16 Wrist Arthritis: Total Versus Limited Fusion Versus Arthroplasty

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16.1 Introduction

Wrist arthritis is a progressive, destructive, deforming and debilitating disease (Fig. 16.1) that results in severe loss of hand function for those affected. This broad term is often used to describe degenerative changes seen in the radiocarpal joint, the intercarpal joints or, in some conditions, both. It can affect the younger, higher-demand patient population as the end stage of Kienböck disease or more commonly in the post-traumatic setting of a SNAC (scaphoid non-union advanced collapse) or SLAC (scapholunate advanced collapse) wrist, post-traumatic arthritis following distal radius fracture or fracture malunion. In older patients it may also present as a post-traumatic condition or as a sequelae of inflammatory arthropathy such as rheumatoid or psoriatic arthritis or as primary osteoarthritis. The diversity of the underlying aetiologies and functional demands of those affected has led to considerable debate and controversy on the optimal management of this condition, namely, motion-sacrificing versus motion-sparing techniques. A significant volume of work has been published on the surgical management of wrist

Fig. 16.1 Radiograph of end-stage degenerative change in the wrist of a patient suffering from rheumatoid arthritis. Note the apparent partial auto-fusion at the radiocarpal joint, the destructive change and subsequent instability at the thumb metacarpal phalangeal joint and previous distal ulnar resection arthroplasty

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arthritis and the authors aim to highlight the evolution and changing trends in this field focusing on total wrist fusion, limited or partial wrist fusion and wrist arthroplasty and the related areas of controversy and debate. It is by no means a treatise on surgical technique or an exhaustive review, the likes of which have already been published and can be easily found through any scholastic online search engine. However, we hope these discussion points might better inform the reader of the surgical options available, evidence behind these options and potential future developments while also drawing attention to several key questions which remain to be answered.

16.2 Treatment Algorithm for the Surgical Management of Wrist Arthritis

Many authors and surgeons have their own treatment algorithm which they employ in the decision-making process to tailor their surgical interventions for each individual patient. These are often based on training, experience and personal preference. Below is an example of the senior author treatment algorithm for the surgical management of wrist arthritis based on the location and extent of the degenerative process (Fig. 16.2). We advocate the use of a detailed, but focused history and examination, as well as appropriate radiographs and higher-order imaging including computed tomography (CT), single-photon emission computed tomography (SPECT) and magnetic resonance imaging (MRI) to fully evaluate each patient. We also advocate the use of diagnostic wrist arthroscopy (Fig. 16.3), particularly in cases where the extent of degenerative change is uncertain, where there is ambiguity between the clinical and radiographic findings and in cases where there is the potential to perform and limited fusion procedure. It should be noted that this algorithm does not include the many patient demographics such as age, aetiology, hand dominance, previous and current hand function, occupation and post-treatment expectations of the patient. Each of these factors should be taken into account when developing a treatment plan in tandem with patient wishes, with reason.

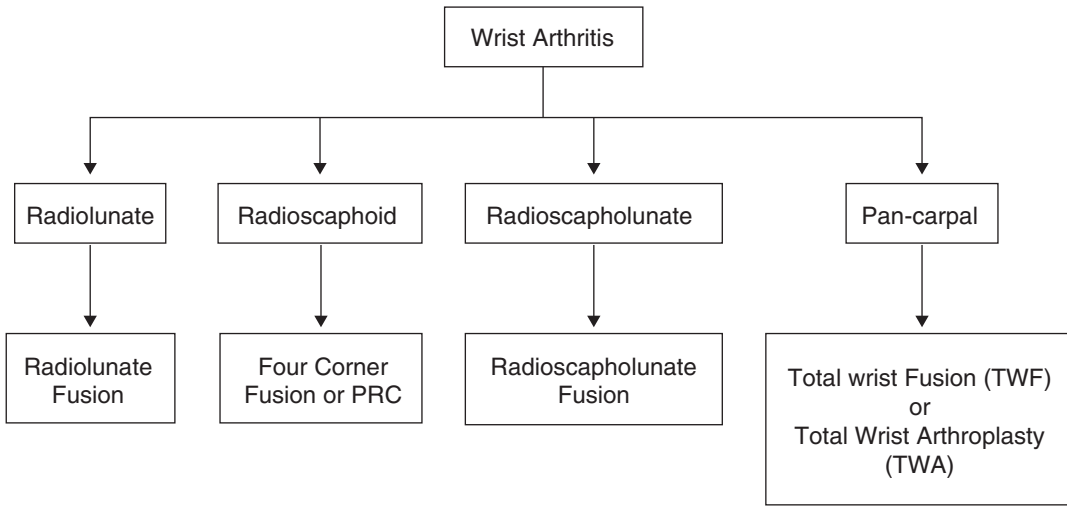

Fig. 16.2 Treatment algorithm for the surgical management of wrist arthritis based on the confirmed location and extent of the degenerative changes within the wrist

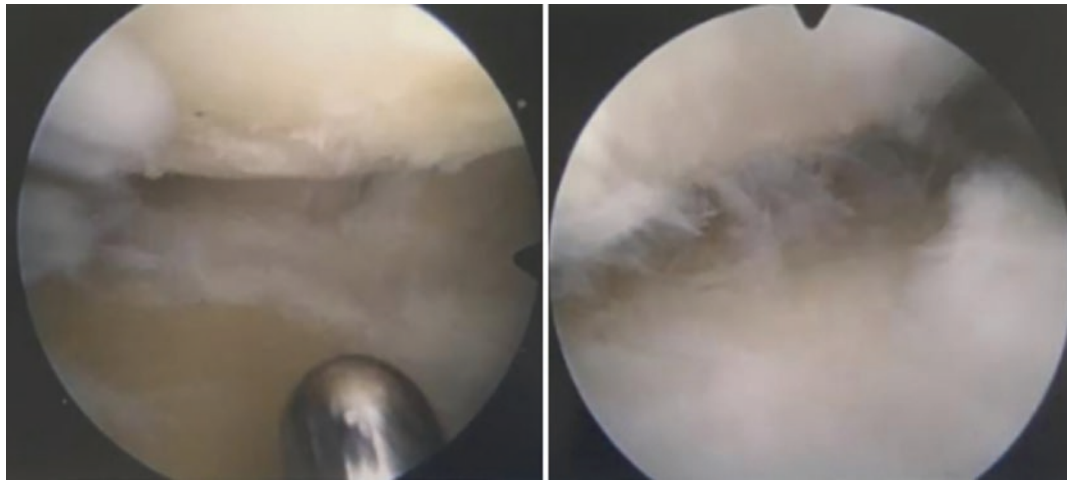

Fig. 16.3 Intraoperative photo taken during diagnostic wrist arthroscopy showing severe articular cartilage loss with bone-on-bone arthritis at the radioscaphoid articulation (left) and severe degenerative change at the radiolunate articulation. The remaining intercarpal articulations were well preserved and this patient went onto radioscapholunate (RSL) fusion

16.3 Normal Wrist Motion and Biomechanics and Its Importance in the Surgical Management of Wrist Arthritis

The importance of dart thrower's motion (DTM) has been emphasized in the literature [1–3]. This describes one of the most frequently used planes of wrist motion, bringing the wrist from a radially deviated extended position (radial extension) to an ulnarly deviated flexed position (ulnar flexion), occurring mainly in the midcarpal joint [4]. This is not aligned with the anatomic sagittal or coronal axes of the wrist [5]. Mapping of all possible wrist positions results in an ellipsoidal shape oriented obliquely to the sagittal plane of motion. It is now believed that DTM actually consists of several different paths that cumulatively contribute to a wide variety of functional activities [6]. Previous total wrist arthroplasty designs have tried to recreate the contour and kinematics of the radiocarpal joint with little attention paid to the midcarpal joint which is either defunct due to PRC or fused. Thus, many total wrist arthroplasties (TWAs) restrict motion to the anatomical directions and minimizing the important dart thrower's arc. Fourth-generation TWA using ellipsoidal polyethylene articular surfaces may improve the general range of motion possible but do not allow for the true replication of the DTM and its functional benefits.

In terms of fusion procedures, total wrist fusion (TWF) abolishes any DTM. Partial wrist fusions such as radioscapholunate (RSL) fusion preserves critical midcarpal motion and carpal height, thus retaining possible DTM. However, RSL fusion may reduce total wrist movement by 40% [7] but has the potential to maintain a greater degree of midcarpal motion and DTM.

16.4 Partial/Limited Wrist Fusion

Partial/limited wrist fusions are most commonly performed for debilitating painful arthritis. The goal of a partial wrist fusion is to fuse the painful, diseased joints while preserving movement of the healthy joints. There are various options of partial wrist fusions, depending on the extent of the disease process. The most common fusions performed include radiolunate, radioscapholunate and four-corner fusions.

16.4.1 Radiolunate Fusion (Chamay Fusion)

Indications for radiolunate (RL) fusion include post-traumatic osteoarthritis of the radiolunate joint typically following die-punch distal radial fractures, rheumatoid arthritis with ulnar and volar translocation of the carpus and complex ligament instabilities deemed unreconstructable [8, 9]. An RL fusion may also be considered for advanced Kienböck disease [10]. The neighbouring radioscaphoid and midcarpal joints need to be free of disease. Methods for fixation include headless compression screws, staples, plate and screws and Kirschner wires.

The lunate is fused in neutral alignment relative to the radius. Radiolunate fusions appear to be associated with low rates of non-union and low rates of progression to total wrist arthrodesis [11].

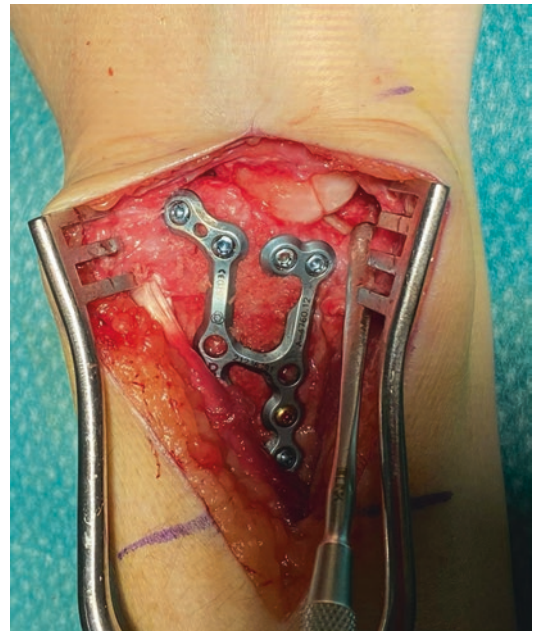

Fig. 16.4 Intraoperative photo taken during radioscapholunate (RSL) fusion for the treatment of end-stage radioscapholunate arthritis using a purpose-specific plate. Note the obvious defect created by the excision of the triquetrum being pointed out by the Freer elevator. This patient also had a distal pole scaphoidectomy

16.4.2 Radioscapholunate (RSL) Fusion

It is more common to have RSL osteoarthritis than RL osteoarthritis in isolation. The midcarpal joint must be intact to proceed with an RSL fusion. However, there is concern regarding the high rates of non-union and progression to midcarpal arthritis [12]. Change from the use of k-wires to memory staples, compression screws, plate and screw fixation and modification of the surgical technique have improved union rates. Wrist motion is significantly affected as the immobile scaphoid bridges the remaining midcarpal joint. Distal scaphoid excision has been shown to release the midcarpal joint. This results in a significantly greater wrist motion as well as reduces the risk of scaphotrapeziotrapezoid (STT) joint and midcarpal joint osteoarthritis and improves union rates [13]. Given the preservation of the midcarpal joint, wrist motion at or above the level of functional wrist motion required to perform most activities of daily living is maintained [11]. The addition of triquetrum excision has been shown to improve range of movement while providing extra bone for grafting [14, 15]. The senior author's preference is distal pole scaphoidectomy, excision of triquetrum and RSL fusion using the purpose-designed RSL fusion plate (Fig. 16.4).

16.4.3 Four-Corner Fusion

Four-corner fusions are widely used to treat symptomatic arthritis seen in scaphoid non-union advance collapse (SNAC) and scapholunate advanced collapse (SLAC). It is typically used when there is involvement of the capitolunate joint but can also be used if the capitolunate joint is preserved and if a fusion is preferred over a proximal row carpectomy. Various methods of fixation include K-wire, screws, staples and more commonly a circular plate and screws, which is the senior author's preference (Fig. 16.5).

Moreover, 40% to 50% of movement and grip strength can be expected post-operatively and overall good long-term outcome is achieved [16]. Non-union remains a concern, particularly at the

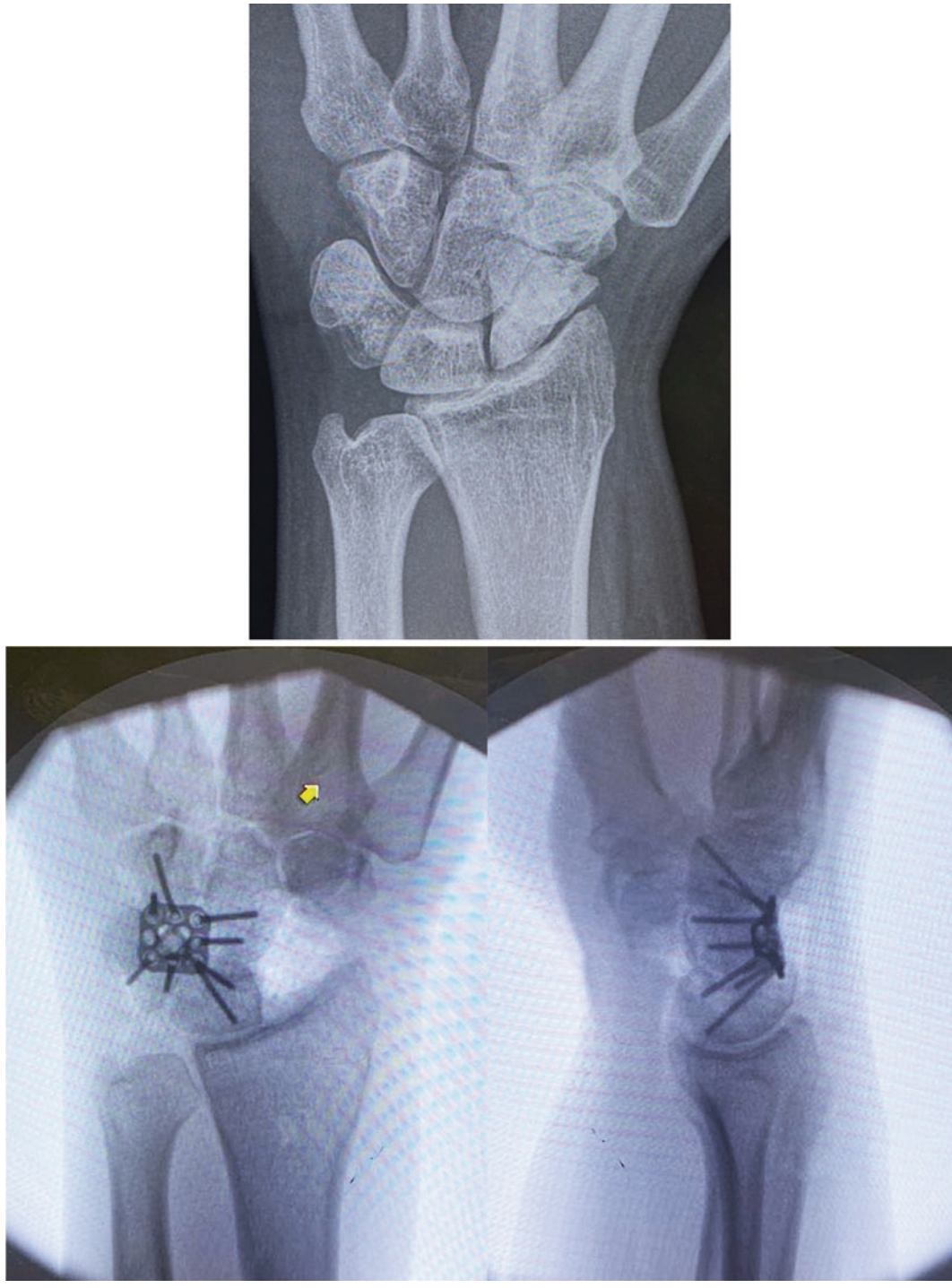

Fig. 16.5 Preoperative and intraoperative images of a patient with localized degenerative at the radioscaphoid articulation treated with a limited intercarpal/four-corner fusion. Note the multiple screw options to ensure appropriate fixation and compression of the fusion mass. Note also how this system allows recession of the plate to limit impingement of the plate against the dorsal lip of the distal radius during wrist extension and to reduce the risk of extensor tendon irritation. Images courtesy of Ms. E. Conroy, University Hospital Kerry

triquetrum. However, union is typically achieved following regrafting and fusion.

More recently, a three-corner fusion has been described, where the triquetrum is excised in addition to the scaphoid. This gives extra bone for grafting and improves ulnar deviation. Higher union rates have also been reported [17]. At the time of writing, the PARTE (PARtial wrist fusion with or without Triquetral Excision) trial is currently underway [18]. This multi-centre double-blind prospective randomized clinical trial will assess the impact of four-corner arthrodesis (without triquetral excision) or three-corner/capitolunate arthrodeses with triquetral excision on grip strength and range of motion in eligible participants with SNAC or SLAC wrist arthritis who have been deemed operative candidates. The results of this study may help to conclude which salvage procedure is best for this cohort.

16.5 Total Wrist Arthroplasty

Total wrist arthroplasty (TWA) has the potential to alleviate pain, improve wrist function and preserve motion for patients with end-stage pancarpal wrist arthritis. These benefits are somewhat offset by their higher complication rates.

Since wrist arthroplasty was first reported in the early 1890s by the German physician and surgeon, Themistocles Gluck (1853–1942) [19], there has been a slow but gradual evolution and refinement in implant design.

First-generation wrist arthroplasties consisted of a single-piece silicone implant that acted as a dynamic spacer at the radiocarpal joint. Although initial studies were encouraging [20], later reports revealed problems such as implant fracture, silicone synovitis [21], osteolysis and implant subsidence. However, the general design principle with a proximal intramedullary radial component and transcapitate/third metacarpal intramedullary distal component is used in fourth-generation implants such as the Motec® (Swemac Orthopaedics, Linkoping, Sweden) prosthesis.

Second-generation designs such as the Meuli (Sulzer Orthopaedics Ltd., Winterthur, Switzerland, and later revised to the MWP III Total Wrist Prosthesis, Zimmer, Warsaw, IN, USA) and Volz (Howmedica Company, Rutherford, NJ, USA) type implants sought to improve durability by using titanium (Meuli) or cobalt chrome (Volz), which were unconstrained ball and socket (Meuli) or semi-constrained hemispherical (Volz) designs with separate radial and carpal components that relied on proximal and distal cement fixation. Unfortunately, distal implant loosening and difficulties in centring the implants in the distal radius and metacarpals due to design constraints made balancing the wrist technically challenging.

Third-generation implants such as the trispherical implants, Biax total wrist prosthesis (DePuy Orthopaedics, Warsaw, IN, USA) and the Universal total wrist implant (Kinetikos Medical, Carlsbad, CA, USA) incorporated features including an axle constraint to lock the radial and carpal components, ellipsoidal (Biax) or toroidal (Universal) polyethylene articulating surface, screw fixation and reduced bone resection to restore soft tissue balance and stability [22–24]. These improvements lead to enhanced patient outcomes but were still hampered with complications including loss of fixation, periprosthetic fracture due to stem breakout and dislocation.

Current fourth-generation designs aim to reduce design-related difficulties and complications, improve biomechanics of the articulation, minimize instability and maximize long-term fixation and bone stock [25]. This has been achieved through improved centralization and greater contact during the total arc of motion, using an ellipsoidal ultrahigh-molecular-weight polyethylene articular surface [26] and uncemented fixation using porous textured surface and locking and fixed-angle screws to encourage osseointegration. The most commonly used modern implants include the Universal 2 and Freedom Total Wrist Implant Systems (Integra Life Sciences, Plainsboro, NJ, USA; Fig. 16.6), ReMotion Total Wrist (Small Bone Innovations, Morrisville, PA, USA) and Maestro Total Wrist System (Biomet, Warsaw, IN, USA), although the latter was voluntarily withdrawn from the marketplace in 2018 despite excellent results. Single-component interposition pyrocarbon

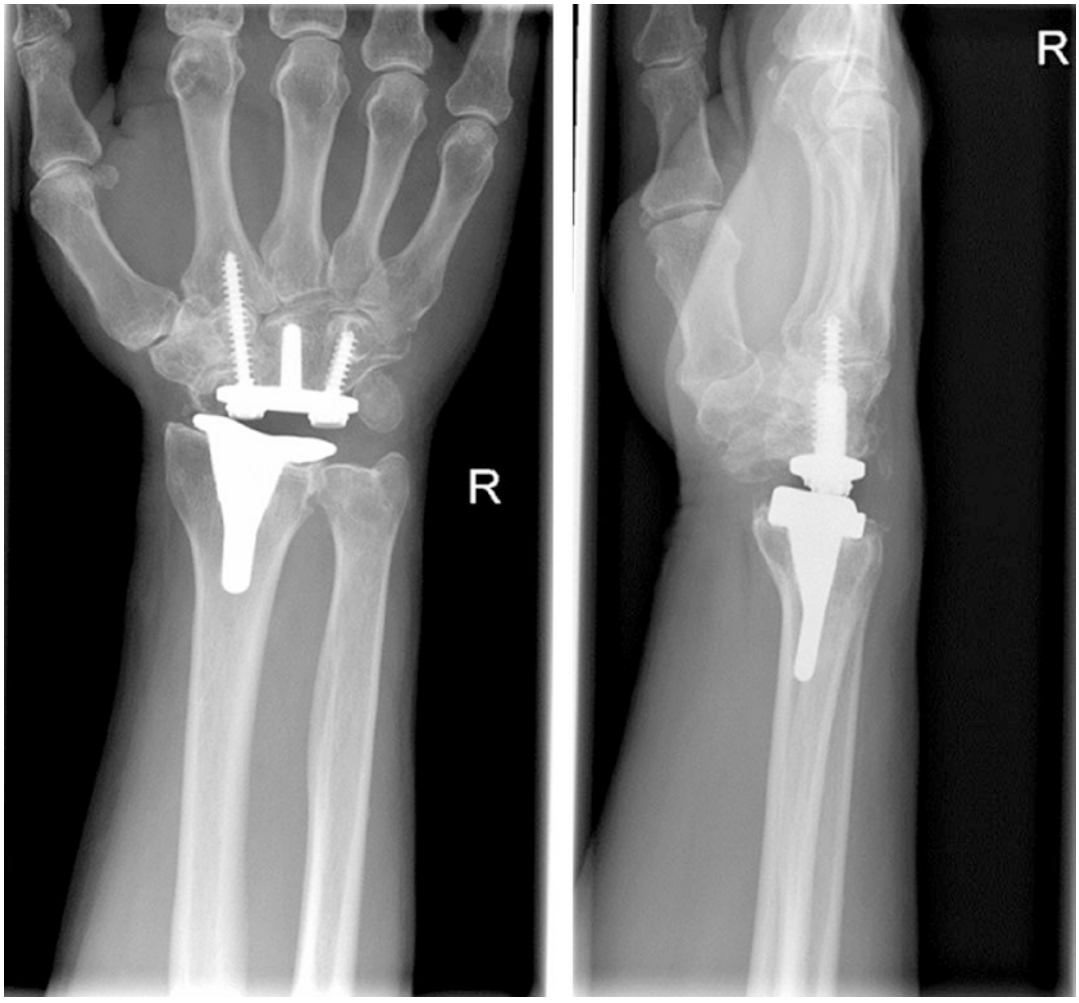

Fig. 16.6 Radiograph of a total wrist arthroplasty using the Freedom Total Wrist Implant System. Images courtesy of Mr. K. O'Shea, National Orthopaedic Hospital, Cappagh, Dublin

arthroplasty such as the Amandys (Tornier SAS–Bioprofile, St. Martin, France) has been recently introduced with encouraging PROMs results. This very different concept uses a quadric elliptical component that acts like a mobile spacer and potentially allows for a ligament-sparring approach to the wrist. However, like the other fourth-generation implants for TWA, only short-term data on their performance is currently available.

Hemiarthroplasty should also be mentioned. As there is less bone and soft tissue resection and dissection, this procedure has been advocated for use in managing younger patients and those with post-traumatic causes including SNAC and SLAC wrist and even in distal radius fractures [27–29]. Depending on the underlying aetiology, a proximal row carpectomy may be undertaken followed by either replacement of the distal radius articular surface alone [27] or in combination with midcarpal resection hemiarthroplasty [28] with maintenance of the distal carpal row or with replacement of the distal carpal row articular surface and maintenance of the distal radius articular surface [29]. Replacement of the distal radius articular surface in isolation has been reported in several centres in Europe for the management of acute distal radius fractures. Midcarpal resection involves using a

monoblock prosthesis implanted into the distal radius and designed to recreate the contour of the proximal carpal row. This is believed to maintain the centre of rotation of the wrist and allow for the dart thrower's motion to occur and hence produce a better functional range of movement [28]. However, due to the very small number of patients treated in specialist and designer centres, the lack of long-term follow-up, significant failure rates reported and availability of reliable, proven procedures, wrist hemiarthroplasty is currently not recommended at this time by the authors.

16.6 Total Wrist Fusion

Total wrist fusion (TWF) is considered the gold standard for the management of end-stage symptomatic wrist arthritis by any surgeon. It affords the ability to correct significant deformity while providing stability and reliable pain relief with lower rates of complications compared to TWA, with high levels of patient-reported satisfaction and function [30] despite the loss of wrist motion requiring adaptation of functional tasks such as perineal hygiene. Failed wrist arthroplasty may be used to salvage wrist fusion, although managing bone loss and achieving bone union are challenging in this setting [30]. There are few contraindications to TWF. These include active infection at the wrist joint or lack of an adequate soft tissue envelope. Poor bone stock in patients with rheumatoid arthritis or after failed wrist arthroplasty has been considered a relative contraindication but modern-day locking plates and refinement in surgical technique have generally overcome this.

During wrist fusion the radiocarpal, intercarpal and midcarpal joints are denuded of articular to expose the preferably bleeding subchondral bone to create the fusion bed. At this time additional procedures involving the extensor tendons or the distal radioulnar joint (DRUJ) can be performed if required depending on the pre-existing pathology and as functional deficits. In the case of patients with severe deformity, proximal row carpectomy (PRC) can be included to de-tension soft tissue structures and help in reducing the hand onto the distal radius. The secondary benefit of this is a ready supply of autologous bone graft from the resected carpal bones. Alternatively, the triquetrum, radial styloid or distal scaphoid can be excised in isolation or in combination to avoid impingement or ulnocarpal impaction.

Historically, fusion constructs consisted of retrograde trans-carpal intramedullary pins (Rush or Steinman, either single or multiple) traversing from the second or third metacarpal to the distal radius. This provided compression and some rotational control, with the use of one or more staples used in modified techniques to provide complimentary fixation. Although largely superseded by plate-assisted fusion (discussed below), this procedure is still advocated in patients requiring concomitant metacarpophalangeal joint implant arthroplasties or in those in whom forearm dissection can be problematic. In such situations, rotational control is achieved using two Steinmann pins [31].

The growing use of the AO (Arbeitsgemeinschaft für Osteosynthesefragen) plating philosophy in the 1970s and 1980s heralded the advent of plate-assisted fusion with plates spanning the metacarpals to the distal radius. Subsequent iterations resulted in purpose-designed pre-contoured, low-contact, dynamic compression titanium and stainless-steel plating systems for wrist arthrodesis, with modern implants employing locking screw holes. Such systems allow compression of the fusion mass by the plate itself and can provide rigid fixation, even in patients with poor bone stock (Fig. 16.7a, b).

From a technical standpoint, ideal wrist fusion position and the joints that should be included in the fusion are still hotly debated in the literature, with no consensus regarding optimal positioning, particularly if arthrodesis is to be performed on both wrists.

Classical techniques are somewhat limited in the position the wrist could be placed because the pin was straight, and the wrist was fused in a neutral flexion-extension position. Some ulnar deviation could be built into the fusion by placing the pin in the second metacarpal, hence offsetting the longitudinal axis of the wrist. In plate-assisted fusion, the position is set by the contour of the

Fig. 16.7 (**a**) Radiograph of a total wrist fusion using a purpose-specific pre-contoured wrist fusion plate spanning from the distal radius to the third metacarpal. (**b**) Radiograph of a total wrist fusion using a modern, low-profile pre-contoured locking wrist fusion plate. Note how the plate extends only as far as the distal carpal row, thus preserving the carpometacarpal (CMC) articulations and also preserving the intramedullary canal of the metacarpal allowing for concomitant metacarpophalangeal (MCP) joint arthroplasty if necessary

plate itself with some minor customization possible. Most modern plates lend themselves to fusing the wrist in some extension and ulnar deviation to maximize post-operative power grip.

The few contraindications to total wrist arthrodesis include an active wrist infection or lack of an adequate soft tissue envelope. Although inadequate bone stock for fusion in patients with rheumatoid arthritis or after failed wrist arthroplasty was historically considered a relative contraindication to plate fixation, the advent of locking plate technology has largely overcome this issue. Major complications include nonunion, ulnocarpal impaction syndrome and implant-related problems, such as plate prominence requiring plate removal due to tenderness and/or extensor tendon irritation and periprosthetic fractures around the plate, mostly metacarpal fractures.

16.7 TWA Versus TWF

Despite the growing body of publication regarding TWA in general, there is a limited volume of level 1 evidence comparing total wrist arthroplasty versus total wrist fusion, the popularly accepted current gold standard. Furthermore, much of this literature deals specifically with rheumatoid arthritis patients [32–34] and hence may not be applicable to other conditions, although this concept is being challenged. There have been several systematic reviews that have tried to address and answer the questions of who the appropriate patients for TWA are and what are the functional benefits for the recipients [30, 32–35].

16.7.1 Indications and Patient Selection

Perhaps the most controversial topic regarding wrist replacement versus fusion is the debate surrounding indications and patient selection with many experts predominantly polarized between the rheumatoid wrist and idiopathic or post-traumatic arthritis. Life expectancy, bone stock and functional demands are frequently cited as determining factors.

TWA may be ideal for frail, low-demand patients with rheumatoid arthritis (RA) or

osteoarthritis, looking for pain relief and maintenance of wrist motion. It is a more functionally acceptable option for patients with a contralateral wrist fusion who wish to maintain wrist motion in one wrist, or in patients with arthritis affecting another ipsilateral upper extremity joint, such as the shoulder, elbow and hand [22], which limits the ability to compensate for a stiff wrist. Ironically, patients with a better soft tissue envelope and bone stock are more likely to achieve better outcomes from TWA [23], which is seldom the case in patients with end-stage inflammatory arthritis.

Whereas wrist arthrodesis may be better suited in younger patients, manual labourers, where there is a history of infection or those requiring the use of a walking aid, or have a pre-existing lack active wrist motion [36]. A wrist arthrodesis is more appropriate in patients whose function will not be improved by a motion-saving procedure such as those suffering from nerve palsy; cervical spinal cord or brachial plexus injury; paralytic, spastic or connective tissue disorders; and bone loss due to underlying inflammatory conditions, trauma or following tumour resection. Wrist fusion can also be considered the treatment of choice in complex carpal instability and salvage for failed total wrist replacement, proximal row carpectomy or limited intercarpal arthrodesis [37].

As the reported functional benefits and survival of TWA improve with fourth-generation implants and modern surgical techniques, including perioperative management, so too have the indications expanded for its use as a treatment method for an increasing number of conditions. In keeping with the management of hip, proximal (and to a lesser extent distal) humeral fractures, TWA has been reported in the primary treatment of acute irreparable distal radius fractures in the elderly [38]. This is still very much experimental, and although good objective and subjective function at 1-year follow-up is reported, its long-term benefit and survival are currently unknown. This, along with other proposed expanded indications for TWA such as SLAC and SNAC wrist, malunited intra-articular distal radius fractures and Kienbock disease, lacks the robust weight of evidence published relating to its use in rheumatoid arthritis, and as such, the authors are reluctant to promote TWA in these conditions currently. However, the Norwegian Registry has reported no difference in revision rates comparing RA with other aetiologies [39] and there is some evidence of equivalent results in rheumatoid and non-rheumatoid patients [36, 40]. In addition, medical advances in the treatment of RA through the use of disease-modifying antirheumatic drugs (DMARDs) has led to the reduction in severe RA progression and subsequent need for hand surgery [41–43]. Therefore, with careful selection, patients may do equally well but there is still a lack of evidence to help surgeons identify which indications lead to the best results with the fewest complications.

16.7.2 Quality Assessment of Studies and Outcomes Reporting Tools

The surgical management of wrist arthritis is by its nature a subspecialist field within hand surgery and does not lend itself to large multi-centre prospective or randomized control trials. Bearing that in mind, it is clear from the literature that most data relate to retrospective observational studies from single surgeons or implant designers, with no blinding, often missing data or high numbers of patients lost to follow-up. Furthermore, significant heterogeneity is commonly observed in terms of the underlying pathology, interventions and procedures undertaken, implants used and outcome measures along with small sample sizes [33, 40]. The nature of the reported data is not amenable to robust statistical testing, so much so that authors have had to choose to do systematic reviews of the topic rather than a meta-analysis [32]. Finally, generic non-validated assessment tools lacking specificity and sensitivity may not be designed to measure specific impairment in this patient cohort and thus fail to recognize if any true functional advantages exist. For example, the DASH (Disabilities of the Arm, Shoulder and Hand) score is frequently used in assessment after TWA

or TWF. This tool is potentially subject to misinterpretation in patients with multiple-joint involvement such as in the case of RA as their scores may be affected by concurrent impairment in other joints of the same upper limb [44]. Generally, it is felt that the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) quality assessment in this field is low, at best.

16.7.3 Motion, Function and Satisfaction After TWA and TWF

As discussed above, wrist biomechanics and kinematics are a complex interplay of radiocarpal and midcarpal movements in several plains occurring simultaneously. Despite advances in component design, current generations of implants simplify normal wrist kinematics to create a stable platform with a functional range of motion. TWA has been shown to improve range of motion (ROM) in absolute terms in all planes with mean post-operative increases of 9o in flexion/extension, 12o in radial/ulnar deviation and 31o in pronation/supination [33]. Although an increase from baseline can be seen, the average total wrist arthroplasty patient fails to achieve a functional active arc of motion as described by Palmer et al. [1]. Moreover, there is little evidence to assess the impact of TWA on improving the dart thrower's motion (DTM), arguably the most important functional wrist movement. Some newly licenced total wrist arthroplasties (KinematX total wrist arthroplasty, Extremity Medical, Parsippany, NJ, USA, and WristMotion Total Wrist Arthroplasty, Anika Therapeutics, Bedford, MA, USA) claim to reproduce the DTM, but long-term, large sample studies in non-designer centres have not been performed to corroborate these claims.

Arthroplasty may improve wrist motion, but for many patients, it offers the potential to preserve their current level of movement. Despite this perceived advantage, it does not appear to reflect an obvious benefit on objective assessment of function, pain relief or complications. That being said, several studies have reported improved function and patient preference towards replacement in those initially treated with TWF and who subsequently received a TWA on the contralateral wrist [45–47]. In contrast, the restricted ROM caused by arthrodesis does not necessarily translate into dissatisfaction or poor function as there are multiple reported retrospective reviews which have found that patients are overall happy with their function after bilateral wrist fusions and have adapted well and the overwhelming majority would repeat the surgery [48]. Greater increases in grip strength for arthrodesis (76% increase from pre-op) compared to arthroplasty (31%) have been reported [33]. Despite these data relating to a group of rheumatoid patients, this raises the possibility that arthrodesis may be a better option for those requiring enhanced grip strength. Satisfaction rates have been found to be high for both interventions (arthroplasty 91% vs. arthrodesis 93%), but TWF provided more reliable pain relief, a lower rate of complications and less frequent need for revision than TWA [31].

16.7.4 Financial Factors Influencing the Choice Between TWA and TWF

TWA is more costly than wrist fusion due to the cost of the implants themselves as well as those associated with complications and revisions should they arise. Counterintuitively, when quality-adjusted life years (QALYs) are taken into account, the incremental cost per QALY accrued for TWA relative to TWF is substantially less ($2328) than the national standard of $50,000/QALY deemed acceptable for adoption in the USA [49] or the £20,000–£30,000/QALY threshold range for adopting new treatment recommended by the National Institute for Health and Care Excellence (NICE) in the UK [50]. Both TWA and total wrist arthrodesis can be considered as very cost effective, and the price of a TWA seems to be within the reasonable cost range. Be that as it may, we believe that total wrist arthroplasty outcomes should be markedly

better than those of TWF to justify the additional costs and risks of the procedure, and the evidence currently available does not support this viewpoint.

16.7.5 Changing Complication Rates Between TWA and TWF

Historically, TWA for end-stage rheumatoid disease of the wrist has been hampered by high rates of complications post-operatively compared to TWF. In counterpoint to this, recent systematic reviews now suggest similar complication rates between TWA and TWF [33, 40]. Complications in TWA are primarily related to prosthetic loosening and dislocation, which in time may be overcome by better prosthetic designs. Indeed, the complication profile of newer fourth-generation prosthesis appears to be improved relative to earlier generations, at least in the short to medium term [33, 40]. However, the complications related to TWF are primarily related to carpal tunnel syndrome, metal work prominence and extensor tendon issues, which may be inherent to the procedure itself and may be less amenable to remedy despite procedural refinement. As the perceived high rate of complications may deter surgeons from offering TWA on a more generous basis, this levelling of the risk profile for TWA could be interpreted as an argument for more widespread, liberal use of TWA. To accurately capture complication rates, as well as long-term clinical outcomes, implant survival and revision data, national joint registries with compulsory reporting for wrist arthroplasty, like those widely seen in hip, knee, shoulder, elbow and ankle arthroplasty, should be established. Such registries are few and far between but may help to address publication bias and portray real-life practices outside of subspecialist and designer centres.

16.8 Conclusions

Multiple surgical options are available for the management of symptomatic wrist arthritis. Partial wrist fusions can be tailored to the specific wear patterns and demographics of the patient, providing good pain relief while still maintaining wrist motion. Total wrist fusion sacrifices effectively all wrist movement but is still considered the gold standard by many because of its reliable outcomes. Total wrist arthroplasty is an attractive option for patients with diffuse symptomatic wrist arthritis. However, due to its complexity, cost implications, high rate of complications (although this may be less problematic with modern implants and arthroplasty techniques) and the existence of reliable alternatives [51], it is best reserved for a select cohort of patients.

Similar to the utility of total hip and knee national joint registries, total wrist arthroplasty registries in conjunction with prospective, randomized controlled trials comparing total wrist arthroplasty with wrist fusion are needed to draw meaningful conclusions on which treatment pathways are likely to provide superior clinical outcomes for patients with wrist arthritis. Standardized pre- and post-operative functional evaluations, quality of life assessments, patient-reported satisfaction and long-term follow-up will be essential to determine the true benefit of these interventions. These robust data will help to inform both patients and surgeons during the decision-making process to identify which patients are likely to gain the greatest benefit from either procedure [4] and will foster discussion and debate to definitively settle the areas of controversy that still remain.

References

1. Palmer AK, Werner FW, Murphy D, Glisson R. Functional wrist motion: a biomechanical study. J Hand Surg Am. 1985;10:39–46.
2. Saffar P, Semaan I. The study of the biomechanics of wrist movements in an oblique plane—a preliminary report. In: Schuind F, An KN, Cooney III WP, Garcia-Elias M, editors. Advances in the biomechanics of the hand and wrist. Springer; 1994. p. 305–11. ISBN: 978-1-4757-9109-9.
3. Wolfe SW, Crisco JJ, Orr CM, Marzke MW. The dart-throwing motion of the wrist: is it unique to humans? J Hand Surg Am. 2006;31:1429–37.
4. Moritomo H, Apergis EP, Herzberg G, Werner FW, Wolfe SW, Garcia-Elias M. 2007 IFSSH committee report of wrist biomechanics committee: biomechan-

ics of the so-called dart-throwing motion of the wrist. J Hand Surg Am. 2007;32:1447–53.
5. Crisco JJ, Heard WM, Rich RR, Paller DJ, Wolfe SW. The mechanical axes of the wrist are oriented obliquely to the anatomical axes. J Bone Joint Surg Am. 2011;93:169–77.
6. Apergis EP, Garcia-Elias M, Werner F, Wolfe S. IFSSH Scientific Committee on Anatomy and Biomechanics 2013.
7. Leventhal EL, Moore DC, Akelman E, Wolfe SW, Crisco JJ. Carpal and forearm kinematics during a simulated hammering task. J Hand Surg Am. 2010;35:1097–104.
8. Linscheid RL, Dobyns JH. Radiolunate arthrodesis. J Hand Surg Am. 1985;10(6 Pt 1):821–9.
9. Garcia-Elias M, Lluch AL, Ferreres A, Papini-Zorli I, Rahimtoola ZO. Treatment of radiocarpal degenerative osteoarthritis by radioscapholunate arthrodesis and distal scaphoidectomy. J Hand Surg Am. 2005;30:8–15.
10. Tambe A, Ali F, Trail I, Stanley J. Is radiolunate fusion a viable option in advanced Kienböck disease? Acta Orthop Belgica. 2007;73(5):598.
11. Fakunle OP, EL DM, Spencer CC, Kumar AD, Gottschalk MB, Wagner ER. Two sides of the same coin: a systematic review of radiolunate and radioscapholunate arthrodesis. J Hand Surg Global Online. 2021;3:81–7.
12. Montoya-Faivre D, Pomares G, Calafat V, Dap F, Dautel G. Clinical and radiological outcomes following radioscapholunate fusion. Orthop Traumatol Surg Res. 2017;103:1093–8.
13. McCombe D, Ireland DC, McNab I. Distal scaphoid excision after radioscaphoid arthrodesis. J Hand Surg. 2001;26:877–82.
14. McNary SM, Heyrani N, Volk I, Szabo RM, Bayne CO. The effect of radioscapholunate fusion with and without distal scaphoid and triquetrum excision on capitolunate contact pressures. J Hand Surg. 2019;44:420.e1–7.
15. Pervaiz K, Bowers WH, Isaacs JE, Owen JR, Wayne JS. Range of motion effects of distal pole scaphoid excision and triquetral excision after radioscapholunate fusion: a cadaver study. J Hand Surg. 2009;34:832–7.
16. Trail IA, Murali R, Stanley JK, Hayton MJ, Talwalkar S, Sreekumar R, et al. The long-term outcome of four-corner fusion. J Wrist Surg. 2015;4:128–33.
17. Delattre O, Goulon G, Vogels J, Wavreille G, Lasnier A. Three-corner arthrodesis with scaphoid and triquetrum excision for wrist arthritis. J Hand Surg. 2015;40:2176–82.
18. Alberta Uo. Randomized comparison of partial wrist fusion with or without triquetral excision (PARTE) 2020. https://clinicaltrials.gov/ct2/show/NCT04580225.
19. Ritt M, Stuart P, Naggar L, Beckenbaugh R. The early history of arthroplasty of the wrist from amputation to total wrist implant. J Hand Surg Br Eur. 1994;19:778–82.
20. Swanson AB, de Groot SG, Maupin BK. Flexible implant arthroplasty of the radiocarpal joint. Surgical technique and long-term study. Clin Orthop Related Res. 1984;187:94–106.
21. Chakrabarti I. Total wrist arthroplasty: a review. J Hand Microsurg. 2009;1:72–5.
22. Kennedy CD, Huang JI. Prosthetic design in total wrist arthroplasty. Orthop Clin. 2016;47:207–18.
23. Nair R. Past, present, and future in total wrist arthroplasty: a perspective. Curr Orthop Pract. 2015;26:318–9.
24. Shepherd DE, Johnstone AJ. Design considerations for a wrist implant. Med Eng Phys. 2002;24:641–50.
25. Srnec JJ, Wagner ER, Rizzo M. Total wrist arthroplasty. JBJS Rev. 2018;6(6):e9.
26. Grosland N, Rogge R, Adams B. Influence of articular geometry on prosthetic wrist stability. Clin Orthop Relat Res. 2004;421:134–42.
27. Morrell NT, Weiss A-PC. Total wrist arthroplasty for treatment of distal radius fractures. In: Arthroplasty for the treatment of fractures in the older patient: indications and current techniques. Borrelli Jr J, Anglen JO, eds. Springer; 2018. pp. 81–90. ISBN: 978-3-030-06812-7.
28. Vance MC, Packer G, Tan D, Crisco JT, Wolfe SW. Midcarpal hemiarthroplasty for wrist arthritis: rationale and early results. J Wrist Surg. 2012;1:61–8.
29. Huish EG Jr, Lum Z, Bamberger HB, Trzeciak MA. Failure of wrist hemiarthroplasty. Hand (NY). 2017;12:369–75.
30. Berber O, Gidwani S, Garagnani L, Spiteri M, Riley N, McNab I, et al. Salvage of the failed total wrist arthroplasty: a systematic review. J Wrist Surg. 2020;9:446–56.
31. Wei DH, Feldon P. Total wrist arthrodesis: indications and clinical outcomes. J Am Acad Orthop Surg. 2017;25:3–11.
32. Cavaliere CM, Chung KC. A systematic review of total wrist arthroplasty compared with total wrist arthrodesis for rheumatoid arthritis. Plast Reconstr Surg. 2008;122:813–25.
33. Hussein A, Sallam A, Elnahas W, Mallina R, Briffa N, Imam M. Wrist arthroplasty leads to better outcomes than arthrodesis for treatment of patients with advanced rheumatoid arthritis of the wrist: a review of literature. Austin Orthop. 2017;2(1):1003.
34. Zhu XM, Perera E, Gohal C, Dennis B, Khan M, Alolabi B. A systematic review of outcomes of wrist arthrodesis and wrist arthroplasty in patients with rheumatoid arthritis. J Hand Surg Eur. 2021;46:297–303.
35. Berber O, Garagnani L, Gidwani S. Systematic review of total wrist arthroplasty and arthrodesis in wrist arthritis. J Wrist Surg. 2018;7:424–40.
36. Nydick JA, Watt JF, Garcia MJ, Williams BD, Hess AV. Clinical outcomes of arthrodesis and arthroplasty for the treatment of posttraumatic wrist arthritis. J Hand Surg. 2013;38:899–903.

37. Jebson PJ, Adams BD. Wrist arthrodesis: review of current techniques. J Am Acad Orthop Surg. 2001;9:53–60.
38. Schmidt I. Can total wrist arthroplasty be an option for treatment of highly comminuted distal radius fracture in selected patients? Preliminary experience with two cases. Case Rep Orthop. 2015;2015:380935.
39. Krukhaug Y, Lie SA, Havelin LI, Furnes O, Hove LM. Results of 189 wrist replacements: a report from the Norwegian Arthroplasty Register. Acta Orthop. 2011;82:405–9.
40. Yeoh D, Tourret L. Total wrist arthroplasty: a systematic review of the evidence from the last 5 years. J Hand Surg Eur. 2015;40:458–68.
41. Gogna R, Cheung G, Arundell M, Deighton C, Lindau TR. Rheumatoid hand surgery: is there a decline? A 22-year population-based study. Hand. 2015;10:272–8.
42. Dafydd M, Whitaker I, Murison M, Boyce D. Change in operative workload for rheumatoid disease of the hand: 1,109 procedures over 13 years. J Plast Reconstr Aesthet Surg. 2012;65:800–3.
43. Aletaha D, Smolen JS. Diagnosis and management of rheumatoid arthritis: a review. JAMA. 2018;320:1360–72.
44. Murphy DM, Khoury JG, Imbriglia JE, Adams BD. Comparison of arthroplasty and arthrodesis for the rheumatoid wrist. J Hand Surg. 2003;28:570–6.
45. Ferreres A, Lluch A, Del Valle M. Universal total wrist arthroplasty: midterm follow-up study. J Hand Surg Am. 2011;36:967–73.
46. Vicar AJ, Burton RI. Surgical management of the rheumatoid wrist—fusion or arthroplasty. J Hand Surg Am. 1986;11:790–7.
47. Goodman MJ, Millender LH, Nalebuff ED, Phillips CA. Arthroplasty of the rheumatoid wrist with silicone rubber: an early evaluation. J Hand Surg Am. 1980;5:114–21.
48. Wagner ER, Elhassan BT, Kakar S. Long-term functional outcomes after bilateral total wrist arthrodesis. J Hand Surg Am. 2015;40:224–8 e1.
49. Cavaliere CM, Chung KC. A cost-utility analysis of nonsurgical management, total wrist arthroplasty, and total wrist arthrodesis in rheumatoid arthritis. J Hand Surg Am. 2010;35(379–91):e2.
50. Gandjour A. Willingness to pay for new medicines: a step towards narrowing the gap between NICE and IQWiG. BMC Health Serv Res. 2020;20(1):343.
51. Rosenfeld JF, Nicholson JJ. History and design considerations for arthroplasty around the wrist. Hand Clin. 2013;29:1–13.