Total Joint Arthroplasty in the Treatment of Advanced Stages of Thumb Carpometacarpal Joint Osteoarthritis

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Purpose: Osteoarthritis of the thumb basal joint is a very common and disabling condition that frequently affects middle-aged women. Many different surgical techniques have been proposed for extensive degenerative arthritis of the first carpometacarpal (CMC) joint. Joint replacement has been an effective treatment of this condition. The purpose of this article is to present the outcome of a total cemented trapeziometacarpal implant in the treatment of more advanced stages of this disease.

Methods: Total joint arthroplasty of the trapeziometacarpal joint was performed on 26 thumbs in 25 patients to treat advanced osteoarthritis (Eaton and Littler stages III and IV) between 1998 and 2003. Indications for surgery after failure of conservative treatment were severe pain, loss of pinch strength, and diminished thumb motion that limited activities of daily living. A trapeziometacarpal joint prosthesis was the implant used in this series. The average follow-up time was 59 months.

Results: At the final follow-up evaluation, thumb abduction averaged 60° and thumb opposition to the base of the small finger was present. The average pinch strength was 5.5 kg (85% of nonaffected side). One patient had posttraumatic loosening, which was revised with satisfactory results. Radiographic studies at the final follow-up evaluations did not show signs of atraumatic implant loosening. One patient complained of minimal pain, and the remaining 24 patients were pain free.

Conclusions: In our series, total joint arthroplasty of the thumb CMC joint has proven to be efficacious with improved motion, strength, and pain relief. We currently recommend this technique for the treatment of stage III and early stage IV osteoarthritis of the CMC joint in older patients with low activity demands. (J Hand Surg 2006;31A:1605.e1–1605.e13. Copyright © 2006 by the American Society for Surgery of the Hand.)

Type of study/level of evidence: Therapeutic IV.

Key words: Carpometacarpal, cemented arthroplasty, osteoarthritis, thumb.

The trapeziometacarpal joint has an exclusive anatomic design that allows arcs of motion in 3 different planes (abduction–adduction, flexion–extension, axial rotation) to place the thumb in a preaxial position to resist axial loads.[1] These variable positions of load may explain why it is common for this joint to develop osteoarthritis (OA) even when other small joints in the vicinity remain uninvolved.[2] It has been shown that there is a strong correlation between basal joint laxity (specifically volar ligament instability) and the evolution of early degenerative changes. These alterations lead to pain, weakness, and adduction deformity.[3]

Restoration of thumb function with a painfree, stable, and mobile joint with preserved strength are the main goals of treatment of painful arthritis of the thumb.[2] Many surgical methods have been proposed to achieve these goals. Procedures such as ligament reconstruction,[4–12] ligament reconstruction and tendon interposition,[7,8,13–20] tendon interposition without ligament reconstruction,[7,14,21–31] and simple trapezial excision[7,8,32–35] all are associated with some loss of thumb length and hence pinch strength. The role of metacarpal osteotomy is not clearly established.[6,36–41] Arthrodesis is associated with loss of mobility and a transfer of reaction forces to the

neighboring joints.[29,42–48] Silicone implant arthroplasty was proposed as an alternative but is associated with instability, silicone wear, synovitis, prosthesis fracture, and prosthesis subluxation.[35,49–64]

Total joint arthroplasty was first described by de la Caffiniere and Aucouturier.[65] This procedure applies the concept of total hip replacement to creating a permanent swivel within the base of the thumb that obviates the need for ligament reconstruction, replaces the joint surface with a mechanical bearing surface for frictionless movement, and provides stability for strong pinch and grasp.[66]

Various implant designs are available on the market for total joint arthroplasty of the thumb.[36,65–85] The de la Caffiniere implant is the most widely used and most extensively studied implant[65,69,70,73–76,78,80–83] Appendix 1 can be viewed at the *Journal's* Web site, http://www.jhandsurg.org). De la Caffiniere first reported his own experience with this implant in 1979[65] and later in 1991.[75] GUEPAR (France) is another implant that has been reported in the French[67,85,86] and German[84] literature (Appendix 2 can be viewed at the *Journal's* Web site, http://www.jhandsurg.org). Even though surgeons in different parts of the world continue to use other implants (Appendix 3 can be viewed at the *Journal's* Web site, http://www.jhandsurg.org), the indications and long-term outcomes of those implants are not reported frequently and hence are not adequately established.

The Braun-Cutter prosthesis (SBI/Avanta Orthopaedics, San Diego, CA) is a commonly used implant for total joint arthroplasty.[36,71,72] In his study[71] in 1982, Braun reported his experience in 22 patients with 29 involved thumbs. Three years later, he reported his experience with 50 patients.[36] These are the only 2 reports regarding the Braun prosthesis, both from its designer. The implant design, cementing techniques, and surgical techniques, however, have changed considerably in the past 20 years. Therefore, the purpose of this article is to report our experience with the Braun-Cutter trapeziometacarpal joint prosthesis and its outcome in the treatment of stage III and select cases of stage IV OA of the thumb carpometacarpal (CMC) joint.

Materials and Methods

Total joint arthroplasty of the trapeziometacarpal joint was performed on 26 thumbs in 25 patients (24 women, 1 man) to treat advanced basal joint OA of the thumb between 1998 and 2003 (Table 1). All patients were initially treated conservatively with nonsteroidal anti-inflammatory medications, splinting, and steroid injections for a minimum of 6 to 12 weeks. Surgical treatment was considered in those patients for whom the conservative treatment had failed and who continued to have severe pain, loss of pinch strength, and lack of thumb motion that limited their activities of daily living.

Table 1. Patient Demographics

Characteristic	Value
Number of patients	25
Number of thumbs	26
Average age, y	71
M:F ratio	24:1
Dominant:nondominant hand ratio	22:3
Average duration of symptoms, y	3
Average follow-up period, mo	46
Average surgery time, min	45
Preoperative pain (no. of patients)	
At rest	20
During strain	25

Before surgery, we measured pain using a visual analog scale, movement using a goniometer, grip strength using a dynamometer (Jamar Digital Hand Dynamometer; Therapeutic Equipment Corp., Clifton, NJ), and pinch strength using a pinch gauge (Preston pinch gauge; JA Preston, New York, NY). Radiographic assessment was performed according to the Eaton-Littler method. Patients with Eaton and Glickel stage III trapeziometacarpal arthritis[87] and selected stage IV patients with clinically painless mild scaphotrapezial joint involvement were included in this study. Patients with clinically painful scaphotrapezial joints and those who had advanced radiologic osteoarthritic changes in the scaphotrapezial joint were excluded from having total joint arthroplasty of the thumb CMC joint. We also excluded patients who were younger than 60 years old or whose jobs involved strenuous manual work, because we believed that more active patients are not good candidates for implant arthroplasty.

Demographics

The average patient age was 71 years; there were 24 women and 1 man. There was 1 bilateral case. The right thumb was involved in 17 patients and the left in 9. The dominant hand was involved in 22 cases and the nondominant in 4. None of the patients had had previous thumb surgery. Most patients com-

Figure 1. Radiographic study from the left thumb of a 67-year-old woman showing complete loss of trapeziometacarpal joint space, subluxation, osteophytes, and subchondral cysts. Total cemented arthroplasty was performed in this patient.

plained of diffuse pain about the thumb basal joint (visual analog scale score, 8 to 9 out of a total of 10) and decreased lateral pinch strength and grip strength. One patient had severe loss of the first web space. Patients experienced symptoms an average of 3 years (range, 1–4 y) before surgery. Positive physical findings included a grind test in all patients. Consistent preoperative radiographic findings were dorsal metacarpal subluxation, the presence of prominent marginal osteophytes on the ulnar border of the distal trapezium, joint space narrowing, cystic changes, and sclerotic bone (Fig. 1). No patients had severe flattening or loss of trapezial height of the trapezium, which would preclude the use of a CMC implant.

Based on radiographic staging, 21 thumbs showed evidence of Eaton stage III OA and 5 of stage IV OA. Additional procedures performed at the time of CMC arthroplasty included endoscopic carpal tunnel release (8 patients), volar capsulodesis of the first metacarpophalangeal joint (4 patients), first extensor compartment release (6 patients), and first web space Z-plasty (1 patient). The average follow-up time was 59 months (range, 26–68 mo). During the follow-up visits, pain (visual analog scale), motion, pinch and grip strengths, and x-ray appearances of the individual patients were evaluated individually. No patient was lost to follow-up study.

Surgical Technique

The Braun-Cutter trapeziometacarpal joint prosthesis was implanted in this series by using a bone cement technique. A 3-cm, longitudinal, lazy-S incision is performed over the dorsal aspect of the base of the thumb. Branches of the superficial sensory radial nerve are identified and protected. Further dissection is performed between the extensor pollicis longus and extensor pollicis brevis tendons isolating and protecting the dorsal branch of the radial artery. The dorsal capsule of the trapeziometacarpal joint is opened longitudinally with a proximal-based flap. The periosteum and the dorsal capsule are reflected proximally as a single flap to be repaired later. A sagittal saw is used to remove the proximal 6- to 8-mm base of the thumb metacarpal. The adductor pollicis is released if required to allow abduction of the thumb metacarpal away from the palm. At this point, longitudinal traction and flexion are applied to better expose the trapezial surface. A rongeur is used to remove the marginal osteophytes and flatten the joint surface of the trapezium. With imaging, the center of the trapezium is identified with a small burr. The center hole is then enlarged to create a deep channel within the trapezium where the polyethylene cup will be cemented. For the thumb metacarpal, a guide is used to open the intramedullary canal, which is broached with a burr to allow for an ample cement mantle. The trapezial cup is first cemented in the trapezium (Fig. 2) with care taken to impact the cement beneath the subcortical bone. Once the cup has been inserted and the cement cured, the thumb metacarpal component is inserted with bone cement (Fig. 3). Because this stem is collarless, it is important to maintain adequate neck length (to prevent subsidence) until the bone cement has cured. Care is taken so that the stem neck does not impinge on the edge of the trapezium. Once the

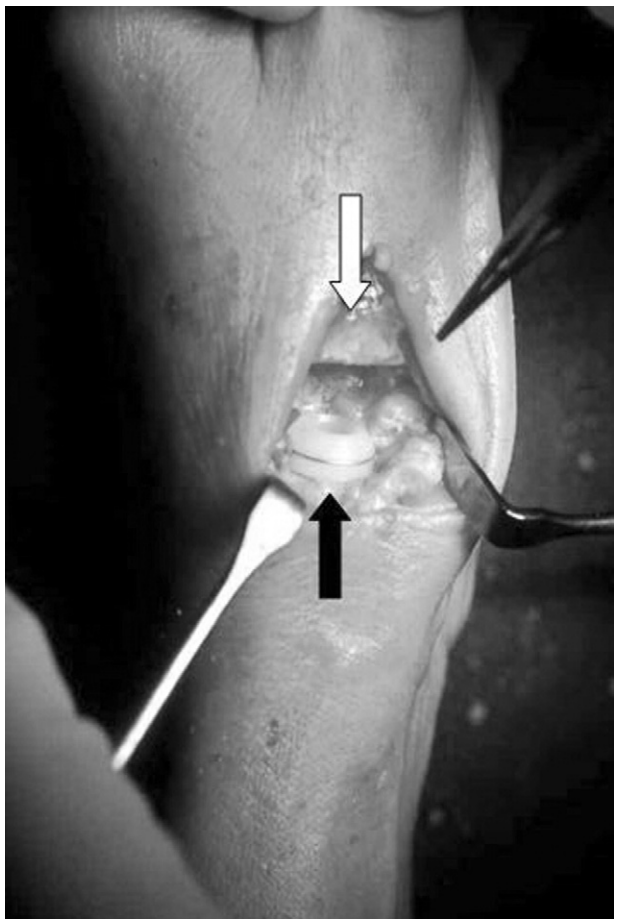

Figure 2. First, the polyethylene cup is cemented in the trapezium. White arrow, metacarpal side; black arrow, trapezial side.

components are implanted and the cement has hardened, the stem is pressed into place in the cup on the trapezium. Stability and circumferential motion are assessed to ensure no impingement on the implant (Fig.4). The proximal-based capsule–periosteum flap is closed with absorbable suture. During the procedure, intraoperative fluoroscopy is performed to check proper alignment and placement of the prosthesis (Fig.5).

We close the skin and the subcutaneous tissue with a resorbable suture and apply a well-padded short-arm thumb spica splint with the thumb in opposition for 1 week, after which rehabilitation is started. An Orthoplast thumb-based spica splint (Johnson & Johnson, New Brunswick, NJ) is applied for further protection when thumb exercises are not performed. Patients rapidly regain thumb–to–base of small finger opposition with an active and gentle active assisted range-of-motion (ROM) protocol.

Clinical Assessment

Follow-up assessments of the patients were performed by an independent examiner who had not been involved in either the surgical procedure or patient care. A VAS was used to assess the pain level (0, absence of pain to 10, severe pain). The frequency of pain was also registered (never, occasional, frequent, constant). The grip strength was determined with a dynamometer (Jamar Digital Hand Dynamometer) and lateral pinch strength was determined with a pinchmeter (Preston pinchmeter). Complete interphalangeal and metacarpophalangeal joint ROMs and radial abduction were recorded with a goniometer. The ability to oppose the thumb to the base of the small finger was recorded as the distance from the thumb distal pulp to the fifth metacarpal head. An objective assessment was performed with the Buck-Gramcko score.[88,89]

Radiologic Evaluation

Posteroanterior and lateral radiographs were obtained at the final follow-up evaluations to evalu-

Figure 3. Cementing and placement of the metacarpal stem in the medullary canal are performed.

Figure 4. Reduction of both components is followed by testing for stability and impingement of the prosthesis.

ate cup migration, stem subsidence, zones of osteolysis, and joint subluxation as defined by Wachtl et al.[83,90]

Results

Clinical Assessment

Pain relief. Complete pain relief was achieved in 24 patients (96%). Mild pain was present in 1 patient after traumatic injury to the hand. A revision of the prosthesis was required for secondary loosening believed to be caused by the injury.

Strength. The preoperative pinch strength was 6.0 kg in the noninvolved side and 3.5 kg in the affected thumb (61% of the contralateral side). The postoperative pinch strength was 6.5 kg in the noninvolved side and 5.5 kg in the affected one (85% of the contralateral side).

Mobility. The final thumb radial abduction was 60° (range, 50°–65°). Palmar abduction was more than 40° in all patients, and all patients were able to comfortably hold large objects between the thumb and index finger. Flexion and extension were not quantified but were satisfactory at the final follow-up examination. The final ROM of the metacarpophalangeal joint was 5°–40°, and thumb opposition reached the base of the small finger in all cases.

Loosening analysis. Radiographic studies at the final follow-up evaluation showed no evidence of implant loosening, cup migration, stem subsidence, or subluxation in either the anteroposterior or lateral views of the thumb (Fig. 6). This was also the case for the 1 patient in the series who had revision surgery performed.

Survival analysis. There was only 1 revision (96% survival) in our series, performed in a woman who fell after the primary replacement and dislocated the components. Closed reduction was obtained, and a thumb spica splint was used. Even though the patient's ROM continued improving she had mild discomfort, and 3 years after the original procedure she had revision surgery using the same type of prosthesis for posttraumatic loosening. At the final follow-up examination (5 years), she did not have any

Figure 5. Fluoroscopic views are obtained to assess proper cementing and correct implant positioning.

Figure 6. Radiographic study at the final follow-up examination with no signs of implant loosening.

pain and radiographic findings were the same as for patients who did not have revision surgery.

Objective assessment. We used the Buck-Gramcko score in this study to objectively assess the outcome. The mean total in our series was 53 points (range, 47–54), constituting an excellent outcome (Appendices 4 and 5) can be viewed at the *Journal's* Web site, http://www.jhandsurg.org). There were 24 excellent results, and the patient who required revision of her joint had good result (47 points) after the revision surgery.

Discussion

Restoration of thumb function ideally should provide pain-free, stable motion at the basal joint with adequate strength and proper balance of the entire ray. In this study, we reported good to excellent results after total joint cemented arthroplasty with the Braun-Cutter implant) for the treatment of CMC OA in select patients. Twenty-four patients in our series had an excellent outcome, and 1 had a good outcome based on the Buck-Gramcko score. Complete pain relief was achieved in 24 patients (96%), and the average strength was 85% of that on the unaffected side. Implant survival was 96% in our study. The only complication seen in our series was an implant dislocation due to trauma in 1 patient that later required revision surgery because of pain and posttraumatic loosening. No spontaneous loosening was found. Fracture or dislocations of the prosthesis and posttraumatic loosening have been reported by few other researchers in the past. In 1985 Braun[36] reported 2 cases of posttraumatic loosening that required revision surgery. Complications such as asymptomatic or symptomatic loosening,[36,65,66,69,70,71,82,83] heterotropic ossification,[36,66,71] cement extrusion with tendon and nerve injury,[36] or reflex sympathetic dystrophy[36] were not seen in our series.

Various surgical procedures have been described for stage III and early stage IV OA of the thumb CMC joint. The literature specifically regarding trapeziometacarpal total joint arthroplasty is rather limited, and the indications are not clearly delineated.

The de la Caffiniere implant is the most widely used and most extensively studied implant[65,69,70,73–76,78,80–83,91] (Appendix 3). The GUEPAR is another implant that has been reported in the French[67,85,86] and German[84] literature. Even though surgeons in different parts of the world continue to use other implants, the indications and long-term outcomes of those implants are not reported frequently and hence are not adequately established. In 1979, de la Caffiniere and Aucouturier[65] reported their experience with a total CMC prosthesis with 34 thumbs in 29 patients with an average follow-up period of 2 years. That series included patients with both OA and rheumatoid arthritis of the thumb. There were 5 cases of radiographic loosening, but the functional results remained adequate and these were not revised. Other researchers have reported similarly good results with the de la Caffiniere prosthesis (Appendix 1). The only exception was the report by Wachtl[83] in 1998. He reported his extensive experience in 84 patients with 88 thumbs involved. Implants required revision surgery in 10 cases with an overall survival rate of 66%, and asymptomatic loosening was detected in 52%. The reasons for his poor results were not clearly evident, but the average age of patients in his series was 61 years. He did not report the activity levels of his patients. Further, he mentioned revision surgery for loosen-

ing but failed to mention whether his patients were symptomatic or not. Recently, De Smet et al[76] reported their experience with the de la Caffiniere prosthesis with 43 thumbs in 40 patients with an average of 26 months of follow-up evaluation. There was no revision surgery in that series, but lucent zones appeared in 44% (most of them occurring in patients younger than 60 years old); progression to clinical loosening was not reported. The Braun prosthesis has been less extensively studied. Braun reported his initial experience in 22 patients in 1982[71] and later in 50 patients in 1985.[36] In the initial report he had to revise 3 cases, and later in the larger series 4 implants required revision surgery. Braun believed that revision is possible in the context of implant failure because of the well-preserved bone stock. There have been no reports by unbiased surgeons on the outcomes with use of this particular implant.

We believe that the appropriate selection of patients for this procedure is an important factor determining the outcome. Trapeziometacarpal total joint arthroplasty is most commonly indicated for late Eaton-Littler stage II and stage III OA. It is important to determine if scaphotrapezial-trapezoidal joint involvement will influence the decision of whether to use an implant, which obviously requires trapezial preservation. North and Eaton[92] found that 47% of cadavers had scaphotrapezial joint arthritic changes along with trapeziometacarpal joint arthritis and suggested that routine complete trapezial excision was not necessary. Several researchers[68,81] included patients with moderate scaphotrapezial joint involvement in their arthroplasty series and concluded that involvement of the scaphotrapezial joint is not a contraindication for total joint implant arthroplasty of the thumb trapeziometacarpal joint. Our clinical experience has also suggested that certain early stage IV cases are amenable to this method of treatment. We clinically assessed the scaphotrapezial-trapezoidal joint by direct palpation of the joint dorsally. A painful scaphotrapezial-trapezoidal joint was considered a contraindication to this procedure, as were advanced radiographic changes in this joint.

Few reports[78,84] have highlighted the importance of trapezial height for good surgical outcome in total joint arthroplasty. With this in mind, we excluded those patients with advanced radiographic OA changes of the scaphotrapezial joint with a wedge-shaped trapezium. We believe this factor might have also contributed to the favorable outcome achieved in our series.

Accurate implant design plays a vital part in developing a dependable and successful system. Different implant designs have been developed in the past. The Braun-Cutter design (SBI/Avanta Orthopaedics) consists of a metallic metacarpal component articulated with a polyethylene cup trapezial component. The form and length of the metacarpal component of the Braun-Cutter prosthesis allows for central placement at an appropriate depth in the medullary canal. Subsidence of this titanium metacarpal component is prevented by 3 transverse troughs strategically located on the stem of the implant. The conical implant shape and porous coated surface provides a good cement–prosthesis interface. The ultra-high–molecular-weight polyethylene of the trapezium component has a cylindric outer shape that resembles a champagne cork and permits pressurization of the cement and proper positioning. Once implanted, the articulated components lie at the normal anatomic level of the trapeziometacarpal joint, which promotes appropriate muscle balance in the thumb. Furthermore, the relation between the neck diameter of the metacarpal component and the open surface and cup walls allows for unrestrained rotation and nearly 90° of motion in any direction without impingement. Apart from implant design, other possible factors responsible for good outcome are appropriate component alignment, proper cementing techniques, and addressing the hyperextension of the thumb metacarpophalangeal joint and metacarpal adduction.[66]

In our series, we revised the implant in only 1 patient. The reason for revision in this case was posttraumatic loosening with a painful joint. This is in contrast to previous studies[36,65,66,68,69,70,71,73,76,77,81–83] in which the most common indication for revision was symptomatic nontraumatic loosening. The sole patient who had revision surgery in our series had a satisfactory result.

Total joint arthroplasty has been shown to give better or comparable functional results compared with other surgical procedures performed for advanced trapeziometacarpal joint OA. Apart from the comparable functional results, another important benefit it offers to patients is rapid recovery and the need for minimal rehabilitation. The constrained design principle obviates the need for prolonged immobilization, because soft-tissue and capsular healing are not critical for implant function. This key element cannot be overemphasized, because most of our patients were elderly patients who lived alone and required rapid recovery to continue living indepen-

dently. Many had physical difficulty getting to the therapy sites. We believe this particular aspect contributed to the high level of satisfaction seen in our patient group. All patients, including the one who had revision surgery, were happy with the outcome and indicated they would have the same procedure performed on the other thumb if the need arose.

We recognize that there are some shortcomings to this study: The study is a prospective, noncomparative study without any control group. Furthermore, this study was performed on a selected subset of patients who were over 60 years of age and were low-demand patients and who had stage III or early stage IV OA of the thumb basal joint. We believe this is the group of patients who would most benefit from this procedure while maximizing success with an implant.

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Appendix 1. Total Cemented Joint Arthroplasty of the Thumb: Outcome Studies in the English Literature

Study	Year	No. of Pts/Joints	Age, y	STJ Involved	Side, D/ND	Gender, M/F	Implant	Follow-Up Period	Outcome				Revision, n (Implant Survival, %)	Complications, n			Relevant Conclusions
									E	G	F	P		ASL	SL	Other	
de la Caffiniere and Aucouturier [65]	1979	29/34	59	Yes	NM	NM	DLC	24 mo	—	20	—	4	4	5	NM	—	—
Braun[71]	1982	22/29	NM	NM	NM	NM	Braun	1–7 y	—	22	—	—	3	3	NM	1 septic looseningHO, 6 CE, 1	Revision possible because of intact bone stock
August et al[69]	1984	20/21	57	NM	2.5:1	1:3	DLC	15 mo			NM		5 (76)	9	5	—	—
Braun[36]	1985	50/50	NM	NM	NM	NM	Braun	6 mo–10 y	—	26	—	—	4	1	4 (2 PT)	—	—
Alnot and Saint Laurent[68]	1985	15/17	56	Yes	NM	NM	DLC	1–10 y; avg, 3 y	—	13	—	—	3	NM	NM	—	Repeat surgery always possible. Pantrapezial disease not a contraindication
Ferrari and Steffee[77]	1986	38/45	61	NM	21/29	7/31	Steffee	2–6 y			NM		3	11	5	1 septic loosening	Loosening does not increase with time. Salvage procedure possible in the event of failure
Cooney et al[66]	1987	57/63	62	NM	39/23	6/56	Mayo	4–6 y	21	28	6	7	12(81)	20	12	1 septic loosening HO, 36%	Careful prosthetic alignment, cementing techniques required
Boeckstyns et al[70]	1989	28/31	62	NM	8/12	3/25	DLC	13–77 mo			NM		4	3	4	—	—
Sondergaard et al[81]	1991	20/22	60	NM	18/7	3/20	DLC	9 y			NM		3(82)	3	3	—	Accelerated tendency of late failure not seen
Nicholas and Calderwood[80]	1992	20/20	57.2	NM	NM	4/13	DLC	10 y	—	—	—	3	NM	1	NM	1 Dis 1 TC	Radiologic lucency does not affect function
Chakrabarti et al[73]	1997	71/93	57	NM	NM	9/62	DLC	6–16 y			NM		11(89)	13	9	1 Dis 1 CE	Implant failed in men younger than 65 y
Wachtl et al[83]	1998	84/88	61	Yes	NM	NM	DLC	63 mo			NM		10 (66.4)	52%	NM	—	Pantrapezial disease not a contraindication. Revision gives satisfactory result. Most revisions occur within 2 y
van Cappelle et al[82]	1999	63/77	62	NM	38/39	11/60	DLC	2–16 y; avg, 8.5 y			NM		16(72)	13	14	—	Cemented prosthesis has better survival
De Smet et al[76]	2004	40/43	54	NM	22/21	3/37	DLC				NM		1	14	10	—	Loosening related to young age

ASL, asymptomatic loosening; avg, average; CE, cement extrusion; D, dominant; Dis, dislocation; DLC, de la Caffiniere; E, excellent; F, fair; G, good; HO, heterotopic ossification; ND, nondominant; NM, no mention; P, poor; PT, posttraumatic; pts, patients; SL, symptomatic loosening; STJ, scaphotrapezial joint; TC, trapezial collapse.

Appendix 2. Total Cemented Joint Arthroplasty of the Thumb: Outcome Studies in Non-English Literature

Study	Year	No. of Patients/ Joints	ST Joint Involved	Implant Used	Follow-Up Period	Conclusions
de la Caffiniere[75]	1991	NM/13	Yes	DLC	12 y	Long-term result seems to be good despite high level of loosening
Alnot et al[67]	1993	32/36	Yes	GUEPAR	1–9 y (avg, 3.5 y)	Trapezial height is an important factor
Alnot and Muller[86]	1998	NM/90	NM	GUEPAR	5.75 y	Trapezial height <7 mm, young age, and dominant hand are adverse factors affecting outcome
de la Caffiniere[74]	2001	NM/13	Yes	DLC	12–17 y	Dominant hand in heavy workers is a contraindication. Involvement of ST joint is not a contraindication. Trapezial height is an important factor.
Guggenheim-Gloor et al[78]	2000	NM/43	NM	DLC	63 mo	This procedure is reserved for elderly patients not involved in strenuous exercise
Masmejan et al[84]	2003	NM/51	NM	GUEPAR	27 mo	Radiologic loosening does not affect clinical outcome
Masmejan et al[85]	2003	60/64	Yes	GUEPAR	29 mo	Revision and salvage procedure possible in the event of failure. Trapezial height is an important factor affecting outcome

avg, average; DLC, de la Caffiniere; NM, no mention; ST, scaphotrapezial.

Appendix 3. Various Implant Designs Available on the Market

Design	Manufacturer	Metacarpal Component	Trapezial Component	Collar in the Stem	Horizontal Grooves in the Stem	Fixation Technique
Lewis[79]	Howmedica (Rutherford, NJ)	Polyethylene cup	Metallic ball	NA	NA	Cement
Mayo[66]	Depuy (Warsaw, IN)	Polyethylene cup	Metallic ball	NA	NA	Cement
de la Caffiniere[65,74–76,91]	Francobal (Francobal, France)	Cobalt chromium stem	Polyethylene cup	Yes	No	Cement
Braun-Cutter prosthesis	Avanta Orthopedics (now SBI) (San Diego, CA)	Titanium	Polyethylene cup	No	Yes	Cement
Braun[36,71]	Zimmer (Warsaw, IN)	Metallic stem	Polyethylene cup	No	Yes	Cement
GUEPAR[67,84,85]	GUEPAR Group (Herouville Saint Clair, France)	Metallic stem	Polyethylene cup	Yes	No	Cement
Steffee[77]	Laure Prosthetics (Portage, MI)	Metallic stem	Polyethylene cup	Yes	No	Cement

NA, not available.

Appendix 4. Objective Outcome Based on Buck-Gramcko Score at Final Follow-Up Evaluation

Measurement	No. of Points	Thumbs
Palmar abduction, °		
≥40	6	26
30–39	4	
20–29	2	
<20	0	
Radial abduction, °		
≥40	6	26
30–39	4	
20–29	2	
<20	0	
Tip pinch compared with contralateral side, %		
≥100	6	
≥80	4	26
60–79	2	
<60	0	

Appendix 5. Subjective Outcome Based on Buck-Gramcko Score at Final Follow-Up Evaluation

Characteristic	No. of Points	Patients
Pain frequency		
Never	6	24
Occasional	4	1
Frequent	2	
Constant	0	
Strength		
Improved	6	25
Same	3	
Worse	0	
Daily function		
No difficulty	6	25
Mild difficulty	4	
Moderate difficulty	2	
Severe difficulty	0	
Dexterity		
Improved	6	25
Same	3	
Worse	0	
Appearance		
Excellent	6	24
Good	3	1
Acceptable	2	
Poor	0	
Would you have surgery again?		
Yes	4	25
No	0	0
Overall assessment		
Excellent	6	24
Good	4	1
Fair	2	
Poor	0	
Grade of total score		
Excellent	49–56	24
Good	40–48	1
Fair	28–39	
Poor		28
Mean total score, points	53	