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Wrist arthroplasty using prosthesis as an alternative to arthrodesis: design, outcomes and future

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Abstract

We developed an uncemented screw-shaped ball-and-socket wrist prosthesis and modified it during a decade of trails from 1996 to 2005. The final Motec® wrist prosthesis was launched in 2006. Since then we have used this prosthesis in 110 wrists (110 patients) from 2006 to 2018. This article reviews the design, functional outcomes, complications, clinical usefulness and possible future modifications of the Motec® wrist prosthesis.

Keywords

Wrist, arthroplasty, Motec, arthrodesis, osteoarthritis

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Introduction

Restoring pain-free, stable and movable wrist joints is the goal of treatment of wrist disorders. Wrist arthrodesis has been the salvage procedure at the cost of motion. Although hip or knee replacements are now routine with good outcomes, wrist arthroplasty using a prosthesis is immature. Several wrist prostheses were introduced in 1980s and 1990s (Cobb and Beckenbaugh, 1996; Meuli and Fernandez, 1995; Volz, 1984), but they are no longer in use due to loosening, instability or subluxation, breakage or wear (Reigstad, 2014; Reigstad and Rokkum, 2014).

Contemporary arthroplasties

Four wrist prostheses are now widely available: Motec® (Swemac Orthopaedics, Linkoping, Sweden), Remotion™ (Stryker, Kalamazoo, MI, USA), Maestro™ (Biomet, Warsaw, IN, USA) and Freedom™ (Integra LifeSciences, Plainsboro, NJ, USA). The basic features of the latter three are similar: uncemented press-fit fixation, distal fixation limited to the carpus (with two additional screws in the carpus and metacarpals), plasma-sprayed titanium coating on chrome-cobalt or titanium-alloy core and chrome-cobalt to ultra-high molecular weight polyethylene (UHMWPE) articulation. Remotion™ and Freedom™ have convex distal UHMWP, and Maestro™ has a convex distal metallic articulation.

The Remotion™ and Maestro™ prostheses were introduced in 2002 and 2005, respectively, and demonstrate good pain relief and range of motion compared with pre-operative measurements. These two have mainly been used in inflammatory disease (Boeckstyns et al., 2013; Sagerfors et al., 2015). Revision for extensive long term periprosthetic osteolysis is a major concern for Remotion™ (Boeckstyns et al., 2014). The Freedom™ is the fourth modification of the Universal wrist arthroplasty system (KMI, San Diego, CA, USA). The first Universal arthroplasty was developed by Menon (1998), modified to the Universal 1 by Adams (Divelbiss et al., 2002), later to the Universal 2 (Anderson and Adams, 2005). The latter was withdrawn in 2014, and substituted by the Freedom™. Although the Universal 1 and 2™ showed good longer term results comparable with Maestro™ and Remotion™ (Badge et al., 2016; Gil et al., 2017), the implant has been thoroughly

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changed, renamed and relaunched as Freedom™. So far there are no results of the newest version, so a comparison with the other arthroplasties is not possible.

Our implant design

Motec® (Swemac Orthopaedics) is the final design of a prototype whose initial development started in our department in 1996. The final commercially available and Conformité Européenne (CE) marked version was put into clinical use in 2006. The design process and the characteristics of the prosthesis are outlined as follows.

Initial design from 2001 to 2003

The design concept that we embraced in early 2000s was an 18-mm metal-on-metal (MOM, highly polished chrome-cobalt) ball-and-socket articulation that diminished wear and provided joint stability and sufficient range of motion. Bone removal was minimized to preserve joint space. The implants were fixed with simple conical screws providing primary stability and modularity on both sides (Figure 1). Grit blasted (Albrektsson and Wennerberg, 2004; Reigstad et al., 2007) Ti6Al4V (Ti-alloy) was chosen as the bearing metal. Ti-alloy is strong and the rough surface is biocompatible (Goldberg et al., 1995; Lintner et al., 1988; Reigstad et al., 2008). The distal radioulnar joint is unaffected by the prosthesis. In case of prosthetic failure, wrist arthrodesis would be easy to perform due to the limited bone removal. The implants with his concept were tested on cadaveric wrists and the components were modified accordingly (Reigstad et al., 2011a).

We produced three lengths of the capitate metacarpal and radius screws. Two neck lengths were available for joint tension adjustment. The special instruments needed for the operation comprised cannulated reamers for the two screw types with marks for every screw length, a reamer for the socket, a screwdriver and trial prostheses (Figure 2).

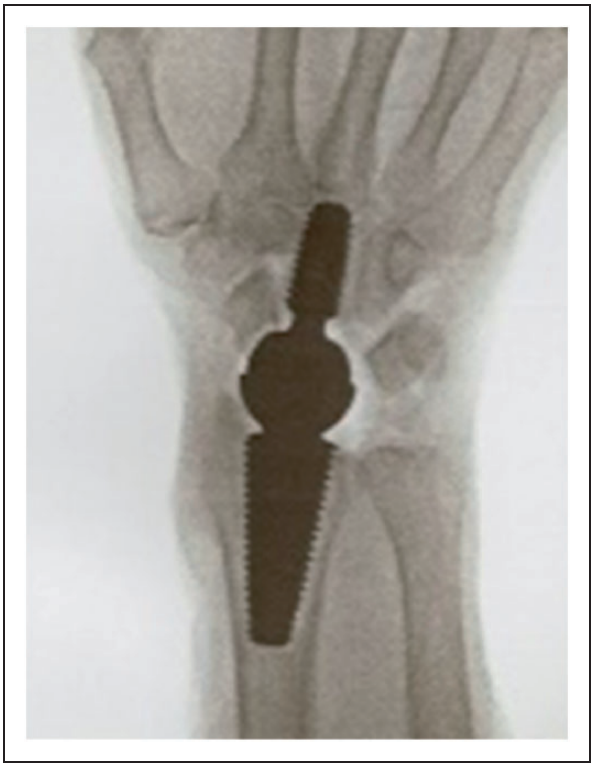

Figure 1. Our initial designed prosthesis shown in fluoroscopic frontal view in a cadaver wrist.

Prosthesis modifications

We revised the design based on the clinical experience with the first eight patients operated from 2001 to 2003 with this prosthesis based on the initial design. The initially designed implants were too bulky and the threads were too coarse, necessitating over reaming to screw the implants home (Reigstad et al., 2011a). The implant diameters and the height of the threads were reduced, and the threads were removed from the cortical area of the radius and third metacarpal. To optimize bone ingrowth, we compared the rough Ti-alloy surface to plasma-sprayed hydroxyapatite and a thin resorbable calcium phosphate coating in animals (Figure 3); the latter showed the best long term performance (Reigstad et al., 2007, 2011b).

The 18-mm articulation was very stable but appeared bulky in some lean patients. Moreover, the rotation centre could be inadvertently placed

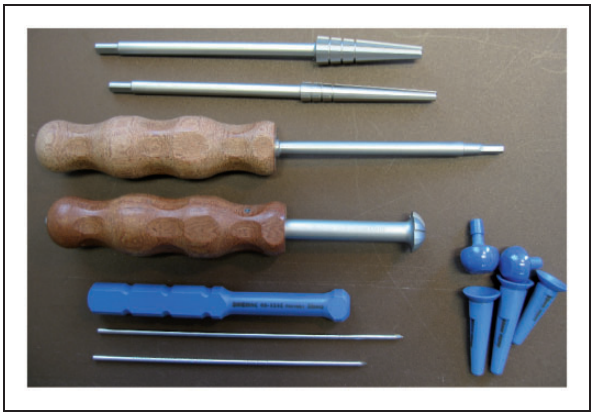

Figure 2. The initial instrument set: radius and metacarpal reamers, screwdriver, counter sinker for the cup, plastic punchdorr, K-wires and trials.

Figure 3. Histological sections (stained Toluidine blue) obtained one year after resorbable calcium phosphate coated implant in rabbit tibia show intimate bone-implant contact around the threaded implant, scale given on the section (×200 magnification).

dorsally resulting in a reduced momentum for the wrist extensors. Therefore, a new 15-mm articulation has become our standard, with 18 mm as an option for unstable cases (not yet experienced). The neck was made available in four lengths (0, 2.5, 5, 7.5 mm) for tension adjustments. The shortest neck gives 58° of motion in all directions before the cup impinges against the distal screw, while the three longer necks (2.5, 5, 7.5 mm) give 72° of motion before impingement. We have seen metal rim wear in wrists using the short neck with indentations in the titanium screw due to fretting of the cup and osteolysis. Therefore, we abandoned the use of short neck. In tight cases, we instead advance the implants further to gain space.

Clinical applications in our patients with 110 prostheses

After the final design of our prosthesis was launched in January 2006, we have used 110 prosthesis in 110 patients up to 2018. The patients averaged 51 years of age (range 18–79) at the time of surgery.

Indications

Our patients were offered wrist prosthesis if sufficient pain and any one of following radiological findings existed.

1. Posttraumatic arthritis of the wrist affecting the radiocarpal and midcarpal joints without preserved cartilage surfaces, excluding limited arthrodesis/resections in scapholunate advanced collapse, scaphoid non-union advanced collapse or after distal radius fracture.
2. Degenerative wrist affecting the radiolunate joint due to Lichtman stage IV Kienböck's disease.
3. Degenerative wrist secondary to inflammatory joint disease of Wrightington Grade 2–4 (Hodgson et al., 1989).
4. Failed four-corner fusion or proximal row carpectomy.
5. Wrist disorder after major hand trauma or replantation with secondary radiocarpal arthritis excluding limited arthrodesis/resections.
6. Painful and dysfunctional wrist arthrodesis (rearticulation).

Contraindications included any cause of wrist imbalance or fixed malposition. They were encouraged to postpone surgery and use analgesics and a brace. In many of our patients, we could postpone the surgery by 1 or 2 years.

Pre-operative clinical evaluation

The clinical evaluation comprises assessment of the radiocarpal and distal radioulnar joint, active range of motion (forearm rotation, wrist flexion, extension, radial and ulnar deviation), grip- and key-pinch strength measurements, as well as subjective evaluation of pain (visual analogue scale) for pain at rest and activity on the ulnar and radial side of the wrist, and function using Quick Disability of Arm, Shoulder and Hand (QuickDASH) and Patient-Rated Wrist and Hand Evaluation (PRWHE) (Hudak et al., 1996; Reigstad et al., 2013).

Radiological evaluation

Four standard views (frontal, lateral, supinated and oblique) of both wrists and a computed tomography of the affected wrist were taken prior to surgery.

Operative techniques

A dorsal incision (8–10 cm) centred just ulnar to Lister's tubercle is developed. The third extensor compartment is opened and the extensor pollicis longus (EPL) tendon held radially. The second and forth extensor compartments are lifted subperiosteally to expose the dorsal, distal radius. A longitudinal capsular incision exposes the carpus from the distal rim of radius to the third carpometacarpal (CMC) joint.

A proximal row carpectomy (leaving a small distal part of the scaphoid) and a generous radial

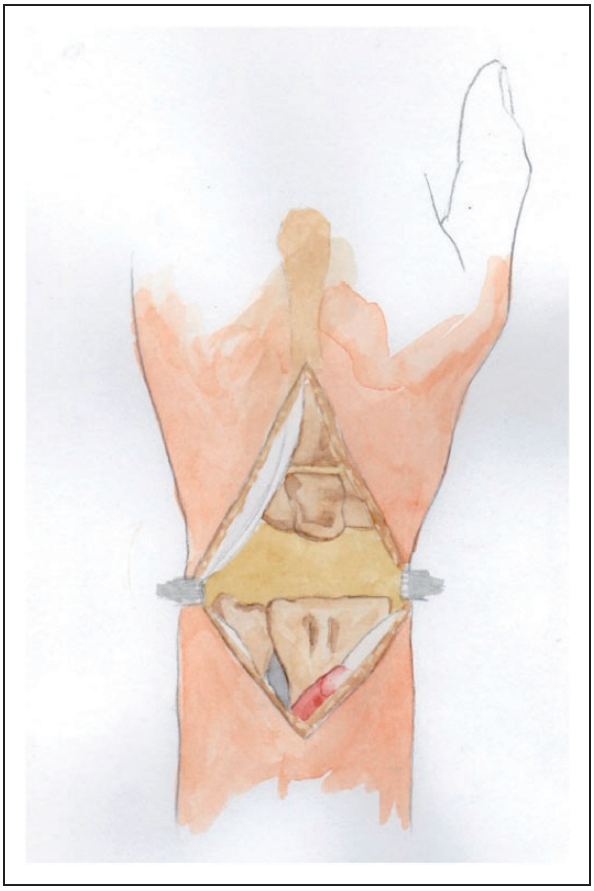

Figure 4. Access to the wrist joint through a dorsal midline longitudinal incision. Expose the carpal bones including the third metacarpal. Then remove the triquetrum, lunate and most of the scaphoid along with a radial styloidectomy. The third CMC joint is opened, cartilage and subchondral bone of this CMC joint are removed.

styloidectomy are performed to provide space for the articulation and to avoid bony impingement after implant insertion (Figure 4). The limitations of the arthroplasty (58° or 72°) will enable a maximum range of motion. We strive to remove the bones in toto, avoiding remnants attached to the capsule that could act as seeds for ectopic bone formation. Initially bone removal was limited to the lunate, the proximal 2/3 of the scaphoid and a minor radial styloidectomy. The triquetrum was spared intending to facilitate potential later wrist fusion. Since some patients experienced ulnar- or radial-sided impingement necessitating secondary bone removal (Reigstad et al., 2017) we started to perform triquetrectomy as well as a generous radial styloidectomy during the primary surgery. We have not seen any disadvantages of the larger bone removal.

A dorsal wedge-shaped resection of the third CMC joint extends the axis of the capitate and the third metacarpal to a straight line; the fusion establishing a 'one bone' for secure fixation of the distal screw. Under fluoroscopic guidance, an awl is introduced in the centre of the head of the capitate and advanced through the capitate and into the diaphysis of the third metacarpal followed by a blunt guidewire. The reamer is carried well past the isthmus, and the length of the appropriate screw is chosen (Figure 5). We choose the shorter screw, or ream 1–2 mm past the mark to ensure that the proximal end of the screw is buried in the capitate and the tip of the implant is distal to the isthmus.

The radial articular surface is then exposed. An awl is introduced into the ridge between the lunate and scaphoid fossa in the frontal view and in the midline on the lateral view. It is passed through the spongy bone to the centre of the diaphysis (frontal and lateral) under fluoroscopic guidance. The blunt guide wire is advanced through the distal half of the radius to secure central placement. The reamer is inserted until engaging the cortical bone volarly and dorsally on the lateral view. The scale on the reamer is read at the distal end of the radius and a one-size-smaller radius screw is chosen (the difference corresponding to the countersinking of the cup). The proximal implant is screwed into place (Figure 6).

Tension and range of motion is tested with trials. A medium or long neck is preferred for maximum range of motion, whereas the short neck should be avoided due to potential impingement between the cup and the softer Ti-alloy screw at 58°. The final articulation is gently tapped in place. Painful radioulnar osteoarthritis is treated with ulnar head resection. Capsular reattachment or reconstruction covers the implants, and the extensor retinaculum is sutured. Experienced wrist surgery (Level 4 or 5) consultants (Tang, 2009; Tang and Giddins, 2016) have performed or assisted the surgeries for all of our patients.

Postoperative protection and therapy

The wrist is protected in a short arm cast in about 20° extension for 6 weeks, leaving the metacarpophalangeal joints free. The patients receive structured hand therapy. Finger, forearm, elbow and shoulder movements are encouraged during the cast period, with special focus on finger motion. After cast removal wrist active motion (flexion, extension, radial and ulnar motion, as well as circumduction) are instructed. Minor weights (0.5 kg) are added and increased during the following weeks. No weight limitations are given after 6 weeks and the patients are encouraged to use their wrist freely.

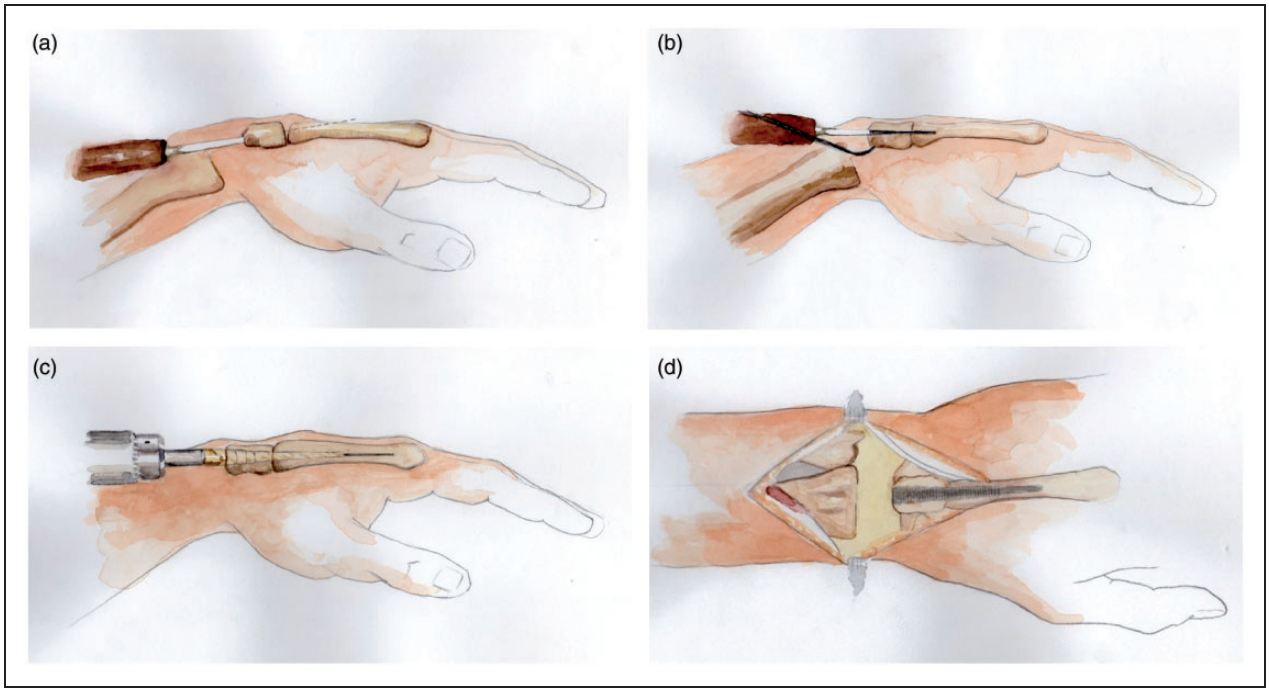

Figure 5. (a) Awl introduced in the capitate, angled dorsally. (b) Extension of the capitate achieving a straight line, advancing the awl into the third metacarpal. (c) Blunt guidewire and reamer past the metacarpal isthmus. Appropriate length is read. (d) Distal implant screwed into place, central position.

Outcomes in our patients

Primary fixation of the implant during surgery has been very reliable due to the rough blasted surgery and coating, combined with the screw and press-fit system of the implant. We have followed all 110 patients prospectively since 2006, 90 for more than 2 years, 65 for 4 years and 63 for more than 5 years. Clinical results are given for the 90 patients with more than 2 years follow-up, complications for all 110 patients. In 63 patients with more than 5 years of follow-up, six had loosening (four were revised). We have not had implant breakage. Stable articulation, significant pain reduction, increased range of motion and grip strength have been achieved in the majority (90%) of the patients with minimum 5 years follow-up.

Pain level

The visual analogue scale pain scale on the radial side of the wrist was reduced from 35 to 8 and 70 to 20 (rest and activity); on the ulnar side from 25 to 15 and 50 to 25 (rest and activity).

Patient-reported outcomes

The QuickDASH score was reduced from 40 to 25 and PRWHE was reduced from 60 to 35 at follow-up (PRWHE was available in Norwegian in 2013, so was only available preoperatively for the past 5 years); the PRWHE at follow-up for all is 25.

ROM, grip strength and key-pinch

Active wrist flexion–extension ulnar and radial deviation increased from 90° to 125° and average grip strength from 20 to 25 kg. Key-pinch at follow-up was equal to the unoperated side. The function remains stable 1–2 years after surgery.

Complications

Complications or reoperations are seen in about 1/3 of the 110 patients: Darrach's procedures in eight wrists; exostoses, ten; tendon surgery, five; revisions due to implant loosening, eight; infection, two; fixed malposition, two; out of the 110 wrists.

The four patients with fixed wrist malposition and stiff wrist joints or infections were the most complicated cases and they ended with conversion to arthrodesis. More details of the complications were presented in our reports regarding more than 5 years' outcomes (Reigstad et al., 2016, 2017).

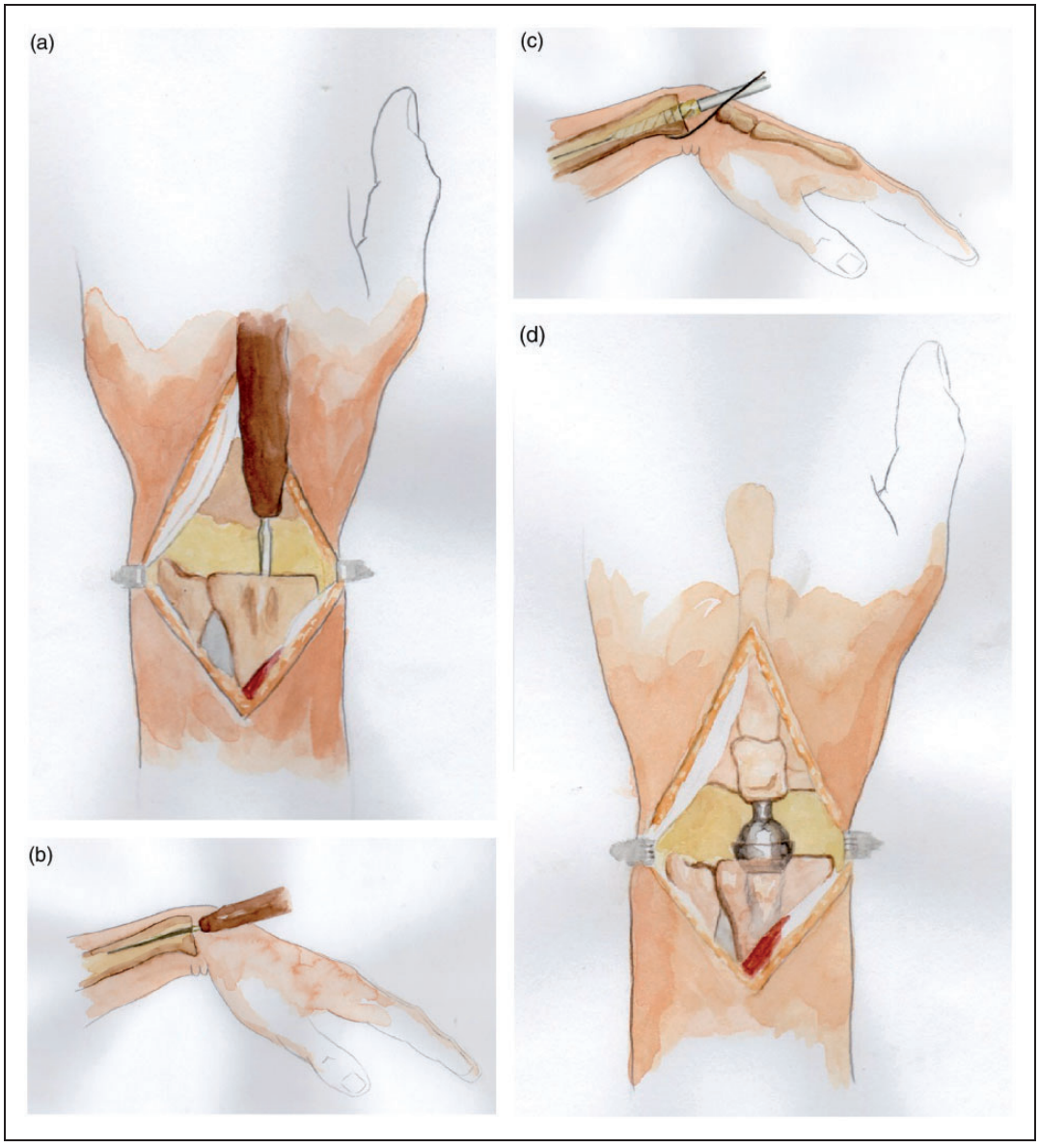

Figure 6. (a) Awl centred in the midline, approximately in line with Lister's tubercle. (b) Awl in the lateral view, midline. (c) Guidewire advanced proximally in the radius, reaming engaging cortex in the lateral view. Length read on distal radius, one size smaller chosen. (d) Implant with articulation in situ.

Revision in our patients

Implant loosening (most common distally) was revised to longer components if the patients were motivated. We extended the cast period to 8 weeks for patients who had revision to longer components. Conversion to arthrodesis was necessary in four patients, which was achieved by bone grafting and rigid fixation (either after implant removal and plate fixation or using securely fixed arthroplasty components and a customized peg).

The results after conversion to arthrodesis are comparable with primary arthrodesis (De Smet and Truyen, 2003; Reigstad et al., 2016). We have used the Motec® prosthesis for revision of loose Motec®, Remotion™ and Amandys® (Tournier, Grenoble, France) arthroplasties (Figure 7). When the diaphyseal bone stock of the third metacarpal and the radius was good, we have achieved solid bone fixation and satisfactory results regularly. The re-revision rate to arthrodesis in our revised patients was higher than

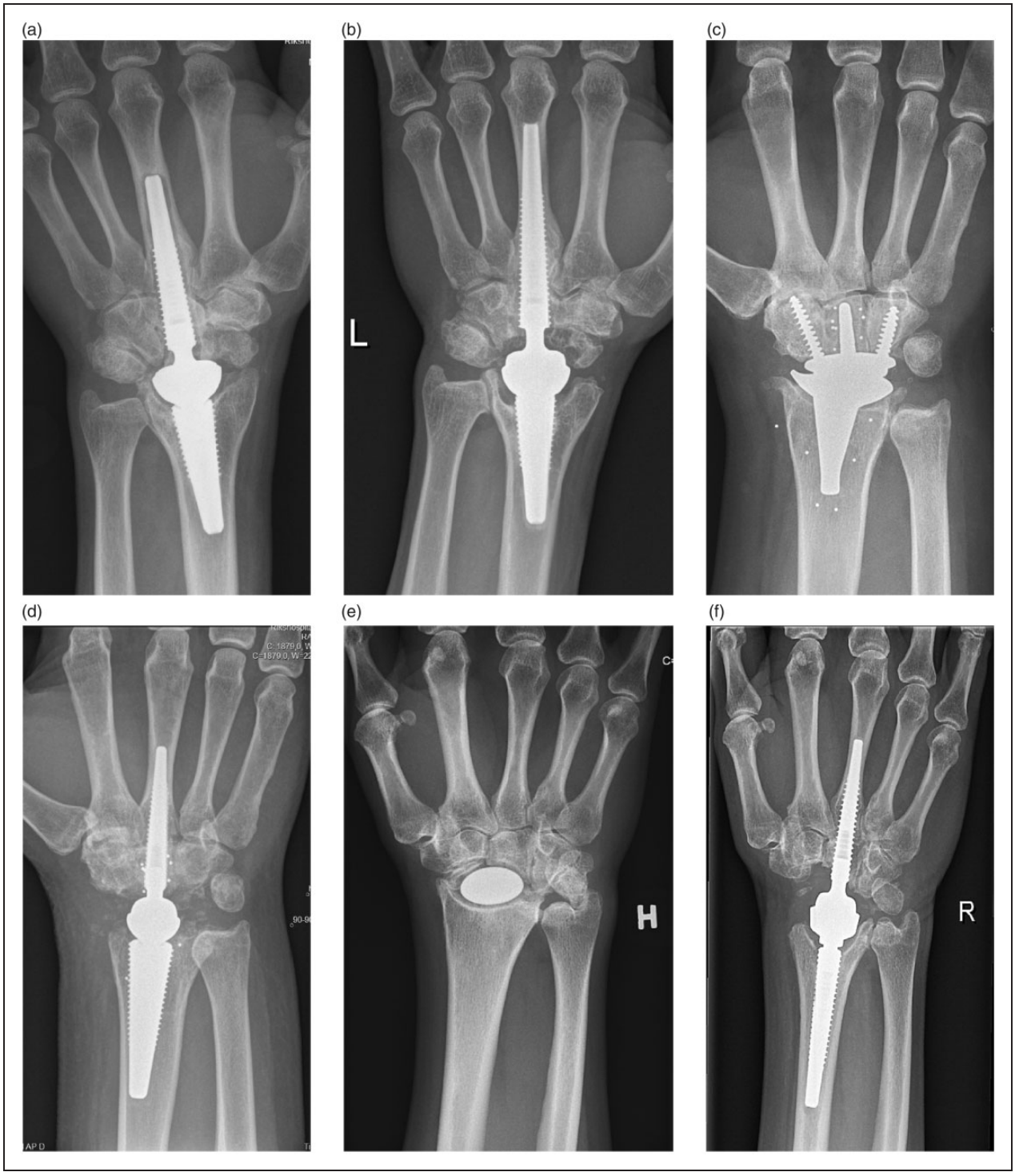

Figure 7. (a) Loose distal Motec®. (b) Revised Motec® with longer distal component, 9 years after revision. (c) Loose distal component Remotion™, tantalum beads for RSA measurements. (d) Revision Motec®, 1 year follow-up. (e) Failed Amandy's arthroplasty (revised twice, unstable). (f) Follow-up 1 year. Metacarpal component used in the narrow radius, PEEK-articulation.

after primary arthroplasty (25% of all our revisions revised to arthrodesis, mostly due to infections) (Reigstad et al., 2018).

The outcomes reported by other team using the Motec® wrist prosthesis

Giwa et al. (2016) found clinical function similar to ours in 24 wrists with up to 5 years follow-up. They experienced one loosening (revised to a new implant) and two conversions to arthrodesis due to pain. Ooms et al. (2018) also reported good clinical function and only one loosening (not revised) in 16 patients after 2.5 years follow-up. They sub-analysed function in regards to the rotation centre of the articulation and found a lower satisfaction among patients having the largest difference between the optimal and the actual centre of rotation.

The challenges and comparisons of currently used wrist prosthesis

The wrist entails additional challenges compared with other joints. The subcutaneous tissue in the wrist is thin, more easily subjecting to infection/oedema. Other important joints – distal radioulnar joint and CMC are close to the wrist, and there is limited bone available for fixation.

Arthroplasties with intra-implant motion have been attempted (for example in the Trispherical and Anatomic Physiologic Handgelenk arthroplasties), but failed for a number of reasons and were withdrawn (O'Flynn et al., 1999; Radmer et al., 2003). Concepts mimicking the distal radius surface (ovoid articulations) (for example Biax, Universal/Universal 1 and Universal 2™) were susceptible to rim wear and instability, resulting in withdrawal (Biax, DePuy Orthopaedics, Warsaw, IN, USA) (Harlingen et al., 2011; Kretschmer and Fansa, 2007) or modifications (three modifications from the Universal to the latest Freedom wrist) (Reigstad and Rokkum, 2014).

In our design, we abandoned the idea of anatomical implant reconstruction and simplified the complex wrist joint to a ball-and-socket joint. A spherical articulation (comparable with hip and shoulder arthroplasties) also provided sufficient functional range of motion (about 130°) (Ryu et al., 1991) in all four directions including circumduction in most of the operated wrists. For the vast majority of patients we have not experienced problems with instability in contrast to some alternative prostheses available during the development period (Harlingen et al., 2011; Kretschmer and Fansa, 2007; Menon, 1998). To minimize rim wear and to provide a maximum range of motion and minimal friction, spherical articulations have been the choice in multidirectional joints like hip and shoulder.

The long-term results are similar between the contemporary arthroplasties (Remotion™/Maestro™/Universal 2-Freedom™) and Motec®, but the patients operated are different. Our patients were younger (50 vs 60 years), more were men (65% vs 20%). Sixty-one per cent of our patients were working at the time of surgery, while working status was not given for the patients treated with the other prosthesis. We operated on a higher percentage of patients with non-inflammatory joint disease (95% of our series vs 18% with the Remotion™/Maestro™), and our patients were not given any restrictions on activity and load of the wrist after surgery (Boeckstyns et al., 2013; Reigstad et al., 2017; Sagerfors et al., 2015).

Decreasing complications: how can an arthroplasty perform better?

The main difference in fixation between Motec® and Maestro™ or Remotion™ or Freedom™, is that the distal fixation of the latter three prosthesis depend just on the capitate. The exclusively cancellous capitate bone may not be strong enough, and the fixation area is short (maximum 2.5 cm). The conical Motec® screws promote controlled and precise reaming, insertion and a maximum of stability and primary bone contact. Secondary bone ingrowth secures long-term implant fixation in the contact area. This has been a strong requisite for the Motec®, which has optimally rough blasted titanium-alloy with additional calcium phosphate coating.

We believe the longer combined cortical and spongy bone fixation will increase implant survival as compared with the other available prosthesis. The flexible, interchangeable modular system is unique for the Motec®, using the available space and bones for implantation and revisions. The weaker link is the articulation material, MOM or poly-ether-ether-ketone (PEEK); none of them are optimal. The articulation is also a weak link of the other arthroplasties, with non-spherical articulations (susceptible to rim wear) and UHMPE on the convex side in two of them. For the Remotion™ arthroplasty, osteolysis was seen in a series of patients (Boeckstyns et al., 2014). None of the contemporary prosthesis have applied the newest articulating surfaces.

Wear products from the articulation affecting the implant fixation are the major concern of initially well fixed implants. Progressive extensive osteolysis has been reported from ovoid, larger, metal-on-UHMWPE wrist prosthesis (Boeckstyns et al., 2014). Although Boeckstyns and Herzberg (2014) did not

believe the osteolysis preceded frank loosening, they emphasized the importance of further follow-up. We have observed osteolysis in well fixed MOM implants affecting the spongy part of the bones. The process has halted in the cortical regions, but the observation time is too short to decide whether the process has stopped or just slowed down due to the strong cortical implant fixation. Wear and failure of the articulation with loosening due to particle production at long-term follow-up (>25 years) is major cause in hip arthroplasties (Kolb et al., 2012) and can be expected in the wrist.

The serious MOM issues have not been encountered in our Motec® wrist patients (Smith et al., 2012). We found a slight increase in full-blood chrome and cobalt (Reigstad et al., 2017), but none of our patients has been near the threshold set by regulatory authorities (Medicines and Healthcare products Regulatory Agency (MHRA), 2012). However, a recent case study describes a patient with pain, high blood levels of metal ions and pseudotumour in a short neck articulation. The radiographs demonstrate a mark in the distal screw after fretting and grinding of the cup on the screw. The wrist was revised with a new articulation. The case illustrates the need to develop alternative bearings (Karjalainen et al., 2018).

Except for Maestro™ with different stem sizes, there is little versatility of the other two (Remotion™ and Freedom™). Exchange to a larger component necessitates exchange of both sides of the articulation. This disadvantage does not apply to Motec®, and implant complications can be handled relatively easy. Since the system is modular, different non-working parts can be exchanged while keeping functioning parts. The variety of component sizes and diameters enables replacement with new implants, even in cases with gross osteolysis (Reigstad et al., 2017). Worn out articulations can be exchanged without removal of osseointegrated implants (Karjalainen et al., 2018).

Table 1. Some key points for planning and surgery with the Motec®.

Before surgery:
1. Performing CT scan of all wrists.
2. Selective evaluation (pain/radiographs/CT) of radial and ulnar sides of the joint (Darrach's necessary?).

During surgery:
1. To create space for articulation and movement: remove proximal carpal row (except the distal scaphoid), radial styloid, dorsal and volar radial osteophytes.
2. Align the capitate and third metacarpal by a wedge-shaped resection of the third CMC joint.
3. Fluoroscope is crucial for correct guidewire placement.
4. Bury the implants in bone and avoid the shortest neck length to get a maximum range of motion and minimize wear.

Key technical points in using our prosthesis

Technical keys in using our prosthesis are summarized in Table 1. Prior to implantation in patients a cadaveric workshop is mandatory. Both surgeon and assistants should have sufficient experience in wrist surgery. The number of procedures needed to stay competent in wrist arthroplasties is not known. For complex procedures in other joints, like ankle and shoulder, significantly lower rates of complications, hospital stays and costs are encountered, with volumes above the 90th percentile (>21 procedures yearly) and after a learning curve (16 arthroplasties) to steady state for reversed shoulder arthroplasties (Basques et al., 2016; Riedel et al., 2010). Wrist arthroplasty using prosthesis should be limited to large hand surgery departments with sufficient operative volume, competent hand therapists and the capability of properly following-up of the patients. In our opinion more than ten operative procedures should be performed within a year or two to reach the experienced level, and thereafter more than five should be performed by the team yearly.

Major advantages and weakness of our prosthesis compared with other three prosthesis

The Motec® wrist has strong primary fixation due to an optimal rough blasted and coated surface with documented secondary bone ingrowth properties (Reigstad et al., 2011b). The modular system is highly versatile, and the components can be chosen depending on the bone available, including the third metacarpal for fixation. In revision cases stable implants can be kept in situ, while loose implants can be revised to longer and wider implants. This feature does not apply for the other three alternative arthroplasties. The ball-and-socket articulation has minimal limitations on range of motion (58° with the shortest neck, 72° with longer necks), and has provided an increased range of motion in our patients (Reigstad et al., 2017). For the Remotion™ and the Maestro™, some surgeons found little difference between the pre-operative and postoperative range of motion (Boeckstyns et al., 2013; Sagerfors et al., 2015). The articulation surface is the weaker part of the Motec® system, a MOM articulation has potential problems with high metal levels, pseudotumour and

failure (Karjalainen et al., 2018), the alternative PEEK articulation is a new concept and has not stood the test of time. Remotion™ and Freedom™ have the polyethylene on the convex side, the former demonstrated wear and osteolysis (Boeckstyns et al., 2014). Polyethylene on the concave side (Maestro™) is a better alternative, similar to other joint arthroplasties.

Other considerations

In selected cases with poor bone stock or poor bone quality or difficult revision cases, systemic or local biological treatment using bisphosphonates, bone morphogenic proteins, parathyroid hormones and other osteoclast inhibitors/osteoblast stimulators can be administered. Regular follow-ups during the first years are mandatory to identify and intervene in patients developing problems or complications. After 2 or 3 years stable well-functioning arthroplasties can be seen every 3 or 4 years.

Arthroplasty of severely arthritic wrist joints gives satisfactory midterm function and pain relief, but has a considerable complication rate for all these four currently used prosthesis, including the Mottec® prosthesis. Nevertheless, failed prosthetic wrists can always be fused relatively straightforward with similar results as primary arthrodesis (Reigstad et al., 2016).

Future perspectives

We believe the future will bring stronger and more stable bone fixation, since surface structure and bone ingrowth are areas of rapid development. Implementation of new surface structures or coatings can increase the fixation and longevity of the arthroplasty, and pharmacological treatment (local or systemic) may also strengthen the fixation. Improved low-wear articulations (ceramics and highly crosslinked polyethylene (XLPE) and metal combinations) are promising. Increased focus on all sides (proper patient selection, knowledge on tribology, bone biology and implant materials and surfaces) of the field of wrist arthroplasty should be a priority.

Metal-on-UHMWP is the choice in all available wrist arthroplasties except for Motec®. The latter is also available with PEEK articulation as an alternative to MOM. PEEK is a strong, wear-resistant polymer, but the clinical experience in arthroplasties is limited (Bohler et al., 2017). We have performed less than 2 years follow-up of 12 patients using PEEK, and are uncertain whether PEEK is better than MOM or UHMWP-metal.

Alternative bearings, such as XLPE, ceramics and newer surfaces coatings, have been implemented successfully in hip arthroplasties (Grieco et al., 2018; Peters et al., 2018; Rajpura et al., 2014), but have not been used in the wrist. Optimizing the articulation should be a future priority for wrist prosthesis to reduce wear, osteolysis and loosening. Especially interesting are new XLPE and ceramic surfaces. For Remotion™, Maestro™ or Freedom™, more flexible modular interchangeable systems would also render a more patient-specific reconstruction and easier revisions.

For the Motec® wrist, the main improvements or modifications would be expected on the articulation, while minor improvements in fixation can be achieved by surface structure modifications.

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