Total wrist arthroplasty

Raj Bhatia
NHS Consultant post at Bristol Royal Infirmary
rajbhatia@doctors.org.uk

Abstract
Will be delivered by the author in due course

Introduction
Total wrist arthroplasty is performed for painful degeneration of the radiocarpal joint usually due to inflammatory conditions, post-traumatic conditions or post-infective conditions. Implant arthroplasty of the radiocarpal joint is performed much less commonly than arthroplasty on many other joints. The Australian national joint registry records 6 primary total wrist replacements performed in the 2012 calendar year. This compares with 105 primary total elbow replacements, 224 primary total ankle replacements, 1 266 primary total conventional shoulder replacements, 27 190 primary total hip replacements and 41 810 primary total knee replacements. The reasons for this are multifactorial. Firstly the number of patients seen with symptomatic wrist arthritis would appear to be lower than for other joints. Secondly, alternative treatments (in particular total fusion) are perceived to be a better option in the wrist than in other joints. Finally, the outcomes of total wrist arthroplasty are seen to be less successful and reliable than arthroplasty of other joints.

History
The first total wrist arthroplasty was performed by Gluck in 1890 for a 19 year old with tuberculosis infection of the wrist. After experimenting with many materials he came up with a design composed of two “forks” with ivory in between. It was received poorly by the wider medical community, in many respects for political reasons. He did, however have to pronounce this case a failure due to development of a chronic sinus. Interest in total wrist arthroplasty was renewed when Swanson introduced a flexible hinged silicone implant in 1967. However, unlike more modern implants it was designed to function more as an interpositional articulated spacer than a true replacement. Many problems became apparent. Reactive synovitis with resulting pain, swelling and progressive osteolysis was extremely common within 3 years of implantation. A series of 53 implants reported excellent results in more than 90% initially but found that this rapidly deteriorated to 61% in 2.5 years with a 25% reoperation rate. Another study showed excellent results in 48% but poor results also in 48%. These silicon implants have been described as first generation implants.
Second generation implants were the first true replacements. They had metal and polyethylene bearings. Meuli introduced his in 1970. It was unconstrained and permitted motion in all planes by way of it’s polyester ball and socket design with rotation centred around the position of the capitate head. Fixation in bone was, like Gluck’s, with uncemented malleable metallic forks. Problems with instability and prosthesis loosening...
were common. Volar displacement of the cup resulting in extension contracture, flexor tendon rupture and carpal tunnel syndrome was also problematic. Cooney et al. reported on 140 Meuli prostheses performed at the Mayo clinic with a major complication rate of 33% and warned that the prosthesis should be ceased. Volz introduced an alternative around the same time. It was a cemented prosthesis with a hemispherical polyethylene component allowing motion in the flexion/extension and ulnar/radial deviation axes without rotation. Early results were promising. Menon published a series showing a complication rate of 44% and reoperation rate of 33%. The main reasons for reoperation were aseptic loosening, dislocation and muscle imbalance. They noted that preoperative deformity was the highest risk factor for complications. A long term outcome review of the Volz prosthesis (Howmedica, Rutherford, NJ) reported on 30 Volz prostheses performed for rheumatoid arthritis at 36-106 months. While they reported good or excellent results in 60% they still found complications in 40% including 24% rate of carpal loosening.

There were many prostheses grouped as early third generation (Biaxial, Trispherical, revised Meuli, revised Volz). The Biax (DePuy, Warsaw, IN) was one of the more popular designs in use in the 1980s. There are similarities to current prostheses with stems each side and an elliptical polyethylene component. It was designed to be implanted with cement. Cobb et al. reviewed 64 Biax total wrist replacements, 57 of which had greater than 5 years of follow up. Only 6% reported moderate or severe pain postoperatively. Range of motion did significantly improve (though not by much). Radiographic loosening occurred in 22%. The implant was deemed to have failed in 11 cases, 8 due to carpal loosening, one due to infection, one due to dislocation and one due to soft tissue imbalance. Another study using a modification of the original prosthesis with a longer distal stem showed similar outcomes in terms of pain and range of motion but reported no failures at mean 6 year follow up. However, other studies showed problems. Van Harlingen et al. reported on 32 biaxial wrists at 5-8 years. 31 had complications, 22 showed radiographic evidence of loosening and 25% had to be revised. The Anatomic Physiologic prosthesis was similar to the Biax but was hydroxyapatite coated for uncemented implantation. It was, however designed with a titanium bearing surface. Early results were promising with no loosening at 18 months in a series of 30. However, the same authors ceased using the implant when their analysis of 40 replacements at a mean of 52 months showed 33 were loose and 39 were revised. Gross titanium metallosis was found at revision and it was suggested it may have played a role in loosening.

Current third generation metal on polyethylene implants are now available. Only three are approved by the US Food and Drug Administration. They will be discussed below.

**Indications**

The primary indication for total wrist arthroplasty is painful radiocarpal arthritis that is significantly impacting on function. The main operative alternative to total wrist arthroplasty is total (or in some cases partial) wrist arthrodesis. Many would consider infection, lack of wrist flexors/extensors, poor soft tissue envelope, lack of adequate bone stock and Charcot arthropathy as contraindications to arthroplasty. Relative contraindications that may drive the decision towards arthrodesis are gross deformity and a high demand patient. Involvement of the contralateral wrist (where one wrist is relied
upon for certain activities involving wrist motion) or ipsilateral surrounding joints (in which the wrist makes a significant contribution to positioning the hand in space) may push the decision more towards arthroplasty to preserve range of motion. However, in a wrist that already has a poor range of motion many of the benefits of arthroplasty are lost making arthrodesis likely to be a more reliable option.

With this in mind, most patients considered for total wrist arthroplasty are those with inflammatory arthropathies as they tend to be lower demand patients with involvement of contralateral and surrounding joints. The wrist is affected in greater than 90% of rheumatoid arthritis patients by 10 years, 95% bilaterally.

It is important to consider in these patients how “low demand” the limb is. In polyarthritis in some cases an upper limb may be highly involved in using a walking aid for ambulation. Any lower limb procedures that may make the patient less reliant on their upper limb for walking aids should take precedence when it comes to the timing of surgery.

Within the inflammatory population care must also be taken with regards to bone stock and stability. Many patients with inflammatory arthropathy are subject to osteopaenia and bony erosions that may compromise implant fixation. Along with this joint subluxation and contracture can make soft tissue balancing difficult. These issues are particularly seen in those patients with active synovitis.

**Biomechanics**

The wrist moves in two planes both of which have an axis of motion located within the capitate head. The normal wrist has a flexion range of 85-90° (65% radiocarpal and 35% midcarpal) and extension range of 80-85deg (35% radiocarpal and 65% midcarpal). Palmer et al defined a functional wrist range of motion as 5deg of flexion, 30deg of extension, 10deg of radial and 15deg of ulnar deviation. Crisco et al have shown that in reality the axes of motion are in reality orientated obliquely to the traditionally described axes. The primary direction being radial extension and ulnar flexion, the so called “dart thrower’s” motion.

**Comparison With Fusion**

Fusion has long been considered a reliable operation with respect to pain relief and return of function in radiocarpal arthritis. It’s main disadvantage when compared to arthroplasty is the lost range of motion which is important, especially in patients with bilateral disease or disease involving surrounding joints. However, how reliable fusion is has started to come into question.

Field et al showed that while patients are subjectively satisfied after wrist fusion they perform poorly when it comes to objective scores of hand and wrist function. They had poor range of motion in their finger MCPJs and thumb MCPJ and IPJ. It has been shown that only 50% return to their preoperative occupation. Vicar and Burton studied patients who had arthrodesis or silicon arthroplasty. In their group four patients had arthrodesis of the dominant and arthroplasty on the non-dominant wrist. All four patients stated they would have preferred the reverse as they struggled to use their fused dominant wrist for many activities of daily living. In a more recent study looking at pain relief from arthrodesis 14/22 arthrodesis patients still had pain and all 22 patients in the study stated
that they would undergo further surgery to restore motion if it were available. De Smet et al showed 30/36 had pain 4 years post arthrodesis. Murphy et al 2003 compared 24 arthrodeses with 27 arthroplasties at a range of 1-5 years. Although there were no statistically significant differences in the Patient Related Wrist Evaluation (PRWE) and Disabilities of the Arm, Shoulder and Hand (DASH) scores, there was a subjective benefit in arthroplasty over fusion with greater ease reported in some activities of daily living. Complication rates were similar between groups. 44% (arthroplasty) and 30% (arthrodesis) reported being somewhat limited by pain and 44% (arthrodesis) and 21% (arthroplasty) reported limitations due to stiffness. Neither of these figures were statistically significant. They concluded that while results were insignificant and patients can generally adapt to a wrist arthrodesis but trends suggest that a successful arthroplasty would, in most cases, be preferred. Cavaliere et al conducted a systematic review comparing arthroplasty to fusion in rheumatoid wrists. They took data from 18 arthroplasty studies including over 500 patients (none using current third generation implants) and 20 fusion studies including over 800 patients. While rates of satisfaction were high for both groups (91% arthroplasty and 93% fusion) they concluded that fusion was more reliable in relieving pain and arthroplasty produced more complications. Only 14 arthroplasty studies reported range of motion and, of them, only three produced a functional range. The same group’s subsequent study was a cost-utility analysis comparing non-operative management, arthroplasty and arthrodesis utilising 49 patients and 109 clinicians (hand surgeons and rheumatologists). The study brought to light what a great emphasis rheumatoid patients place on wrist motion, showing that despite the previous study showing more predictable pain relief and lower complications for fusion and despite the increased prosthetic costs total wrist arthroplasty was still cost effective in terms of quality adjusted life years. Cavaliere et al also published a study comparing the attitudes of rheumatologists and hand surgeons to operative treatment of the rheumatoid wrist. Again it showed that both groups placed a high value on maintaining motion and, overall, arthroplasty was preferred to fusion. Swanson himself stressed the importance of a few degrees of wrist motion in increasing finger reach and improving function in a limb with multiple joint involvement.

McCullough et al designed a study to assess upper extremity function in patients undergoing total wrist arthroplasty with the Universal 2. 46 patients were recruited, 8 of which completed the whole protocol. All were assessed 12-36 months after their wrist replacement. They were asked to complete questionnaires (DASH, Patient Related Wrist Evaluation and Arthritis Impact Measurement Scale 2), the Jebsen Hand Function Test and were asked to perform activities of daily living while being monitored by a motion analysis system. They concluded that motion preserved by the wrist in arthroplasty does improve hand function in daily activities.

Outcomes
The biggest problem in assessing total wrist arthroplasty is the lack of availability of long-term data. Probably the best we have is the Norwegian registry data but none of the prostheses with long-term follow up are currently in use. The Norwegian joint registry has been collecting data on wrists since 1994. Their data includes 189 wrists (90 Biax (80 uncemented), 23 Elos (three different versions, all
precursors to the Gibbon prosthesis) and 76 uncemented Gibbon prostheses (Swemac,
Linkoping, Sweden) (a ball and socket type prosthesis that changed name to the Motec in
2010)) between 1994 and 2009. The reported 5 year survival is 78% (85% Biax, 77%
Gibbon at 4 years and 57% at 5 years for Elos), 10 year survival is 71%. Females had
three times higher revision rates than males but otherwise no there were no significant
differences in factors associated with revision. There were no significant differences
between inflammatory and non-inflammatory diagnoses. Of the 39 revisions 21 were for
distal component loosening,10 for pain, 5 for proximal component loosening 4 for deep
infection and 5 for instability or dislocation\textsuperscript{9}.
The relevance of this data is now of questionable value as none of the three total wrist
arthroplasty designs that are currently approved by the US FDA are included. These are
the Universal 2 (KMI, San Diego, CA), ReMotion (SBI, Morrisville, PA) and Maestro
(Biomet, Warsaw, IN). As these three prostheses are currently the most commonly
implanted it is their outcomes that are of most interest. Most series are small one surgeon
series (utilizing one particular prosthesis) with short to mid-term follow-up. They have,
therefore, been grouped by prosthesis.

**Universal 2**
The Universal total wrist arthroplasty was developed by Menon. Aimed to improve distal
fixation it had a central stem cemented into the capitate and two screws each side. The
metallic radial implant had 20° of volar tilt to replicate normal anatomy. A convex
toroidal (ie. an ellipse but with an ovoid base) polyethylene was attached to the distal
baseplate with varying thicknesses to aid balancing. It was unconstrained. Intercarpal
fusion was recommended to aid distal fixation.

Menon published his initial series of 37 wrists in 31 patients with mean 6.7 year follow
up (4-10 years). Excellent pain relief was seen in 88%, only marginal improvement was
seen in range of motion (extension and radial deviation). There was a 32% complication
rate including 5 volar dislocations. No distal loosening was seen but in two instances
there was loosening of the proximal component. Menon criticised himself for not having
different thicknesses of implant and for excessive bony resection in early cases causing
instability\textsuperscript{31}.

Divelbiss et al\textsuperscript{32} published the results of 22 Universal total wrist arthroplasties in 19
patients all with rheumatoid arthritis. His results were similar to Menon’s results with
reliable pain relief and improved DASH scores. In their study there was a significant
increase in range in extension, radial deviation and supination. 3 volar dislocations
occurred, two of which went on to arthrodesis, the authors blamed this on highly active
rheumatoid arthritis causing laxity. 5 occurred in the first series and 1 in the second series
after the range of implant sizes had been increased. No component loosening was seen
but the follow up period was short (1-2 years).

Ward et al published a paper with longer follow up and failed to reproduce Menon’s
results. They were able to obtain > 5 year follow up data for 19 total wrist arthroplasties
in 15 patients. Only 50% implant survival was seen with survival of 75% at 5 years and
60% at 7 years. Carpal loosening was the most common reason (45%). The success of
intercarpal fusion was a major difference between success and failure. Most failures were
seen in severe active rheumatoid arthritis. No significant improvement in range of motion
was seen\textsuperscript{33}.

Grosland et al\textsuperscript{34} compared toroidal and ellipsoidal polyethylene components in a
laboratory study. They found that ellipsoid polyethylene components gave better capture and congruity through range of motion giving more stability and less poly wear. The toroidal design only maintained congruency during radial and ulnar deviation. This led to Adams’ development of the Universal 2 with an ellipsoidal rather than toroidal polyethylene component in an attempt to reduce instability and improve wear. The carpal and radial components were changed to porous titanium removing the need for cement and variable angle screws were added to the distal baseplate. A new design of radial implant gave the option to preserve the ulnar head.

Anderson and Adams reported on the Universal 2 implanted in 25 patients. DASH scores improved 20% and pain relief was reported as good in all patients, with mild ulnar-sided wrist pain seen in 5. No dislocations were seen. 3 carpal component stem fractures were seen in patients with the initial version of the Universal 2. The component stem design was then changed to a larger diameter and a full porous coat added.

Ferreres et al reported a series of 21 Universal total wrist replacements (two of which were Universal 1 and the remainder Universal 2) with mean 5.5 year follow up (3-8 years). Three had some lucency around carpal component, one of which had subsided and tilted 18deg. No dislocations or revisions were reported.

**ReMotion**

In the Remotion total wrist arthroplasty an ellipsoid polyethylene is securely locked on a ball on the carpal plate. This added articulation allows 10\(^\circ\) of rotation of the polyethylene ball with respect to the carpal plate. This was designed to reduce torque stress on the distal component and may also add to preserve some of the intricate “dart throwers” motion. Distal fixation is similar: a central porous peg with a radial and ulnar variable (up to 30 degrees) angle screws to compress the plate to the bone. The plate is designed to maintain the distal carpal arch by placing the two screws in a more palmar position on the plate compared with the central peg and thus avoid flattening the carpal curvature. There is 10\(^\circ\) each of volar tilt and radial inclination in the radial component. Bony cuts are minimised on the radial side potentially preserving the stabilising ligamentous attachments and also the sigmoid notch, thereby allowing preservation of the distal radioulnar joint.

Herzberg reported 20 Remotion total wrist arthroplasties in 19 patients with an average of 32 months follow up (12-76 months). Loosening was seen in two (one proximal and one distal) neither requiring revision.

Herzberg et al reported results of a multicenter study that included 215 Remotion arthroplasties, 129 were performed for rheumatoid arthritis and 86 for other diagnoses. Average follow up was 4 years. Significant improvements were seen in both groups in QuickDASH and pain scores. Survivorship was 96% in rheumatoid and 92% non-rheumatoid. Satisfaction rates were 88% in rheumatoid and 95% non-rheumatoid patients. The 6 revisions performed in rheumatoid patients were for loosening (4), ankylosis (1) and deep infection (1) and the 5 revisions in non-rheumatoid patients were for loosening (2), dislocation (1), malpositioning (1) and ankylosis (1). Boeckstyns et al have also published favourable results in the same group of patients but analysed 65 wrists in 60 patients with 5-9 years follow up. They had a probability of 90% implant survival at 9 years in both rheumatoid and non-rheumatoid patients. The only significant improvements in range of motion were in supination and ulnar flexion.
Maestro
The main difference between the Maestro and the other two current prostheses is its concave polyethylene locked to the proximal component. This is intended to replicate successful designs in total hip and knee arthroplasty in which the polyethylene is on the concave side. The distal component is similarly fixed by a porous central peg and radial and ulnar variable angle screws. It is also possible through augmentation to resect the entire scaphoid and thereby makes intercarpal fusion of the scaphoid to the capitate unnecessary.
Nydick et al reported on 23 Maestro total wrist arthroplasties in 22 patients with a mean of 28 months of follow up (4-55 months). 7 complications were seen. 4 wrist contractures, 1 deep infection, 1 case of instability and 1 of synovitis. Significant improvements were shown in pain scores and radial deviation. All but five had non-rheumatoid diagnoses.
Dellacqua reported good results in a short (18-36 month) follow up period in 19 patients with successful pain relief and some gains in range of motion in all patients.

Other Alternatives
Other more novel techniques have also appeared over the last few years. Of note the Amandys (Tornier, Grenoble, France) is a free interposition pyrocarbon implant. It is designed to replace the lunate, proximal scaphoid and capitate head. It is mobile and not fixed to bone in any way. It is elliptical in a manner designed to articulate with the distal radius on one side and the distal carpal row on the other. The rationale is to avoid complications associated with loosening by avoiding fixation. The fact that there is no concern regarding loss of fixation also means that activity restriction is not so important and, therefore the implant has been advocated even in manual workers. Instability is avoided by maintaining the native capsuloligamentous stabilisers, firstly by retaining the distal scaphoid, the triquetrum and the distal radius (excluding part of the styloid) and their ligamentous attachments.
Bellemere et al reported on 25 Amandys implants at mean 2 year follow up (12-36 months). Only pronation and supination motion significantly improved. There were significant improvements in QuickDASH and PWRE scores. 96% reported being satisfied. 6 complications were seen (3 had complex regional pain syndrome and 3 instances were seen in which the implant had rotated 90° on its proximodistal axis). 2 of the latter complications required revision but at final follow up all prostheses had been retained.
Daruwalla et al reported on 6 Amandys implants. Only one was not satisfied. There was one volar dislocation (in a patient who reported being very satisfied). This implant was relocated and the volar capsule repaired. Pain scores improved in all patients. Range of motion improved in three patients and DASH scores in 5.
Pierrart et al reported on 11 patients receiving the Amandys implant with average 11 month follow up (6-21 months). Pain scores improved in nine cases. In the other two cases one was revised to total wrist fusion due to pain and one revised to total wrist fusion for instability of the implant. Another dislocation occurred but the patient did not require revision. Grip strength was decreased from preoperative values in all but one patient. They noted that all their cases of instability were in patients who had previous proximal row carpectomies and therefore have ceased using the prosthesis in this group.
The RCPI (Tornier, Grenoble, France) is another pyrocarbon alternative consisting of a stemmed capitate resurfacing combined with a proximal row carpectomy. Again there are several small promising series.47 48

Discussion
Total wrist replacement has been sparingly used in the armamentarium of surgeons for treatment of radiocarpal arthritis. This is partly due to the infrequency of instances of symptomatic radiocarpal arthritis especially now that rheumatoid disease is generally well controlled by medical means. It is also due to the impression that total wrist arthrodesis is well tolerated and reliable which may not be as much of a certainty as is believed. It appears that arthrodesis does not reliably lead to complete pain relief and that the loss of motion is significant.

Older style implants have also given arthroplasty of the wrist a bad reputation with high failure rates due to poor fixation and articulations causing high rates of loosening and instability. Newer implants are beginning to improve the reputation of arthroplasty of the wrist. However, the numbers are still small and the follow up periods short. Larger series including multiple centres such as that reported by Herzberg et al40 are important in providing evidence for the newer prostheses.

More multi-centre reports are important, as is the inclusion of wrist arthroplasty on national joint registries as the numbers of wrist arthroplasties implanted by single surgeons/centres are often too low to obtain significance. Interestingly some of the larger series are also failing to show the traditionally held notion that patients with non-inflammatory diagnoses perform poorly when it comes to wrist arthroplasty, though, again, short follow-up periods make this conclusion less definitive.

The ultimate indication for a wrist replacement is when the contralateral wrist has already been fused, it is then desirable to retain motion in one wrist in-order to improve overall function. The patient has to be fully counseled regarding expected outcomes and advised that long-term outcomes are presently not known. Patients with good bone stock, without radio-carpal subluxation and who are low demand are the best candidates for replacement. The senior author (RB), has had experience of all three third generation arthroplasties. His implant of choice is the maestro for its anatomical design, including the curved carpal plate and distal scaphoid augment allowing greater surface area for carpal fixation and sparing of the sigmoid notch thus not interfering with DRUJ function. Furthermore the polyethylene is on the concave side as in successful hip and knee arthroplasties.

Wrist arthroplasty still has a long way to go in achieving the title of “gold standard” for treatment of wrist arthritis as has happened for hip, knee and even, arguably, elbow arthroplasty. It is, however, moving in the right direction.