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Original article

Results of interposition arthroplasty with the Amandys® pyrocarbon implant in rheumatoid wrist at a mean 5 years' follow-up

Résultats de l'arthroplastie d'interposition de poignet en pyrocarbone Amandys® pour des atteintes rhumatoïdes avec un recul moyen de 5 ans

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ABSTRACT

Management of severe joint involvement in rheumatoid wrist is controversial. The gold-standard is total wrist fusion, but total wrist replacement offers a motion-conserving alternative. The purpose of this study was to present the results of interposition arthroplasty with the Amandys® pyrocarbon implant in rheumatoid wrist. We performed a retrospective review of 28 arthroplasties for rheumatoid wrist arthritis. Eighteen females and 5 males were included, with a mean age of 55.7 years. Mean follow-up was 64 months. We measured range of motion, grip strength, and pain (on VAS). Function was evaluated preoperatively and at last follow-up with the DASH and PRWE scores. Mean range of motion in flexion–extension was maintained while mean inclination and rotational range of motion showed significant improvement. Mean grip strength increased from 10 kg to 17 kg. Mean pain score decreased from 6/10 to 2/10. Mean PRWE and QuickDASH scores decreased from 62/100 to 25/100 and from 62/100 to 36/100, respectively. Three patients underwent early reoperation to reposition a dislocated implant. No implants had to be removed. Amandys® pyrocarbon arthroplasty is a reliable alternative to total fusion or total replacement in rheumatoid wrist. Indications must be limited to well-aligned wrists with competent capsule-ligament structures.

Mots-clés:
Poignet
Arthrite Rhumatoïde
Arthroplastie
Pyrocarbone
Interposition

RÉSUMÉ

La gestion des atteintes articulaires sévères du poignet rhumatoïde est controversée. Le traitement de référence est l'arthrodèse totale du poignet, mais la prothèse totale du poignet offre une alternative préservant les mobilités. Le but de cette étude était de présenter les résultats de l'arthroplastie d'interposition avec l'implant en pyrocarbone Amandys® sur les poignets rhumatoïdes. Nous avons effectué une revue rétrospective de 28 arthroplasties pour arthrite rhumatoïde du poignet. Dix-huit femmes et cinq hommes ont été inclus, avec un âge moyen de 55,7 ans. Le suivi moyen était de 64 mois. Nous avons mesuré les mobilités articulaires, la force de poigne, la douleur (EVA) et les scores DASH et PRWE en préopératoire et au dernier recul. Au dernier recul, l'arc de mobilité en flexion–extension était maintenu, alors que les arcs de mobilité en rotation et inclinaison étaient significativement augmentés. La force moyenne avait augmenté de 10 kg à 17 kg. Le score moyen de douleur avait diminué de 6/10 à 2/10 en postopératoire. Les scores moyens PRWE et QuickDASH étaient passés de 62/100 à 25/100 et de 62/100 à 36/100 respectivement. Trois patients avaient dû être réopérés précocement pour repositionnement de leur implant qui était instable. Aucun implant n'avait dû être retiré. Cette arthroplastie d'interposition en pyrocarbone est une alternative fiable à l'arthrodèse totale ou à la prothèse totale du poignet dans le traitement du poignet rhumatoïde. Les indications doivent être limitées à un poignet axé avec un appareil capsuloligamentaire compétent.

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1. Introduction

Recent medical treatments have significantly reduced the frequency and severity of rheumatoid arthritis (RA), making surgical treatment rather rare [1]. Even so, severe erosive damage to the wrist was reported in up to 68% of patients after 10 years' medical treatment [2]. In advanced disease, surgical treatment still has a role to play, and total wrist fusion (TWF) or total wrist replacement (TWR) are the most frequent options.

Cavaliere and Chung reviewed 18 studies of arthroplasty, for 503 procedures, and 20 of fusion, for 860 procedures, in RA [3], and concluded that all patients were satisfied by both techniques; however, TWF provided better pain control with lower complication and revision rates than TWR.

Mannerfelt in 1971 and Millender in 1973 popularized TWF by intramedullary fixation in severe rheumatoid wrist disease, but with high rates of non-union [4–6]. The development of TWF by plate fixation improved consolidation rates [7]; however, the technique is not always possible in rheumatoid patients due to the low quality of their bone stock.

In case of failure of TWR, revision is often not possible, due to significant bone loss associated with implant loosening [8,9]. Conversion to TWF is then the only therapeutic option, and bone consolidation is a challenge [10].

Recently, the Amandys® pyrocarbon implant was designed to treat panosteoarthritis of the wrist without instability or major malalignment [11,12]. Pyrocarbon has been used for several years to treat several hand pathologies, with encouraging results [13–15]. This material has high wear resistance and excellent long-term biocompatibility [16]. Its very low friction coefficient allows it to slide and roll between cartilage and ligaments when subjected to compression forces. Its elastic modulus is similar to that of cortical bone, providing even distribution of pressure between bone and implant. To date few studies have reported results for the Amandys® implant and there are no studies analyzing outcome in rheumatoid and inflammatory diseases of the wrist. Given the drawbacks of TWF and TWR, the Amandys® interposition implant is an interesting option in the management of advanced rheumatic osteoarthritis.

The main objective of the present study was to evaluate the functional and radiological results of the Amandys® implant in patients suffering from rheumatoid osteoarthritis or inflammatory disease.

2. Patients and methods

2.1. Implant

The Amandys® implant (Wright-Medical, Tornier, Montbonnot Saint Martin, France) is a free interposition implant made of pyrocarbon, designed for radiocarpal interposition arthroplasty. It replaces the proximal two-thirds of the scaphoid, the lunate, and the proximal pole of the capitate. It is a mobile spacer, not attached to the bone, maintained by the bones and radiocarpal capsule-ligament structures. It comprises four elliptic shapes. The two proximal elliptical curvatures, orthogonal to each other, mimic the proximal anatomical curvatures of the scaphoid and lunate which articulate with the radial surface. The two distal curvatures of the implant are less marked than the proximal ones, and articulate with the capitate and distal pole of the scaphoid [11].

The implant comes in eight sizes according to length (24 or 26 mm) and thickness (S, M, L, XL).

Bone surfaces in contact with the implant may slip and roll, and slight rotation is also possible. Bone resection is minimal and mainly intra-articular, and the triquetrum and distal third of the scaphoid are conserved, thus sparing the major extrinsic ligaments of the wrist.

2.2. Surgical technique

The arthroplasty was performed under locoregional anesthesia with tourniquet. The approach was dorsal or radial, the dorsal approach being preferred in rheumatoid wrists, to allow hardware removal in case of revision surgery, filling of bone cysts, and capsule reinforcement plasty in case of distension.

The dorsal incision was sinuous or straight. The extensor retinaculum was incised at the radial or ulnar edge of the 4th extensor compartment to allow the dorsal capsule to be strengthened at end of procedure. Tenosynovectomy of the extensor tendons could be associated in case of tenosynovitis. Capsulotomy was multiple, median, or aiming to spare the extrinsic carpal ligaments [17].

Partial resection of the scaphoid was performed at the junction between the proximal two-thirds and distal third, using an oscillating saw. The lunate was removed after releasing all its capsule and ligament attachments. The head of capitate was then partially resected, at a level corresponding to the partial scaphoidectomy.

The joint surfaces were then prepared with an ovoid bur. The radial surface was burred to eliminate the crest separating the scaphoid and lunate fossae, and the midcarpal neo-joint was slightly deepened, resulting in two concave homogeneous ovoid surfaces on both axes. Bone spurs were resected when present, and joint synovectomy was performed, taking care to conserve capsule and ligament structures. Bone cysts at the contact of the articular surfaces were grafted with the bone obtained from resection.

The final implant was chosen after testing under dynamic fluoroscopy. The goal was to obtain a stable implant during passive mobilization of the wrist, without anteroposterior (AP) dislocation, rotation around the proximo-distal axis, dorsal subluxation of the distal row or modification of the ulno-triquetral space compared to preoperative views.

After final implantation, the capsule was closed by 3/0 or 4/0 absorbable suture. The capsule was reinforced if distended, with palmar capsule overlapping suture in case of palmar distension, an extensor retinaculum flap via a dorsal approach in case of dorsal distension, or first extensor compartment flap via a radial approach in case of radial subluxation.

The wrist was immobilized in neutral position for a minimum 15 days, followed by self-rehabilitation. No special restrictions were imposed beyond week 6.

2.3. Patients

Between November 2009 and June 2017, 28 procedures were performed in 23 patients (5 bilateral cases). Eligibility criteria comprised rheumatoid arthritis or inflammatory disease, painful wrist despite well-controlled disease, no history of wrist joint infection, and good or acceptable radiocarpal alignment in both axes (Simmen and Huber type 1 or 2, or Simmen and Huber type 3 without major carpal subluxation) [18]. Exclusion criteria comprised degenerative, post-traumatic or microcrystalline osteoarthritis, and major radiocarpal subluxation or bone loss. Inclusion was retrospective and consecutive. All patients were operated on in our unit, by five different confirmed (level 4 to 5) hand surgeons (including authors PB, EG, YK and TL) [19].

2.4. Clinical and radiological data

Pre- and post-operative clinical assessment comprised flexion, extension, radial and ulnar inclination, pronation and supination, measured using a standardized goniometer. Grip strength was

measured using a Jamar dynamometer (Performance Health R, Charleville Mézière, France), with three successive readings, wrist in neutral position.

Two questionaries were used for pre- and post-operative subjective functional evaluation: the Patient-Rated Wrist Evaluation (PRWE) and the short version of the Disabilities of the Arm, Shoulder and Hand questionnaire (Quick-DASH). Pain was assessed pre- and post-operatively on a 0–10 visual analog scale (VAS). At last follow-up, satisfaction was reported as very satisfied, satisfied, quite satisfied, or dissatisfied.

X-ray measurements were collected pre- and post-operatively on AP and lateral views including the metacarpal heads:

- sagittal subluxation, measured on lateral view as the ratio D/L1, where D is the distance between the radius axis and the axis of the 3rd metacarpal and L1 is the length of the 3rd metacarpal;
- radial carpal deviation, measured by Shapiro's angle [20];
- ulnar carpal translation, measured by the Youm index [21];
- carpal height, measured by the McMurtry and Youm index [22].The McMurtry index was also measured on immediate postoperative views to assess the progression of carpal height once the implant was in place.

We also noted onset or absence of bone reaction (lysis, densification) or periarticular reaction (ossification), and the position of the implant (subluxation, subsidence).

2.5. Statistical analysis

Normal distribution of numerical parameters was checked graphically and tested on Shapiro–Wilk test. Pre- to post-operative comparison of range of motion (RoM), functional scores and wrist strength used a rank test. The significance threshold was set at $p < 0.05$. Statistical analyses used SAS software (SAS Institute, version 9.4).

3. Results

Mean follow-up was 64 months (standard deviation (SD) = 21; range, 21–101 months). Seventeen cases (61%) had more than 5 years' follow-up.

3.1. Series

The population consisted of 18 women and 5 men, with an average age of 55.7 years (SD 8.7; range, 41–72). The dominant wrist was operated on 17 patients; there were as many right hands as left hands treated (n = 14 each). Osteoarthritis consisted in rheumatoid osteoarthritis in 19 patients (24 wrists), ankylosing spondylitis in 2 patients, psoriatic arthritis in 1 patient, and juvenile chronic arthritis in 1 patient.

Five wrists (18%) were Simmen-Huber stage 1, 14 (50%) stage 2, and 3 (11%) stage 3. Two of the 3 stage 3 patients showed intracarpal instability without sagittal subluxation and the other had moderate wrist subluxation. Six well-aligned wrists had undergone previous carpal bone surgery and did not fit into Simmen and Huber's classification.

In 19 wrists (68%), this was the first procedure. Nine wrists (32%) had already been operated on: 2 for synovectomy, 5 for partial wrist fusion (3 four-corner fusions, 1 radioscapholunate fusion and 1 lunotriquetral fusion), 1 had failed TWF with a broken Rush pin, and 1 had a Darrach procedure.

A procedure on the distal radio-ulnar joint (DRUJ) was associated in 7 cases (25%): 4 Sauvé-Kapandji procedures, 1 of which in a patient with ankylosing spondylitis (Fig. 1), 2 Darrach procedures, and 1 DRUJ replacement by an Eclypse® prosthesis (Wright-Medical, Tornier, Montbonnot Saint Martin, France). One patient with caput ulnae syndrome required extensor carpi radialis longus tendon transfer lassoing the extensor carpi ulnaris and then attached to the ulnar border of the extensor carpi radialis brevis. One patient undergoing bilateral Amandys® arthroplasty had associated scaphotrapeziotrapezoid Pyrocardan® arthroplasty in 1 wrist, and, during follow-up, bilateral DRUJ replacement by Eclypse® arthroplasty (Fig. 2).

On the contralateral side, 2 patients had had a previous Sauvé-Kapandji procedure, including 1 with extensor tendon reanimation. During follow-up, 2 patients underwent contralateral TWF with Rush pin fixation, including 1 Darrach procedure.

3.2. Clinical results

At last follow-up, mean flexion was 33° and mean extension 33°: i.e., a loss of 3° flexion and a gain of 3° extension, both being non-significant ($p = 0.08$, $p = 0.5$) (Table 1). Mean ulnar and radial deviation were respectively of 20° and 10° postoperatively: i.e., a significant improvement of 3° in ulnar inclination ($p = 0.027$) and a non-significant improvement of 2° in radial inclination ($p = 0.082$).

Pronation and supination increased significantly, by 7° in pronation ($p = 0.02$) and 9° in supination ($p = 0.04$). Patients undergoing DRUJ surgery had a mean arc of motion of 101° preoperatively, compared to 146° the other patients, increasing postoperatively to 132° and 155° respectively, for a mean gain of 31° and 9°. The two subgroups were too small (8 patients) for statistical analysis of the mean difference.

Mean grip strength was 10 kg (54% of the contralateral side) preoperatively and 17 kg (78% of the contralateral side) postoperatively, for a significant gain of 7 kg ($p < 0.001$).

Pain improved significantly by a mean 4 points, from 6/10 preoperatively to 2/10 postoperatively ($p < 0.001$) (Table 2). At last follow-up, 20 patients (71%) reported no or minimal pain (VAS 1–3). One patient (3.5%), RA flare at the time of examination, reported severe pain (VAS 7–9).

QuickDASH and PRWE scores showed a significant mean decrease 26 and 37 points, respectively ($p < 0.001$ for both) (Table 2). At last follow-up, 10 patients were satisfied (36%) and 18 very satisfied (64%) with the procedure.

3.3. Radiological results

Mean sagittal subluxation was 0.12 preoperatively, and 0.10 postoperatively: i.e., a non-significant decrease of −0.02 ($p = 0.16$) (Table 3). Mean radial deviation (Shapiro angle) was 119.5° preoperatively and 111.5° postoperatively: i.e., a significant decrease of 8° ($p = 0.001$). Mean ulnar carpal translation (Youm index) was 0.3 preoperatively and 0.28 postoperatively: i.e., a non-significant decrease of −0.02 ($p = 0.41$). Mean pre- and post-operative values in the series were within the normal range (N = 0.27−0.33).

Carpal height (McMurtry and Youm index) was 0.44 preoperatively, showing preoperative carpal collapse (normal value = 0.54 +/-0.03), and 0.38 postoperatively: i.e., a significant mean decrease of −0.06 ($p = 0.003$). On immediate postoperative X-rays, carpal height was 0.38 (SD, 0.08; range, 0.24−0.50) and 0.38 at last follow-up, for a non-significant mean difference of 0.01 (SD, 0.06; $p = 0.44$), showing no subsidence of the implant during follow-up.

Preoperative radiological values indicated no major radiocarpal subluxation in the wrists to be operated on. This absence of misalignment was a major requirement before indicating the Amandys® implant.

Radiological results showed preoperative carpal collapse which remained stable over time. There was no implant subsidence during follow-up.

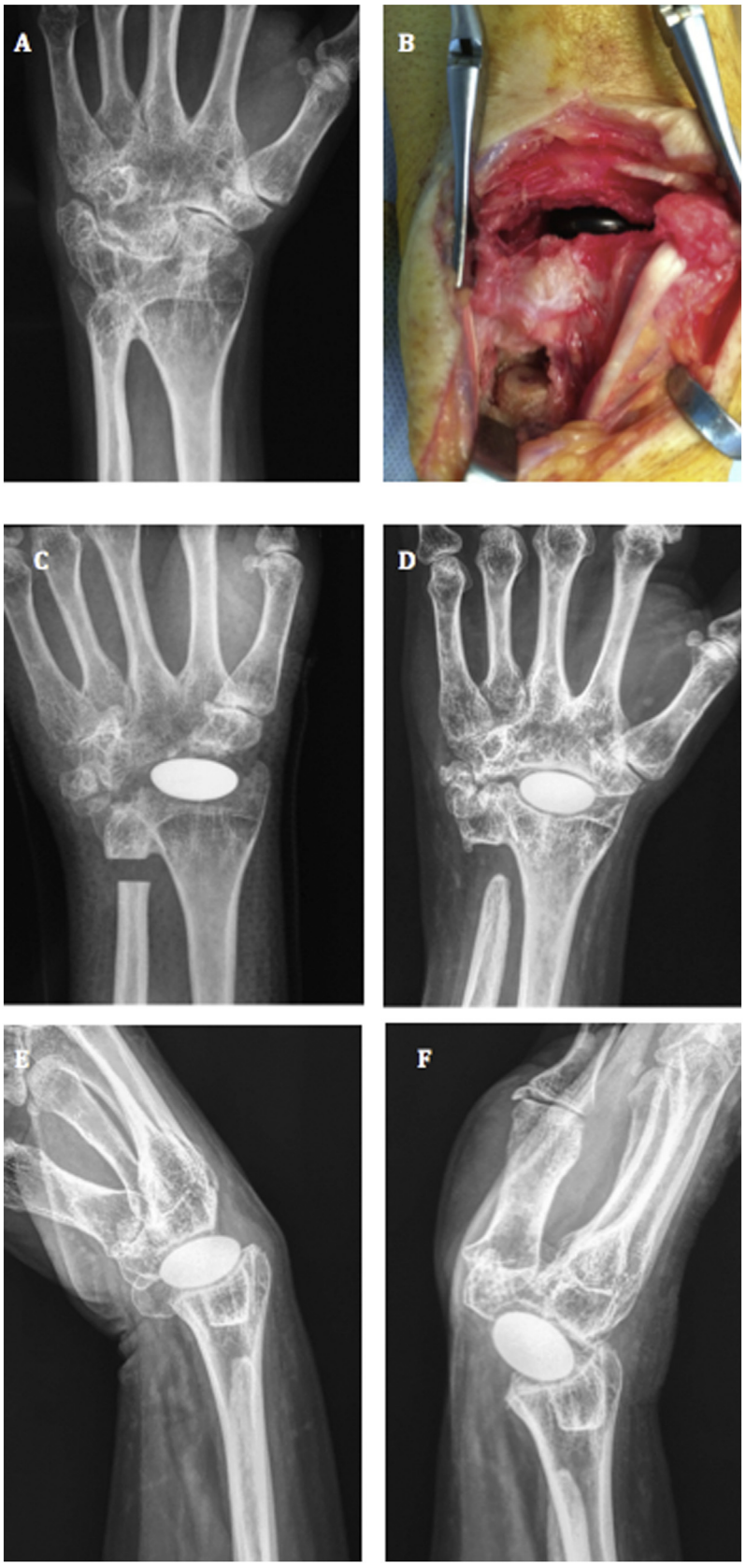

Fig. 1. 50-year-old patient with ankylosing spondylitis presenting complete fusion of the radioulnar and radiocarpal joints and with conserved midcarpal joint treated with an Amandys® implant and Sauvé Kapandji procedure. Preoperative AP X-ray (A). Intraoperative picture (B). Postoperative AP X-ray (C). AP X-ray at 40 months' follow-up, showing bone condensation surrounding the implant (D). Dynamic lateral X-rays at 40 months' follow-up showing the mobility of the wrist in extension (F) and flexion (E) without any implant dislocation.

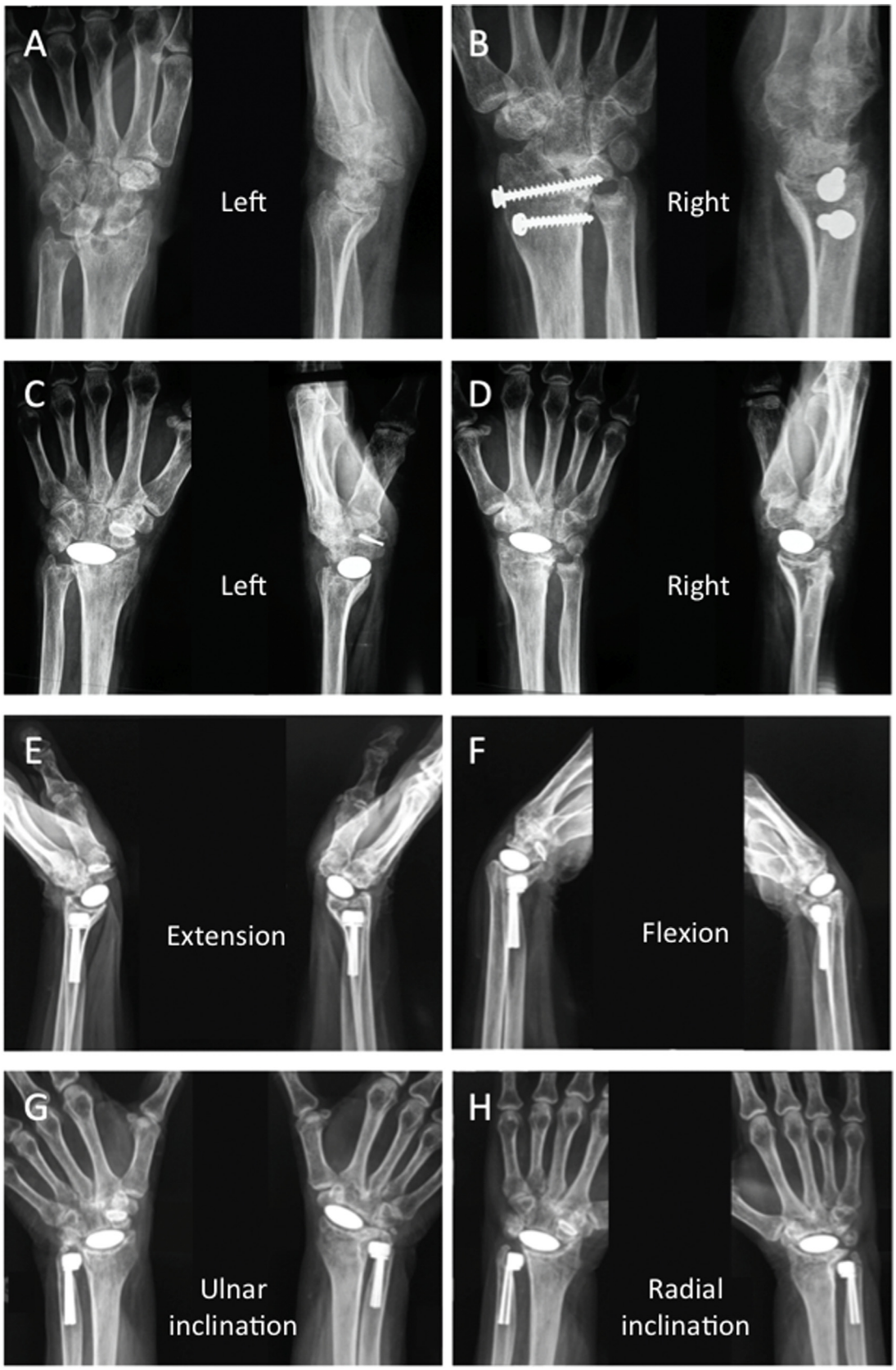

Fig. 2. 55-year-old patient treated with bilateral Amandys® interposition arthroplasty associated to scaphotrapeziotrapezoid Pyrocardan® arthroplasty on the left side. The patient was operated a year later for bilateral DRUJ replacement with Eclypse® arthroplasty. Preoperative PA and lateral X-rays of the left wrist (A). Preoperative PA and lateral X-rays of the right wrist which had undergone previous radioscapholunate fusion in another center (B). Postoperative PA and lateral X-rays of the left wrist (C). Postoperative PA and lateral X-rays of the right wrist (D). Dynamic lateral X-rays in extension (E) and flexion (F), and dynamic PA X-rays in ulnar inclination (G) and radial inclination (H) at 63 months of follow-up on the right and 64 months of follow-up on the left.

Table 1
Objective clinical results: Preoperative and postoperative ranges of motion (degrees) and grip force (kilograms).

Variable	Preoperative	Last follow-up (Mean = 64 Months)	Difference	P
Flexion (°)	36 (15; 10–65)	33 (11; 15–55)	3 (19; −35–40)	0.88
Extension (°)	30 (19; −30–50)	33 (13; 12–70)	3 (20; −20–47)	0.5
RoM F/E (°)	66 (25; 20–115)	66 (18; 39–100)	0 (29; −45–55)	0.48
Ulnar inclination (°)	17 (11; 0–40)	20 (8; 10–40)	3 (10; −20–22)	**0.027**
Radial inclination (°)	8 (7; −10–20)	10 (6; 0–20)	2 (9; −10–30)	0.082
RoM inclination (°)	25 (13; 0–55)	30 (10; 10–60)	5 (15; −25–40)	0.019
Pronation (°)	66 (21.9; 0–80)	73 (12; 40–80)	7 (11; 0–40)	**0.002**
Supination (°)	64 (22; −10–80)	75 (13; 45–90)	9 (15; 0–65)	**0.004**
ROM P/S (°)	130 (42; 0–160)	147 (24; 100–170)	17 (25; 0–100)	**0.001**
Grip strength (kg)	10 (5; 4–23)	17 (5; 8–27)	7 (6; −4–18)	**0.001**

RoM: range of motion; *F/E*: flexion/extension; *P/S*: pronation/supination. Values are reported as mean, with standard deviation and range in brackets. The significance threshold is set at 0.05. Values in bold are significant.

Table 2
Preoperative and postoperative subjective results.

Variable	Preoperative	Last follow-up (Mean = 64 Months)	Difference	P
Quick-DASH/100	62 (18; 34–100)	36 (22; 0–75)	−26 (31; −100–28,5)	**0.001**
PRWE/100	62 (16; 32–89)	25 (22; 2–70,5)	−37 (30; −81–23,5)	**0.001**
VAS/10	6 (2; 1–8)	2 (2; 0–7)	−4 (3; −8–2)	**0.001**

QuickDASH: short version of the Disabilities of the Arm, Shoulder and Hand Questionnaire; PRWE: Patient-Rated Wrist Evaluation; VAS: pain on visual analog scale. Values are reported as mean, with standard deviation and range in brackets. The significance threshold is set at 0.05. Values in bold are significant.

Table 3
Preoperative and postoperative X-ray results.

Variable	Preoperative	Last follow-up (mean = 64 months)	Difference	P
Carpal sagittal subluxation	0.12 (0.06)	0.10 (0.05)	−0.02	0.16
Youm index	0.3 (0.07)	0.28 (0.06)	−0.02	0.41
Shapiro's angle	119.5 (5.47)	111.5 (7.68)	−8	**0.001**
McMurtry and Youm index	0.44 (0.08)	0.38 (0.08)	−0.06	**0.003**

Values are reported as mean, with standard deviation in brackets. The significance threshold is set at 0.05. Values in bold are significant.

One patient with bilateral Amandys® arthroplasty showed implant rotation around the proximo-distal axis, without adverse clinical impact at 68 and 71 months' follow-up: in the right wrist, pain = 1/10, wrist flexion and extension 30°and 20°, PRWE = 23/100, QuickDASH = 26/100; in the left wrist, pain = 2/10, wrist flexion and extension 30° and 40°, PRWE = 23/100, QuickDASH = 26/100.

3.4. Complications and revision

One patient presented rupture of the extensor pollicis longus 18 months after surgery and required extensor indicis proprius transfer. One patient, after a fall 11 months postoperatively, presented a non-displaced fracture of the distal radius which healed after non-operative treatment.

Three patients (11%) showed early subluxation of the implant, within 6 weeks. They were treated surgically to refine the bone surfaces, and in 2 cases palmar capsular reinforcement was performed by an overlapping Gore-Tex suture.

4. Discussion

Amandys® interposition arthroplasty for rheumatoid patients gives reliable results in the medium term.

In our study, wrist RoM was maintained but not improved. All mean RoMs were within the range of functional amplitudes reported by Palmer [23]: 5° flexion, 30° extension, 10° radial deviation, and 15° ulnar deviation. The same was found in other Amandys® series, with mean RoMs within a functional range [11,12,24,25]. One of the advantages of TWR is that RoM is conserved. Considering the functional ranges of motion reported by Palmer, Cavaliere and Chung [3] in their systematic review of TWR in RA, only 3 of the 14 studies with appropriate data had all mean RoMs within the functional range [26–28]. Yeoh and Tourret [29] in their review of 8 TWR studies, not exclusively for RA, found only 1 with all wrist RoMs within functional ranges [30]. Recent results in 4th generation arthroplasties likewise did not report all RoMs within functional ranges [31–34].

In our study, mean postoperative grip strength was 17 kg, for a significant mean gain of 7 kg. Bellemère et al., in two Amandys® studies, reported no significant improvement on grip strength at 24 months' follow-up: 16 kg (+1 kg) and 19 kg (+2 kg), respectively [11,12]. Pierrart et al. studied the Amandys® implant at 11 months' follow-up and found that all but 1 patient lost strength, with a mean 8.3 kg [25]. Tanwin et al. compared the results between 2 and 7 years' follow-up in 63 Amandys® implants and found significant improvement in grip strength between the two time-points [35]. At their last follow-up, mean strength was 20 kg, versus 12 kg preoperatively. These longer-term results, not specifically in RA, were in line with the present findings, with significant medium-term improvement in wrist strength. A significant increase in grip strength was also observed after TWF and TWR [31,34]. However, the risk of mechanical

complications after TWR limits analysis in terms of strength, as the recommended maximum load should not exceed 4.5 kg [36]. In our practice of Amandys® arthroplasty, no limitations on the use of the wrist are imposed after the 3rd postoperative month.

In our series, pain improved significantly by 4 points. The same was also found in other series studying Amandys®, with final pain relief ranging from 3 to 4.9 points [11,12,24]. Statistically significant improvements in pain scores were also observed with TWF [7,37,38] and TWR [31,34,39] in rheumatoid patients, with lower overall pain scores in TWF (0.8–1.9 out of 10) than TWR, where scatter was wider (0.4–5.4 out of 10) [32]. For instance, in their series of Universal 2® 4th-generation prosthetic wrist replacement in rheumatoid patients, Badge et al. [31] achieved postoperative VAS scores of 5.4/10 in 94 cases, while Gil et al. [39], in a series of 39 prostheses, achieved a mean score of 0.4/10.

In our series, function was significantly improved at 64 months' follow-up. Our results were slightly better than those obtained in the Amandys® series of non-rheumatoid wrists reported by Bellemère et al. [11] and Pierrart et al. [25] at shorter follow-up (24 and 11 months respectively). Berber et al. [32], in their literature review, reported only one study of TWF that showed significant improvement in function [38]. Sauerbier et al. also showed that patients who received TWF had specific difficulties in certain activities such as carrying a heavy object, opening a heavy door (50%) or with personal hygiene (80%) [7]. In contrast, significant improvement in function is frequently observed after

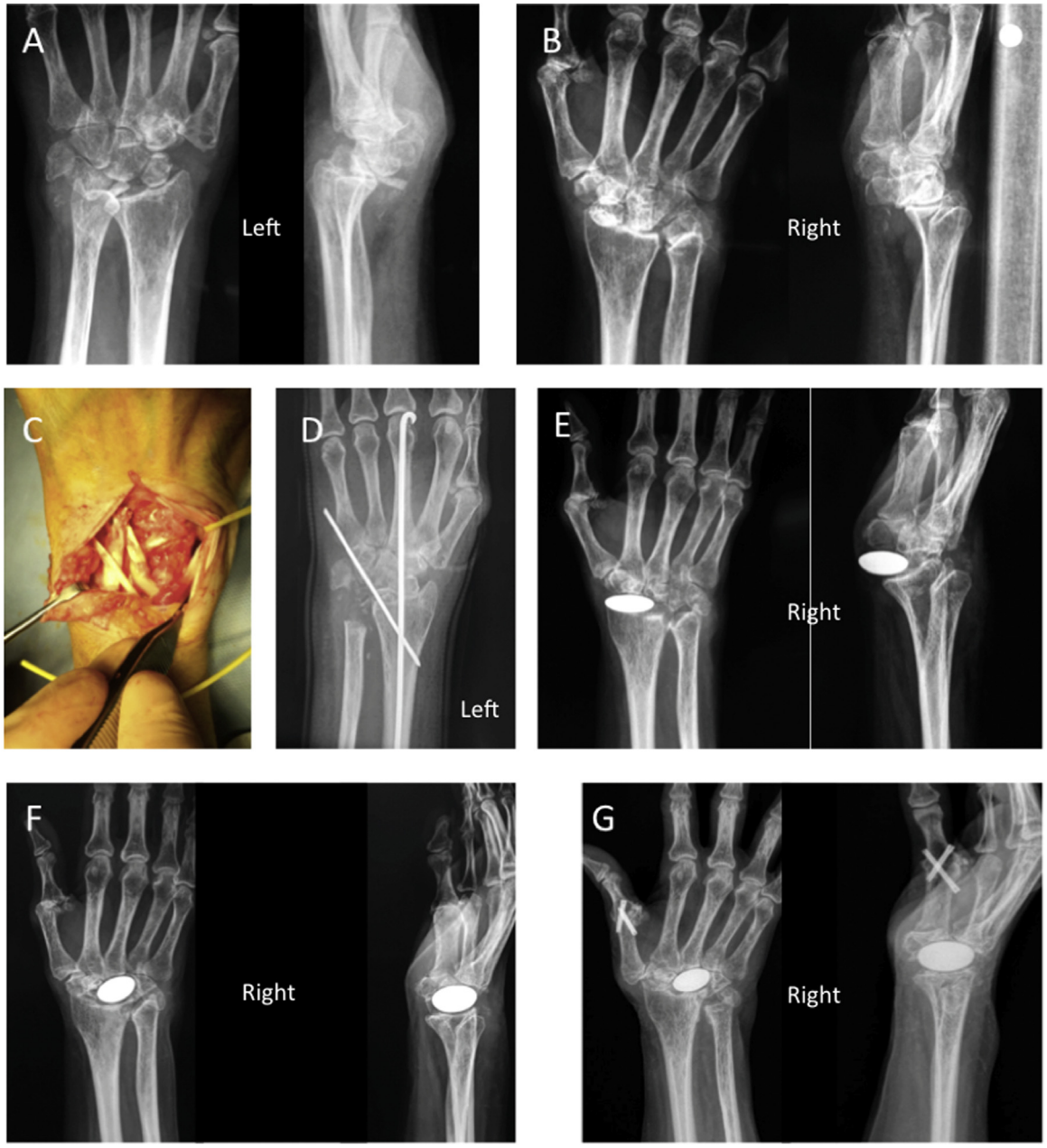

Fig. 3. 45-year-old patient suffering from psoriatic arthritis. Preoperative PA and lateral X-rays of the left wrist showing severe volar carpal subluxation (Simmen and Huber stage 3) (A). Preoperative PA and lateral X-rays of the right wrist showing moderate volar carpal subluxation (Simmen and Huber stage 3) (B). Intraoperative picture of the right wrist showing a tendon transfer of the extensor carpi radialis longus to the extensor carpi ulnaris for a caput ulnae syndrome (C). Postoperative PA X-ray of the left TWF (D). Postoperative PA and lateral X-rays of the right wrist 6 weeks after surgery, showing early dislocation of the implant (E). Postoperative PA and lateral X-rays of the left wrist after surgical revision for implant dislocation, consisting in new bone preparation as and capsule reinforcement (F). PA and lateral X-rays at 78 months' follow-up without any implant dislocation (in the meantime, the patient underwent thumb metacarpophalangeal joint fusion) (G).

TWR [3,31,34]. Sagerfors et al. compared the functional results of the Universal 2®, Re-motion® and Maestro® 4th-generation prostheses in a series of 219 wrists including 85% rheumatoid wrists, with 7 years' follow-up [34]. All patients showed significant improvement in DASH and PRWE scores. There was no significant difference between types of implant. Improvement in DASH score ranged from 12.3 to 16.8 points. However, these functional results reported for 4th-generation implants in rheumatoid patients were poorer than in the present study.

In our series, early dislocation occurred in 1 patient with Simmen-Huber stage 3 and caput ulnae syndrome and history of TWF in the contralateral wrist (Fig. 3). This indication was at risk of failure, but the contralateral fusion motivated the patient to try to maintain RoM of one of her wrists. Another patient, operated on via a radial approach, had early palmar subluxation; this could have been avoided using a dorsal approach, which allows a better view for checking the articular soft tissues and can enable anterior capsular reinforcement.

The complications rate in our study (11%) was comparable to those of other studies using Amandys® [11,12]. For our patients, revision after early displacement always achieved implant stabilization and no conversion to TWF was necessary. However, Pierrart et al. reported 18% conversion to fusion 18% (2 patients) after Amandys® implantation, due to significant persistent pain [25]. The initial indication for these two patients was first row carpectomy failure in non-rheumatoid patients. Such wrists without the distal pole of the scaphoid and triquetrum are at greater risk of implant dislocation and thus of complications [11].

In rheumatoid wrists, the complications rate after TWR is 30%, compared to 17% for TWF [3]. In series not specifically focused on RA, complication rates are also higher after TWR than after TWF, whilst there is no difference when using 4th-generation TWR [32]. The main complications of TWF are related to metalwork issues, leading to a 6.1% rate of hardware removal [32]. Periprosthetic osteolysis is one of the major problems of TWR. In a recent study with a minimum follow-up of 5 years in rheumatoid patients, Matsui et al. reported 5 cases (out of 19: 26%) of asymptomatic loosening of the carpal components, not requiring revision [40]. Implant loosening is less problematic with newer 4th-generation implants, which have porous coatings to encourage osteointegration and carpal fixation that limits stress transfer to the carpal component [32].

Survival rates for 4th-generation implants were 78% at 15 years for Universal 2®, 94% at 8 years for Re-Motion®, and 95% at 8 years for Maestro® [33,34,39]. Follow-up in the present study was insufficient to compare survival, which was 100% at 64 months.

The various complications observed with Amandys® are avoidable, as they are due to technical issues or indication errors related to the learning curve. Patient selection and rigorous technique can reduce revision rates. In case of dislocation or non-tolerance of the implant, there is no associated bone loss which could make conversion difficult, in contrast to failed TWR [41]. TWR or TWF are possible without major technical additional difficulty.

5. Conclusion

Amandys® radiocarpal interposition arthroplasty is a reliable option for the treatment of rheumatoid wrist osteoarthritis. In this study, the implant was well tolerated clinically and radiologically. The results showed that this pyrocarbon wrist replacement implant was effective in relieving pain and improving overall function. Unlike many total wrist replacements, mean RoM was conserved and was greater than minimal functional requirements. Grip strength was similar to that found after total wrist fusion. Functional results were better than in total wrist replacement. No implants had to be removed, and the rate of complications requiring surgical revision was low; the complications can be attributed to errors in choice of surgical approach or technical errors related to the learning curve. At medium-term follow up, the results in our series showed that Amandys® is a valid alternative to more conventional and invasive procedures such as TWF or TWR. Indications for Amandys® arthroplasty in RA require selection of patients without major carpal subluxation or bone loos.

Disclosure of interest

P. B. receives royalties and fees from Wright-Medical, Tornier, France.
The other authors have no conflicts of interest to disclose.

Contributorship details

Victor LESTIENNE and Youssouf TANWIN did the research and did the follow-up. Victor LESTIENNE wrote the manuscript. Camilo CHAVES translated the manuscript. Philippe BELLEMERE, Thierry LOUBERSAC, Etienne GAISNE and Yves KERJEAN operated the patients. Philippe BELLEMERE revised the manuscript.

References

[1] Shourt CA, Crowson CS, Gabriel SE, Matteson EL. Orthopedic surgery among patients with rheumatoid arthritis 1980-2007: a population-based study focused on surgery rates, sex, and mortality. J Rheumatol 2012;39:481–5.
[2] Toyohara I, Ishikawa H, Abe A, Nakazono K, Murasawa A. Disease activity and the course of wrist joint deterioration over 10 years in the patients with early rheumatoid arthritis. Mod Rheumatol 2009;19:47–52.
[3] 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.
[4] Mannerfelt L, Malmsten M. Arthrodesis of the wrist in rheumatoid arthritis. A technique without external fixation. Scand J Plast Reconstr Surg 1971;5:124–30.
[5] Clendenin MB, Green DP. Arthrodesis of the wrist-complications and their management. J Hand Surg Am 1981;6:253–7.
[6] Millender LH, Nalebuff EA. Arthrodesis of the rheumatoid wrist. An evaluation of sixty patients and a description of a different surgical technique. J Bone Joint Surg Am 1973;55:1026–34.
[7] Sauerbier M, Kluge S, Bickert B, Germann G. Subjective and objective outcomes after total wrist arthrodesis in patients with radiocarpal arthrosis or Kienböck's disease. Chir Main 2000;19:223–31.
[8] Cooney 3rd WP, Beckenbaugh RD, Linscheid RL. Total wrist arthroplasty. Problems with implant failures. Clin Orthop Relat Res 1984;187:121–8.
[9] Ferlic DC, Jolly SN, Clayton ML. Salvage for failed implant arthroplasty of the wrist. J Hand Surg Am 1992;17:917–23.
[10] Rizzo M, Ackerman DB, Rodrigues RL, Beckenbaugh RD. Wrist arthrodesis as a salvage procedure for failed implant arthroplasty. J Hand Surg Eur 2011;36:29–33.
[11] Bellemère P, Maes-Clavier C, Loubersac T, Gaisne E, Kerjean Y. Amandys® implant: novel pyrocarbon arthroplasty for the wrist. Chir Main 2012;31:176–87.
[12] Bellemère P, Maes-Clavier C, Loubersac T, Gaisne E, Kerjean Y, Collon S. Pyrocarbon interposition wrist arthroplasty in the treatment of failed wrist procedures. J Wrist Surg 2012;1:31–8.
[13] Parker W, Moran SL, Hormel KB, Rizzo M, Beckenbaugh RD. Nonrheumatoid metacarpophalangeal joint arthritis. Unconstrained pyrolytic carbon implants: indications, technique, and outcomes. Hand Clin 2006;22:183–93.
[14] Pequignot JP, Lussiez B, Allieu Y. A adaptive proximal scaphoid implant. Chir Main 2000;19:276–85 [in French].
[15] Tian CL, Hetherington VJ, Reed S. A review of pyrolytic carbon: application in bone and joint surgery. J Foot Ankle Surg 1993;32:490–8.
[16] Cook SD, Beckenbaugh RD, Redondo J, Popich LS, Klawitter JJ, Linscheid RL. Long-term follow-up of pyrolytic carbon metacarpophalangeal implants. J Bone Joint Surg Am 1999;81:635–48.
[17] Berger RA. A method of defining palpable landmarks for the ligament-splitting dorsal wrist capsulotomy. J Hand Surg Am 2007;32:1291–5.
[18] Simmen BR, Huber H. The wrist joint in chronic polyarthritis: a new classification based on the type of destruction in relation to the natural course and the consequences for surgical therapy. Handchir Mikrochir Plast Chir 1994;26:182–9 [in German].
[19] Tang JB, Giddins G. Why and how to report surgeons' levels of expertise. J Hand Surg Eur 2016;41:365–6.
[20] Shapiro JS. A new factor in the etiology of ulnar drift. Clin Orthop Relat Res 1970;68:32–43.
[21] Youm Y, McMurtry RY, Flatt AE, Gillespie TE. Kinematics of the wrist. I. An experimental study of radial-ulnar deviation and flexion-extension. J Bone Joint Surg Am 1978;60:423–31.
[22] McMurtry RY, Youm Y, Flatt AE, Gillespie TE. Kinematics of the wrist. II. Clinical applications. J Bone Joint Surg Am 1978;60:955–61.

[23] Palmer AK, Werner FW, Murphy D, Glisson R. Functional wrist motion: a biomechanical study. J Hand Surg Am 1985;10:39–46.
[24] Daruwalla ZJ, Davies KL, Shafighian A, Gillham NR. Early results of a prospective study on the pyrolytic carbon (pyrocarbon) Amandys® for osteoarthritis of the wrist. Ann R Coll Surg Engl 2012;94:496–501.
[25] Pierrart J, Bourgade P, Mamane W, Rousselon T, Masmejean EH. Novel approach for posttraumatic panarthritis of the wrist using a pyrocarbon interposition arthroplasty (Amandys®): preliminary series of 11 patients. Chir Main 2012;31:188–94.
[26] Cobb TK, Beckenbaugh RD. Biaxial total-wrist arthroplasty. J Hand Surg Am 1996;21:1011–21.
[27] Courtman NH, Sochart DH, Trail IA, Stanley JK. Biaxial wrist replacement. Initial results in the rheumatoid patient. J Hand Surg Br 1999;24:32–4.
[28] Stegeman M, Rijnberg WJ, van Loon CJM. Biaxial total wrist arthroplasty in rheumatoid arthritis. Satisfactory functional results. Rheumatol Int 2005;25:191–4.
[29] 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.
[30] Nydick JA, Greenberg SM, Stone JD, Williams B, Polikandriotis JA, Hess AV. Clinical outcomes of total wrist arthroplasty. J Hand Surg Am 2012;37:1580–4.
[31] Badge R, Kailash K, Dickson DR, Mahalingam S, Raza A, Birch A, et al. Medium-term outcomes of the Universal-2 total wrist arthroplasty in patients with rheumatoid arthritis. Bone Joint J 2016;98-B:1642–7.
[32] Berber O, Garagnani L, Gidwani S. Systematic review of total wrist arthroplasty and arthrodesis in wrist arthritis. J Wrist Surg 2018;7:424–40.
[33] Cooney W, Manuel J, Froelich J, Rizzo M. Total wrist replacement: a retrospective comparative study. J Wrist Surg 2012;1:165–72.
[34] Sagerfors M, Gupta A, Brus O, Pettersson K. Total wrist arthroplasty: a single-center study of 219 cases with 5-year follow-up. J Hand Surg Am 2015;40:2380–7.
[35] Tanwin Y, Maes-Clavier C, Lestienne V, et al. Medium-term outcomes for Amandys implant, a five years minimum follow-up of 63 cases. J Wrist Surg 2021. http://dx.doi.org/10.1055/s-0041-1726406. published online, ahead of print.
[36] Weiss KE, Rodner CM. Osteoarthritis of the wrist. J Hand Surg Am 2007;32:725–46.
[37] Lautenbach M, Millrose M, Langner I, Eisenschenk A. Results of Mannerfelt wrist arthrodesis for rheumatoid arthritis in relation to the position of the fused wrist. Int Orthop 2013;37:2409–13.
[38] Riches PL, Elherik FK, Dolan S, Unglaub F, Breusch SJ. Patient rated outcomes study into the surgical interventions available for the rheumatoid hand and wrist. Arch Orthop Trauma Surg 2016;136:563–70.
[39] Gil JA, Kamal RN, Cone E, Weiss A-PC. High survivorship and few complications with cementless total wrist arthroplasty at a mean followup of 9 years. Clin Orthop Relat Res 2017;475:3082–7.
[40] Matsui Y, Minami A, Kondo M, Ishikawa J, Motomiya M, Iwasaki N. A minimum 5-year longitudinal study of a new total wrist arthroplasty in patients with rheumatoid arthritis. J Hand Surg Am 2020;45:255.e1–7.
[41] Beer TA, Turner RH. Wrist arthrodesis for failed wrist implant arthroplasty. J Hand Surg Am 1997;22:685–93.