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Total wrist arthrodesis in patients with advanced osteoarthritis: current implants and outcomes

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Abstract

Total wrist arthrodesis can be used to treat symptomatic end-stage wrist osteoarthritis after failed conservative treatment. It can also be considered the last-resort option when partial fusion, proximal row carpectomy, denervation or prosthetic arthroplasty is unsuccessful. Currently anatomic pre-contoured low-profile plates with angle stable screws are available with or without inclusion of the carpometacarpal joints. Generally, patients are satisfied after total wrist arthrodesis, although they are not always pain-free, even when wrist flexion and extension remain limited or absent. Complications and reoperations occur frequently, most often due to incomplete bone fusion or hardware-related problems. It is still not known which type of implant is best for degenerative osteoarthritis and if the carpometacarpal joint should be included in the arthrodesis. Future prospective randomized trials may shed more insights on these questions.

Keywords

Failed wrist arthroplasty, post-traumatic osteoarthritis, radiocarpal osteoarthritis, total wrist arthrodesis, wrist osteoarthritis, wrist salvage operation

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Indications

The decision to perform a total or partial arthrodesis, along with any additional procedures, depends on the degree and location of cartilage loss, particularly at the midcarpal and/or the distal radioulnar joint. Total wrist arthrodesis is primarily indicated for painful end-stage wrist osteoarthritis (OA) after unsuccessful conservative treatment. Degenerative OA of the wrist can be idiopathic, post-traumatic or related to carpal bone necrosis. It may also be secondary to infection, autoimmune (rheumatoid arthritis, systemic lupus, spondylarthritis) and metabolic diseases (calcium pyrophosphate deposition disease, gout, haemochromatosis) (Rouanet et al., 2023; Rodriguez-Merchan et al., 2023).

At intermediate stages of OA, other solutions can be carried out, such as partial wrist arthrodesis or proximal row carpectomy, which spare some wrist motion. Conversion to total wrist arthrodesis can occur after failed partial fusion, proximal row carpectomy, total wrist arthroplasty (TWA) or denervation. According to a systematic review (Andronic et al., 2022), 6% of wrists were converted to total wrist arthrodesis at a mean follow-up of 11 years after a four-corner arthrodesis. A 5% incidence was reported after failed proximal row carpectomy at a mean follow-up of 7 years in a retrospective study of 1070 cases by Zeidan et al. (2023). Other studies have reported no significant difference in percentages of conversion to total wrist arthrodesis when comparing proximal row carpectomy and four-corner arthrodesis (Chammas et al., 2022; Reyniers et al., 2023; Wagner et al.,2017; Williams et al. 2018). Patients aged under 50 years were more likely to need total wrist arthrodesis after proximal row carpectomy (Wagner et al., 2017; Zeidan et al., 2023). In a systematic review by

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Fakunle et al. (2021), mean progression to total wrist arthrodesis after radioscapholunate (RSL) (Figure 1) and radiolunate (RL) arthrodesis was 4% (7/180 cases) and 0% (0/94 cases), respectively. After scaphotrapeziotrapezoidal (STT) joint arthrodesis, 4% of wrists were converted to a total wrist arthrodesis in a study that analysed 1429 procedures performed on 1404 patients (Stephens et al., 2022).

TWA may be associated with a high number of complications and revisions, and total wrist arthrodesis remains one of the options for a salvage procedure after a failed implant arthroplasty. The incidence of conversion to total wrist arthrodesis is difficult to estimate owing to the varying generations of implants and the long follow-up required to produce an accurate estimate (Zijlker et al., 2022). In a prospective study of 56 wrist arthroplasties with a mean follow-up of 8 years using the Motec (Swemac, Linkoping, Sweden) implant, eight (14%) wrists were reoperated, four (7%) with an arthrodesis and four (7%) with revision arthroplasty (Reigstad et al., 2017). Wrist denervation is another variable that may be effective initially but may deteriorate over time. A total of 100 denervated wrists were retrospectively reviewed at a mean follow-up of 7 years, with 31% needed additional surgery including a total wrist arthrodesis in 5% (O'Shaughnessy et al., 2019).

The effectiveness of wrist arthrodesis on pain relief can be predicted preoperatively by the response to intra-articular anaesthetic infiltration (Ribeiro et al., 2023). Use of a wrist splint in the arthrodesis position is a crucial preoperative assessment tool. This can evaluate both the patient's tolerance for postoperative immobilization and anticipated pain relief. Bone scintigraphy helps identify the predominant site of symptomatic OA when the diagnosis is uncertain or when multiple areas are involved. Surgical indications for total wrist arthrodesis are based solely on pain after unsuccessful conservative treatment. Preoperative planning must also address factors that may increase the risk of surgical failure, such as smoking (Foster, 2023), osteopenia and limited bone stock. Additional procedures for distal radioulnar joint OA include distal ulna resection (Darrach procedure) (Figure 2), total distal radioulnar joint arthroplasty and ulnar head arthroplasty (Dittman et al., 2023).

Figure 2. (a, b) Radiographs depicting total wrist fusion with associated distal ulna resection for combined radioulnar and radiocarpal joint osteoarthritis (Darrach procedure) after hardware removal.

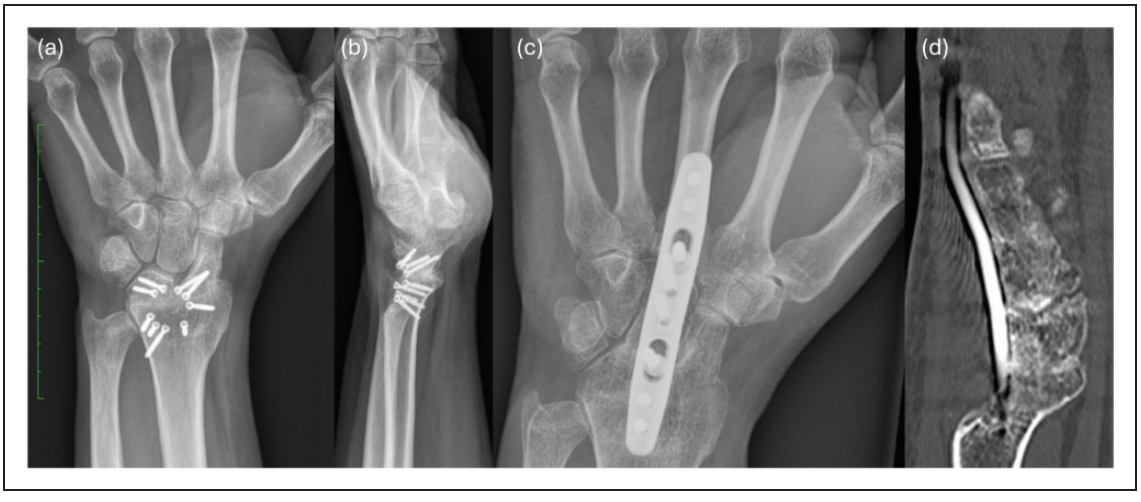

Figure 1. (a, b) Radiograph showing radioscapholunate arthrodesis. (c) Radiograph showing unsuccessful radioscapholunate fusion converted into a total wrist arthrodesis and (d) CT illustrating bone fusion.

The indications for total wrist arthrodesis (painful end-stage wrist OA) are the same as for TWA. While TWA preserves some wrist mobility and is preferred for those with moderate functional demands, the incidence of complications was 30% (Berber et al., 2018; Redfern et al., 2024; Reigstad and Rokkum, 2018), increasing with the duration of observation but decreasing in later-generation prostheses models (Redfern et al., 2024). Decision-making for surgery is influenced by factors such as patient age, occupational demands and predicted prosthetic longevity. Prosthetic arthroplasty is generally not recommended for young individuals or those engaged in heavy labour.

Implants

To reduce complications with traditional techniques such as Steinmann pins, bulky standard plates or multiple K-wires, special wrist arthrodesis plates have been introduced. In general, these are low-profile pre-contoured anatomical plates often made out of titanium or steel with options to use locking screws and inclusion of the carpometacarpal (CMC) joints. The implants can be divided into spanning (fixed on the dorsal side of the distal radius and the metacarpal shaft) and non-spanning plates (fixed dorsally on the distal radius and carpus). Examples of spanning plates currently available are the LCP Wrist Fusion System (Depuy-Synthes, Raynham, MA, USA) (Figure 3(a)), the APTUS 2.5 TriLock Wrist Fusion Plate (Medartis, Basel, Switzerland) (Figure 3 (b)), the Total Wrist Fusion Plating System (Acumed LDT, Sheffield, UK) (Figure 3(c)) and the Variax 2 wrist fusion (Stryker, Kalamazoo, MI, USA). The APTUS 2.5 TriLock Wrist Fusion Plate (Medartis, Basel, Switzerland) is also available as a non-spanning plate that does not include arthrodesis of the CMC joint (Figure 3(d)).

Spanning total wrist arthrodesis

The procedure typically involves securing a pre-contoured dorsal plate from the radius to the third, or sometimes the second, metacarpal to fit the dorsal aspect of the wrist, ensure stable fixation (Rioux-Forker et al., 2023; Zijlker et al., 2022) and to preserve carpal height (Rancy et al., 2018).

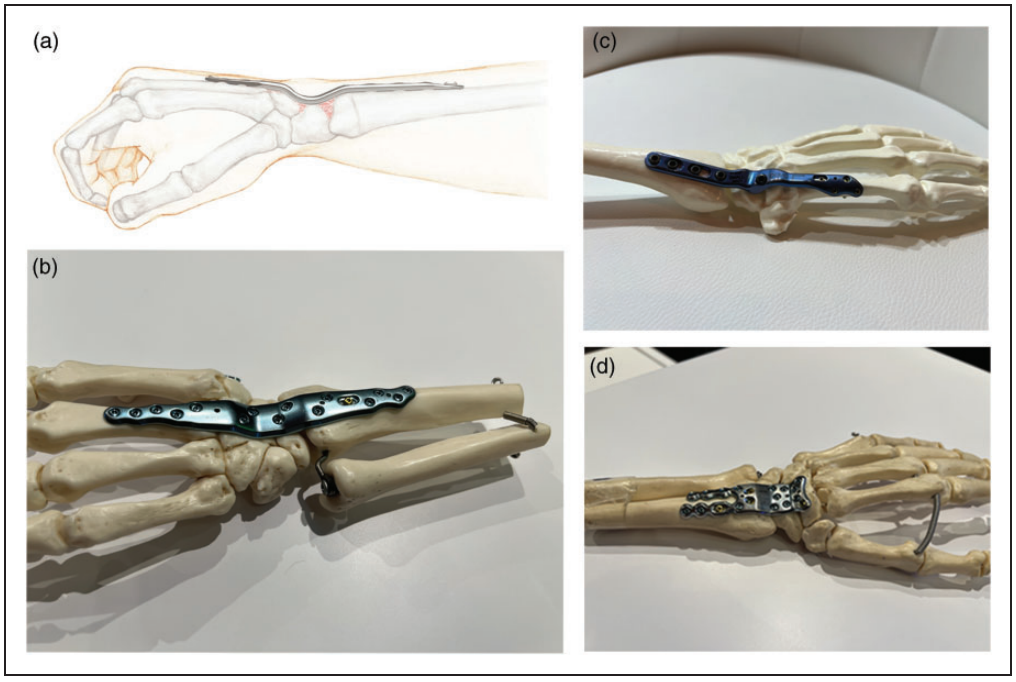

Figure 3. Examples of anatomic pre-contoured wrist fusion plates. (a) Pre-contoured low-profile CMC joint spanning plate (standard end plate LCP Wrist Fusion System; Depuy-Synthes, Raynham, MA, USA). (b) Pre-contoured low-profile CMC joint spanning plate for medium to large wrist (APTUS 2.5 TriLock Wrist Fusion Plate with long bend; Medartis Basel, Switzerland). (c) Pre-contoured low-profile CMC joint spanning plate positioned on the right second metacarpal (Total Wrist Fusion Plating System; Acumed LDT, Sheffield, UK) and (d) CMC joint non-spanning plate with long bend for medium to large wrist, that enables the CMC joint to be spared (APTUS 2.5 TriLock Wrist Fusion Plate-Fusion; Medartis Basel, Switzerland). CMC: carpometacarpal.

Bending the plates is generally avoided to prevent creating weak spots, particularly if bending occurs near a screw hole. The wrist is positioned in 10° to 20° of extension and slight ulnar deviation to optimize finger closure and grip strength (Rancy et al., 2018). In cases of bilateral involvement, the non-dominant hand might be positioned in a slight flexion to facilitate perineal care (Hayden and Jebson, 2005).

In cases where prosthetic arthroplasty has failed, spanning total wrist arthrodesis remains possible (Smith et al., 2022; Zijlker et al., 2022). Removal of bone during the primary procedures, bony erosion and bone loss during implant extraction will decrease the bone stock that is available for arthrodesis. Massive auto- or allografts may be needed, and stable fixation, restoring carpal height and achieving bony union can be difficult.

There is ongoing debate about whether to include arthrodesis of the third CMC joint. In a biomechanical study, plates that included third CMC joint arthrodesis were stiffer and failed at a significantly greater load and number of cycles than plates mounted to models without CMC joint arthrodesis. Incorporation of the CMC joint in total wrist arthrodesis may protect against plate failure (Owen et al., 2023).

A second metacarpal plate with the Total Wrist Fusion Plating System (Acumed LDT, Sheffield, UK), puts the wrist into ulnar deviation. This is intended to allow better grip strength and reduce extensor tendon irritation (Figure 3(c)).

Non-spanning total wrist arthrodesis

Rancy et al. (2018) used an anterior distal radius locking plate with locking screws contoured on the dorsal surface of the distal radius and distal carpal row. The APTUS 2.5 TriLock Wrist Fusion Plate-Fusion (Medartis, Basel, Switzerland) (Figure 3(d)) is specially designed to secure the carpus to the radius. Non-spanning wrist arthrodesis allows an estimated 7° flexion/extension CMC joint motion in the third CMC joint (El-Shennawy et al., 2001).

At times, a total wrist arthrodesis may be required for patients who had previously undergone a proximal row carpectomy or simultaneously with the total wrist arthrodesis in cases of non-reducible wrist flexion contracture (Rodríguez-Nogué and Martínez-Villén, 2022). The Aptus 2.5 TriLock Wrist Fusion Plate (Medartis, Basel, Switzerland) is also designed for total wrist arthrodesis combined with proximal row carpectomy.

Alternative techniques for plate fixation

Intramedullary fixation with Steinmann pins may be indicated in patients with rheumatoid arthritis who have a poor soft tissue envelope, but this is not advisable for degenerative OA. With a locked intramedullary device, a high number of complications have been reported (Kachooei et al., 2022; Walker et al., 2021).

Nazerani et al. (2019) described an arthroscopic technique involving cartilage removal through radiocarpal and midcarpal portals, and the placement of cannulated screws under fluoroscopic guidance in four patients with satisfactory results, but with a minimum follow-up of only 3 months.

In cases of a failed Motec wrist prosthesis without loosening, it is possible to do an arthrodesis while retaining the radial and metacarpal stems and connecting those with a fixed intermediate peg that has variable angulation (Figure 4).

Patient-reported outcomes

Rouanet et al. (2023) looked at outcomes of 42 arthrodeses for post-traumatic OA with a radiocarpal or radiometacarpal plate using Medartis plates at a mean follow-up of 8 years. They reported that 83% of patients were satisfied, a mean Quick Disabilities of Arm, Shoulder, and Hand (DASH) score of 23, and 72% went back to their previous job (Rouanet et al., 2023). A retrospective study using the Medartis CMC joint sparing plate assessed the outcomes of one bilateral and 18 unilateral wrist arthrodesis with a mean follow-up of 17 months. Out of 18 patients, 17 were satisfied. The grip strength was 87% of the contralateral side, the mean DASH score was 24, all patients returned to work and the mean pain score was 1.3/10 (Briotti et al., 2024).

Knie and van Schoonhoven (2023) evaluated 68 patients at a mean follow-up of 12 years after arthrodesis for degenerative OA with the LCP Wrist Fusion System (Dupuy-Synthes). Of the patients, 67 were satisfied, although the mean DASH score was 30 and only 15 patients were completely pain-free.

In another study, outcomes of 41 wrists were reported after arthrodesis with LCP or Variax 2 plates at a median follow-up of 6 years. Of the patients, 36 (90%) were satisfied. The mean preoperative visual analogue scale score for pain decreased from 8.8 to 1.3 postoperatively, while the mean grip strength increased from 13 kg to 19 kg. The mean QuickDASH decreased from 74 to 30 and overall 63% of patients returned to work. Not all patients had been operated for degenerative OA and other indications included post-traumatic arthritis ($n = 23$), Kienböck's disease ($n = 7$), rheumatoid arthritis ($n = 6$), tuberculosis ($n = 2$), failed TWA ($n = 2$) and a tumour in one wrist (Rodríguez-Nogué and Martínez-Villén, 2022).

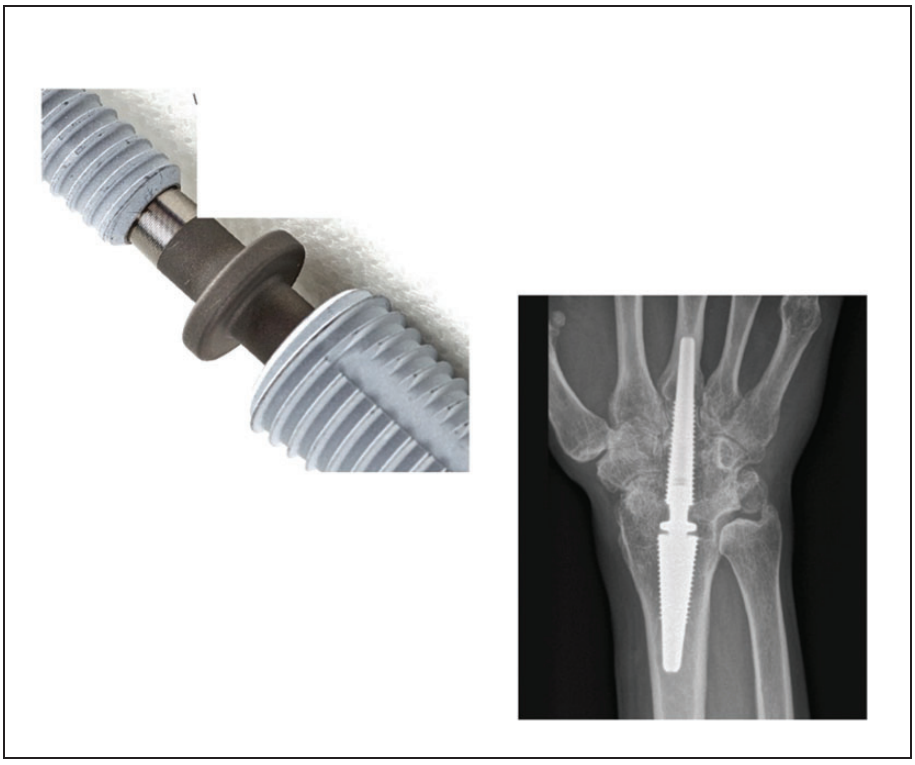

Figure 4. Custom-made titanium alloy peg (straight or double Taper) facilitating arthrodesis with the original Motec (Swemac, Linkoping, Sweden) total wrist arthroplasty in place.

Smith et al. (2022) described outcomes of 34 patients after an arthrodesis with an LCP plate at a mean follow-up of 15 years. Indications for surgery were post-traumatic arthritis ($n=12$), rheumatoid arthritis ($n=9$), avascular carpal necrosis ($n=9$), Madelung's deformity ($n=2$), psoriatic arthropathy ($n=1$) and seronegative idiopathic polyarthropathy ($n=1$). Of the patients, 83% were satisfied and the mean QuickDASH was 42.

Zijlker et al. (2022) used two different plates (Acumed and Dupuy-Synthes) in 71 patients, of whom 27 had rheumatoid arthritis. The median reported satisfaction score was 8 (on a scale of 1–10, with 10 being maximal satisfaction) in patients with a primary arthrodesis ($n=39$) and 7 for patients with an arthrodesis after failed TWA ($n=32$). The mean patient-rated wrist hand evaluation score was 38 in the first group and 43 in the second group. Total absence of pain during activity was reported by nine patients in the primary arthrodesis group and by seven patients in the secondary arthrodesis group.

Complications

Complications of total wrist arthrodesis using a plate include nonunion, hardware failure and soft tissue problems. In the study by Rouanet et al. (2023) with 42 arthrodeses using a Medartis plate, 13 patients required hardware removal and one required surgery for infection. Briotti et al. (2022) reported plate removal in four out of 23 wrist arthrodeses in a retrospective study with the Medartis CMC joint sparing wrist plate, with a mean follow-up of 17 months.

Out of 68 patients, three (4%) nonunions were reported in the study by Knie and van Schoonhoven (2023) with the LCP plate. Broken screws were present in 17 wrists. Plates had already been removed in 23 patients. Two broken plates were reported, one after a fall and one associated with nonunion. There was one case with severe extensor tendon synovitis.

Three out of 41 cases were reported with hardware loosening in the study by Rodríguez-Nogué and Martínez-Villén (2022) with LCP or Variax 2 plates. There was nonunion in one wrist.

Smith et al. (2022) reported six cases of hardware removal and two cases of prominent metalwork out of 34 cases treated with LCP plates. One patient underwent revision surgery for nonunion.

In the study by Zijlker et al. (2022) of 71 arthrodeses using Acumed and Dupuy-Synthes plates, 31 additional operations in 27 patients were reported: plate and screw removals ($n=13$); distal radioulnar joint arthroplasty ($n=2$); extensor pollicis longus

tendon reconstruction ($n = 3$); tenolysis ($n = 8$); and carpal tunnel decompressions ($n = 3$). There were 12 nonunions and one deep infection.

Hazewinkel et al. (2020) reported outcomes of a retrospective study of 215 patients with a median follow-up of 6 years after wrist arthrodesis with a dorsal spanning plate. Half the cases were treated for degenerative or post-traumatic OA. A bone graft was used in 89% (auto or allograft). Of the patients, 41 (19%) underwent reoperation at a median of 7 months for symptomatic implants (7%), implant failures (20%), infections (17%) and nonunions (15%). Total wrist arthrodesis of the dominant hand was linked to a higher number of reoperations.

A flexor tendon rupture was reported in one out of 11 of cases involving LCP spanning plates (Rancy et al., 2018).

An example of another tendon problem is that the extensor pollicis longus may have become unstable if the third compartment was opened without proper re-suturing or bowstringing if the extensor digitorum communis tendons were caught on a deficient extensor retinaculum, as illustrated in Figure 5. Figure 6 shows an example of a failed total wrist arthrodesis that was converted to a TWA.

Comparative studies

Spanning versus non-spanning plates

Hernekamp et al. (2020) retrospectively compared ten patients operated with the spanning plate from Dupuy-Synthes with ten patients operated with the non-spanning Aptus 2.5 Trilock plate from Medartis and found similar results. A larger randomized controlled study is being conducted (Owen et al., 2021).

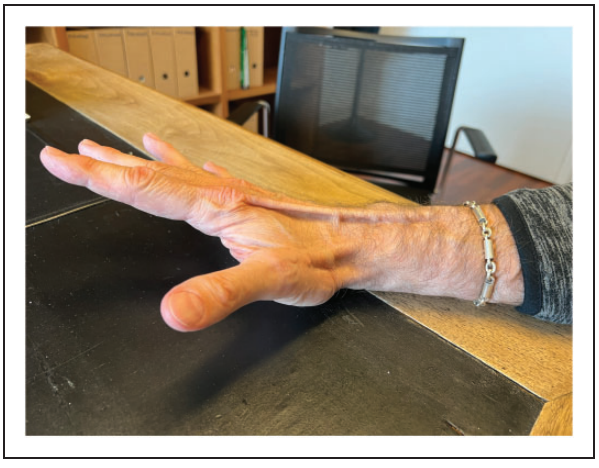

Figure 5. Bowstringing of the extensor indicis proprius and digitorum communis tendons following total wrist arthrodesis due to deficiency of the extensor retinaculum.

With or without CMC joint arthrodesis

In a retrospective study by Nagy and Büchler (2002) of 146 total wrist arthrodesis, a dynamic compression plate was used in 62 wrists and the precontoured and tapered 3.5/2.7 mm AO-titanium wrist arthrodesis plate was used in 84 wrists. In 79 wrists, the third CMC joint was arthrodesed, requiring reoperation in 23% of cases. In 67 wrists, the third CMC joint was bridged, leading to one case of plate removal. The authors recommended against CMC joint arthrodesis because of the frequency of CMC joint nonunions and pain after hardware removal.

Contradictory outcomes were reported in a study by Rioux-Forker et al. (2023) in which 139 total wrist arthrodeses with arthrodeses of the third CMC joint wrist were compared with 43 wrists without CMC joint arthrodesis. A modern wrist arthrodesis plate was used. Only 41% of patients were operated for OA. Other indications included rheumatoid or inflammatory arthritis (20%), neurological disorders (18%), avascular necrosis (15%) and infection (6%). The median follow-up was 18 months (range 3 months–11 years). Hardware complications occurred in 22% of the wrists with CMC joint arthrodesis and in 67% of the wrists without. The inclusion of the third CMC into the arthrodesis was associated with a significantly reduced rate of radiographic nonunion at the radiocarpal or midcarpal joints (3% vs 12%).

In cases of localized pain or joint degeneration, concomitant CMC joint arthrodesis with a spanning plate should be considered. In case of bridging without CMC joint arthrodesis, there is no risk of CMC joint nonunion, but the metacarpal screws can break because of the remaining mobility in the CMC joint. Plate removal was advised before any breakage occurred (Owen et al., 2021; Rioux-Forker et al., 2023).

Primary versus secondary arthrodesis

Zijlker et al. (2022) retrospectively compared outcomes of primary wrist arthrodesis with an arthrodesis for a failed TWA. The results were slightly in favour of patients with a primary prosthesis. Nonunion was present in seven out of 32 wrists in the group with the converted arthrodesis and in five out of 39 wrists in the group with primary wrist arthrodesis.

The timing for total wrist arthrodesis, whether primary or as conversion, could influence patient outcomes. Arthrodesis could be considered the first line in cases of questionable indications of partial arthrodesis on a stiff wrist because the results were better without previously having surgery (Roulet et al., 2023).

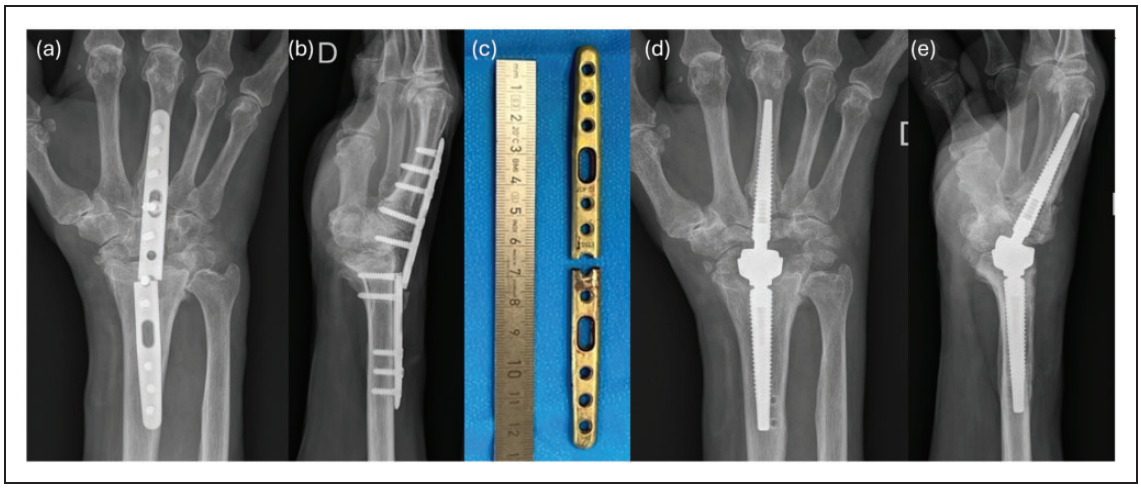

Figure 6. (a, b) Radiographs showing a failure to fuse and breakage of a spanning plate. (c) Operative view of the spanning plate breakage and (d, e) radiographs illustrating the conversion from total wrist arthrodesis to total wrist arthroplasty.

Arthrodesis with or without proximal row carpectomy

Bartoletta et al. (2022) compared outcomes of total wrist arthrodesis in 87 wrists with proximal row carpectomy and 96 wrists without. A dorsal spanning plate was used and patients with indications other than degenerative OA were included. The median follow-up was 18 months. No differences in incidences in nonunion, revision and hardware removal were found.

In a systematic review, no statistically significant differences were found in union between wrist arthrodesis with proximal row carpectomy and wrist arthrodesis without proximal row carpectomy (Ruskin et al., 2021).

Future directions and innovations

Prospective randomized trials, as have been announced by Owen et al. (2021), will help hand surgeons decide which plate to choose. The ongoing refinement of wrist arthrodesis focuses on improving plate designs and materials to decrease complications and increase durability. Future innovations may include the development of absorbable hypoallergenic materials that could reduce the need for hardware removal. In addition, research in regenerative medicine is exploring ways to improve the incidence of fusion and non-operative management of OA.

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