Total Wrist Arthroplasty

Abstract

Over the past 40 years, total wrist arthroplasty (TWA) has emerged as a cost-effective treatment option for wrist arthritis. First-generation implant designs have changed tremendously; current devices are designed to enhance wrist stability, provide greater implant longevity, and minimize surgical and postoperative complications. Although arthrodesis remains the standard for surgical management, TWA outcomes demonstrate that the procedure has excellent clinical promise. Additional prospective studies are needed to compare outcomes of wrist arthrodesis with those of TWA with current implants.

First performed by Gluck in 1890,1 total wrist arthroplasty (TWA) continues to evolve. Device design, mechanics, durability, and surgical technique now provide improved functional stability, surgical outcome, and quality of life for patients with wrist arthritis. Total wrist arthrodesis remains the standard of care for management of wrist arthritis, largely because of its low complication rate and durability.2 In 2008, 1,181 total wrist arthrodeses were billed to Medicare, compared with just 179TWAs.3 Nonetheless, in some reports, patients preferred TWA because it preserved wrist motion4-6 and allowed patients to perform certain activities of daily living with ease.7 As TWA continues to evolve and demonstrate improved clinical outcomes, it may soon become a more favorable option for management of wrist arthritis.

History

Modern TWA can be attributed to Swanson, whose Silastic spacer was developed as an adjunct to resection arthroplasty of the radiocarpal joint in patients with rheumatoid, post-traumatic, or degenerative arthritis of the wrist.8 Although early reports indicated that TWA provided moderate pain relief and stability with a limited number of surgical complications,9 further studies described such complications as giant cell synovitis8 and a significant incidence of prosthetic breakage10,11 (Figure 1).

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Second-generation Implants

Second-generation prostheses moved away from Swanson’s one piece Silastic design because of implant fracture, favoring separate radial and carpal components with either ball-and-socket or hemispherical articula-
tion. Meuli’s ball-and-socket design and the implant designed by Volz both incorporated a double-pronged carpal component that was secured to the second and third metacarpals. Both implants initially provided excellent pain relief and patient satisfaction, but later resulted in significant joint deformity, imbalance, and dislocation. The MWP III Total Wrist Prosthesis (Zimmer), Meuli’s revised implant, demonstrated a 26% revision rate, with component loosening cited as the most common complication.

Third-generation Implants

Third-generation prostheses attempted to ameliorate the instability, dislocation, and degenerative properties associated with previous implants by better balancing the soft tissues. The newer designs also reduced the amount of bone resection required for implantation, thereby preserving additional bone stock for future revision, if needed. Design changes include an axle constraint that locks carpal and radial components to prevent dislocation, an ellipsoidal articulating surface to improve joint stability, and screw fixation to prevent carpal component loosening.

The trispherical prosthesis includes a cemented carpal component with one long and one short stem inserted into the second and third metacarpals, respectively. The cemented radial component and spherical head make contact with the carpal component, creating an axle constraint through the articulation to prevent dislocation. A study of 67 trispherical total wrist arthroplasties reported that implant survivability was 97% at 5 years postoperatively and 93% at 10 and 12 years. Often, trispherical implant failure was the result of metacarpal loosening and subsequent perforation of the stem.

The biaxial total wrist implant, which is no longer marketed, included a proximal radial stem with a polyethylene articulating surface and a double-stemmed distal component; the long stem was inserted into the third metacarpal and the short stem was inserted into the trapezoid. The articulating surface was ellipsoidal in shape, which served to reproduce the natural motion and stability of the wrist. Manufacturers elongated the long stem of the distal component after studies revealed a high incidence of distal component loosening. The redesign reduced the implant’s failure rate; however, Takwale et al found no correlation between the length of the metacarpal stem and the need for revision, radiological evidence of loosening, or migration of the carpal component. Rather, the authors found that uncemented fixation was more predictive of eventual distal implant loosening. The most recent review of the BIAx Total Wrist prosthesis (DePuy Orthopedics) reported that implant survivability was 85% at 5 years postoperatively, with a revision rate of 20% at a median follow-up of 9.3 years. Loosening of the distal component was the most commonly cited reason for revision.

Menon developed the Universal Total Wrist Implant (Kinetikos Medical) in 1980. The device is a nonconstrained joint with a Y-shaped titanium radial component that can be inserted with or without the use of cement. The distal component is a titanium oval plate that has three screw holes for fixation to the carpus. A toroid-shaped, convex polyethylene insert locks over the carpal plate and articulates with the concave proximal component. Menon used the implant to treat 31 patients (37 wrists) with symptoms of pancarpal arthritis. By a mean 6.7-year follow-up, the implant was removed in three wrists (8%) due to infection and recurrent dislocation, with arthrodesis subsequently performed. Of the remaining 34 wrists, excellent pain relief was reported in 30 (88%). Twelve of 37 wrists (32%) had complications, with dislocation being the most common.

In a study of 19 patients (22 wrists) with RA who underwent TWA with the Universal Total Wrist Implant, Devibiss et al supported Menon’s early results, noting significant improvement in total arcs of motion (ie, flexion-extension, radial-ulnar deviation, pronation-supination) in all wrists. The complication rate was 14% and was attributed to prosthetic dislocation in patients with highly active RA. Mid- and long-term follow-up of patients with RA who were treated with Menon’s implant design has revealed a revision rate of 50%, most commonly resulting from carpal component loosening.

In a study of 5- and 10-year outcomes of TWAs performed with the Universal implant, Ward et al reported that implant survivability of
the original components was 75% at 5 years and 60% at 7 years.

**Fourth-generation Implants**

Current prostheses require screw fixation to the carpus exclusively and have a porous surface to improve osteointegration if the implant is placed without using cement. Previous implants are approved only for use with cement. However, most fourth-generation implants are uncemented, relying on bone ingrowth instead of cement for fixation, which improves prosthesis durability and reduces bone destruction that may complicate potential revision. Nonetheless, many current-generation implants offer the option to use cement for fixation. Several of these newer implants are currently on the market.

The Universal 2 Total Wrist Implant System (Integra LifeSciences) is a redesigned version of Menon’s third-generation prosthesis (Figure 2, A). The modifications address the articulation instability associated with the original design and include a reduction of the radial component’s inclination, addition of a beaded porous coating to the component surfaces to improve osteointegration, alteration of the carpal plate’s shape from toroidal to ellipsoidal, and a wider radial component. The new system includes a cobalt chrome (CoCr) radial component; a titanium carpal component that can be fixed with two titanium screws; and an ellipsoidal, ultra-high-molecular-weight polyethylene (UHMWPE) articular interface. Distal component fixation requires two screws instead of three because the central stem is inserted into the capitate. Screws are passed through the scaphoid, trapezoid, and second carpometacarpal (CMC) joint radially and through the hamate ulnarly, with care taken to avoid passing the screw through the fourth or fifth CMC joint. The system can be cemented or un cemented based on surgeon preference. Early evaluation of the system using computer modeling predicted improved rotational stability of the wrist, and clinical outcomes have been promising, as well. In a study of 17 TWAs performed in 15 patients, van Winterswijk and Bakx reported complications in two wrists (12%) at a mean 3.8-year follow-up: carpal plate loosening in one wrist, which required plate removal, and one dislocation that was successfully treated nonsurgically. In a study of 21 patients who underwent TWA, Ferreres et al reported no dislocations or revision arthroplasty at a mean follow-up of 5.5 years. Two patients (10%) had radiographic evidence of osteolysis about the second CMC screw that did not progress, and one patient (5%) had loosening of the distal component with significant carpal plate subsidence. In a study of 30 patients who underwent un cemented TWA with a Universal 2 prosthesis, carpal plate loosening was reported in two patients (7%) at an average 5-year follow-up.

The RE-MOTION Total Wrist System has three components: a radial stem, a carpal plate, and a carpal ball (Figure 2, B). The CoCr radial and carpal components are coated with porous titanium to promote osteointegration. The distal stem of the carpal component inserts into the capitate and may penetrate to the base of the third metacarpal. The plate is fixed to the carpus via two CoCr screws inserted through the scaphoid, trapezoid, and base of the second metacarpal on the radial aspect and through the hamate on the ulnar aspect. The UHMWPE carpal ball snap fits onto a rounded peg on the proximal surface of the carpal plate and facilitates primary articulation between the radial and carpal components. Secondary articulation between the rounded peg on the carpal plate and the polyethylene ball allows 10° of rotation that may provide additional range of motion and dampen torque, thus reducing the risk of implant loosening. In a pro-

![Photographs demonstrating three current-generation total wrist implants. A, Universal 2 Total Wrist Implant System (Integra LifeSciences). B, RE-MOTION Total Wrist System (Small Bone Innovations). C, Maestro Total Wrist System (Biomet). The radial and carpal components have a porous coating and can be secured with carpal screw fixation. (Courtesy of Arnold-Peter C. Weiss, MD, Providence, RI.)](image-url)
spective study with a 32-month follow-up, 20 wrists were treated with the RE-MOTION system. Loosening of one carpal and one radial component was reported but did not require reoperation. Additionally, no dislocations were reported, and there was overall improvement in clinical scores.34

The Maestro Total Wrist System, the most recent of the fourth-generation wrist implant designs, includes a titanium alloy radial stem, a CoCr and UHMWPE radial body, cobalt alloy carpal plate and head, a titanium alloy capitare stem, and two titanium alloy carpal screws (Figure 2, C). The radial and capitare stems are coated with a titanium plasma spray to promote osteointegration. The capitare stem and two screws are used to secure the carpal component. The capitare stem also acts as a proximal screw attachment for the convex carpal head that articulates with the concave polyethylene radial component. Both the capitare stem and modular radial stem are cemented to their attachments.35 Although outcomes data are limited, Dellacqua35 reported on 19 patients treated with the Maestro system. At a mean follow-up of 27 months, all patients had satisfactory pain relief and improved motion. Overall outcome was rated good to excellent in 57% of patients and fair in 43%.

Management of Arthritis

Patients with pancarpal arthritis typically present with restricted and painful wrist range of motion that limits performance of activities of daily living. Nonsurgical management includes a trial of splinting, activity modification, and anti-inflammatory medication or corticosteroid injection. Continued pain with limited ability to perform activities of daily living despite nonsurgical treatment measures are an indication for TWA. Physical examination of the wrist focuses on active range of motion and ensures appropriate neuromuscular control and active use of the wrist and hand. Range of motion is typically limited, with decreased strength and pain reported throughout range of motion. The presence of soft-tissue contractures or instability should be noted because they can lead to limitation of motion or chronic imbalance and instability following a TWA.

PA and lateral radiographs are obtained to detect the presence of bony deformity and the extent of osteopenia or bony erosions. The use of autograft or cement may be planned to augment carpal component fixation based on the adequacy of bone stock. Radiographic imaging is also used for preoperative templating of the radial and carpal components as well as placement of radial and ulnar carpal screws.36

Surgical Considerations

The ideal surgical candidate for a TWA has unremitting pain associated with pancarpal wrist arthritis that is refractory to nonsurgical management, maintains a low-demand lifestyle, and is interested in a motion-preserving treatment option that will allow performance of activities of daily living. Traditionally, patients with RA have been ideal candidates for TWA because of their sedentary lifestyle; however TWA is increasingly offered as a treatment option to patients with osteoarthritis or posttraumatic arthritis if they are able to maintain certain activity restrictions (eg, avoiding heavy lifting, hyperextension loading of the wrist, vigorous sports). TWA is not recommended in young and active patients who have activity levels that would place increased stress on the wrist implant.36,37 In less active patients, particularly the elderly and those who are not reliant on the upper extremity for ambulatory support or transfers, TWA may be an appropriate option to reduce pain and maintain a modest arc of motion.36

As with all joint arthroplasty, adequate bone stock is necessary to support a TWA. Close attention to the severity of bony erosions, osteopenia, and joint deformity is necessary to ensure that both carpal and radial components can be fixed adequately and to avoid premature implant loosening. Contraindications to TWA include a prior surgical procedure that would limit implant fixation into the carpus, soft-tissue infection, septic wrist joint, or insufficient neuromuscular control. Relative contraindications include inadequate soft-tissue balance and inadequate bone stock to support the implant components.36

Surgical Technique

The basic principles for TWA described here can be applied to TWA with any newer, fourth-generation implant. The procedure is performed on a hand table using either an axillary block or general anesthesia with an upper arm tourniquet. Preoperative antibiotics are administered to the patient.

The surgical approach is similar to that described by Menon.27 A dorsal longitudinal incision is created in line with the third metacarpal and is extended approximately 4 cm proximal to the radiocarpal joint. Skin flaps are created, with care taken to avoid injury to the cutaneous branches of the radial and ulnar nerves. The extensor carpi ulnaris compartment is opened, and the retinaculum is elevated radially to the septum between the first and second compartment. The retinaculum may be opened in a step-cut fashion with radial-
ulnar-based flaps created as needed to augment capsular closure later.
If a Darrach procedure is planned in the setting of an arthritic distal radioulnar joint or RA, the capsule overlying the distal ulna is incised and an osteotomy is performed (Figure 3, A). A tenosynovectomy can be performed if needed following evalu-
ation of the extensor tendons. The wrist capsule is opened using a distally based flap, with the radial and ulnar capsules incised at the floors of the first and sixth compartments. The wrist is hyperflexed, and a synovectomy is performed as needed. Before or after carpus preparation, the distal radius is prepared according to the technique for the implant being used. The radius is cut, broached, and trialed according to the preoperative plan, with proper protection in place to minimize the risk of injury to the volar radiocarpal ligaments and to avoid detachment of the ligaments by excising their origins off the distal radius (Figure 3, B and C). The carpus can then be prepared. For modern implants, the technique for preparation of the carpus varies; however, in general, it is prepared with a cut made perpendicular to the long axis of the forearm (Figure 3, D). Kirschner wires can be used to stabilize the carpal bones and minimize mobility before carpal preparation.

After confirming that the orientation of the carpal cut is perpendicular to the third metacarpal and forearm, a sagittal saw is used to complete the cut while the volar capsule is protected (Figure 3, E). After the trial radial component is reinserted, a trial polyethylene carpal component is inserted and the wrist is reduced. Range of motion, soft-tissue balance, and prosthesis stability are now examined. Approximately 35° of flexion and 35° of extension are expected, with moderate soft-tissue tightness at full extension. If extension is limited, it may be caused by a tight volar capsule, and extending the distal radius cut an additional 1 to 2 mm may allow for increased extension.

In the setting of volar instability, the volar capsule should be inspected to determine whether it is detached; if so, the capsule can be sutured back onto the radius. If the capsule is intact, a larger polyethylene component should be inserted until the soft-tissue balance allows for stable range of motion. If flexion contracture of the wrist is noted preoperatively, stepwise elongation of the wrist flexor tendons may be necessary to achieve balance. Once balance is achieved, the trial components are removed and final components are placed (Figure 3, F). In implants that require screw fixation of the carpal component, screws can cross the second CMC joint, but should not cross the mobile fourth or fifth CMC joint. The intercarpal articular surfaces may be removed, and autograft can be placed just before final placement of the carpal component to enhance carpal fusion. Although some investigators have used cement for carpal fixation, we have achieved successful results with low revision rates by placing the carpal component without using cement.

The dorsal capsule is closed proximally through the dorsal distal radius, and the radial and ulnar capsulotomies are closed, as well. If an insufficient amount of capsule is available to allow for closure during full wrist flexion, the distal limb of the extensor retinaculum is passed underneath the extensor tendons and used to augment capsular closure. The remaining retinaculum is closed over the extensor tendons, and a drain is placed subcutaneously before skin closure. A bulky dressing is applied and the wrist is splinted for 1 week. The splint is then discontinued and a short-arm cast is used for 3 weeks. When the cast is removed, the patient can begin a hand therapy regimen to regain motion and strength.

Radiographs obtained at the first postoperative visit can be used to confirm adequate alignment of the implant (Figure 4). Activity is restricted to avoid increased stress on the implant. If good implant stability
is noted intraoperatively, we immobilize the wrist for a total of only 2 to 3 weeks postoperatively.

**Clinical Outcomes**

Although evidence indicates that arthrodesis may be superior to TWA in alleviating pain with less risk of complications, continued improvement in implant design and technique has made comparison difficult. In a systematic review of literature comparing TWA and total wrist arthrodesis outcomes, Cavaliere and Chung found that 91% of patients who received a third-generation implant had no pain or mild pain at follow-up compared with 98% of patients who underwent arthrodesis. The major complication rate among patients with third-generation TWA implants was 21% compared with 13% of patients treated with arthrodesis. In terms of patient satisfaction, 91% of TWA patients were satisfied with their outcome versus 93% of those treated with arthrodesis. Although fourth-generation implants show clinical promise, literature on long-term outcomes remains inadequate.

In several studies with an average follow-up of 3.8 to 5.1 years, patients who underwent TWA with the Universal 2 implant showed improvement in pain scores, with 81% to 100% reporting mild to no pain; an average complication rate of 5% to 7%; and satisfaction rates ranging from 95% to 100%. Reported arcs of motion following TWA with a Universal 2 implant are similar, with average combined flexion/extension of 67° or 68° and combined radial/ulnar deviation ranging from 24° to 27°.

A prospective series of 20 wrists managed with TWA using the REMOTION system showed overall clinical improvement and no dislocations at a 32-month follow-up; component loosening was found in 2 wrists (10%) but did not require reoperation. A study of 19 TWA patients who received the Maestro system reported satisfactory pain scores, improved motion, and overall outcomes of good to excellent in 57% of patients at an average follow-up of 27 months. Improved outcomes may be due to the improved design of fourth-generation implants as well as less reliance on cement fixation; however, additional studies are needed.

**Complications**

Complication rates of TWA implants vary significantly based on the generation of the design and the method of fixation. Although Swanson's first-generation implants caused reactive synovitis and had a high incidence of prosthetic fracture, second-generation implants failed because of the lack of appropriate soft-tissue balance and attempted fixation of the carpal component in the metacarpal shafts. Third- and fourth-generation implants have achieved better soft-tissue balance; however, some long-term studies show failure through either dislocation or aseptic component loosening. Although aseptic loosening of both the radial and carpal components occurs from mismatch of the elastic modulus of the implant and bone, loosening of the carpal component from presumed micromotion can cause radiographic lucency, pain, and TWA failure.

The incidence of radiographic loosening of the carpal component and secondary pain continue to decrease with the use of modern TWA implant designs, and our own results using uncemented implants suggest that this leads to a decreased incidence of both implant loosening and dislocation. The focus of revision associated with loose or failed implants is to improve carpal component fixation, which often requires cement fixation because of the loss of bone stock. Wrist arthrodesis is recommended in the setting of unsalvageable TWA failure with significant bone loss or reconstruction following implant removal for uncontrolled infection. Traditionally, union rates in this setting have been inferior to those of primary wrist arthrodesis; however, satisfactory results have been reported with the use of either iliac crest or femoral head autograft, local host bone, or allograft.

**Cost**

In a cost-utility analysis of TWA and total wrist arthrodesis, Cavaliere and Chung reported that the total cost of TWA and arthrodesis (adjusted for current complication rates and the associated additional cost) was $18,478 and $6,607, respectively. This includes the cost of a typical implant and fees for the surgeon, anesthesia, and ambulatory surgery center based on 2008 Medicare CPT codes (and adjusted according to the authors’ geography). The authors also examined the incremental cost-utility ratio in patients with a rheumatoid wrist who underwent nonsurgical treatment, total fusion, or TWA. The authors found that arthroplasty patients gained the greatest number of quality-adjusted life years (QALYs), whereas nonsurgical patients gained the least number of QALYs. Using the previously mentioned total respective costs to calculate the incremental cost-utility ratio, Cavaliere and Chung found that arthrodesis and TWA are cost-effective and that TWA has only a small incremental cost per QALY over the more widely accepted procedure, total ar-
throdesis. They concluded that TWA should be considered for management of the rheumatoid wrist and should not be considered cost-prohibitive.

**Summary**

Over the past four decades, variable outcomes have been reported in patients with pathologic wrists treated with TWA using several generations of wrist implants. Widespread application of the procedure among surgeons has been slow to develop, largely because of high complication and failure rates associated with early-generation implants. Although current fourth-generation implants have shown clinical promise and are a cost-effective option, additional outcome studies and prospective randomized trials are needed to compare TWA with total wrist arthrodesis for management of pancarpal arthritis.

**References**

*Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 2 and 40 are level II studies. References 4-16, 18, 19, 21-30, 32, 34, 38, and 39 are level IV studies. References 17, 20, and 35-37 are level V expert opinion. References printed in bold type are those published within the past five years.*


