Arthroplasty of the Wrist:
Part I Radio-Carpal Joint

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This review will focus on newer arthroplasties developed for use in the wrist and intended to recreate normal anatomy and biomechanics. The surgical implications of these new implant designs are quite different from the traditional silastic arthroplasty in which the implant acts as an internal splint allowing the soft tissues to rebalance. Whilst silastic joint replacement certainly has an important role generally in the management of inflammatory arthropathy with anatomical implants, attention must be paid to soft-tissue attachments, bone resection and alignment to avoid issues of instability, maximise movement and provide longevity. In this review, we would consider surgical anatomy, biomechanics, implant design, reported outcomes and complications for implants of the radio-carpal (wrist) and distal radio-ulnar joints (DRUJ). Readers are directed to the implant manufacturers’ literature for information on implantation technique.

Radio-carpal (wrist joint)

The development and usage of total wrist arthroplasty has slowly followed that of the other major joints. However, even today it has not found widespread acceptance in that most surgeons prefer to recommend arthrodesis to their patients. Certainly, arthrodesis simply performed does not have the same number of potential long term complications. However, with the advent of a newer prosthesis, attitudes are generally changing, particularly for patients associated with bilateral inflammatory of the wrist. Indeed, a number of recent articles have demonstrated high patient preference for arthroplasty.

Surgical Anatomy

Like all arthroplasties, every wrist replacement design is constrained by anatomy. For the distal radius there are a number of bone- and soft tissue-limiting structures. Firstly, to align the base of any component perpendicular to the shaft seems appropriate both to maximise the surface area of contact and evenly distribute the forces transmitted. To do this optimally requires the use of an alignment jig as well as a stem on the implant. If you consider the anatomy of the radius, this obviously entails the stem being offset in a more radial and, to a lesser degree, dorsal position. Secondly, the level of cut is important as for surgical ease this should be at the level of the most proximal articular surface which, in most cases, even for the severe rheumatoid, is the lunate fossa. Obviously, however, this can be quite proximal if there is a lot of erosion resulting in significant removal of bone as well as a disruption of the distal radio-ulnar joint. An alternative to this would be bone grafting of the defect or modifying the prosthesis, allowing it to fill the defects. Neither of these options, however, is in common usage.

For the carpus the principal if not insurmountable difficulty for designers is the number of bones and articulating surfaces. Obviously, it is not possible to fix a prosthetic satisfactorily to any one of these small bones or, indeed, replace each individual bone. As a consequence, virtually all designs use the second and third metacarpals for stem fixation, the carpal bones themselves either being resected to a large degree or fused into one mass. For the former, whilst excision of the lunate and triquetrum is relatively straightforward, as is removal of the head of a capitate, the distal pole of the scaphoid can be difficult to excise given its ligamentous attachment and the proximity of vital structures on the volar side of the wrist. Obviously the more bone that is removed the bigger the space and the larger the implant to fill the gap. If attempts are made to fuse the bones patently, this requires additional procedures and methods of fixation, usually wires or screws. At this time, whilst this technique seems to have some advantages, it is not known whether the fusion actually occurs in all cases or indeed how effective it is in the long term.

Biomechanics and Implant Design

The biomechanics of the wrist joint is both complex and as yet incompletely understood. This difficulty is compounded by the number of small bones in the wrist that make up the various articulations. As it will be appreciated for arthroplasty,
it is not possible to reconstruct the wrist in this fashion and, as a consequence, significant assumptions have to be made. What is known, however, and is of particular importance to arthroplasty are the forces transmitted through the wrist and the movements that normally occur. For load distribution, dependent on variance, it is generally acknowledged that between 70% to 80% or more of the load passes through the radius and 10% to 15% through the ulna. This has significant implications for total wrist arthroplasty design in that it would be difficult to design an implant to replace both the distal radius and ulna. Effectively all implants currently available replace the distal radius and not the ulna. The importance of removing the head of the ulna if diseased is obvious, although plainly this has a potential deleterious effect on ulnar stability, as all ulna based ligaments are effectively divided. What effect this has on the long term survivorship of a radio-carpal arthroplasty remains, however, unknown.

For the carpus, research has again indicated that approximately 60% of load passes through the scaphoid and 40% through the lunate fossa. At the mid-carpal joint 40% passes through the capitohamate row, which is further divided between the scapho-capitate and 20% through the scapho-trapezium/ trapezoid. The relevance of this with regard to implant design is that, for most implants currently available, the majority of the scaphoid and the whole of lunate and triquetrum are removed to allow the implant to be inserted. Effectively, therefore, forces are transmitted, predominantly from the radius to the capitate, hamate and trapezoid and then secondarily through the respective carpo-metacarpal joints. Even then the overall contact area is probably no more than 40% of the available joint surface.

With regard to movement the normal flexion-extension arc can vary from 140°-155°, movement being almost equally split between the radio-carpal and mid-carpal joints. The radio-ulnar deviation arc can range from 60° to 75°; again occurring at both joints. Radial deviation is often significantly less than ulnar deviation. Whilst the majority of pronosupination, which in some instances can be close to 180°, occurs at the radio-ulnar joint, 10% is said to occur at the radio-carpal joint. This rotational movement therefore can measure up to 15°. Any implant design should obviously have the facility for this rotation built into its design, otherwise significant torsional forces will be imparted to the components.

With regard to what movement is optimal in a design, whilst the ‘holy grail’ would be normal movement, in diseased wrists this would rarely be possible. Fortunately satisfactory function can be obtained with significantly less movement. Research undertaken in Syracuse, New York, using a triaxial electro-goniometer in normal subjects undertaking a number of standardised tasks, found that the vast majority of these can be undertaken with 5° of flexion, 30° of extension, 10° of radial deviation and 15° of ulna deviation.

Thirdly, it would seem advisable for the axis of rotation of any implant to be similar, if not identical, to the normal wrist. Research to date has shown that the axis of rotation of the normal wrist for radio-ulnar deviation is 3mm ulnar to the longitudinal axis of the third metacarpal and distal radius and for flexion-extension 9 to 10 millimetres volar to the longitudinal axis of the third metacarpal and distal radius. It is important to note however, that these axes do not intersect.

A further important feature is that any implant should obviously be stable. This is particularly difficult to achieve at the wrist in so much that at surgery the majority of patients do not have the normal soft tissue stabilising structures. More specifically they have often either been destroyed by disease or released during the surgical procedure itself. Whilst generally this problem can be overcome by correct seating of the implant and, to a degree, design, patently care must be taken with subsequent stabilisation. What is important, however, is that range of motion and appropriate incongruity are not sacrificed to excessive inbuilt stability of the implant. The latter would undoubtedly result in impingement at the edges of the implant, with ultimate loosening. Indeed, this has been seen in the author’s revision practice. Added to this is the fact that a significant number of tendons cross the wrist joint on both the volar and dorsal aspects. Any design must allow these tendons to function normally. This in practice would involve the absence of sharp edges and indeed any structure which could lead to tendon attrition. In addition, appropriate carpal height should be restored to allow optimal finger and thumb movement as well as grip strength to be generated. Finally, whilst many authors have disagreed over implant design, all agree about the importance of soft tissue balancing at the time of surgery. That is that any pre-operative deformity should be corrected by releases and tendon transfers where appropriate.

With regard to stem design and positioning for the radial component, various lengths have been used; generally, however, they average between 5 and 8 cms and lie, if anything, slightly radial and dorsal to the midline. Whether this was chosen simply to better align the implant within the shaft of the radius is unclear. It has, however, proved highly successful, particularly with the latest designs. For the carpal components stem, most implants align along the third metacarpal and as such have a stem which passes down its shaft, crossing the carpo-metacarpal joint. Additional short spikes or stems have been added, often in the line of the second or, in some cases, the fourth metacarpal to give better fixation. However, due to a high incidence of loosening, the use of a stem alone has been superseded by the addition of screws down both the second and fourth metacarpals. This, combined with a distal carpal row fusion, was first successfully used by the Guepar group in 1988 and Menon in the early 1990s.
The shape of the articulating surfaces, whilst not controversial with regard to being either convex or concave, has shown some variation as to whether the convex or concave side should be proximal or distal. Most designers have mirrored the normal anatomy of the radio-carpal joint, putting the convex articulation distally and the concave proximally; this does appear to have been the most successful. With regard to the choice of materials, convention taken from work in hip and knee replacements would indicate that the convex material should be made of metal and the concave high density polyethylene. Whether the reverse causes any long-term problems, only time will tell.

Finally, the use of methylmethacrylate cement is becoming less controversial. Whilst, historically, it was used to secure both components, its usage initially proximally and more recently distally has fallen.

Reported outcome in the Universal Total Wrist Arthroplasty

The results of the Universal total wrist implant were first reported by Menon in 1998. Here he reported on thirty-seven implants in thirty-one patients, with a mean follow up of 6.7 years. Unfortunately, in three of the patients, the prosthesis had to be removed due to infection and persistent dislocation. Of the remaining thirty-four, however, 88% achieved excellent pain relief. Otherwise, complications occurred in twelve cases (32%), although the majority were resolved with appropriate treatment. The most common complication appeared to be instability.

In 2002, a prospective study of 19 patients with rheumatoid arthritis with a minimum follow-up of one year was reported. At follow-up the flexion/extension arc had improved from 48° to 76° with radial-ulnar deviation from 17° to 28°. DASH scores reduced from 46 to 22.4. Complications, including instability, occurred in 3 cases, all of which required further surgery.

Ferreras et al reported their results of 21 consecutive patients who underwent a Universal total wrist as a primary procedure. They reported a significant reduction in pain and improvement in function, with 20 out of the 21 patients being satisfied or very satisfied with the procedure. Complications were generally minor and infrequent. Only one patient had early signs of loosening of the distal component. The latest work from Wrightington Hospital, as yet unpublished, revealed in a series of 93 consecutive cases, undertaken predominantly for rheumatoid arthritis, that the majority achieved satisfactory pain relief. Movements were preserved, with a mean dorsi flexion of 24° and palmar flexion of 23°. Function and patient satisfaction were high, the Kaplan-Meier survivorship being 91% at 7.8 years (95% CI: 7%). With regard to the incidences of major complications, these were only 8%, which was lower than the comparable smaller series.

Reported outcome of other total wrist arthroplasties

Nylick et al reported initial results with the Maestro total wrist system, in their series of 23 prosthesis in 22 patients, suffering with a variety of diagnoses, including post-traumatic arthritis and Kienböck’s disease. In a short follow-up there was a marked improvement in pain, with a flexion extension arc of 90° and a grip strength of 60% of the contralateral side. Radiographs showed no evidence of loosening. Complications, however, occurred in 7 of the 23 patients, one of which was a deep infection requiring complete revision.

Finally, Reigstad et al reported their results with the Motec cementless modular metal-on-metal ball-and-socket wrist arthroplasty, again, a small series with a short follow-up of predominantly patients with post-traumatic arthritis. Clinically and radiologically, most prostheses had integrated well, with no evidence of dislocation or implant breakage. Two implants, however, had been converted to an arthrodesis for persistent pain. Added to that, there was one further case of loosening at five years. Clinical results were also encouraging.

Conclusion

Wrist arthroplasty has been undertaken at Wrightington Hospital for many years, this being the result of the large number of patients with inflammatory arthritis who are treated at our institution. The first implant to be used was the silicone implant designed by Swanson. Essentially, and at least in the short term, this was successful in that patients achieved satisfactory pain relief with some movement and improved function. Ultimately, however, it did appear, due to a material problem, that movement and function diminished; more specifically, the wrist became stiff or the implant fractured. As a consequence, for the last ten years or so, the Swanson implant has been replaced by the Biaxial total wrist arthroplasty. Our experience of this implant has been published and, again in the short to medium term, in patients with inflammatory arthritis we have had good results. Subsequently however, with a longer follow-up, problems with the distal carpal component have come to light. Effectively, in a number of cases, the implant has loosened with the stem extending out dorsally from the third metacarpal. Indeed, all the implants that failed seem to fail in the same fashion. An analysis of the reasons for failure indicates that, unless the implant is put in perfect alignment, the likelihood of failure is significantly higher. The shape of the wrist joint itself and the implant unfortunately do not lend themselves every time to perfect insertion.

As such, again, the Biaxial total wrist arthroplasty has fallen from favour and is no longer available for use. Having said that, valuable lessons have been learned, particularly that the radial component did not show any evidence of loosening within the
period of review. This finding has also been reported by a number of other authors. It should be noted that this implant was put in an uncemented fashion, with porous coating only in the majority of cases. This design of radial component would therefore seem to be optimal at this time. Secondly, patients who had undergone total wrist replacement were generally highly satisfied and pleased with the outcome. In a particular sub-group of patients who had had arthrodesis on the contralateral side, the vast majority of patients indicated that they preferred arthroplasty to arthrodesis. Indeed, it was often difficult to persuade a patient who had had an arthroplasty on one side to have an arthrodesis on the other, despite the fact that, objectively, we felt that the arthroplasty had had a poor outcome. In light of this, we have no doubt that arthroplasty has a role in patients with bilateral inflammatory wrist arthritis.

With regard to the future, the fixation system designed by Menon for the distal carpal component appears to be the most successful. Certainly, medium- to long-term results of the Universal implant do not show any evidence of significant loosening at this site. Proof of this is that other implants are now copying this type of fixation. In light of this we have no doubt that a combination of the Biaxial radial component with a Universal distal component will become the mainstay in the design of total wrist arthroplasty. Most have the view that this will result in significantly improved long term survivorship.

Outside of patients with inflammatory arthritis, whether this implant should be used in primary osteoarthritis or, indeed, after trauma remains a moot point. We have no doubt, however, that these more modern implants will be used more and more for these clinical situations and only time will tell whether they are successful. We would say, however, at this time that it is not our practice to recommend to patients who suffer with these conditions that they have an arthroplasty. Having said that, in the older patients and where other treatment modalities, including partial wrist fusion/proximal row carpectomy, are not possible, then this may be a viable option.

Finally, with regard to further implant development, there are currently some concerns with regard to the high density polyethylene being on a convex surface in certain implants, the concern being that high density polyethylene in an unconstrained environment could lead to creep and excess wear. Having said that, given the relatively low forces transmitted across the wrist, this may not be of significant clinical importance. What is of importance, however, is modularity, insomuch that these new implants allow far more soft tissue balancing than their predecessors. This should allow stability to be retained and allow a better range of motion. Added to this, significant improvements in instrumentation allow better alignment of the components and resection of the radius and carpus; again, this should result in improved outcome. Obviously, however, all this will need to be combined with improved training, as total wrist arthroplasty is undoubtedly a technically demanding surgical procedure.

References


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