Total Wrist Arthroplasty

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Although the wrist was one of the first joints treated by prosthetic replacement, the evolution of total wrist arthroplasty has been much slower than hip and knee arthroplasty. The lower prevalence of symptomatic wrist arthritis and the availability of other acceptable treatments, such as limited or complete arthrodesis, have dampened the interest for the design and manufacturing of wrist implants. In addition, the small size and complexity of the wrist have been obstacles to engineering. Small components place high demands on materials, resulting in more rapid wear and implant breakage. Attempts to simulate the natural, multi-articulated wrist and its normal motions using complex designs, such as multiple bearing surfaces, resulted in instability, loosening, and implant breakage.1-3

Historical Perspective

Swanson designed the first wrist implant, having widespread commercial distribution in the United States. The implant was made of silicone, acting as a flexible spacer, with wrist motion resulting from a combination of implant flexibility and pistoning within the medullary canals of the radius and metacarpal.4 Early results generally were gratifying with good pain relief and an acceptable range of motion; however, restoration of wrist height and hand balance was unpredictable. Longer follow-up revealed subsidence within the bone and a high incidence of implant breakage, reaching 52% at 72 months (Figure 1).2,5-6 Silicone synovitis became an important issue later, although the incidence was lower than with carpal implants.7

Early articulated total wrist prostheses incorporated bearings for joint motion, various stem designs for fixation in the radius and carpus, and different degrees of constraint.8-14

Figure 1: Radiograph 5 years postoperatively reveals silicone wrist implant breakage.

Figure 2: Ulnar imbalance with a Voltz prosthesis.
Carpal component loosening, periprosthetic bone resorption of the distal radius, and wrist imbalance were serious problems (Figure 2). In an attempt to reduce wrist imbalance and distal component loosening, the Bi-axial (DePuy, Warsaw, Ind), Trispherical (Osteonics, Allendale, NJ), revised Volz (Howmedica, Rutherford, NJ), and revised Meuli (Sulzer Orthopaedics Ltd, Winterthur, Switzerland) were each designed to more accurately reproduce normal wrist kinematics. Early results were mixed, with persistent loosening, subsidence, and imbalance.

Because distal component loosening continued to plague the longevity of wrist replacement, in 1980, Menon developed a new approach to implant fixation within the carpus. Previous designs relied on fixation in the metacarpal canals, usually with cement, and were associated with a high incidence of loosening, metacarpal erosion, and implant penetration. The distal component of the Universal total wrist system (Kinetikos Medical Inc [KMI], San Diego, Calif) is fixed by a short central stem into the capitate and two deep-threaded screws into the radial and ulnar aspects of the carpus. The fixation is combined with an intercarpal arthrodesis to provide long-term, solid bony support. Because the distal component supports the entire carpus, proximal migration of the first and fifth rays is prevented. The radial component is inclined to replicate the slope of the normal distal radius. Soft-tissue balancing can be adjusted by variations in polyethylene sizes. These design features offered better wrist balance and more normal load transfer. The oblique osteotomy of the radius and proximal osteotomy through the carpus result in minimal bone resection and

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wrist capsule preservation. Because the resection is limited, more bone stock is available to salvage the wrist by arthrodesis if the prosthesis fails.

The articular surface of the Universal distal component is shaped like a toroid (donut), which is intended to match the contour of the proximal carpal row.22 The long-term fixation of this prosthesis proved to be substantially better than previous prosthetic designs. Dislocation, however, was a major problem, with a 9% frequency. Overall experience with different designs during the past three and half decades strongly suggests specific criteria optimize clinical results (Table).

Universal2 Total Wrist

Introduced in 2002, the Universal2 Total Wrist System (KMI) includes the positive features of the first generation Universal prosthesis along with several enhancements and changes consistent with the specifications listed in the Table. Using both computer modeling techniques and laboratory testing, an elliptical-shaped distal articular surface was designed to create an optimum balance between motion and stability. The shape provides consistent congruity and centralization of the contact area on the polyethylene over the entire range of prosthetic motion. The result is low stress and wear on the polyethylene and better articular stability without creating a fully constrained joint (Figure 3).22 The shape also allowed a broad anteroposterior articular surface dimension for additional stability, including the potential for early active range of motion.

Beaded porous coating is applied to the radial and carpal components for possible fixation by osseous integration. Uncemented fixation is thus possible when considered appropriate by the surgeon. The articular surfaces are offset volarly relative to the stems to improve wrist extension, further increase stability, and better match the cut surface of the radius for close capsule healing around the implant. The radial component stem is minimally flared to preserve the biologically active metaphyseal bone for osteointegration. It also is long and straight to obtain an initial mechanical press fit. An option to preserve the distal ulna exists, which is more relevant in the non-rheumatoid patient for improved strength and reduced morbidity. Logical and efficient instrumentation ensures accuracy and reproducibility.

Indications

The objective of total wrist arthroplasty is to maintain wrist motion while relieving pain and correcting deformity. Patients who are afflicted by arthritis within multiple upper extremity joints and those with specific needs or desires have the greatest need for maintaining wrist motion. Patients with rheumatoid arthritis who have bilateral wrist arthritis and elbow and shoulder involvement are good candidates. Studies have found that individuals who have had a wrist fusion on one side and total wrist arthroplasty on the other prefer the arthroplasty.23 Basic activities of daily living such as perineal care, fastening buttons, combing hair, and writing are made easier if some

<table>
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<th>TABLE</th>
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<tr>
<td>Specifications for the Optimum Total Wrist Prosthesis</td>
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<table>
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<tr>
<th>Distal Component Fixation</th>
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<tbody>
<tr>
<td>Primarily within carpus (avoid metacarpal canals)</td>
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<tr>
<td>Intercarpal fusion (solid foundation for component)</td>
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<tr>
<td>Uncemented (porous coated in-growth/screws)</td>
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<table>
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<tr>
<th>Articulation</th>
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<tr>
<td>Broad (resists imbalance)</td>
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<tr>
<td>Ellipsoidal (balance of constraint and contact area)</td>
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<tr>
<td>Semi-constrained (resists dislocation/early motion)</td>
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<table>
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<th>Proximal Component</th>
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<tr>
<td>Replicate radius (optimizes motion and load transfer)</td>
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<tr>
<td>Minimize bone resection (preserves soft-tissues)</td>
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<tr>
<td>Uncemented (porous coated in-growth, press-fit)</td>
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To be considered for total wrist arthroplasty, patients should have a functional hand, active wrist extensor power, adequate bone stock, and no infection.
wrist motion is preserved.\textsuperscript{24,25} Patients with post-traumatic or degenerative osteoarthritis may also be candidates for total wrist arthroplasty if they are willing to comply with permanent activity restrictions.

To be considered for total wrist arthroplasty, patients should have a functional hand, active wrist extensor power, adequate bone stock, and no infection. Total wrist arthroplasty is contraindicated in rheumatoid patients with highly active synovitis, as the risk of loosening is substantially increased. Young active patients and individuals with high physical demands are not good candidates.\textsuperscript{26,27}

Preoperative Planning

Patients with rheumatoid arthritis should have a full preoperative evaluation including the cervical spine. Total hip or knee replacement should be performed prior to wrist arthroplasty to prevent weight bearing on the wrist prosthesis. Wrist replacement may be performed before or after shoulder or elbow surgery but prior to hand surgery to improve hand balance and optimize rehabilitation of the digits. To reduce the risk of infection and wound healing problems, temporarily stopping medications such as methotrexate and other immune-modulating medications should be considered after consultation with a rheumatologist. Decreasing or eliminating nonsteroidal anti-inflammatory agents for at least 10 days preoperatively and 5 days postoperatively is recommended to reduce the risk of bleeding complications.

Radiographic assessment of bone quality, erosions, carpal collapse, carpal ulnar translation, volar subluxation, and the distal radioulnar joint will prepare the surgeon for potential technical difficulties. Implant size and alignment within the bones can be predicted using radiographic templates. In the posteroanterior view, the radial component should not extend beyond the edge of the radial styloid. The carpal component should not extend >2 mm over the margins of the carpus at the osteotomy. In general, the smaller implant should be selected when deciding between two sizes.

Operative Technique

A dorsal longitudinal incision is made over the wrist in line with the third metacarpal, extending proximally from its midshaft. The skin and subcutaneous tissue are elevated together off the extensor retinaculum, with care to protect sensory branches of the radial and ulnar nerves. The extensor carpi ulnaris compartment is opened along its volar margin and the entire retinaculum is elevated radially to the septum between the first and second extensor compartments. An extensor tenosynovectomy is performed if needed. The extensor carpi radialis brevis must be intact or reparable and

Figure 4: Exposure of the distal radius and carpus through a radially based retinacular flap and distally based capsular flap.

Figure 5: Guide rod placed to align cutting block and broach for radius resection.

Figure 6: Radial cutting block applied to resect the articular surface at the proper angle.
The extensor carpi radialis longus should be functional. The dorsal wrist capsule is raised in continuity with the dorsal distal radial ulnar joint capsule and periosteum over the distal 1 cm of the radius as a distally based rectangular flap. The sides of the flap are made in the floors of the first and sixth extensor compartments. The brachioradialis and first extensor compartment are elevated subperiosteally from the distal styloid (Figure 4). The wrist is fully flexed to expose the joint. Synovectomies of the radiocarpal and distal radioulnar joints are performed when needed. If the distal radioulnar joint is arthritic or the distal radius is severely eroded, the distal ulna is resected through its neck.

The radial alignment rod of the instrument set is inserted through a hole 5 mm below the dorsal rim of the radius and just radial to Lister’s tubercle. Fluoroscopy confirms central placement of the rod in the canal (Figure 5). The guide bar and cutting block are mounted on the rod and positioned to remove only the articular surface (Figure 6). Pins are inserted through the block and the osteotomy is completed. The guide rod is reinserted and the appropriate size broach is mounted on the rod. Aligning the broach with sigmoid notch and dorsal rim of the radius, the broach is driven into the radius until its collar becomes flush with the cortex (Figure 7). A trial radial component is inserted. The scaphoid and triquetrum are temporarily pinned if they are mobile to facilitate the carpus osteotomy. The lunate is excised by sharp dissection or rongeur. Using the drill guide, a hole is made in the center of the capitae. The guide bar and cutting block are inserted and positioned to resect the proximal 1 mm of the hamate, a small amount of the capitate head, and approximately half of the scaphoid and triquetrum (Figure 8). The trial component is inserted and the screw holes are made using the drill guide (Figure 9). The trial screws and radial and poly trial components are inserted. The prosthesis typically is stable and should demonstrate approximately 35° of flexion and 35° of extension with modest tightness at full extension.

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mately 35° of flexion and 35° of extension with modest tightness at full extension. If soft-tissue tension is tight, it is adjusted by step-cut tendon lengthening of the wrist flexors or further resection of the radius. If tension is insufficient, the palmar joint capsule may need to be repaired to the rim of the distal radius or a thicker polyethylene may be required.

Prior to implanting the final prosthesis, three horizontal 3-0 polyester mattress sutures are placed through small bone holes along the dorsal rim of the distal radius for eventual capsule closure. If the ulnar head was resected, sutures also are placed through the dorsal neck. The articular surfaces are removed from the triquetrum, capitate, hamate, scaphoid, and trapezoid and previously resected bone is packed in the spaces to achieve an intercarpal arthrodesis. The final implants are impacted in place and the screws are inserted tightly. The capsule repairs to completely enclose the implants. The extensor retinaculum is repaired, leaving the extensor carpi radialis longus and brevis and the extensor pollicis longus superficial.

Postoperative Management

The postoperative dressing and plaster splint are removed on day 3 and a supervised exercise program is begun, including gentle active flexion, extension, radial and ulnar deviation, pronation, supination, and digital motion. Strengthening is added at week 4. The patient is advised against impact loading of the wrist and repetitive forceful use of the hand.

Results

In Menon’s first report of 37 Universal prostheses with a mean follow-up of 6.7 years (range: 4-10 years), no case demonstrated radiographic evidence of distal component loosening. In a further follow-up study including 57 implants, carpal component loosening was not reported. Subsidence of the radial component was observed but was not progressive or symptomatic. Similar to other prostheses, the Universal implant provided consistently good pain relief (90%) and a functional range of motion. Average postoperative motion was 36° extension, 41° flexion, 7° radial deviation, and 13° ulnar deviation. Dislocation was the most common complication, with 5 occurring in the first 37 cases and a total of 6 among the 57 cases in the later follow-up.

Dislocation continued to occur with a 9% overall incidence. Distal component loosening occurred in 4 patients, all of whom had persistently active synovitis and failed to achieve...
an intercarpal fusion resulting in lack of solid bony implant support.

Early results with the Universal2 prosthesis in 25 patients (20 women and 5 men) operated by 2 surgeons, have been excellent. Twenty patients had rheumatoid arthritis, 2 post-traumatic arthritis, and 3 osteoarthritis. All prostheses were implanted un cemented. Results revealed excellent fixation with an average of 37° flexion, 33° extension, 22° ulnar deviation, and 9° radial deviation. Pain relief was rated good by all patients but mild ulnar-sided wrist discomfort persisted in 5 patients. Pain relief and motion often did not reach their maximum improvements for 6 months. Average DASH scores improved 20% and Patient Related Wrist Evaluation scores improved 35%. Radiographic implant loosening was not noted, but 1 patient with osteopenia had 3 mm of subsidence, which plateaued. No dislocations or implant loosening or revisions have occurred (Figure 10). An additional surgeon survey found no reported dislocations or revisions in >125 wrists implanted in the United States.

Discussion

Revision arthroplasty, arthrodesis, and resection arthroplasty are options for salvaging a failed total wrist arthroplasty due to imbalance, loosening, or instability. Revision arthroplasty is an option for aseptic loosening if adequate bone stock exists or if bone grafting is feasible. The thickened capsule must be widely released to allow wrist flexion and extraction of the components. If substantial subsidence is present, lengthening of the wrist flexors and extensor tendons may be required. Iliac crest bone graft may be needed to fill defects and re-establish the basic architecture of the carpus.

When using the Universal2 prosthesis for revision, the graft can be transfixed to the remaining carpus using the carpal component fixation screws. The decision to perform a revision depends on the integrity of the bone and soft tissues. Patients with poor bone stock, inadequate capsular tissue, or particulate synovitis are not candidates for revision arthroplasty. An established infection should be treated by implant removal and primary or delayed conversion to an arthrodesis.3,32

References