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Current Concepts in Total Wrist Arthroplasty: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Introduction: Total wrist arthroplasty was envisioned to give patients with severe and debilitating pain the opportunity to regain independence. Prior to the first generation of implants, the standard of care for patients suffering from end-stage arthritis of the wrist was total wrist fusion which provided significant pain improvement at the expense of wrist movement.
Current Techniques: The first three generations of wrist implants showed promise of restored wrist function but were unfortunately plagued with poor long-term outcomes and significantly higher revisionist rates due to joint instability and peri/post-operative fractures. The current fourth generation of implants have shown the most promise in both preserving/restoring wrist motion and providing pain relief on par with the total wrist fusion.
Complications Associated with Total Wrist Arthroplasty: The current generation of implants still face complications of lower long-term survival rates and increased revisionist surgeries as compared to total wrist fusions.
Future Innovations in Surgical Wrist Interventions: Future innovations will focus on less bone resection and greater bone integration on a molecular level. Also, the relatively novel technique of wrist hemiarthroplasty shows promise as an acceptable alternative to total wrist arthroplasty.
Conclusions: Though the current generation of TWAs still have a lower survival rate and higher complication rate vs TWF, the functional gains associated with current models and the novel implants and techniques currently in development make TWA still a promising option.

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Keywords: Total wrist arthroplasty; surgical wrist interventions; surgical techniques; survival rates.

1. INTRODUCTION

Total Wrist Arthroplasty (TWA) is an ever-evolving field of study in orthopaedics as surgical techniques and procedures improve. TWA originally gained popularity in the 1970's as an alternative to total wrist fusion (TWF). Though TWF has survival rates in upwards of thirty years, relatively low revision rates, excellent pain relief and prevents further progression of disease, the loss of functionality in the wrist significantly decreases the quality of life for individuals. Therefore, the purpose behind TWA is to allow patients to maintain most of their wrist mobility while still providing relief of symptoms. The desire to maintain mobility combined with complications of wrist instability, further joint degradation, and subsequent revisionist surgeries of previous implant generations has led to immense efforts in design improvement and surgical technique enhancement [1]. This following article reviews current indications for TWA, modern TWA models, surgical techniques advancements, and future directions for the field.

Because of its structural and biomechanical mobility, the wrist is one of the defining aspects of human anatomy. Normal wrist movement, therefore, is essential for humans to perform daily tasks as simple as dressing and as complex as surgical procedures. Total loss of or even slightly decreased in wrist motion can drastically affect a patient's quality of life, no matter the underlying etiology. It is estimated that 13.6% (about one in seven adults) of the US population suffers from a physician-diagnosed wrist arthritis and often times is the presenting symptom of underlying systemic disease. The most common cause of wrist arthritis is rheumatoid arthritis (RA) making up 75% of cases, followed by osteoarthritis (OA) and metabolic derangements [2]. Wrist arthritis secondary to RA occurs in upwards of 90% of patients and initially involves conservative therapy with analgesics, systemic therapy with disease modifying antirheumatic drugs, and wrist joint synectomy (in select patients) [3]. With further progression of the disease and exhaustion of other measures, TWA or TWF is then undertaken. In select surveys and longitudinal studies, TWA has been shown to be effective at providing relief to and improving quality of life-years (QALYs) in RA patients compared to TWF [4-5]. Osteoarthritis (OA) of the proximal wrist typically arises from secondary sources, rather than pure mechanical forces like other joints, with the most common being posttraumatic sequalae and metabolic derangements. In traumatic cases, proximal carpal ligamentous lesions can lead to disruption and instability of the wrist creating excessively abnormal compression forces between the radio-scaphoid and/or scapho-lunate joints predisposing to OA. Metabolic derangements like articular chondrocalcinosis and gout also predispose to proximal wrist OA. Similar to RA, surgical interventions for proximal wrist OA is reserved for end-stage presentations [6-7].

In order to assess the postoperative clinical output for wrist surgeries, orthopedists utilize the DASH (Disability of Arm, Shoulder, and Hand) score as a quantitative analysis of disability in treated patients. The lower the score, the better the outcomes for patients and vice versa. Additionally, comparing pre-operative, immediate post-operative, and subsequent follow-up visits allow the surgeon track the improvement (or lack there of) of their intervention [8].

2. CURRENT TECHNIQUES IN WRIST ARTHROPLASTY

The concept of wrist prostheses was envisioned in the late 19^{th} Century by the German physician, Dr. Themistocles Gluck who also designed early sketches for hip, knee, and shoulder replacements as well.9 It wasn't until the 1970's, however, that the modern wrist arthroplasty began to take form. The first generation of TWA prosthetics utilized a Silastic spacer as a more functional alternative than total arthrodesis. Subsequent implant fractures, joint subluxations, and decreased survival rates compared to TWFs led to the second-generation of implants: the MWP III ball-and-socket and Volz hemispherical implants. These also suffered from high complication rates due to joint imbalance and metacarpal loosening and revision rates were as high as 26% [9-10]. The third generation Biaxial and Universal implants sought to correct for joint imbalance with central stems on the proximal and distal ends with a round saddle-like carpal prosthesis. These implants required greater bone resection than previous generations and utilized metacarpal/radial fixation via long stems in order to achieve joint stability. Initial trials showed promise as patients reported less pain and slightly more mobility compared to the second-generation. Follow-up with these patients and subsequent longitudinal studies, however, reported significantly distal stem loosening, metacarpal fractures, and revision rates ranging from 20-25%. Additionally, a proportion of patients reported increased pain with daily activities that required even more resection of the ulna [11-13]. The previous generations of wrist prostheses provided excellent recovery of activity level but subsequent failure rates and excessive pain levels were still significantly higher compared to a TWF. These flaws led to the development of the fourth (and current) generation of wrist implants including the Universal 2 (U2), Re-Motion, and Maestro prostheses.

Developers envisioned a more “anatomical” design to the implant that required less radial/ulnar resection while incorporating porous implant surfaces to enhance stability on a molecular level. In a retrospective cohort study, Cooney et al. compared survival rates and pain relief among the Biaxial, U2 and Re-Motion implants after a 3.5-9 year follow up. All three had comparable pain relief (with the exception being those that later required revision) but the fourth generations had survival rates of 97% compared to the Biaxial’s 50%. The functionality of the new implants were also assessed via the Mayo scoring system and revealed a significant superiority for the U2 and Re-Motion over the Biaxial implant [14]. Additionally, two systematic reviews compared the fourth-generations to earlier implants in terms of survival and complication rates. The U2, Re-Motion, and Maestro implants were found to have estimated survival rates of 78-100%, 90%, and 95% at 8-15 years follow-up respectively [15-17]. Subsequent case series and retrospective studies reflect these impressive survival rates. In two retrospective studies, the Universal 2 implant averaged a survival rate of 74-78% [18-19]. Among the fourth-generation implants, the Maestro and Re-Motion appear to have the most stability and best long-term survival rates. Earlier studies revealed promising pain relief, exceptional mobility, and satisfactorily low radiographic loosening rates as compared to the U2 implant, but limitations to these studies were their small sample sizes and short-term follow-up. Subsequent larger trials of 200 or more patients exhibited survival rates of 90-94% for the Remotion and 88-95% for the Maestro implants at 8-12 years follow-up. Again, similar radiographic loosening rates and pain scores were noted as with earlier trials providing further evidence of increased stability with the fourth-generation implants [20-26].

3. COMPLICATIONS ASSOCIATED WITH TOTAL WRIST ARTHROPLASTY

Though TWAs initially tend to have greater functionality and lower DASH scores, the complications, even with the 4^{th} generation implants, are still significantly higher compared with TWFs. Notable complications such as contractures, significant radiographic joint/implant loosening, and intra-/post-operative fractures all require revision surgeries. One systematic review found that the third-generation implants had a major complication rate requiring as high as 25% compared to 13% in TWF with a mean survival rate of 50-78% at 12 years [27]. While the fourth-generation improved to a mean survival rate of 85-95% at 8-15 years follow-up, the revision rates were still around 20-50%. The subsequent revision surgeries, however, did lead to prolonged survival rates for 92-95% at follow-up compared to revision rates in previous generations [28-35]. Although newer TWA implants have similar outcomes compared to TWF in terms of grip strength and pain, implanted wrists still have another disadvantage compared to TWF; TWA joints are non-weight bearing (no more than 10 pounds). Though previous cost-utility analyses have found similar QALYs between TWA and TWFs, few studies have been done on outcomes in younger/traumatic wrist patients [36-37] Table 1.

4. FUTURE INNOVATIONS IN SURGICAL WRIST INTERVENTIONS

Although no new generation of implants have been released or designed, there has been a select for studies modifying the current fourth generation of implants. One study designed an implant with a press-fitted (rather than cemented) proximal component and a polyether ether ketone (PEEK) articulating surface that is distally fixed via screws. This study was done on cavaderic wrists and suggested that the implant will have similar biomechanical and ROM function to a native wrist [38]. Of course, the main limiting factor being that this was not a clinical trial or even placed on actual patients but it does provide some (albeit minimal) preliminary data for this new design.

Other approaches have been to reassess the surgical technique and opt for a hemiarthroplasty rather than a total arthroplasty. This involves normal radial and proximal carpal resection but utilizes the native distal carpal bones as the articulating surface for the radial prosthesis.

Table 1. Summary of current total wrist implant generations for end-stage wrist arthritis with their respective survival rates and specific complications for each

Total wrist implant	Survival rates	Complication notes
First Generation: Swanson Silastic Spacer	42-60% at 6.5 years	75% significant fracture rate, 40% foreign body reactions
Second Generation: Volz MWP III	57-78% at 4-5 years	13.3-41.7% revision rates, 47% radiographic loosening, neurologic sequela, or other complication rates
Third Generation: Biaxial Universal	Biaxial: 81-85% at 5 years Universal: 60-83% at 8-12 years	20-40% revision rates, 30-68% radiographic loosening, neurologic sequela or other complication rates
Fourth Generation: Universal 2 Re-Motion Maestro	Universal 2: 74-100% at 8-15 years Re-Motion: 90-94% at 8-15 years Maestro: 88-95% at 8-15 years	3.5-50% revision rates, 13% radiographic loosening, neurologic sequela, or other complication rates

Initial studies found improved range of motion on par with the TWA but similar stability (immediate post-operatively) as the TWF. Furthermore, the revision rates were lower at short term follow-ups compared to the TWA wrists. There also appeared to be similar outcomes independent of etiology of the wrist arthritis (RA vs OA) [39-42]. One small study (n=9), however, found that the hemiarthroplasty wrist had significant ulnar wrist pain and a 45% failure rate [43]. As with any novel surgical technique however, longer clinical follow-ups are needed to assess and truly compare the survivorship, complication rates, and cost-utility of hemiarthroplasty to TWA and TWF.

5. CONCLUSIONS

Although the TWA has not reached 10-year survival rates or complication rates similar hip and knee arthroplasties, the evolution of both implant design and improved surgical technique can potentially lower long-term complication rates and improve overall wrist function in patients with wrist arthritis [44-45]. In fact, patients who have a TWF on one wrist and a TWA on the contralateral, tend to prefer the latter [46]. Newer prosthetic designs provide a functional dart-throwing range of motion, better wrist balance, reduced risk of loosening, and better implant stability compared to older designs. As with arthroplasty in other joints in general, precise osteotomies, proper soft-tissue balancing, and meticulous capsule closure are necessary to achieve consistent and satisfactory results.We recommend TWA as an alternative in patients with intractable wrist pain and limited function as a result of inflammatory, idiopathic, or post-traumatic arthritis. In a low-demand patient with wrist arthritis who understands and appreciates the risks, we offer the alternative of TWA because of the benefits of wrist range of motion for certain activities of daily living. We avoid TWA in the presence of infection and in patients younger than 50 years of age, those using walking aids, and those unable to adhere to activity restrictions or maintain active wrist extension The importance of maintaining anatomic kinematic motion of the wrist is vital for humans to function as it provides a sense of independence for patients. Novel wrist prostheses will have to use anchoring screws and articulating surfaces that better imitate anatomic alignment as well as utilizing less invasive carpal resections that preserve patients' bone stock for better healing. Future prosthetic surfaces may utilize antibiotic coatings (as with some knee arthroplasty) and greater porosity in order to reduce revision rates for patients. The success of total wrist arthroplasty depends on appropriate patient selection, careful preoperative planning, and sound surgical technique with current newer implant designs. Although TWA may currently have higher complication rates when compared to TWF, the satisfaction and QALYs gained is priceless to most patients.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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