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Trapeziometacarpal total joint arthroplasty for osteoarthritis: 199 patients with a minimum of 10 years follow-up

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Abstract

We report outcomes of 228 consecutive patients with total joint arthroplasty using the Arpe® prosthesis, among which 216 trapeziometacarpal joints in 199 patients had a minimum of 10 years follow-up. The cumulative survival rate of the 216 implants at 10 years using the Kaplan–Meyer method was 93%. Two hundred joints were functional and painless. We found good integration and positioning of the components in 184 (93%) of the joints. Sixteen prostheses failed. We conclude that this implant has acceptable long-term survival rate and restores good hand function. We also report our methods to improve implant survival and to decrease the risk of component malpositioning, and failure rate.

Level of evidence: II

Keywords

Arpe®, ball and socket arthroplasty, carpometacarpal osteoarthritis, long-term results, trapeziometacarpal joint

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Introduction

Symptomatic osteoarthritis (OA) of the thumb carpometacarpal (CMC) joint may require surgery after conservative treatment has failed. Trapeziectomy has been the proposed treatment (Gangopadhyay et al., 2012, Salem and Davis, 2012). Less frequently used procedures are thumb CMC joint arthrodesis and total joint arthroplasties with joint prosthesis (Brunton et al., 2010). Arthrodesis of the CMC joint is an effective treatment because it stabilizes the thumb and provides strength but is associated with the loss of mobility and with more complications (Mureau et al., 2001). The short-term outcomes of joint prosthesis are superior to trapeziectomy and its variants (Cebrian-Gomez et al., 2019; Jager et al., 2013; Jurca et al., 2016; Martínez-Martínez et al., 2016), but the long-term complications are often higher (Giddins, 2012; Huang et al., 2015).

Over the past decades, different implants for the CMC joint have been developed, among which the most often used is the ball-and-socket-type implant (Apard and Saint Cast, 2009; Badía and Sambandam, 2006; Brutus and Kinnen, 2004; Chakrabarti et al., 1997; Comtet, 2000; Cootjans et al., 2017; De la Caffiniere and Aucouturier, 1979; Johnston et al., 2012; Martin-Ferrero, 2014; Sondergaard et al., 1991; Toffoli and Teissier, 2017; Vissers et al., 2019). The long-term outcomes are a common concern of surgeons.

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The aim of this study was to report the results of a series of consecutive patients treated with the ball-and-socket Arpe® prosthesis for thumb CMC joint OA, with a minimum of 10 years follow-up.

Methods

A follow-up study was performed at our hand unit with patients who had undergone surgery between May 1999 and May 2008. The consecutive patients included in the study had undergone thumb CMC total joint arthroplasty (TJA) for OA of this joint using a modular, non-cemented, hydroxyapatite-coated, unconstrained Arpe® implant (Biomet France, Plateau de Lautagne, Valence, France). We decided to include around 225 prostheses because this quantity guarantees us to obtain the percentage of failure for the implanted prostheses with an estimation error less than 4% (for a confidence level of 95%). We assumed in this calculation that 10% was the true failure percentage. Finally, we included 228 prostheses.

The data on age and sex and type of OA and implant were recorded, written informed consent was obtained from all the patients, and ethical approval from the local Hospital Research Ethics Committee was acquired.

Inclusion and exclusion criteria

When we started using the prostheses, we followed the criteria of De la Caffiniere and Aucouturier (1979) to place them in the patients for whom they had obtained good results. Because the Arpe® prosthesis is not cemented in place, we have not used it in patients with rheumatoid arthritis. Based on our experience, we have slightly adjusted the original criteria. The inclusion criteria were as follows: patients with CMC joint OA degree II and III of Eaton and Littler (Eaton et al., 1984) and some degree IV, patients age between 50 and 70 years, patients with small or medium demands and medium-to-hard manual tasks such as assembly line workers handling light objects, cooks, and hairdressers. We excluded patients with marked ulnar instability or fixed hyperextension of the metacarpophalangeal joint, severe scaphoid trapezium trapezoid OA degree III (Crosby et al., 1978), severely dysplastic trapezium, rheumatic diseases, and heavy manual work requirements such as hammering and drilling.

Changes in the surgical procedure

A single surgeon (MMF) performed the replacement of the first 104 joints (93 patients) from May 1999 to April 2004 using a lateral-palmar (original technique) approach recommended by the designer of the Arpe® prosthesis (Comtet, 2000). In May 2004, MMF introduced important changes that facilitated the surgical technique, which is the current one. This entailed changing to a pure dorsal surgical approach, performing a more extensive resection osteotomy of the base of the first metacarpal to improve access to the trapezium and no longer performing a trapezial osteotomy but only resecting peripheral osteophytes, which preserves the distal subchondral bone and improves the primary support of the cup. From May 2004 and using the current technique, another surgeon (CSP) performed replacement surgery in 34 of the most recent 124 joints (106 patients). MMF is a surgeon of level 4 expertise, and CSP is a surgeon of level 3 expertise for this procedure (Tang, 2009; Tang and Giddins, 2016).

Current surgical technique

A 3-cm longitudinal incision is made over the dorsal aspect of the base of the thumb, centred on the CMC joint. The extensor pollicis brevis is released and retracted ulnarly. Branches of the superficial radial nerve are identified and protected. The dorsal capsule is exposed, and an inverted L-shaped capsulotomy is performed with the transverse leg located 5 mm distal to the base of the metacarpal and the longitudinal leg following the dorsal border of the abductor pollicis longus tendon (Figure 1(a)). The capsule and periosteum are released from the bony structures and are reflected towards the ulnar side to facilitate later repair (Figure 1(b)). A sagittal saw is used to cut the proximal 5 mm of the base of the thumb metacarpal, and the cut is slightly oblique from dorsal to volar in order to resect the volar metacarpal beak osteophyte (Figure 1(c)). A gouge is used to remove the marginal osteophytes of the trapezium. The proximal part of the first metacarpal is extensively released from its soft tissues to allow displacement in the volar direction using a Hoffman retractor. This allows complete exposure of the distal articular face of the trapezium. Once exposed, the geometric centre is identified by direct vision. A surgical awl is used to create a small starter hole. The initial starting point hole is enlarged with curettes, then drilled and reamed using the supplied instruments. The use of power tools is avoided (Figure 1(d)). Once the trapezium is prepared, we focus on the metacarpal. The proximal entry of the medullary canal of the first metacarpal is exposed, and an initial penetration is performed using an awl that is then enlarged using the rasps provided in the instrument tray.

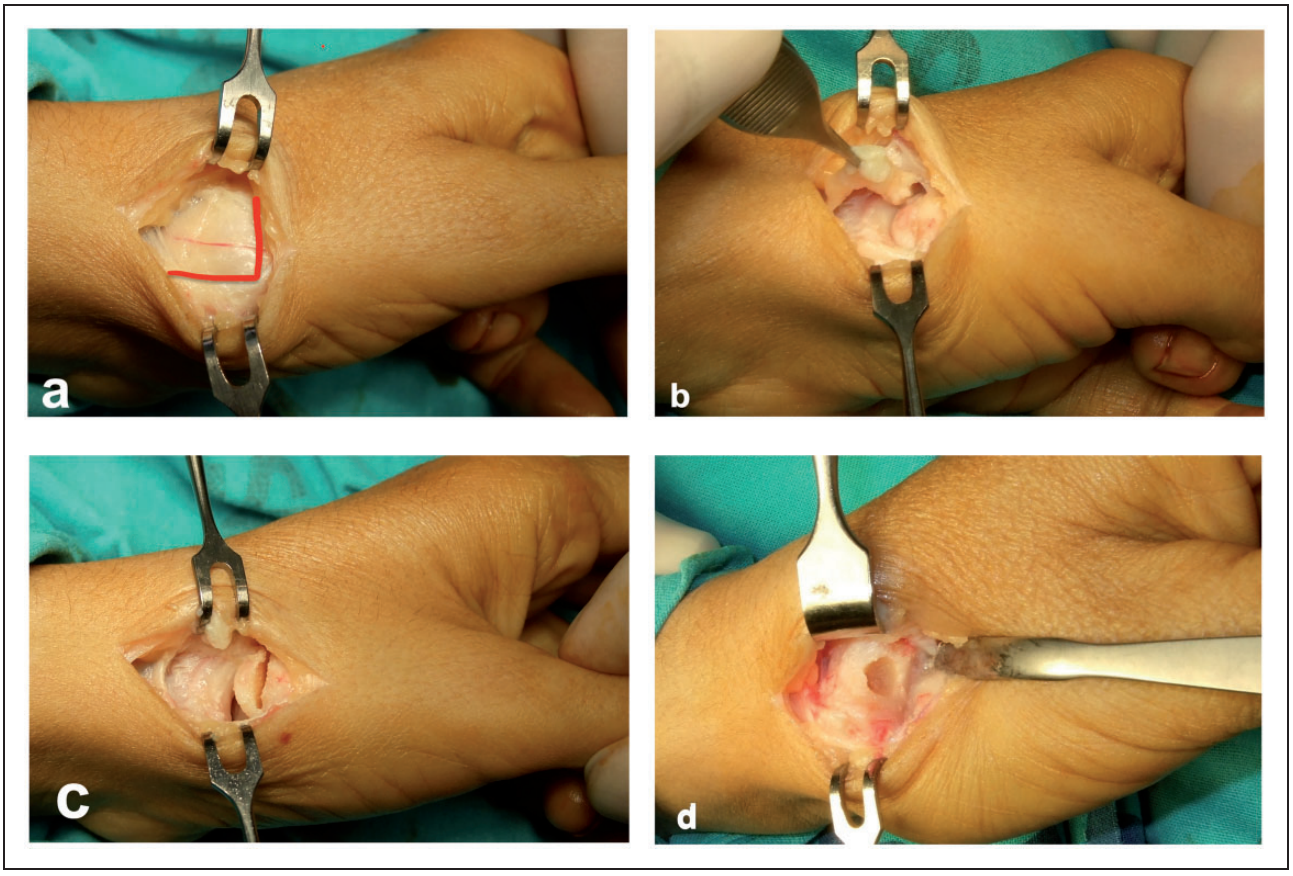

Figure 1. Surgical procedures of the current method. (a) Inverted L-shaped capsulotomy was performed with the transverse leg located 5 mm distal to the base of the metacarpal and the longitudinal leg following the dorsal border of the abductor pollicis longus tendon. (b) Capsule and periosteum released. (c) Osteotomy of the base of the first metacarpal (slightly oblique from dorsal to palmar). (d) The proximal part of the first metacarpal was extensively released from its soft tissues to allow displacement in the volar direction using a Hoffman retractor.

After preparing the bone, we use prosthetic trials to test for stability. Thereafter, we insert by press fit technique the definitive cup, ensuring that it is positioned as much as possible on the subchondral bone to increase primary stability. Following trapezial cup placement, the metacarpal implant stem is inserted, and a neck test performed. In our experience, the angled neck is almost invariably used. The implant is reduced and assessed for stability and bone impingement in stress positions (Figure 2). A suspicion of instability or impingement requires further adjustments of the prosthesis under fluoroscopy. The length of the neck of the prosthesis is calculated by placing the thumb in retro-position with the volar crease of the interphalangeal joint matching the proximal volar crease of the hand. The definitive neck-head is inserted once the neck length is assessed and the joint is reduced and reassessed. The capsule periosteal flap is closed with an absorbable suture. A short-hand plaster cast is applied with the thumb in a functional position and left in place for 3 weeks. In most instances, patients rehabilitate themselves by following a comprehensive exercise programme, but a specialist in hand therapy is available if required.

Follow-up and clinical assessment

Clinical and radiological assessments were performed preoperatively and then postoperatively at 3 months, 5 years, and 10 years. The clinical examination consisted of measurement of the range of motion of the thumb using the criteria of International Federation of Societies for Surgery of the Hand (IFSSH, 2019), measurement of the thumb opposition using the Kapandji method (Kapandji, 1986), and measurement of the key pinch strength using pinch gauge (B&L Engineering, Alimed Inc., Dedham, MA, USA).

The radiological examination comprised posterior-anterior and oblique radiographs (Figure 3). Preoperative radiographs were classified by the Eaton criteria (Eaton et al., 1984), and postoperative

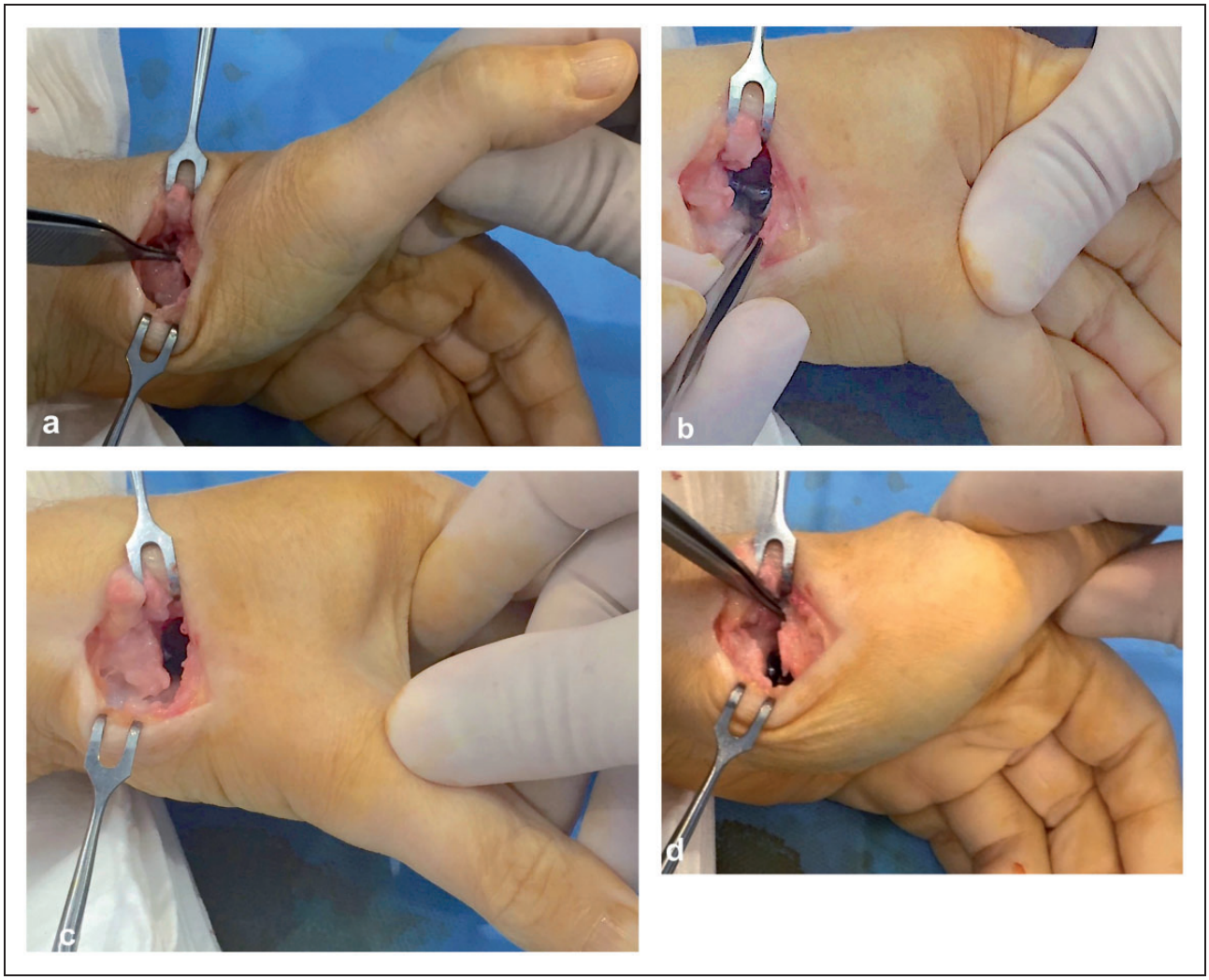

Figure 2. Surgical procedure of the current method: Before closing the joint capsule it is essential to check the stability of the implant in forced positions of thumb movements to observe and correct when necessary any bony impingements that could cause a later dislocation of the prosthesis: (a) Extension. (b) Flexion. (c) Palmar abduction. (d) Retroposition.

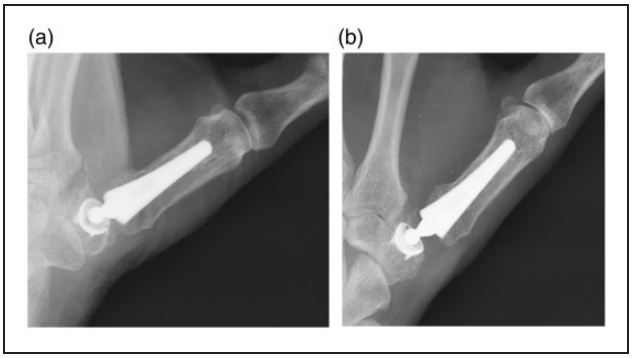

Figure 3. X-ray films 3 months after surgery with the current method. (a) With the thumb abducted. (b) With the thumb adducted. The prosthesis has enough space to move without bone impingement.

radiographs were evaluated to observe the following factors: implant component alignment, implant loosening and/or subsidence, and ectopic calcification. The pain level was measured using a visual analogue scale (VAS) (ranging 0–10), and patient satisfaction was measured using the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire validated to Spanish (Rosales et al., 2002). The first 145 patients completed the DASH questionnaire at 5 years post-surgery, and all completed the DASH questionnaire at 10 years post-surgery.

Definition of outcomes

We developed criteria to scale the implant performance. Prostheses were considered to be *functional* if

the patient could use the hand normally for activities of daily living, had a VAS pain score <3, was functional with a DASH score <30, and showed no adverse radiological changes.

Prostheses were considered to have *failed* if one of the following major factors had occurred in isolation: implant dislocation, loosening or poor position of either component, VAS ≥5, DASH ≥40, or thumb stiffness with radial abduction ≤20° or Kapandji score ≤6.

The prosthesis was also considered failed if three or more minor factors were present: radiolucency lines around the cup or stem with no positioning changes of the components, subluxation of components, subsidence of any of the components, ectopic calcification around the implant, VAS of 3–4, DASH of 30–40, radial abduction of 20°–30°, or Kapandji score of 7–8.

Statistical analysis

Parametric data were presented as the means (standard deviation, SD) and non-parametric data as medians (interquartile range, IQR) for continuous variables or as percentages for dichotomous variables. Kaplan–Meier analysis was performed to assess the distribution of survival. Differences between the preoperative and follow-up measures regarding clinical numerical variables were assessed using *post hoc* Student *t*-test after analysis of variance. Fisher's exact test was applied to check the association between outcome dichotomous variables and the two subgroups given by the implant date. *P*-values lower than 0.05 were consider statistically significant.

Results

Two hundred twenty-eight joints treated with the Arpe® prosthesis (199 patients, 29 bilateral) entered the study. Nine patients (10 prostheses) had died before the 10-year follow-up. It was not possible to follow two other patients (two prostheses). Ten patients (11 prostheses) could not attend the review and were interviewed over the telephone (these are included in clinical results only).

Arthroplasty was performed with approximately the same frequency in both the dominant and non-dominant hands. The most common aetiology was osteoarthritis. Forty per cent of patients had co-existing pathologies. The most common cup size was 9 with a stem size of 8 or 9, with most of the necks angled and of medium size (Table 1).

In total, 216 joints after replacement (11 patients telephonically interviewed) completed the 10-year

Table 1. Descriptive characteristics of the patients (199 patients with 228 prostheses) who underwent first carpometacarpal total arthroplasty.

Variables	Results
Sex (*n*, %)	
Male	10 (5%)
Female	188 (95%)
Age (years)	59 (SD 8)
Age (years)	
<50	19 (10%)
50–70	165 (83%)
>70	15 (7%)
Occupation (physical stress) (*n*, %)	
Light	10 (5%)
Moderate	140 (70%)
Hard	38 (19%)
No information	11 (6%)
Affected dominant hand (*n*, %)	108 (54%)
Aetiology (*n*, %)	
Osteoarthritis	153 (77%)
Multiple osteoarthritis	46 (23%)
Concomitant pathology (*n*, %)	
No concomitant pathology	117 (59%)
Carpal tunnel syndrome	49 (25%)
De Quervain	11 (5%)
Synovial cyst	5 (3%)
Trigger finger	13 (6%)
Dupuytren	3 (2%)
Eaton (*n*, %)	
Stage 2–3	178 (89%)
Stage 4	21 (11%)
Cup size (*n*, %)	
9	219 (96%)
10	6 (3%)
No information	3 (1%)
Stem size (*n*, %)	
7	16 (7%)
8	113 (50%)
9	89 (39%)
10	7 (3%)
No information	3 (1%)
Neck type (*n*, %)	
Angled	222 (97%)
Straight	3 (1%)
No information	3 (1%)
Neck size (*n*, %)	
Normal	177 (78%)
Long	48 (21%)
No information	3 (1%)

Data are expressed as either number (*n*) and percentage (%), or as mean (SD).

follow-up (median: 10.5 y; 25th, 75th percentile (10.0 y, 11.4 y)), among which, 200 (93%) were functional and 16 (7%) had failed.

Survival rate

The Kaplan–Meier curve is shown in Figure 4. The cumulative survival rate of the complete series at 10 years was 92% (95% CI (89%, 96%)). Prostheses performed using the current dorsal approach showed survival greater than the average of the series, being 94% (95% CI (90%, 99%)), but this was not statistically significant.

The patients with functional arthroplasties after 10 years of follow-up showed little or no pain (VAS preoperative: 8.2 SD 1.2; VAS at 10 years: 1.1 SD 0.9 ($p < 0.001$)) and good function [DASH preoperative: 59 SD 9.4; DASH at 10 years: 13 SD 11.6 ($p < 0.001$)). Similar figures were observed for the Kapandji's score (94% were over 9 score) and radial abduction degrees (91% were over 30°). The key pinch was 3.1 SD 1.4 kg preoperatively and 4.5 SD 1.8 kg at 10 years.

Radiological assessment was performed in 187 (94%) of functional joints. Of these 174 (93%) showed good implant integration without any loosening. Thirteen (7%) presented some ectopic calcification and slight radiolucency, but these were not associated with any adverse symptoms. The mean distance from the cup bottom to the scaphoid trapezium trapezoid joint was 4.9 mm (SD 1.5). Radiological implant positioning was better in prostheses that had been inserted using the current dorsal approach. There was a lower incidence of adverse oblique alignment of the stem (44 (42%) vs 11 (9%) in the first and second technique, respectively; $p < 0.001$)), reduced implant subluxation (23 (22%) vs 5 (4%), respectively; $p < 0.05$)), and less cup subsidence (11 (10%) vs 1 (0.1%), respectively, $p < 0.005$).

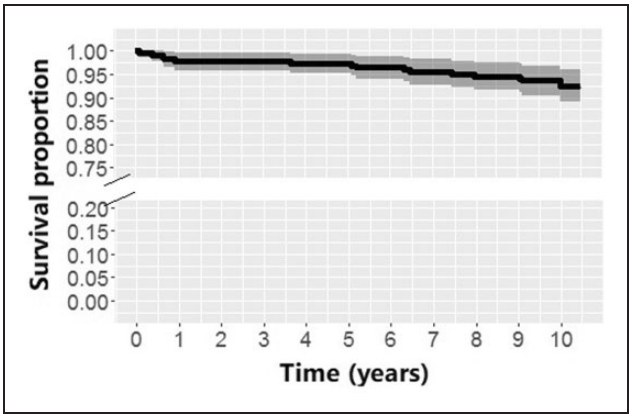

Figure 4. Kaplan–Meier survival curve from the complete series.

Complications

Perioperative and early postoperative complications included fractures of the trapezium in three patients (two of them were resolved with immobilization for 4 weeks and the other one, more complex, is a failed prosthesis); two excessive trapezium osteotomies (both failed); and one stem penetration of the cortex of the thumb metacarpal, which remained functional in situ without evidence of loosening during the follow-up. Thirteen patients complained of moderate paraesthesia or dysesthesia dorsally on the thumb (10 with the original technique and three with the current dorsal technique. Two of these patients reported persistent symptoms at the 10-year review. Three patients experienced transient complex regional pain syndrome type I. There were five cases of suture reaction. There was no evidence of deep infection.

Late complications included cup loosening in ten (4.6%) (two early and eight late). Two were successfully treated with cup revision in addition to autologous bone grafting. Twelve prostheses (5.3%) dislocated (four early and eight late). Seven of these were resolved by closed reductions in four and open reductions in three; five remained dislocated at the final follow-up. They were offered reconstructive surgery. No complete loosening of the stem was present. Three implants showed partial radiolucency proximally.

The frequency of small trapeziums (12 out of 16) in the failed cases was higher than in functional outcomes (30 out of 200). Nine prostheses failed in the initial 104 CMC joints and seven occurred in remaining 124 CMC joints after we changed the surgical technique (Table 2).

Discussion

This is a series of 228 CMC joint Arpe® prostheses in a consecutive series of patients with a follow-up of at least 10 years. In addition to the large number of consecutive patients with low attrition, two other considerations validating the results exist. First, surgical indication criteria were established before the patients were included; second, we tried to define the characteristics that functional and failed prostheses must have to evaluate the results. Thus, our experience with the Arpe® prosthesis is quite satisfactory, observing a 10-year Kaplan–Meier survival rate of 93%.

The present study can justifiably be criticized for studying the practice of two surgeons undertaking

Table 2. Failed prostheses according to the order of the series in which they were operated.

Age[a]	TPZ size	MCP joint[b]	Surgery date	Surgical techniques	Postoperative X-ray findings	Functional time	Causes of failure	Restorative surgery	Ten-year follow up
56	Small	Lax	16/09/1999	Imperfect: bad implant placement	Dislocated	1 month	Dislocation	Reject	01/04/2010 Dislocated
60	Medium	Lax	22/10/1999	Imperfect: excessive trapezium osteotomy	Oblique stem	7 years	VAS 4, DASH 45	Reject	01/08/2010 Painful
58	Medium	Normal	30/06/2000	No alterations noted	Correct position	7 years	Cup loos. by hypocalcaemia	Reject	01/06/2012 cup loosened
46	Small	Normal	01/04/2001	Imperfect: bad implant placement	Cup malposition	8 years	Cup loosening	LRTI (stem left in)[a]	15/02/2012 Removed
68	Small	Lax	10/01/2002	Imperfect: excessive trapezium osteotomy	Oblique stem	8 years	VAS 6, DASH 50	Reject	08/02/2012 Painful
71	Small	Normal	13/06/2002	No alterations noted	Correct position	6 years	Cup loosening	LRTI (stem left in)	15/10/2014 Removed
54	Small	Lax	15/11/2002	Imperfect: instability	Correct position	4 years	Dislocation	Eaton-reject	10/10/2012 Dislocated
58	Small	Normal	30/05/2003	No alterations noted	Correct position	9 years	Cup loosening	LRTI (stem left in)	10/10/2014 Removed
74	Small	Normal	17/10/2003	Imperfect: bad implant placement	Cup malposition	5 years	Dislocation	Reject	29/01/2014 Dislocated
46	Medium	Lax	05/11/2004	Imperfect: bad implant placement	Oblique stem	8 years	VAS 3, DASH 59	Ligamentoplasty MCP	10/08/2016 Painful. Reject more surgery
46	Medium	Normal	25/11/2004	Imperfect: bad implant placement	Cup malposition	7 years	Cup loosening	LRTI (stem left in)	15/06/2016 Removed
57	Small	Normal	27/01/2005	No alterations noted	Correct position	6 years	Dislocation	Reject	13/07/2016 Dislocated
57	Small	Lax	03/03/2005	Imperfect fixation of the cup	Correct position	6 months	Cup loosening	Cup replacement	16/07/2016 Painful. Reject more surgery
64	Small	Lax	22/12/2006	No alterations noted	Correct position	1 years	Dislocation and crutches	Reject	02/09/2016 Dislocated
54	Small	Normal	12/04/2007	Imperfect: bad implant placement	Protruding stem	6 months	Cup loosening	LRTI (stem removed)	01/12/2016 Removed
62	Small	Lax	25/10/2007	Imperfect: trapezium fracture	Trapezium fracture (cerclage)	4 months	Cup loosening	LRTI (stem removed)	10/11/2017 Removed

[a]All patients are women.
[b]MCP joint laxity is defined as having more than 30° of hyperextension or ulnar deviation.
TPZ: trapezium; MCP: metacarpophalangeal; VAS: visual analogue scale; DASH: Disabilities of the Arm, Shoulder, and Hand; LRTI: ligament reconstruction tendon interposition.

this type of operation over a long period of time, rather than the outcomes achieved by more surgeons. Another weakness is that the study design did not reduce the potential for bias, because the treating surgeons and members of our staff carried out all the preoperative and follow-up assessments. However, although there is a risk that subconscious bias affected the objective outcome measures, the subjective outcomes were free from observer bias as the patients completed the VAS and DASH questionnaires on their own. Initially, we used the inclusion and exclusion criteria established by De la Caffiniere and Aucouturier (1979), and then we slightly adjusted them as we gained experience. The classification criteria introduced in this article to consider arthroplasty as functional or failed must be verified and discussed in subsequent studies.

Long-term reviews of De la Caffiniere prostheses (Chakrabarti et al., 1997; Johnston et al., 2012; Sondergaard et al., 1991) showed survival rates ranging from 76% to 82% and loosening up to 40%. The long-term studies of current ball-and-socket prostheses (Apard and Saint Cast, 2009; Cootjans et al., 2017; Martin-Ferrero, 2014; Toffoli and Teissier, 2017; Vissers et al., 2019) report better survival (89%–96%) and lower loosening rates (4%–7%) in these prostheses, but may experience dislocation at a frequency of approximately 5%. These data were expected because De la Caffiniere implants, despite being a ball-and-socket design, have the important drawbacks of being constrained and cemented, while current prostheses are modular, uncemented, and unconstrained. It is also worth noting the similarity of the survival rates of these current implants to those reported by Allami et al. (2006) on the 10-year survival of total hip arthroplasty (93%), which is the standard reference in orthopaedic prosthetics.

If we compare this study with our previously published study on the first 69 arthroplasties of this series (Martin-Ferrero, 2014), all the data are quite similar, but Kaplan–Meier survival was decreased slightly in the current study (94% in the first, compared with 93% in the second), likely due to the use of more definitive and restrictive evaluation criteria.

Based on this experience, we changed the technique of how to place and fix the Arpe® prosthesis to bone and thereby improved the results. The current dorsal approach permits better access to the distal trapezium to improve the cup positioning, allows a better introduction and control of the direction of the stem into the first metacarpal, and diminishes the incidence of radial neuritis. Regarding the positioning of implant components, the results of the current technique improved with statistical significance ($p < 0.005$) compared with those of the former. Survival rate was possibly superior with the current technique, although statistical significance was not detected.

When analysing the causes of prostheses failure, we identified that small trapeziums were present in 75% of the failed prostheses and in 15% of functional prostheses. Brutus and Kinnen (2004) reported similar findings. This fact does not prevent the use of a prosthesis, but a special caution must be adopted during the surgical procedure in patients with small trapeziums. The preoperative first metacarpal adduction and the laxity of the metacarpophalangeal joint associated with CMC joint OA contribute considerably to the future prosthetic dislocation or subluxation, as also reported by Badía and Sambandam (2006). Therefore, we treat both the prosthesis and these associated alterations at the same time to avoid complications. In case of failure, after removing the prosthesis, a trapeziectomy and ligament reconstruction was performed. Sometimes the stem is left in place if it is fully integrated. Results were similar to those of primary trapeziectomies and ligament reconstruction (Cooney et al., 2006). This large series of patients with long follow-up has demonstrated that Arpe® prostheses are long lasting, effective and reliable alternative for surgical treatment of CMC joint OA if it is undergone with the criteria of surgical indication and surgical technique described throughout the study.

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Ethical approval Written informed consent was obtained from all patients, and ethical approval from the local Hospital Research Ethics Committee (University Hospital of Valladolid, Spain) was obtained.

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References

Allami MK, Fender D, Khaw FM et al. Outcome of Charnley total hip replacement across a single health region in England: the results at ten years from a regional arthroplasty register. J Bone Joint Surg Br. 2006, 88: 1293–8.

Apard T, Saint Cast I. Midterm results of ARPE prosthesis for the basal thumb osteoarthritis. J Bone Joint Surg Br. 2009, 91(Supp 1): 96.

Badía A, Sambandam SN. Total joint arthroplasty in the treatment of advanced stages of thumb carpometacarpal joint osteoarthritis. J Hand Surg Am. 2006, 31: 1605–13.

Brunton LM, Wilgis ES. A survey to determine current practice patterns in the surgical treatment of advanced thumb carpometacarpal osteoarthrosis. Hand. 2010, 5: 415–22.

Brutus JP, Kinnen L. Remplacement prothétique total trapézométacarpienne au moyen de la prothèse ARPE dans le traitement de la rhizarthrose: notre expérience à court terme dans une série personnelle de 63 cas consécutifs. Chir Main. 2004, 23: 224–8.

Cebrian-Gomez R, Lizaur-Utrilla A, Sebastia-Forcada E, Lopez-Prats FA. Outcomes of cementless joint prosthesis versus tendon interposition for trapeziometacarpal osteoarthritis: a prospective study. J Hand Surg Eur. 2019, 44: 151–8.

Chakrabarti AJ, Robinson AH, Gallagher P. De la Caffinière thumb carpometacarpal replacements. 93 cases at 6 to 16 years' follow-up. J Hand Surg Br. 1997, 22: 695–8.

Comtet JJ. ARPE prostheses. In: Simmen BR, Allieu Y, Lluch A et al (eds) *Hand Arthroplasties*. London, Martin Dunitz, 2000: 249–56.

Cooney WP, Leddy TP, Larson DR. Revision of thumb trapeziometacarpal arthroplasty. J Hand Surg Am. 2006, 31: 219–27.

Cootjans K, Vanhaecke J, Dezillie M, Barth J, Pottel H, Stockmans F. Joint survival analysis and clinical outcome of total joint arthroplasties with the Arpe implant in the treatment of trapeziometacarpal osteoarthritis with a minimal follow up of 5 years. J Hand Surg Am. 2017, 42: 630–8.

Crosby EB, Linscheid RL, Dobyns JH. Scaphotrapezial trapezoidal arthrosis. J Hand Surg Am. 1978, 3: 223–34.

De la Caffiniere JY, Aucouturier P. Trapezio-metacarpal arthroplasty by total prosthesis. Hand. 1979, 11: 41–6.

Eaton EG, Lane LB, Littler JW, Keyser JJ. Ligament reconstruction for the painful thumb carpometacarpal joint: a long-term assessment. J Hand Surg Am. 1984, 9: 692–9.

Gangopadhyay S, McKenna H, Burke FD, Davis TRC. Five- to 18-year follow-up for treatment of trapeziometacarpal osteoarthritis: a prospective comparison of excision, tendon interposition, and ligament reconstruction and tendon interposition. J Hand Surg Am. 2012, 37: 411–7.

Giddins G. Thumb arthroplasties. J Hand Surg Eur. 2012, 37: 603–4.

Huang K, Hollevoet N, Giddins G. Thumb carpometacarpal joint total arthroplasty: a systematic review. J Hand Surg Eur. 2015, 40: 338–50.

International Federation of Societies for Surgery of the Hand (IFSSH) Terminology for Hand Surgery, 2019. www.ifssh.info/TerminologyOfHandSurgery.html (accessed 21 February 2019).

Jager T, Barbary S, Dap F, Dautel G. Evaluation of postoperative pain and early functional results in the treatment of carpometacarpal joint arthritis. Comparative prospective study of trapeziectomy vs. MAIA® prosthesis in 74 female patients. Chir Main. 2013, 32: 55–62.

Johnston P, Getgood A, Larson D, Chojnowski AJ, Chakrabarti AJ, Chapman PG. De la Caffiniere thumb trapeziometacarpal joint arthroplasty: 16-26 year follow up. J Hand Surg Eur. 2012, 37: 621–4.

Jurča J, Němejc M, Havlas V. Surgical treatment for advanced rhizarthrosis. Comparison of results of the Burton-Pellegrini technique and trapeziometacarpal joint arthroplasty. Acta Chir Orthop Traumatol Cech. 2016, 83: 27–31.

Kapandji A. Clinical test of apposition and counter–apposition of the thumb. Ann Chir Main. 1986, 5: 67–73.

Martin-Ferrero M. Ten-year long-term results of total joint arthroplasties with Arpe® implant in the treatment of trapeziometacarpal osteoarthritis. J Hand Surg Eur. 2014, 39: 826–32.

Martínez-Martínez F, García-Hortelano S, García-Paños, Moreno-Fernandez JM, Martin-Ferrero MA. Comparative clinical study of two surgical techniques for trapeziometacarpal osteoarthritis. Rev Esp Cir Ortop Traumatol. 2016, 60: 59–66.

Mureau MA, Rademaker RP, Verhaar JA, Hovius SE. Tendon interposition arthroplasty versus arthrodesis for the treatment of trapeziometacarpal arthritis: a retrospective comparative follow-up study. J Hand Surg Am. 2001, 26: 869–76.

Rosales RS, Delgado EB, Diez de la Lastra I. Evaluation of the Spanish versión of the DASH and carpal tunnel syndrome health-related quality-of-life instruments: cross-cultural adaptation process and reliability. J Hand Surg Am. 2002, 27: 334–43.

Salem H, Davis TRC. Six-year outcome excision of the trapezium for trapeziometacarpal joint osteoarthritis: is it improved by ligament reconstruction and temporary Kirschner wire insertion? J Hand Surg Eur. 2012, 37: 211–9.

Sondergaard L, Konradsen L, Rechnagel K. Long-term follow-up of the cemented Caffiniere prosthesis for trapeziometacarpal arthroplasty. J Hand Surg Br. 1991, 16: 428–30.

Tang JB. Re: Levels of experience of surgeons in clinical studies. J Hand Surg Eur. 2009, 34: 137–8.

Tang JB, Giddins G. Why and how to report surgeons' levels of expertise. J Hand Surg Eur. 2016, 41: 365–6.

Toffoli A, Teissier J. MAIA trapeziometacarpal joint arthroplasty: clinical and radiological outcomes of 80 patients with more than 6 years of follow-up. J Hand Surg Am. 2017, 42: 838–e1–e8.

Vissers G, Goorens CK, Vanmierlo B et al. Ivory arthroplasty for trapeziometacarpal osteoarthritis: 10-year follow-up. J Hand Surg Eur. 2019, 44: 138–45.