mail: jlorbay@gmail.com).

Abstract

Total wrist arthrodesis is commonly performed using fixation plates, which can produce soft tissue irritation, often require removal, and limit the ability to position the hand in space. The Skeletal Dynamics IMPLATE is an intramedullary total wrist fusion device designed to provide stable fixation while avoiding the problems associated with plates. Radial and metacarpal locked intramedullary nails are inserted and joined by a connector. Desired hand placement is achieved by selecting the proper connector length and angle, then orienting it appropriately. Fusion mass compression is obtained by virtue of longitudinal threads on the radial nail that allow for length adjustment. Seven wrists in three men and four women were treated with this device and followed for a minimum of 24 weeks. In all cases, local cancellous bone graft was used and the third carpometacarpal (CMC) joint incorporated into the fusion. The median age was 49 (range, 28–71) years. Indications for fusion were two posttraumatic arthritides, three rheumatoid arthritides, one spastic deformity, and one infection. Patients were evaluated before surgery and at final follow-up using the Fernandez pain score and grip strength measurements using a hand-held dynamometer. All patients improved their grip strength and decreased their pain scores. All fusions united, and none of the patients presented dorsal soft tissue problems or required implant removal. One rheumatoid patient required secondary surgery for removal of a retained palmar osteophyte. This device delivers stable fixation, facilitates hand placement, and does not require removal.

Keywords

- wrist
- fusion
- intramedullary
- modular
- arthrodesis

Intramedullary pin fixation of total wrist arthrodesis fails to provide longitudinal or rotational stability and is indicated only in cases of inflammatory arthritis.¹ Plate fixation has been shown to be reliable, delivers a very high fusion rate, and has proven effective for the more difficult posttraumatic cases.^{2,3} Plate fixation does present drawbacks, however. Wrist fusion plates are bulky and can cause discomfort under the skin and extensor tendon irritation. Often, dorsal plates need removal after fusion has been achieved.¹ Also, plates limit the ability to place the hand in space; flat plates can be bent only in one plane, limiting rotational and angular options.

The IMPLATE wrist arthrodesis nail (Skeletal Dynamics, Miami, FL; ►**Fig. 1**) was developed as a less invasive alternative and to overcome the limitations of dorsal plate arthrodesis. It obtains fixation by means of unicortical locking screws

that create compression between the nail and the endosteal surface, providing rigid stability comparable to that of a plate.⁴ The device is placed inside the medullary canals of the metacarpal and the radius, avoiding soft tissue irritation and obviating the need for removal. The implant consists of a rigidly fixed metacarpal nail, a radial nail that can translate longitudinally to compress the fusion site, and a modular connector that comes in several lengths and angles to provide freedom in positioning the hand (►**Fig. 2**). These connectors come in three lengths and four angles (0°, 7.5°, 15°, 22.5°) and are rotationally stable. The desired position of wrist fusion is obtained by first choosing the connector with the appropriate angle. It is then engaged into the ends of the metacarpal and radial nails with the angle of the connector placed in the direction (i.e., rotation) that delivers the appropriate combination of flexion-extension and radioulnar deviation to the

Fig. 1 The IMPLATE wrist arthrodesis device provides fixation by means of unicortical compression screws that generate rigid and stable fixation. The single screw to the right locks the metacarpal nail; the three screws on the left engage longitudinal threads and allow the nail to slide proximally to compress the fusion site prior to being locked.

Fig. 3 Complete decortication of the radiocarpal and intercarpal joints is needed to ensure union. Decortication and fusion of the carpometacarpal (CMC) joint is also necessary to prevent later painful micromotion.

hand. Compression across the fusion site is delivered by the radial nail. Longitudinal slots in this nail present longitudinal threads that engage the locking screws while allowing axial translation. These slots allow up to a centimeter of translation before the screws are tightened; tightening the screws locks the radial nail. This device delivers rigid and stable fixation and allows unrestricted positioning of the hand while avoiding soft tissue irritation and the need for implant removal.

Surgical Technique

The wrist is approached through a standard dorsal incision. The third extensor compartment is opened and the extensor pollicis longus (EPL) retracted radially. The extensor retinaculum is managed as per surgeon's discretion. Wide H-shaped

capsular flaps expose the radiocarpal and intercarpal joints. Wrist flexion facilitates the necessary decortication of the radiocarpal and intercarpal joints (►Fig. 3). Resection of the proximal carpal row can help manage flexion deformity, provide ample material for bone grafting, and avoid ulnocarpal impingement. A notch made on the lunate and scaphoid helps seat the implant. The entrance point for the metacarpal nail is located on the distal capitate, just proximal to the flare for the carpometacarpal (CMC) joint (►Fig. 4). An awl is directed under fluoroscopy toward the third metacarpal canal and removed. A guide-wire is inserted up to the metacarpal head, and cannulated reamers are advanced over it. Either a 4.0 mm or a 4.6 mm metacarpal nail is chosen according to the diameter of the canal. The entrance of the tract and the dorsal surface of the capitate are now worked with the awl or power

Fig. 2 The two nails are joined by a connector (a) that comes in several lengths (b) and angles (c) to provide freedom in positioning the hand. The desired combination of flexion-extension and radioulnar deviation is obtained by first selecting the correct length and angle of connector, then placing the plane of the connector in the direction that delivers the intended position of fusion. Splines make the construct rotationally stable, and setscrews lock it.

Fig. 4 The entrance point for the metacarpal nail is located on the dorsum of the distal capitate, just proximal to the flare for the CMC joint. This delivers a “straight shot” into the metacarpal canal and preserves the proximal pole for fusion.

reamer to seat the nail. It is important to fuse the CMC joint as well; the top 80% of the joint surface must be removed and bone graft applied prior to inserting the nail. The metacarpal nail is then inserted using the nail insertion guide. The distal locking screw is measured using the depth gauge and placed through a small separate incision, or by extending the original incision. The extensor tendons must be protected. The radial nail is located between the lunate and the entry point for the scaphoid fossae and just below the joint line (►Fig. 5). Its tract is started with the awl and expanded with the radial reamers. The short or long nail is selected according to the diameter of the radius and inserted using the guide. The nail is temporarily secured to the radius with a 0.062 transfixing Kirschner wire (K-wire) inserted through the guide. The holes for the locking screws are now drilled and measured and the screws loosely inserted; they must not be tightened yet. The connector is now chosen according to the desired fusion position: neutral facilitates hand dexterity while extension favors power grip.

Fig. 6 The connector has been inserted into the metacarpal nail and is about to be inserted into the radial nail. The plane of the connector was rotated into extension and ulnar deviation to deliver the desired position of fusion in this patient. The connector splines must be fully seated into both nails.

Fig. 5 The entry point for the radial nail is located at the ridge between the lunate and scaphoid fossae and just below the dorsal joint line.

The connector is placed first into the metacarpal nail with the plane (angle) of the connector in the direction that delivers the intended combination of flexion-extension and radioulnar deviation (►Fig. 6). It is imperative that the connector splines fully seat into both nails. Failure to seat is usually due to bony impingement, in which case either bone should be removed or a longer connector chosen. A laminar spreader allows disassembling and adjusting the connector. When the surgeon is satisfied with the position of fusion, the construct is locked using setscrews (►Fig. 7). The transfixion K-wire is now removed to allow the radial nail to slide proximally. Bone graft to augment the CMC and wrist fusion is applied. The fusion site is compressed manually and the radial locking screws tightened serially, like lug nuts (►Fig. 8).

Patients and Methods

All patients that underwent total wrist arthrodesis at our center from October 2010 to March 2012 were treated with this method and were included in the study. Immediately after surgery, elevation, active finger motion, and functional use of the hand were encouraged. Patients were referred to therapy at their first follow-up visit, where they had a removable splint manufactured and rehabilitation was individualized to the patient's specific clinical needs. In general, patients started functional use of their hands by the first postoperative week. Heavy lifting, however, was not allowed until union was radiographically confirmed (i.e., 6–12 weeks). Except for patients with distal radioulnar joint (DRUJ) arthroplasty, active forearm rotation was started at the first week. For those with DRUJ arthroplasty, a sugar tong splint was used until the fourth week. The follow-up protocol was 1 week, 6 weeks, 3 months, and 6 months. All patients underwent clinical and radiographic assessment before surgery and at every visit measuring the following parameters: finger and forearm range of motion, grip strength, and pain according to the Fernandez pain score^{5,6} (►Table 1). Digital motion was assessed by measuring the distance from the fingertips to the distal palmar crease; forearm motion was measured with a

Fig. 7 When satisfied with the position of fusion, the surgeon locks the construct together using setscrews.

goniometer and standard clinical practice; grip strength was measured using a Jamar dynamometer on the second position and compared with the contralateral side. As for the radiographic evaluation, standard plain roentgenograms of the wrist were obtained and bone healing, maintenance of alignment, and radial length were evaluated. Bone healing was defined as the presence of bridging bony trabeculae across the fusion site on both the anteroposterior and lateral views of the roentgenograms.

Fig. 8 Finally, the transfixion K-wire is removed to allow for compression. Bone graft is applied to augment the fusion; the fusion site is compressed manually and the radial screws tightened to lock in the compression.

Results

Patients were followed for a minimum of 24 weeks. There were seven patients with seven wrists, of whom three were male and four were female. No patient was lost to follow-up. The median age was 49 (range, 28–71) years. There were three dominant and four nondominant wrists. Indications for fusion were posttraumatic arthritis in two wrists (none work-related), rheumatoid arthritis in three, a spastic flexion contracture in one, and the sequela of infection in one. Three

Table 1 Degree of residual wrist pain, described by the patients⁵

Degree of Pain	Description
None	Absence of pain in carrying out all activities
Mild	Presence of pain only at extreme effort No physical or psychological disturbance was noted
Moderate	Presence of pain during heavy manual labor Physical or psychological disturbance or both was noted
Severe	Presence of pain during activities of daily living and even at rest

Fig. 9 Posteroanterior (PA) and lateral views of an unstable and painful rheumatoid wrist.

rheumatoid wrists underwent concomitant resection arthroplasty of the DRUJ (**—Figs. 9, 10**). In all cases the third CMC joint was incorporated into the fusion and local cancellous bone graft used. All fusions united between the sixth and twelfth weeks. Most patients recuperated full digital motion by the first week. At final follow-up, all patients were able to reach the palm with their fingertips. Patients without a DRUJ arthroplasty recovered full forearm rotation within the first

six weeks. Forearm rotation increased in patients who underwent distal ulnar arthroplasty (supination improved from an average of 68° to 80° and pronation from 80° to 85°). The Fernandez pain scores improved from preoperative scores of 5 severe pain and 2 moderate pain to postoperative scores of 3 nil pain, 3 mild pain, and 1 moderate pain. Grip strength improved from an average of 58% of the contralateral side to an average of 73% of the contralateral side. Radiographically,

Fig. 10 PA and lateral views after locked intramedullary total wrist arthrodesis and resection arthroplasty of the DRUJ.

maintenance of length, alignment, and integrity of fixation were noted in all cases. No patient complained about pain or discomfort relating to the implant, and no implant required removal. One rheumatoid patient required secondary surgery for removal of a retained palmar osteophyte that was causing flexor tendinitis; after removal through a palmar approach, all symptoms resolved.

Discussion

Traditional methods of fixation for total wrist arthrodesis present drawbacks. Intramedullary fixation utilizing Steinman or Rush pins is notoriously unreliable, as these devices do not provide rotational or longitudinal stability. If these pins are bent to position the hand as desired, they can easily rotate along their longitudinal axis and result in malpositioning. Often, this form of fixation is combined with other methods, such as staples, to overcome this problem.^{7,8} Pin fixation is currently indicated only in cases of inflammatory arthritis, as these heal more readily.

Plate fixation provides great stability in all directions and delivers a high fusion rate. It has improved the results of total wrist arthrodesis in posttraumatic arthritis. On the other hand, plate fixation is a rather invasive procedure that requires the application of a bulky plate on the dorsum of the wrist and hand immediately underneath and adjacent to extensor tendons. Common problems associated with wrist arthrodesis plates are plate discomfort and tendon irritation. The size of the implant results in the skin tenting over the plate and rendering it vulnerable to frequent trauma. This is especially significant when a branch of the radial sensory nerve is involved, is repetitively traumatized, and develops a neuroma. Also, the outcropping muscles of the forearm and the long digital extensors to the index and long fingers course over the fusion plate and are subject to mechanical irritation. These problems are the reason for a significant number of reoperations for hardware removal following plate arthrodesis^{1,3,7}. Because fixation plates are flat and bend only in one plane, it is often difficult to place the hand in the desired position of fusion. Often, when the plate is secured to the dorsum of the radius, a malrotation is induced that limits pronosupination; revising plate placement or twisting the plate may be difficult. At other times a straight plate fixed along the radius to the second or third metacarpal will not provide the desired radioulnar deviation.

It is for these reasons that the technique described here was developed. Intramedullary implant placement prevents soft tissue impingement, as only the flat heads of the locking screws protrude above the bone surface, eliminating the need for hardware removal. Also, the modular nature of the implant provides a virtually unlimited range of positions for wrist fusion. The splined connectors engage in a rotationally fixed manner with the radial and metacarpal nails. This allows the surgeon to fuse the wrist in that rotational position that takes full advantage of the available forearm rotation. The connectors come in several angles from 0° to 22.5°; by rotating the plane of a connector along

the longitudinal axis, the hand can be placed anywhere within a cone in space swept by the connector's angle. By choosing the correct connector angle, the hand can be placed where needed. The technique is easy to learn and requires the same surgical approach as plate arthrodesis with perhaps a smaller incision. It can be performed with a resection of the proximal row as the proximal pole of the capitate is preserved. Because some patients have a significant amount of CMC joint motion, the CMC joint must be fused with this technique to prevent potential loosening of the distal metacarpal locking screw. CMC fusion is also recommended by proponents of plate fixation to prevent later metacarpal fixation problems. The implant provides for compression of the fusion site, as is also recommended with plate fixation. Resection of a small amount of bone from the scaphoid and lunate is necessary for seating the implant; this is of no consequence in achieving union. The nails are fixed to the metacarpal and radius by virtue of unicortical compression screws. These have a broad, flat head that distributes loads over a large surface area and engage the nail by means of threads. When these are tightened, fixation is rigid because of friction between the nail and the endosteal surface, identical in principle to that of a plate.⁹ Rigid fixation delivers less postoperative pain and faster rehabilitation and allows for primary bone healing, which is desired in an arthrodesis.

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Grant information
None

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