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ARTICLE

Total wrist fusion versus total wrist prosthesis: a comparative study

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ABSTRACT

We present a comparative study of 41 total wrist fusions (TWFs) with contoured plate and 22 total wrist prostheses using the Universal 2™ model, with a mean follow-up of 6 years for the fusion and 6.5 years for the prosthesis. We evaluated grip strength, pain according to the visual analogue scale, functional results using the Quick Disabilities of the Arm, Shoulder and Hand and the Patient-Rated Wrist Evaluation, degree of satisfaction and complications, with no significant differences being observed in any of these variables. The results allow us to conclude that total wrist prosthesis implanted in patients with low or moderate functional demands offers medium-term functional results similar to TWF without increasing the number of complications.

Level of evidence: III

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Total wrist fusion; total wrist prosthesis; post-traumatic arthritis; rheumatoid arthritis; Kienböck's disease

Introduction

For decades, total wrist fusion (TWF) has been the treatment of choice for advanced radiocarpal joint degeneration of any aetiology, providing satisfactory results with predictable cost-effectiveness and low failure rates [1]. Various methods of fixation have been developed for TWF with the contoured plate being the most common to date [2,3]. Due to the high number of supplementary operations, the lack of complete improvement of functional results and the absence of universal return to work, it has been argued that TWF is not the ultimate solution to complex wrist problems [4]. Moreover, the disability caused by the loss of movement after a TWF has led to the development of numerous implants in the last 40 years. The fourth-generation total wrist prosthesis (TWP) is currently an alternative that aim to preserve pain-free movement in a stable wrist [5–8]. There has been much controversy concerning the advantages and disadvantages of TWP compared with TWA for a given indication. However, there are very few original studies comparing both procedures [9,10] and the few systematic reviews that have been conducted are compromised by bias [11,12]. The aim of the study was to compare the functional results, complications and subjective satisfaction of patients undergoing TWF or fourth-generation TWP.

Materials and methods

Following Institutional Review Board approval of the Autonomous Community of Aragon (CEICA) (CP-CI. PI19/132), and informed consent from all patients, we carried out a comparative study between two cohorts in a consecutive series of patients undergoing TWF between 2005 and 2021 using two models of contoured plate made from titanium alloy (LCP® (Synthes, Oberdorf, Switzerland) and VariAx® 2 (Stryker, Selzach, Switzerland)) or undergoing TWP between 2003 and 2021 using the Universal 2™ model (Integra, LifeSciences Corporations, Plainsboro, NJ, USA). The selection process excluded patients with brachial plexus palsy, congenital anomalies, TWF or TWP using implants other than those mentioned, follow-up time under 2 years for TWF and 3 years for TWP, patients who were unable to be contacted, or patients who refused to participate in the study.

All patients were operated on by the same senior surgeon (GMV) with an experience level of 4 [13]. Data were collected retrospectively in the TWF group and prospectively in the TWP group. In the TWF group, an independent observer (LRN) collected the demographic and clinical variables (age, gender, laterality, dominant hand, aetiology, associated surgical procedures, surgery time, complications and radiological changes) from the medical records. In the TWP group, GMV performed the prospective follow-up collecting the same variables explained for the TWF group. Finally, LRN conducted an interview in the hospital to all patients in both groups at the end of follow-up to carry out the physical examination, the final radiological follow-up, to fill in the questionnaires and to assess the degree of satisfaction. Pain was measured using a visual analogue scale (VAS, range 0–10). Hand grip strength was estimated in kilograms using a Jamar™ hydraulic dynamometer (Sammons Preston Inc., Bolingbrook, IL, USA). Postoperative complications and the need for revision surgery were also documented. Patients completed the validated Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) [14], and Patient-Rated Wrist Evaluation (PRWE) [15] questionnaires. In patients with TWP, active range of motion in flexion and extension and in radial and ulnar deviation of the wrist was measured using a goniometer. A postoperative study was performed on all patients in both groups with anteroposterior and lateral radiographs of the wrist immediately after operation, 1 month later and then annually until the end of the follow-up to assess radiocarpal fusion in TWF, or osteolysis around the implant components, signs of breakage in any area of the prosthesis or implant migration, according to a zone system for TWP: the carpal component is divided into five zones (1: ulnar side of the carpal plate, 2: ulnar screw, 3: central stem, 4: radial screw and 5: radial side of the carpal plate) and the radial component in another five

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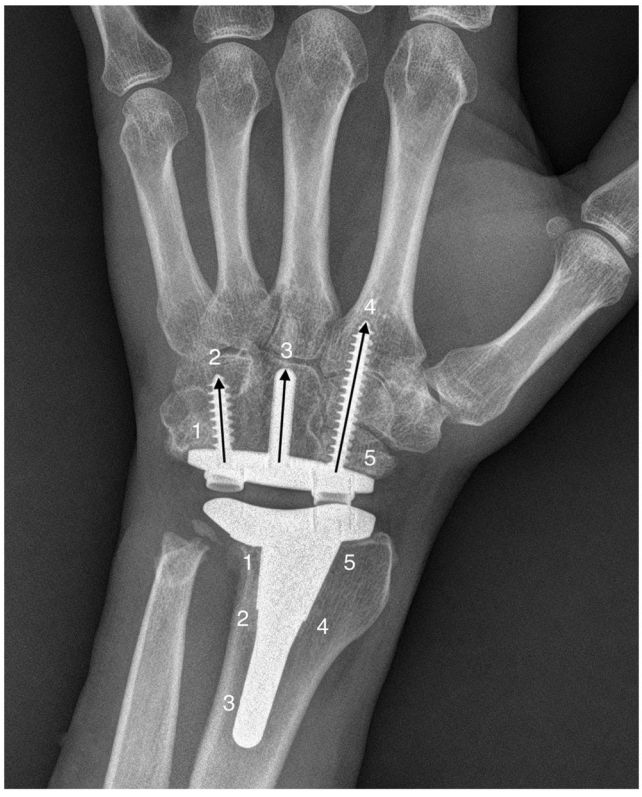

Figure 1. Radiographic zone system of a total Universal 2 wrist prosthesis showing the five possible points of periprothetic osteolisys for each radial and carpal components.

zones (1: medial distal third, 2: medial middle third, 3: proximal third, 4: lateral middle third and 5: lateral distal third) [7] (Figure 1). The degree of patient satisfaction was estimated using a qualitative scale with three options: very satisfied, satisfied and dissatisfied.

TWF was performed following the surgical technique in the AO Hand Study Group [16], including a proximal row carpectomy in some patients. After surgery, the wrist was immobilised with a plaster splint for four weeks, beginning strengthening exercises from the sixth week. Consolidation is achieved in a period of ~8–10 weeks. If there are no complications, the patient can return to work after the third month.

The TWP was implanted according to the technique described by Menon [17]. After surgery, the wrist was immobilised with a plaster splint for two weeks, subsequently starting rehabilitation to improve the range of motion. Between the rehabilitation sessions, a wrist brace was placed to protect the joint until the eighth week. If there are no complications, the patient can return to work after the third month, avoiding lifting weights greater than seven kilograms in order to prevent mechanical stress, which shortens the durability of the implant.

Statistical analysis

The Shapiro-Wilk test was used to estimate the normality of the distribution of each of the quantitative variables. To compare two independent quantitative variables, we used Student's t-test when the variables had a normal distribution or the Mann-Whitney U-test when the variables did not follow a normal distribution. To contrast the differences between two qualitative variables, we used the chi-squared test. The level of significance was $p < 0.05$.

Table 1. Patients demographics.

	TWF	TWP	*p*-value
Age (years)	52 (15) (range 27–86)	56 (9) (range 42–70)	0.270
Gender (M/W)	27/14	9/13	0.056
Laterality (R/L)	21/20	13/9	0.550
Dominant hands	23	12	0.906
Follow-up (years)	6 (3) (range 2–13)	6.5 (4) (range 3–17)	0.812

Data presented as mean (SD) or number.
L: left; M: man; R: right; W: woman.

Table 2. Functional results at the end of follow-up.

	TWF	TWP	*p*-value
Grip strength (kg)	19 (12)	16 (8)	0.448
VAS pain	1.3 (3)	0.9 (2)	0.962
QuickDASH	30 (21)	26 (16)	0.734
PRWE	28 (24)	26 (18)	0.977

Data presented as mean (SD).
kg: kilograms; PRWE: patient-rated wrist evaluation; QuickDASH: quick disabilities of the arm, shoulder and hand; VAS: visual analogue scale.

Results

Of the 61 TWFs initially included, 20 were excluded: six brachial plexus palsies, two congenital anomalies, seven with a follow-up time under 2 years, one performed with Kirschner wires as a fixation system, three patients who were unable to be contacted and one who refused to participate in the study. Of the 27 TWPs initially included, 5 were excluded because they were performed with the Freedom™ model and had a follow-up time under 3 years. Finally, 63 wrists (61 patients) met the selection criteria: 41 underwent TWF and 22 TWP, with an average follow-up time of 6 (2–13) and 6.5 (3–17) years, respectively. One patient underwent bilateral fusion, and another patient underwent fusion on one side and prosthesis on the other. The TWPs in this study which were converted to TWF were only included in the TWP group, without being part of the TWF group. The demographic variables of both groups are shown in Table 1. The average surgery time was 99 (SD 18) minutes for TWF and 122 (SD 15) minutes for TWP, with statistically significant differences ($p < 0.001$). Thirty-one TWF were associated with a proximal row carpectomy, 24 of them at the same time as the TWF surgery, and seven at previous operations. Darrach procedure was performed in six TWF and 17 TWP.

The indications for TWF were 23 post-traumatic arthritis, seven Kienböck's disease, six rheumatoid arthritis, two failed TWPs, two tuberculosis infections and a distal radius metaphyseal tumour. In the TWP group, the indications were 14 post-traumatic arthritis, six rheumatoid arthritis and two Kienböck's disease.

The mean range of postoperative movement at the end of follow-up in the wrists after TWP was: 27° (SD 13) in flexion, 37° (SD 12) in extension, 9° (SD 9) in radial deviation and 21° (SD 7) in ulnar deviation. There were no significant differences between TWF and TWP in terms of grip strength, pain and QuickDASH and PRWE results (Table 2). At the last follow-up review, 18 patients with TWF were very satisfied, 20 were satisfied and three dissatisfied, while in the group of patients undergoing TWP, there were 11 very satisfied patients, ten satisfied and one dissatisfied. The difference between the groups was not significant ($p = 0.851$).

Radiologically, the fusion of the radiocarpal joint united in 40 of the 41 cases. In three patients, we observed radiological changes due to loosening of the osteosynthesis plate and had to remove the implant (Figure 2). In two of them, the bone fusion had already taken place while in the third, an elderly woman

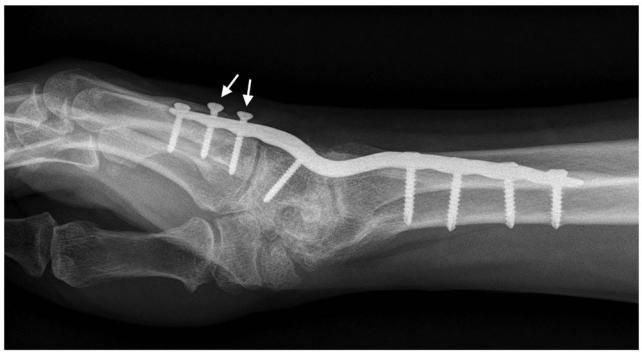

Figure 2. Loosening of the screws (white arrows) in the distal segment of a contoured plate in TWP.

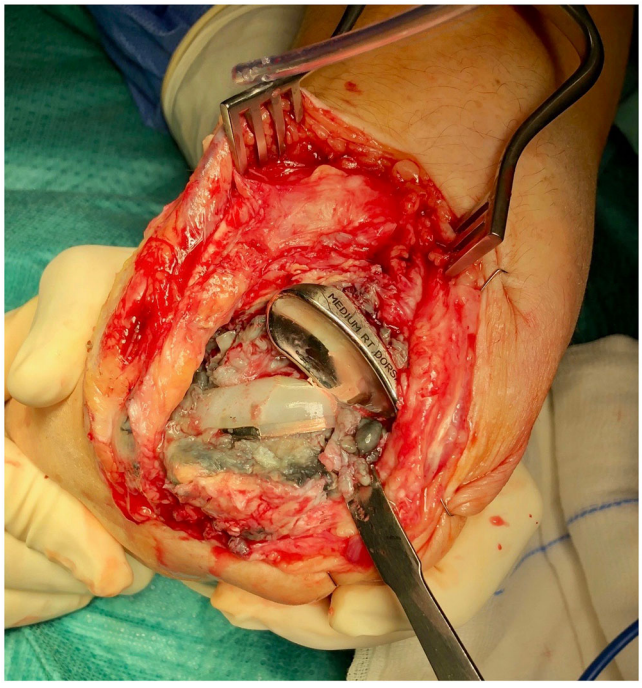

Figure 3. Periprosthetic metallosis from the titanium in the carpal component, which has completely loosened and dislocated in TWP.

reinfected with tuberculosis and with associated polypathology, the plate was removed and the wrist definitively protected with a rigid brace. In TWF group, there were three further complications: one patient suffered a superficial infection affecting the back of the hand with the fusion already consolidated, which was resolved through surgical debridement, removal of the implant and antibiotic therapy; one patient exhibited protrusion of the plate on the third metacarpal, which required removal of the implant; and another patient suffered a peri-implant fracture of the third metacarpal after a traffic accident, which required a new procedure to remove the fusion plate and stabilise the fracture.

In the TWP group, eight implants with a mean follow-up of 3.3 (range 3–3.7) years showed no radiological changes. Fourteen prostheses with a mean follow-up of 9 (range 4.5–17) years presented a mean of six points of osteolysis in the zone system (Figure 1). In one prosthesis, the central stem of the carpal tray broke, without functional consequence. There were radiological signs of loosening and migration of the implants in two prostheses, 4.8 and 8.2 years after the surgery.

Three patients with TWP exhibited metallosis pseudotumours and required revision surgery. Two of them occurred in patients with loosening of the implant (Figure 3), which was removed in favour of a TWF. The third pseudotumour was excised without alterations to the stability of the implant. Twenty of the 22 TWPs survived at the end of follow-up. In three patients with ulnocarpal pain, we performed an ulnar shortening osteotomy and two Darrach's procedures at a second operation. There were no significant differences when comparing the number of complications between both groups (six in TWF and seven in TWP) ($p = 0.108$).

Discussion

Patients with advanced radiocarpal arthropathy undergone TWF obtain good functional results, pain relief and high levels of satisfaction in exchange for a complete loss of wrist mobility. As a surgical alternative, TWP achieves an acceptable range of motion with short-term results similar to TWF, but with the risk of loosening and the need for new rescue surgeries in the medium and long term.

One of the arguments supporting indications for a TWP is advanced age and low functional demand, TWF being reserved for young people with demanding jobs [18]. However, opinions differ in the literature we consulted. While some authors present a series of older patients with TWP [11,19,20], others register no important differences [9,10,12]. In our experience, patients with TWP were older than those with TWF, although there were no statistically significant differences. There are varying explanations for these contradictions and the interpretation of the results is often affected by bias, including factors dependent on the underlying pathology, the surgeon's preference and experience or the patient's profession. This means there are young patients with rheumatic disease and good bone stock in their wrist, or in professions that are less demanding on their hands in whom it would be proper to for TWP to be indicated. Therefore, the age factor in itself should not be a priority when choosing the surgical technique and the individual's characteristics should be considered.

When we analysed the pathology that caused the surgical indication, we found that the results of the TWF were worse in patients with rheumatoid arthritis than in patients with post-traumatic arthritis [21] due to poor bone quality, the higher risk of complications and the increase in mechanical stress caused by the fusion on the other upper limb joints, which are usually also compromised by the disease. This, combined with the rheumatic patient's low physical demand made them the ideal candidate for TWP at the time [22–24]. However, the young post-traumatic patient with no underlying pathology has good bone quality, and their work prospects after surgery will determine which technique is more suitable. With fourth-generation designs, TWP indications for post-traumatic patients are more and more common [10,25].

In terms of complications, Berber et al. [11] found no significant differences between fourth-generation TWPs (13%) and TWFs (28%). We did not observe any significant differences when we compared both procedures.

In terms of durability, both TWF and TWP provide satisfactory results in the medium term, despite the radiological images of osteolysis that may appear in TWP. The periprosthetic osteolysis detected in many patients was asymptomatic and did not compromise the functioning of the implant. Therefore, there may be doubts about results for the long term, where TWF appears to be more reliable than TWP, a supposition that cannot be verified due to a lack of studies with sufficiently long follow-up. In any case, evidence shows that TWP has an inevitable tendency towards

gradual deterioration [7,22,23,26,27], which carries a high risk of long-term failure.

In the comparative analysis of TWF and a TWP, functional assessment and quality-of-life questionnaires are essential [9,10]. In our series of patients, we did not observe any statistically significant differences with either QuickDASH or PRWE, but we observed patients with TWP had a tendency to obtain higher scores in the PRWE activities related to using the toilet tissue or doing up buttons, although it was not specifically studied.

In the analysis of the degree of patient satisfaction, TWF and TWP presented very similar results without any statistically significant differences [9–12]. When the decision-making dilemma concerns patients with an issue with both wrists, we prefer prosthesis in the dominant hand so that it can be used in works requiring accuracy and fusion in the non-dominant hand to perform works requiring strength. Authors like Murphy et al. [9] or Melamed et al. [20] observed that, in this situation, patient satisfaction is greater when the wrist underwent prosthesis rather than fusion, as we could corroborate in the patient of our series who was in this situation. This has resulted in some authors preferring a TWP in each wrist, considering the benefits of radiocarpal movement and the possibility of converting a failed TWP into TWF [22,23,28–31].

A factor that has traditionally made TWP implants less attractive is the cost of the procedure, which is almost three times greater than TWF. Research by Cavaliere and Chung [32] demonstrated that both procedures are highly cost-effective, and the higher price of the TWP should not be considered prohibitive in the choice of treatment.

Our study has some weaknesses, such as the reduced sample size—despite it being the most extensive we have found published: 51 wrist (24 TWF and 27 TWP) in Murphy et al. [9] and 22 wrist (15 TWF and 7 TWP) in Nydick et al. [10]—the medium-term follow-up, the aetiological diversity in both groups, the use of two similar fusion plates but with some different characteristics, the absence of randomisation and the lack of classification of complications according to their severity.

Conclusion

The results of this research lead us to conclude that, at present, TWP in patients with low or moderate functional demands offers medium-term functional results similar to TWF without increasing the number of complications. In any case, the advantages and disadvantages of each procedure will determine the surgical indication based on the patient's characteristics, and it is very important for long-term studies to be conducted.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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