14 Primary Carpometacarpophalangeal Joint Arthroplasty

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Introduction

Osteoarthritis of the thumb base is a common condition in the general population, affecting up to 75% of women over 70 years of age [1]. Postmenopausal women are particularly affected, with a radiographic prevalence of 33%. A quarter of patients also shows radiographic signs of scapho-trapezio-trapezoidal (STT) osteoarthritis [2]. Only one in three patients affected will actually complain of basal thumb pain [3]. The majority of people will not seek medical attention because they remain asymptomatic or learn to cope with some degree of disability.

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The first phase of management is conservative, including immobilization, anti-inflammatory drugs, physiotherapy, or intra-articular injections. The use of night splinting for 1 year has shown to result in a significant improvement in pain [4]. The current evidence on the use of injection therapy is equivocal. Corticosteroid injections demonstrated a more positive effect on medium-term pain scores compared to hyaluronic acid injections [4]. Multimodal treatment, combining an intra-articular corticosteroid injection and splinting, has a long-lasting effect on pain in up to 80% of patients with Eaton stage 1 osteoarthritis [5]. Khan showed that in cases with more advanced degeneration (Eaton stages 3–4), the effect duration of a single corticosteroid injection decreases [6]. Manual therapy, combined with therapeutic exercises, has shown short- to medium-term improvements on pain scores [7]. In general, nonoperative treatment has demonstrated to postpone or avoid surgery in 70% of cases [8].

When conservative treatments fail, surgery may be indicated. A wide range of procedures has been described for the surgical management of thumb base osteoarthritis. In selected cases, symptomatic early-stage osteoarthritis can be managed with joint-sparing surgery. Denervation of the CMC joint has been described as a measure to relieve pain with less morbidity and rehabilitation. This technique is rarely considered, but some authors have published favorable results in

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small case series. Lifchez et al. demonstrated 75% pain improvement in 11 of 12 cases; Loréa reported excellent pain relief in 12 out of 14 patients [9, 10].

Minimally invasive arthroscopic techniques are gaining popularity in the treatment of small joint problems of the hand. In the CMC joint, arthroscopy is being used for articular debridement and synovectomy, capsular shrinkage, removal of loose bodies, and partial or complete resection of the trapezium [11]. A series of 18 patients undergoing arthroscopic partial trapeziectomy with capsular shrinkage and temporary pinning demonstrated functional improvements and a significant increase in tip and key pinch strength at 7-year follow-up [12]. No further surgery was needed in this small series of patients, despite advanced osteoarthritis in some cases. Arthroscopic treatment techniques are further advancing and might play a more important role in the treatment of CMC osteoarthritis in the future.

Metacarpal abduction-extension osteotomy, as described by Wilson, was developed to unload the palmar joint area of the CMC joint during pinch [13]. A 9.9-year follow-up of 13 patients after metacarpal osteotomy demonstrated ten patients (77%) being satisfied or very satisfied with a mean VAS pain score of 2 [14]. Ligamentous stabilization procedures (Eaton-Littler) are available to provide pain relief and functional improvement. Ligamentous stabilization surgery aims to reconstruct the attenuated volar beak ligament (palmar oblique ligament) that causes subluxation of the CMC joint in early OA. Goubau et al. modified the classic Wilson osteotomy by combining it with a trapezial opening wedge osteotomy and ligamentous stabilization [15]. While indications are limited, these procedures are mainly reserved for younger patients, as they do not compromise further procedures when needed.

Arthrodesis has primarily been proposed in younger patients and manual workers, where loading of the thumb is essential. It provides a final solution when fusion is obtained, but there is a relatively high risk of non-union (8–21%), and it requires a long period of immobilization [16]. Although it is a reliable procedure for power grip, the absence of a mobile CMC joint can hinder during dexterous tasks in daily living, and the procedure can cause secondary degenerative changes at the neighboring STT joint over time.

Gervis first described the trapeziectomy procedure in 1949 [17]. In order to improve outcome, many alterations and additions have been made to the original stand-alone excision of the trapezial bone. The most common ones are the interposition of tendon or synthetic spacers, often in combination with ligamentous stabilization (Burton-Pellegrini [18], Weilby [19], Delsignore [20]). Over recent years the use of suture-button suspension following trapeziectomy is gaining popularity, in order to minimize donor morbidity of tendon grafts and prevent shortening of the thumb ray [21].

Trapeziectomy with ligament reconstruction and tendon interposition (LRTI) is currently considered to be the gold standard, and good long-term outcome results have been reported [22–24]. However, the recovery time can be long, and a significant number of patients remain unsatisfied, complaining of residual pain, esthetic concerns, and loss of mobility and pinch strength [25]. This has led to a continuous quest for alternative procedures, including total joint replacement [26]. Considering its success in orthopedics as a whole, and specifically in hip and knee replacements, many attempts have been made to match these results for the thumb base [27].

Since its introduction by De la Caffinière in 1974, the CMC total joint replacement has become the treatment of choice in some parts of Europe over these last decades [28]. Many implant designs that were developed and used have been abandoned because of poor results and unacceptable failure rates. Nevertheless, more recent reports of larger series with good outcome and longer-term survival rates became available for other implants, to support this treatment option. This chapter will provide a guide on clinical and surgical decision-making, with a focus on implants that have stood the test of time, are supported by a minimum of 5 years of clinical follow-up, and are currently still available on the market.

Patient Selection

Signs and symptoms of thumb base osteoarthritis include pain, loss of functionality, and decreased grip strength. Patients typically complain of radial-sided wrist pain and fatigue over the thenar mass. Key and tip pinch and power grip are painful, leading to a marked disability during activities of daily living and manual labor. The classic “shoulder sign” refers to swelling that may occur over the thumb base secondary to inflammation, osteophyte formation, and dorsal subluxation of the metacarpal.

Clinical examination reveals tenderness over the CMC joint line with palpation. Axial loading and circumduction (grinding or crank test) will often provoke pain and crepitus. The neighboring MCP and STT joints are carefully examined for local tenderness, as pathology here will affect the choice of surgical treatment. The STT joint is palpated about 1 cm proximal to the CMC joint line and just distal to the scaphoid tubercle.

Longstanding dorsal subluxation of the CMC joint leads to adduction of the first metacarpal and contracture of the first webspace. Secondary metacarpophalangeal (MCP) hyperextension due to progressive volar plate attenuation and increased pull of the extensor muscles leads to the so-called Z-deformity of the thumb and is associated with decreased pinch strength [29]. The MCP joint needs to be carefully checked for range of motion and hyperextension deformity, which can be flexible and correctable, or become a fixed extension contracture in chronic disease. This is a prognostic factor for poor functional outcome and will impact further decision-making. Stabilization with capsulodesis or arthrodesis has been suggested for MCP hyperextension beyond 35° when symptomatic or causing functional impairment [29, 30]. A significant decrease in MCP joint hyperextension has been demonstrated following total joint replacement, often obviating the need for further stabilization (Fig. 14.1). In a reported study of 96 arthroplasties, Toffoli specifically looked at the impact on MCP joint deformity. In cases where MCP hyperextension was limited to less than 30°, no residual hyperextension was present in 72% of cases, and 80% of correctable Z-deformities were completely corrected [31]. In contrast, following trapeziectomy, an increase of MCP hyperextension is anticipated and soft tissue procedures to address this tend to stretch over time [32]. Robles-Molina found an MCP hyperextension of 3.5° and 17.8° following total joint replacement versus LRTI, respectively [33]. For fixed extension contractures or when degenerative changes are present at the MCP joint, an arthrodesis of the joint in a functional position is the preferred treatment option.

Medical Imaging

The standard radiographic workup should include a posteroanterior (PA) and lateral view of the thumb and CMC joint (Kapandji views) and a Robert’s view (shoulder flexion and internal rotation, and forearm hyperpronation) to obtain a true AP view of the CMC and STT joint [34] (Fig. 14.2). Stress views (PA view with thumbs pressed together) can be used when CMC insta-

Fig. 14.1 Preoperative MCP hyperextension of 45° with marked subluxation of the thumb CMC joint, volar MCP capsulodesis was performed combined with total joint replacement

Fig. 14.2 Preoperative radiographic workup with Kapandji PA and lateral views and Robert's view

bility is suspected, especially in younger patients [35]. Radiographs should be assessed for joint space narrowing, loose bodies, osteophyte formation, joint congruency, and bone cyst formation. The trapezium is checked for general bone stock, looking closely at the height, depth, and width. A dysplastic shape of the trapezium might influence treatment options and should be noted at this point. Early degenerative changes may be undetectable on plain radiographs, whereas CT scan will show joint space narrowing of the volar corner of the CMC joint [36]. When prosthetic replacement of the joint is indicated, and there is doubt about the bone quality or the size of the trapezium to accommodate a standard-sized cup (9 mm diameter in most implants), a CT scan can also aid in planning. MRI is rarely indicated but can assist in the diagnosis in younger patients or when a discrepancy is present between the clinical signs and radiographs.

Staging

Two descriptive radiological staging systems have been proposed, one by Eaton-Littler in 1973, modified by Glickel in 1987 (Table 14.1), and one by Dell in 1978 (Table 14.2) [37, 38]. Both are useful for guiding treatment and for research purposes, but the correlation with intraoperative findings or patient complaints is limited [39].

Table 14.1 The four stages of the Eaton-Littler (modified by Glickel 1987) classification

Stage	Description
I	Subtle carpometacarpal joint space widening
II	Slight carpometacarpal joint space narrowing, sclerosis, and cystic changes with osteophytes or loose bodies <2 mm
III	Advanced carpometacarpal joint space narrowing, sclerosis, and cystic changes with osteophytes or loose bodies >2 mm
IV	Arthritic changes in the carpometacarpal joint as in stage III with scaphotrapezial arthritis

Ladd et al. introduced the thumb osteoarthritis (ThOA) index as a measurable alternative or addition to the Eaton classification [39]. The ThOA index is measured on a single Robert's view radiograph and is based on the width and height of the trapezium. It has shown a better correlation with intraoperative findings and eburnation of the trapezial bone. Further validation of the ThOA index and correlation with patient-reported outcome measures is needed.

Indications and Contraindications (Table 14.3)

When considering CMC joint arthroplasty, the typical patients are elderly women with limited forceful activities in daily life, Eaton stage 2–3 osteoarthritis on radiographs, who have failed a course of conservative treatment. Total joint arthroplasty (TJA) is rarely indicated in younger patients with heavier daily activities, and when there is an indication, they need to be well instructed about the risk of failure and revision surgery. As with any prosthetic implant, components will wear out faster with increased loading. However, these patients may benefit more from the improved recovery of strength and function after total joint arthroplasty.

Insufficient bone stock due to severe osteoporosis or eburnation of the trapezium needs to be considered, as it may impede stable impaction of the components. Concomitant asymptomatic osteoarthritis of the STT joint is considered a relative contraindication for CMC arthroplasty. In symptomatic pantrapezial osteoarthritis, trapeziectomy is the better option as it addresses both degenerative joint surfaces. Generalized joint laxity is no formal contraindication, but in hyperlax patients, extra caution is warranted to minimize the risk of prosthetic dislocation. In this patient population, the use of more constrained or dual-mobility implants should be considered.

Table 14.2 Dell classification of thumb OA (1978)

Stage	Radiological description
I	Joint narrowing or subchondral sclerosis but neither subluxation nor osteophyte formation
II	Small osteophyte at the ulnar border of the distal articular surface of the trapezium, increased density of the subchondral bone. Subluxation <1/3 of metacarpal surface
III	Prominent osteophyte at the ulnar border of the trapezium. Metacarpal subluxated radially and dorsally ⩾ 1/3 of its base
IV	Complete loss of joint space. Frequent subchondral cysts

Implant Types

Over the past decades, several implants have been designed. Currently available implants can be categorized into three large groups based on their principal design type: interposition arthroplasty, hemiarthroplasty (HA), and total joint arthroplasty (TJA) [26].

Interposition Arthroplasty

Interposition arthroplasty is the insertion of a nonabsorbable synthetic implant between the partially recessed articular surfaces of the trapezium and metacarpal base. Different shapes of implants and materials are available (spherical, saddle joint, biconcave). These implants are not fixed but act as spacers to preserve the length of the thumb while preserving motion. Mixed outcome results have been published following interposition of soft synthetic spacers (RegJoint®, Artelon®). These implants show high failure rates mainly due to osteolysis, collapse, and foreign body reactions [40–43]. The PyroDisk® (Ascension Orthopedics Inc., Austin, TX, USA) is a biconcave pyrocarbon disc interposed between the partially recessed trapezium and the first metacarpal (Fig. 14.3). Smeraglia et al. have published good clinical outcomes using this implant with a 94% survival rate after a minimum follow-up of 8 years [44]. There are no other data available that confirm these long-term results. Oh et al. conducted a retrospective study comparing

Table 14.3 Indications and contraindications for CMC arthroplasty

Indications	Contraindications	Relative contraindications
Eaton-Littler stage II–III OA	Symptomatic STT OA	Asymptomatic STT OA
	Insufficient bone quality	Age younger than 50
	Insufficient trapezium size	Heavy manual labor
	Infection	Dysplastic trapezium
		Metal hypersensitivity

Fig. 14.3 Postoperative radiograph PyroDisk® interposition arthroplasty

Fig. 14.4 Postoperative radiograph of the BioPro® Modular Thumb implant

LRTI to the PyroDisk® implant with a minimum of 2-year follow-up. These authors reported similar objective and subjective outcomes. Pinch strength was significantly higher in the PyroDisk® group. Although there were some radiographic changes around the implants, no revision surgery was needed [45].

Hemiarthroplasty

In hemiarthroplasty (HA) only the metacarpal base is replaced to articulate with a partially recessed trapezium. The trapezial resection can be either concave or convex, depending on the corresponding shape of the prosthesis. The hemiarthroplasty was introduced to minimize thumb ray collapse after total or partial trapeziectomy. Swanson silicone hemiarthroplasty implants were first introduced in the 1970s [46]. After initial satisfying results with these implants, long-term complications were reported. Instability and silicone synovitis led to a high revision rate, and this implant was abandoned [47]. Subsequent hemiarthroplasty implants were made of titanium, pyrocarbon, or cobalt-chrome and have shown promising short- to mid-term results [48–50]. The available evidence beyond 5 years, however, is limited, and good outcome reported by the inventors has not always shown to be reproducible. In contrast to the excellent survival rate reported by Pritchett et al. using the BioPro® Modular Thumb implant (BioPro, Port Huron, MI, USA), others have reported a 50% failure rate using this implant [51, 52] (Fig. 14.4).

NuGrip® (Ascension Orthopedics Inc., Austin, TX, USA) is a PyroCarbon hemiarthroplasty implant with a spherical head that articulates with a concavely recessed trapezium (Fig. 14.5). A small series of ten patients with 9.5 months mean follow-up was published. Within this short follow-up, 30% had revision surgery due to implant instability [53].

Persistent pain, loosening of the metacarpal stem, and subsidence through the trapezium are among the biggest concerns in hemiarthroplasty. To address the problem of instability and in search of a more anatomical, saddle-shaped implant, the Stablyx® Arthroplasty System (Skeletal Dynamics, LLC, Miami, FL) was developed. It is commercially available since 2013, but only a small series of 12 patients with a follow-up of 2 years has been published [54].

Fig. 14.5 Postoperative radiograph of the NuGrip® PyroCarbon hemiarthroplasty

Total Joint Arthroplasty

In total joint arthroplasty (TJA), both the trapezial and metacarpal sides of the CMC joint are replaced with a prosthetic implant. A ball-and-socket implant replaces the native saddle joint, allowing for a greater arc of motion in all directions while eliminating translation.

The latest generation of implants has evolved to an uncemented cup and stem with a metal-on-polyethylene (PE) ball-and-socket articulation (Fig. 14.6).

The metacarpal stem preparation and implant insertion rarely cause problems, but the alignment of the stem has an important impact on the ROM and stability of the implant. The stem shape can be anatomical (slightly curved) or non-anatomical (straight). Modern implants use a modular neck system with an adaptable neck angle and length to ensure optimal congruency and stability. The trapezial component consists of a conical or hemispherical cup. Precise positioning and fixation of the cup into the trapezium is the most critical step in the procedure and is achieved through either impaction of a press-fit implant or screwing in of a threaded cup. To ensure initial stability and improve bony ingrowth, most available cups are coated with porous titanium and/or hydroxyapatite.

Fig. 14.6 Postoperative radiograph of the Arpe total joint arthroplasty

Complications

The most common complication after CMC arthroplasty is dislocation, which is mostly attributed to technical errors when it occurs in the early postoperative period. The main reasons are wrong positioning and orientation of the cup or insufficient osteophyte removal (Fig. 14.7). Late dislocations are usually caused by advanced polyethylene wear or trauma.

A trapezial fracture with secondary cup loosening or dislocation of the prosthesis can occur early following a perioperative iatrogenic fracture or technical error. Certain types of implants, using a screw cup and metal-on-metal articulation, demonstrated a high incidence of early cup loosening attributed to metallosis (3–47% with the Elektra® metal-on-metal TJA) [55, 56].

Persistent pain after CMC replacement can have multiple reasons such as low-grade infection, instability, bony impingement, loosening, metal hypersensitivity, or symptomatic STT osteoarthritis. Goubau et al. reported a high inci-

Fig. 14.7 3D reconstruction image of an insufficiently removed ulnar osteophyte leading to impingement and instability

dence of De Quervain tendinopathy as a complication of joint replacement, but found no relation to the potential lengthening of the thumb ray as was previously suggested [57]. Some authors therefor suggest to routinely combine a prophylactic release of the first extensor compartment with total joint arthroplasty [33].

Reported Outcomes

Many authors have published case series using different implants evaluated by a variety of objective and patient-reported outcome measures making a comparison between implants and surgical techniques challenging [58–60].

Non-randomized trials comparing total joint arthroplasty to trapeziectomy with LRTI demonstrated that TJA had some significant advantages. Robles-Molina et al. found in a retrospective comparative study with a mean 4.8 year follow-up that patients following Arpe® prosthesis (Zimmer Biomet, Warsaw, IN, USA) had a significantly higher pinch strength (11.8 kg vs 8.4 kg) and greater arc of motion. The Kapandji opposition score was marginally higher in the TJA group versus the LRTI group (9.5 vs. 9.0). More important was the decreased retropulsion found in 40% of LRTI cases. An increase in preoperative MCP hyperextension was observed following LRTI, but no significant change was observed in the Arpe® group. There was no difference in QuickDASH scores or VAS pain scores between the two groups. But reoperation rates were higher in the TJA group, 9.7% versus 5.9% [33]. Reoperations in the Arpe® group were needed for three dislocated implants, and two patients in the LRTI group underwent subsequent surgery for MCP hyperextension.

A prospective comparative trial conducted by Cebrian-Gomez et al. using the Ivory® prosthesis (Stryker, Memometal, Bruz, France) with a minimum follow-up of 2 years (mean 4 years) also showed higher pinch strength and better abduction. These authors found a significant difference in QuickDASH score and VAS pain score in favor of the Ivory® group. Furthermore, in the prosthesis group, 93% of patients would have the same surgery again, compared to 79% of patients in the LRTI group. Three revision procedures were reported in the Ivory® group, and none in the LRTI group. Patients with TJA returned significantly faster to daily activities and work [61]. Ulrich-Vinther et al. confirmed these favorable clinical outcomes in a 1-year follow-up study [62]. Patients reached significantly better strength and range of motion at a faster rate in comparison to LRTI. There was one revision for early loosening of a cup. However, these authors used the Elektra® prosthesis (Small Bone Innovations International, Péronnas, France) which has shown to develop catastrophic failure rates due to cup loosening [55, 56].

The only randomized controlled trial comparing trapeziectomy and LRTI to TJA was recently published. Thorkildsen et al. demonstrated a significantly better recovery of range of motion (Kapandji score) and strength values in the first 6 months following TJA, but found no significant difference in strength and QuickDASH or Kapandji score after 12–24 months. Abduction and extension remained significantly better after 2 years in the arthroplasty group. Unfortunately, owing to the use of the Elektra® metal-on-metal prosthesis, five cups had to be revised in the first year because of loosening [63].

Long-term survival rates depend on the type of implant and the length of follow-up. Generally, the uncemented, metal-on-PE, ball-and-socket arthroplasties that are still on the market (Maïa®, Arpe®, and Ivory®) have shown favorable long-term results (Table 14.4).

Two studies were published with patients treated with the Ivory® implant with a minimum follow-up of 10 years and demonstrated survival rates of, respectively, 85 and 95%. Vissers et al. published their results in 24 patients. Two patients showed loosening of the cup [64]. Tchurukdichian et al. reported a 5.5% revision rate mainly due to dislocation or trapezial fracture. A 7.3% dislocation rate was found in 110 arthroplasties, leading to implant removal in four cases and one cup revision; three implants could be reduced in a closed manner. After 10 years 88% of patients remained satisfied or very satisfied [65].

Table 14.4 Results of available long-term follow-up studies on primary CMC arthroplasty

	n	Implant	Mean follow-up (months)	Survival rate %	Mechanism of failure	RR %
Interposition arthroplasty						
Smeraglia et al. 2020 [44]	46	Pyrodisk	113	94	Painful instability	6.5
Hemiarthroplasty						
Krukhaug et al. 2014 (NAR) [47]	326	Swanson silastic	120	89	Dislocation (18) Pain	10
Krukhaug et al. 2014 (NAR) [47]	71	Swanson titanium	120	94	Pain	5.6
Phaltankar et al. 2002 [48]	18	Swanson titanium	34	94	Dislocation loosening	5.3
Pritchett et al. 2012* [51]	143	BioPro Modular Thumb	72.1	94	4 stem loosening 2 subluxations	4.2
Florez et al. 2018 * [54]	12	Stablyx Arthroplasty System	24	100	None	0
De Aragon et al. 2009 [49]	54	PyroCarbon Ascension MCP	22	80	Loosening dislocation	27.8
Total joint arthroplasty						
Vissers et al. 2019 [64]	26	Ivory	130	82	PE wear	15
Tchurukdichian et al. 2020 * [65]	110	Ivory	120	95	Traumatic dislocation, trapezial fracture	7.3
Martin-Ferrero 2014 [67]	65	Arpe	120	93.9	Dislocation, cup loosening	7.7
Dumartinet-Gibaud et al. 2020 [68]	80	Arpe	138	85	Cup loosening, dislocation, instability	26.2
Cootjans et al. 2017 [66]	166	Arpe	80	95	Dislocation, PE wear	3
Benaiss et al. 2011 [86]	61	Rubis II	143	84	Dislocation	11.5
Dehl et al. 2017 [87]	115	Rubis II	120	89	Dislocation, loosening	4.3
Toffoli et al. 2017 [31]	96	Maïa	76.5	93	Cup loosening	8.3
Krukhaug et al. 2014 (NAR) [47]	29	Elektra	60	90	Dislocation, instability, cup loosening	6.9
Semere et al. 2015 [88]	64	Roseland	150	91	Cup loosening, subsidence	9.4
Johnston et al. 2012 [69]	39	De la Caffinière	192	73.9 26 (radiographic)	Cup loosening, pain	26
Tchurukdichian et al. 2019 [82]	200	Moovis (dual mobility)	48.2	97	1 dislocation	0.5

RR revision rate
* indicates publications co-authored by the designer of the implant/device

The Arpe® total joint arthroplasty also demonstrated good medium- to long-term survival rates. Cootjans et al. published a 5-year survival rate of 96% in a series of 166 prostheses [66]. Martin-Ferrero reported a 93.9% survival rate at 10 years of follow-up, with the main complication being dislocation [67]. Dumartinet-Gibaud et al. published a survival rate of 85% and 80% at 10 and 15 years, respectively. These authors, however, reported a high rate of early failures caused by surgical technical errors, confirming the steep learning curve of TJA. When excluding the first 30 cases, survival rates were 92% and 85% at 10 and 15 years, respectively. They observed a steady decline in implant survival beyond 15 years, independent of age, manual labor, and surgical approach. The mean time to revision was 212 months [68].

The "De la Caffinière"® cemented total joint arthroplasty has the longest published follow-up of 39 implants but is no longer commercially available. The survival rate at 26 years, with failure defined as "revision or removal of the implant," was 74%. When failure was considered as "at risk" (signs of radiographic loosening), survival dropped to 26% [69]. This high loosening rate is probably one of the reasons of why cement fixation has been abandoned and replaced by porous-coated implants.

Authors' Preferred Technique

The patient is installed in a supine position with the hand on a hand table. The surgery is generally performed under locoregional nerve block with an upper arm tourniquet, but in selected patients, we have also used WALANT anesthesia. It has the advantage that implant stability and active ROM can be tested during the procedure. Following preparation of the arm in the usual sterile manner, thumb length is marked, and preoperative range of motion of the CMC and MCP joints is checked.

Approach

Multiple approaches to the basal thumb joint have been described and are commonly used. The authors prefer to use a dorso-radial approach, as it allows optimal visualization of the CMC joint. It is also their preferred approach for resection of the trapezium, so that at any point during the procedure, the treatment plan can be adapted if needed.

A 3-centimeter incision is made starting over the proximal aspect of the first metacarpal, further extended in proximal direction over the anatomical snuffbox, centered between the extensor pollicis longus and extensor pollicis brevis tendon (Fig. 14.8). Subcutaneous veins and sensory branches of the radial nerve are identified and retracted. The fascia is incised, and the radial artery is identified at the level of the scaphotrapezial joint, running from proximal volar to distal dorsal. Using blunt dissection, the artery is mobilized and retracted dorsally. This allows for a safe longitudinal incision of the CMC joint capsule. The capsule is released of the base of the first metacarpal in a T-shape, leaving two flaps for later reinsertion and closure. The capsule is further released of the trapezium, to fully expose the saddle joint and the dorsal and volar horns of the trapezium. With the use of an oscillating saw, a minimal (2–3 mm) resection of the base of the first metacarpal is performed. The cut is made perpendicular to the long axis of the metacarpal and parallel to the joint surface, directed about 10° distally to remove the osteophytes at the volar beak. Alternatively, the volar osteophytes can be removed with a rongeur. Next, a minimal trapezial cut is made just below or level with the lowest central point of the concave saddle joint in order to remove the horns of

Fig. 14.8 A 3-centimeter incision is marked, centered over the CMC joint for the dorso-radial approach

the trapezial bone (Fig. 14.9). It is important to remove all osteophytes and loose bodies, particularly on the medial side of the trapezium between the first and second metacarpal. Failing to do so will lead to impingement with the first metacarpal and increase the risk of dorsal dislocation of the prosthesis with thumb adduction-opposition. The direction of the trapezial cut should be in the "plane of the trapezium." The direction of the STT joint or proximal articular surface of the trapezium can be used as a reference (Fig. 14.10).

Metacarpal Stem

The metacarpal medullary canal is prepared with broaches of increasing size, until a press fit with rota-

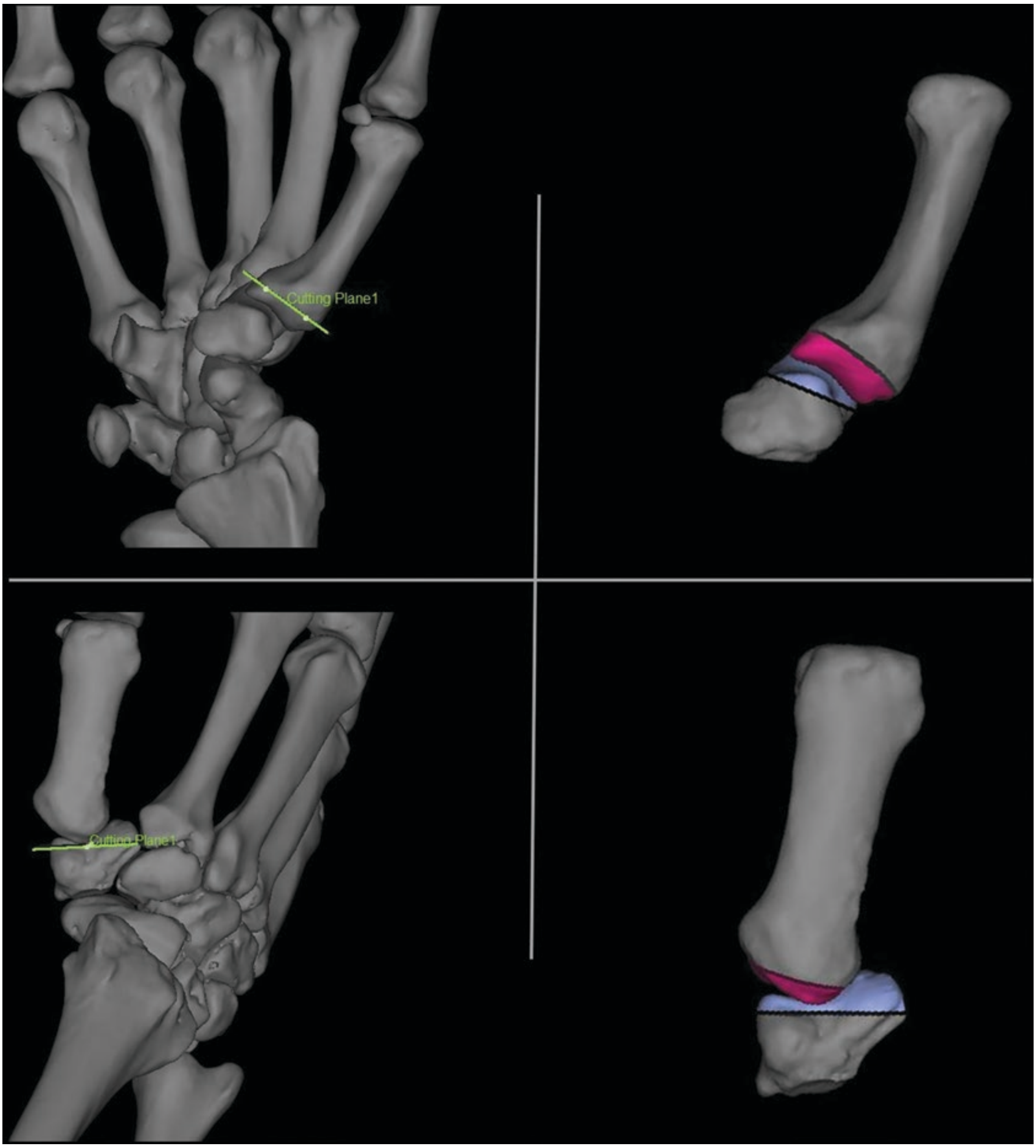

Fig. 14.9 3D reconstructed image showing ideal direction of cutting planes

Fig. 14.10 Intraoperative image of articular gap after bone resection

Fig. 14.11 Marking the center of the trapezium with a hemostat

Fig. 14.12 Intraoperative fluoroscopic control of central cup positioning

tional stability is achieved. Cortical contact is not essential to prevent subsidence of the stem [70]. The size of the final implant will therefore be more dependent on bone quality than on the size of the intramedullary canal. At this point, a trial stem of the appropriate size is inserted, flush with the metacarpal base.

Trapezial Cup

Precise cup positioning is the most technically demanding step in total joint arthroplasty, given the size and position of the trapezium and the non-anatomical shape of the cup.

The center of the trapezial surface is marked using a sharp instrument (awl or mosquito) (Fig. 14.11). Osteophyte formation on the trapezium can be misleading, so the correct position of the entry point is checked under fluoroscopy on AP and lateral views (Fig. 14.12). Ideally, this central point on the trapezium should be in line with the central axis of the first metacarpal when positioned in a neutral position (30° abducted and extended in relation to the axis of the second metacarpal). Subsequently, the trapezium is reamed down to the appropriate size cup with a shaped rasp (Fig. 14.13). When the subchondral bone is

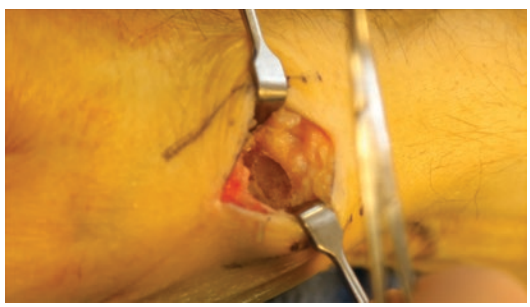

Fig. 14.13 Reaming of the trapezium, demonstrating the small margin for error

very sclerotic, the use of high-speed burr can be helpful in the initial preparation of the trapezium. It is essential to have good access to the trapezium at this stage of the procedure, and further release of the first metacarpal base may be indicated to obtain this. The cup needs to be positioned well centered in the trapezium to allow not only stable impaction of the final implant but also for biomechanical reasons. Eccentric positioning of the cup may lead to impingement and instability of the final prosthesis. The definitive cup is impacted using the instrumentation provided by the manufacturer.

If a trapezial fracture should occur during surgery or if the trapezial bone quality is deemed insufficient for stable implant insertion, the treatment plan needs to be adapted, and conversion to a trapeziectomy with ligament reconstruction and tendon interposition can be performed. Failing to recognize this complication will most likely lead to early cup loosening, secondary displacement, and instability.

Head and Neck

Modern implants have the choice between a straight and offset modular neck in different lengths with 2 mm increments. After the cup is placed in the correct position, different neck lengths can be tested for trial reduction, checking stability, and range of motion (Fig. 14.14). The authors prefer an offset neck over the straight neck for two reasons. Our own experience when using 3D preoperative planning of the procedure confirmed that an offset neck provides a better reconstruction of normal anatomy and alignment, and it has been shown to decrease neck-cup impingement [71]. After confirmation of stability and range of motion of the joint replacement with longitudinal traction, maximal retropulsion, abduction, and opposition, the definitive metacarpal component and head and neck component are implanted (Fig. 14.15). If needed, the insertion depth of the metacarpal stem can be adjusted, to obtain the correct tension. The dorsal capsule is closed primarily or reattached to the metacarpal base using a looped nonabsorbable suture around the metacarpal stem (Fig. 14.16).

Aftercare

The thumb is placed in a padded splint or cast for 2 weeks, leaving the thumb interphalangeal joint free to prevent tendon adhesions. At 2 weeks postoperatively, a removable thumb splint is fit-

Fig. 14.15 Insertion of the definitive stem with looped suture for capsule reattachment

Fig. 14.14 Reduction of the ball-and-socket articulation

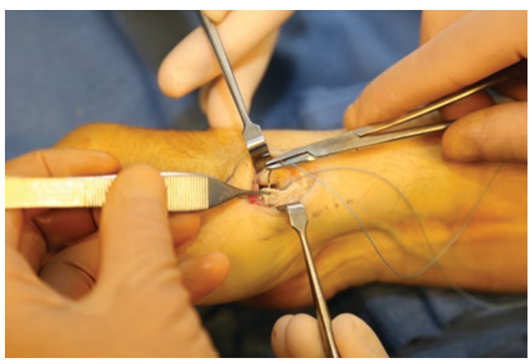

Fig. 14.16 Primary closure of the capsule

Fig. 14.17 Typical patient at 2 weeks after TJA, demonstrating a near normal range of motion with minimal pain

Table 14.5 Tips and tricks in total joint arthroplasty

Sufficient release of the first metacarpal to allow unrestricted access to the trapezium
Minimal bone resection of the trapezium, to keep enough bone stock for stable impaction of the trapezial cup
Complete resection of all osteophytes around the CMC joint to prevent impingement and instability
Use fluoroscopy to confirm the correct starting point for reaming of the trapezium
Correct positioning and orientation of the cup to prevent instability
Confirmation of unrestricted range of motion and complete stability with different head and neck components, before implantation of the final components
Stable fixation of the capsule to increase stability and allow early return to function

ted, and rehabilitation is started with gentle active range of motion exercises (Fig. 14.17). At 6 weeks postoperatively, the splint can be discarded, and passive range of motion exercises can be started to further increase mobility if needed. Return to normal daily activities is allowed at this stage, although patients are advised to refrain from heavy loading of the thumb for 3 months (Table 14.5).

Discussion

Many procedures have been suggested for the surgical treatment of CMC osteoarthritis, and all have their inherent advantages and disadvantages. Studies that have compared different treatment options were not able to prove superiority of one treatment option [23, 24, 33, 45, 60–63, 72, 73]. This complicates decision-making, and final treatment will depend on specific patient factors and surgeon preferences.

Based on the available literature, there are limited arguments for interposition arthroplasty or hemiarthroplasty, given the lack of qualitative long-term follow-up data. Implant arthroplasty with the PyroDisk could be a potential alternative, but more comparative studies to LRTI and TJA are needed to determine its place in the treatment of CMC osteoarthritis [44, 45, 74]. Data concerning modern TJA is more compelling, with favorable clinical outcome and long-term survival rates (Table 14.4).

As mentioned earlier, TJA leads to a faster recovery, improved function, and better restoration of thumb alignment and cosmesis (Fig. 14.18). In comparison to the gold standard, the significantly faster convalescence and better strength are most noticeable in the first year following TJA. Beyond 1 year, an increased range of motion and pinch strength will remain, compared to LRTI [33, 61, 63]. These potential benefits need to be discussed with the patient and weighed against the increased cost of implant arthroplasty and the significantly higher risk of complications (Table 14.6).

A recent and detailed systematic review compared pooled failure rates of trapeziectomy to failure rates of all implants published in the lit-

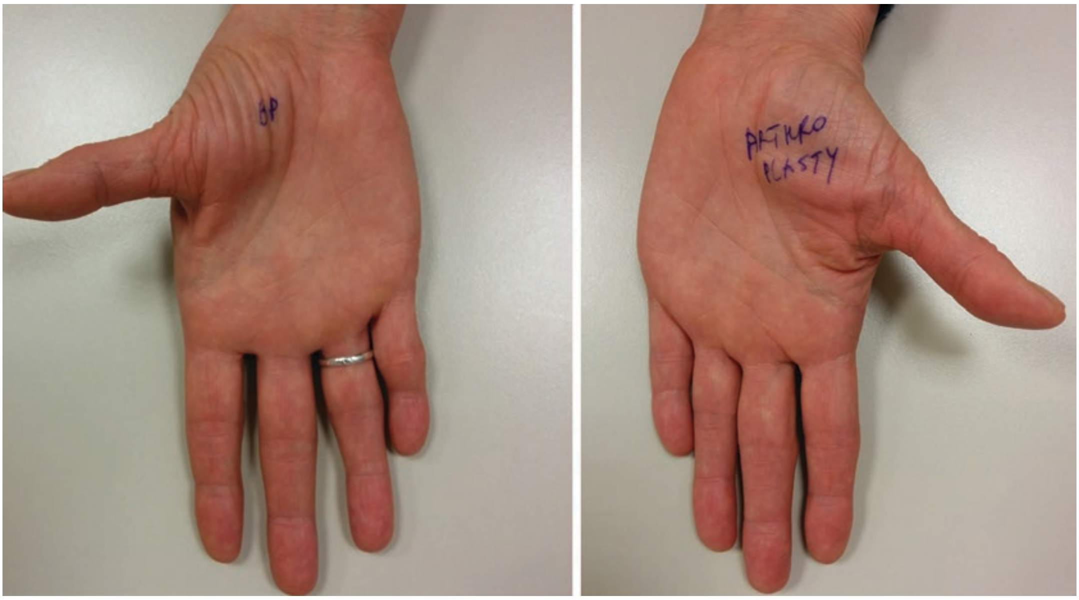

Fig. 14.18 Clinical postoperative image of a patient who underwent an LRTI (left photo) and total joint arthroplasty (right photo), note the better restoration of thumb length and cosmesis

Table 14.6 Why (not) consider CMC total joint replacement?

Advantages	Disadvantages
Less painful	More expensive implant
Earlier return of function	Technically demanding [68]
Better key and tip pinch strength	Learning curve (30 cases)
Greater arc of motion	Higher complication rate: Dislocation, loosening
Better restoration of thumb length and cosmesis	Long-term survival uncertain
Stabilizes MCP hyperextension deformity	
Good medium- to long-term results	
Conversion to trapeziectomy possible	

erature [59]. These data demonstrated an overall higher revision rate per patient-year for all implant arthroplasties compared to trapeziectomy. TJA had a more favorable revision rate compared to interposition and hemiarthroplasty. The criterion for failure was not related to patient outcome, but defined by the fact that revision surgery had been performed. This criterion is open for debate as it may have influenced the conclusion. Revision options following arthroplasty are straightforward and will often consist of implant removal and trapeziectomy, with an outcome comparable to primary trapeziectomy [75, 76], whereas revision options following trapeziectomy are limited, have an unpredictable outcome, and are therefore less commonly performed. The difference in revision rates between implant types could be attributed to errors in surgical technique or implant design flaws, as some implants have been shown to have high early failure rates.

Total joint arthroplasty is a technically demanding procedure, and errors will lead to complications and poor outcome (Fig. 14.19). One of the more critical steps in the procedure is the precise and stable positioning of the trapezial component. Guidelines on ideal cup orientation are limited. Lussiez et al. reported up to 22% of cup mispositioning on postoperative radiographs when using the second metacarpal as a reference [77]. Brauns et al. investigated the effect of cup orientation on the stability of the total joint prosthesis. These authors demonstrated that an orientation parallel to the proximal articular surface of the trapezium (PAST) is a reliable and reproducible method. Neutral positioning of the cup allows for a physiological range of motion of the joint and minimizes the risk of dislocation. Of all

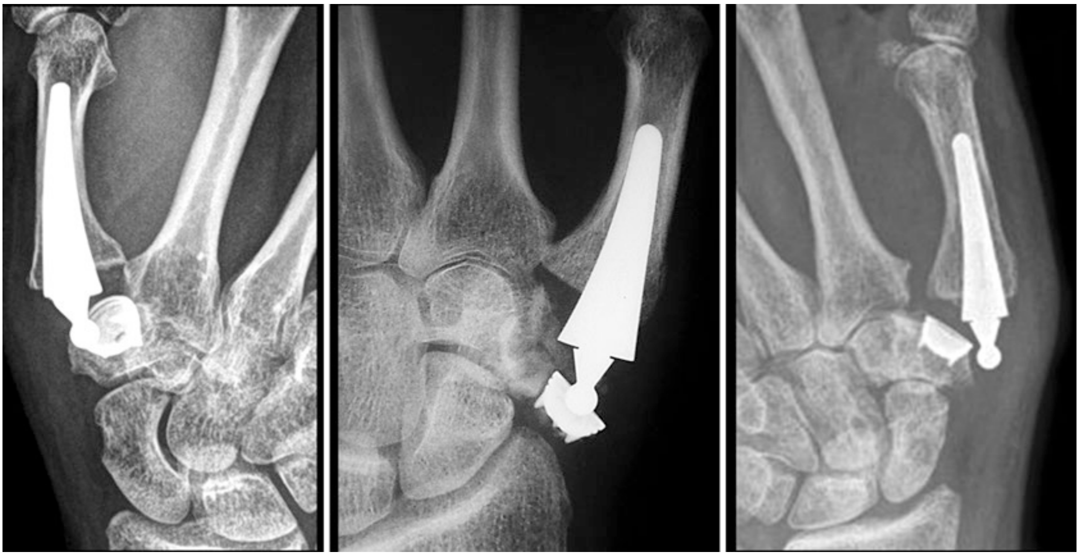

Fig. 14.19 Total joint arthroplasty is a technically demanding procedure, and errors will lead to complications

movements, thumb adduction and opposition carry the highest risk for dislocation of the head in dorsal direction, and this risk increases with dorsal inclination of the cup [71, 78]. Current implant designs are essentially non-anatomical, transforming a biconcave saddle joint into a ball-and-socket joint [79]. This has proven to be a successful design but introduces some inherent problems, such as possible instability, fixation issues of the trapezial component, and limited revision options. There is a clear trend in orthopedic arthroplasty toward resurfacing designs, aiming to restore normal anatomy and biomechanics through limited bony resection and ligament balancing. Although attempts have been made to mimic this approach for CMC arthroplasty, the results have not yet been successful. Some specific problems that complicate this approach for the CMC joint are the high load and complex biomechanics, the relatively small size of the trapezium, marked osteophyte formation, ligament wear, and joint deformity [80].

Dislocation, cup loosening, and polyethylene wear are among the biggest concerns with total joint replacement. A newer generation of total joint implants tries to address these problems through the use of a dual-mobility interface. This concept has since long been used in hip arthroplasty and has some potential advantages. Due to the larger head size, the distance to prosthetic dislocation is increased. It decreases stress and wear on the trapezial implant because loads are shared between the two articulations. The combination of the small and big articulation results in a greater arc of motion [81]. The first reported 4-year outcome of the Moovis® (Stryker) dual-mobility implant shows a 97% survival with 0.5% dislocation [82]. It remains to be seen if the theoretical advantages will translate into better clinical outcome and longer survival. Concerns about increased polyethylene wear in dual-mobility have not been confirmed with the latest design and PE quality in hip arthroplasty [83, 84]. Another factor to consider is the metal composition of the trapezial cup. Titanium has traditionally been used here for its biocompatibility. In the dual-mobility concept, the inner aspect of the cup becomes a bearing surface and titanium may be less effective due to poor wear characteristics. One of the newer designs on the market, the Touch® prosthesis (KeriMedical, Geneva, Switzerland), has therefore replaced titanium for stainless steel in cup production. Polyethylene wear of the cup liner is occasionally seen in patients with longer follow-up, specifically when performing heavy activities. It can cause pain and instability and eventually accelerate loosening of the components. Advances in polyethylene cross-linking, diffusion of vitamin E, and addition of nanomaterials are potential ways to reinforce PE and reduce wear in future implants [85].

As many designs had to be retracted because of high failure rates, the widespread use of national registries would be of great benefit to closely monitor outcome. Not only could it allow for early tracking of failures; it would also facilitate the collection of reliable long-term outcome data on a large number of patients, as has been proven successful for hip and knee arthroplasty follow-up in some countries.

Conclusion

No surgical procedure has been shown to be overall superior, and high-quality outcome research is lacking. Resection of the trapezium, often combined with interposition and ligament reconstruction, has traditionally been the most commonly performed procedure and has the lowest complication rate and cost. Nevertheless, TJA has become a valid treatment option. It allows for a shorter rehabilitation time, and there is evidence that it leads to a better functional recovery, range of motion, and strength. Medium- to long-term studies demonstrate good functional results and survival rates of a selected group of implants. However, longevity beyond 15 years is to be determined. Patient and implant selection together with a flawless surgical technique are paramount to achieve the best possible results. When salvage is necessary because of complications, the conversion to trapeziectomy is possible with an outcome similar to primary resection of the trapezium. New implant designs try to address some of the current disadvantages of CMC arthroplasties, but further research and longer follow-up are needed.

References

1. Sodha S, Ring D, Zurakowski D, Jupiter JB. Prevalence of osteoarthritis of the trapeziometacarpal joint. J Bone Joint Surg. 2005;87:12.
2. Becker SJE, Briet JP, Hageman MGJS, Ring D. Death, taxes, and Trapeziometacarpal Arthrosis. Clin Orthop Relat Res. 2013;471(12):3738–44.
3. Armstrong AL, Hunter JB, Davis TRC. The prevalence of degenerative arthritis of the base of the thumb in post-menopausal women. J Hand Surg. 1994;19(3):340–1.
4. Riley N, Vella-Baldacchino M, Thurley N, Hopewell S, Carr AJ, Dean BJF. Injection therapy for base of thumb osteoarthritis: a systematic review and meta-analysis. BMJ Open. 2019;9:e027507.
5. Day CS, Gelberman R, Patel AA, Vogt MT, Ditsios K, Boyer MI. Basal joint osteoarthritis of the thumb: a prospective trial of steroid injection and splinting. J Hand Surg. 2004;29(2):247–51.
6. Khan M, Waseem M, Raza A, Derham D. Quantitative assessment of improvement with single corticosteroid injection in thumb CMC joint osteoarthritis? Open Orthop J. 2009;3(1):48–51.
7. Villafañe JH, Valdes K, Pedersini P, Berjano P. Thumb carpometacarpal osteoarthritis: a musculoskeletal physiotherapy perspective. J Bodyw Mov Ther. 2019;23(4):908–12.
8. AJ-DJM B. Reduction in the need for operation after conservative treatment of osteoarthritis of the first carpometacarpal joint: a seven year prospective study. Scand J Plast Reconstr Surg Hand Surg. 2001;35(4):415–7.
9. Tuffaha SH, Quan A, Hashemi S, Parikh P, O'Brien-Coon DM, Broyles JM, et al. Selective thumb carpometacarpal joint denervation for painful arthritis: clinical outcomes and cadaveric study. J Hand Surg. 2019;44(1):64.e1–8.
10. Loréa PD. First carpometacarpal joint denervation: anatomy and surgical technique. Tech Hand Upper Extrem Surg. 2003;7(1):26–31.
11. Wong CW Yee, Ho P Cheong. Arthroscopic management of thumb carpometacarpal joint arthritis. Hand Clin . W.B. Saunders. 2017. Vol 33 p. 795–812.
12. Hofmeister EP, Leak RS, Culp RW, Osterman AL. Arthroscopic hemitrapeziectomy for first carpometacarpal arthritis: results at 7-year follow-up. Hand. 2009;4(1):24–8.
13. Hobby JL, Lyall HA, Meggitt BF. First metacarpal osteotomy for trapeziometacarpal osteoarthritis. J Bone Joint Surg Series B. 1998;80(3):508–12.
14. Chou FH, Irrgang JJ, Goitz RJ. Long-term follow-up of first metacarpal extension osteotomy for early CMC arthritis. Hand. 2014;9(4):478–83.
15. Goubau JF, Ackerman P, Kerckhove D, van Hoonacker P, Berghs B. Addition–subtraction osteotomy with ligamentoplasty for symptomatic trapezial dysplasia with metacarpal instability. J Hand Surg Eur Vol. 2012;37(2):138–44.
16. Rizzo M, Moran SL, Shin AY. Long-term outcomes of trapeziometacarpal arthrodesis in the management of trapeziometacarpal arthritis. J Hand Surg Am. 2009;34(1):20–6.

17. Gervis WH. Excision of the trapezium for osteoarthritis of the trapeziometacarpal joint. J Bone Joint Surg. 1949;31-B(4):537–9.
18. Burton RI, Pellegrini VD. Surgical management of basal joint arthritis of the thumb. Part II. Ligament reconstruction with tendon interposition arthroplasty. J Hand Surg Am. 1986;11(3):324–32.
19. Weilby A. Tendon interposition arthroplasty of the first carpo-metacarpal joint. J Hand Surg Br. 1988;13(4):421–5.
20. DelSignore JL, Accardi KZ. Suture suspension arthroplasty technique for basal joint arthritis reconstruction. Tech Hand Up Extrem Surg. 2009;13(4):166–72.
21. DeGeorge BR, Chawla SS, Elhassan BT, Kakar S. Basilar thumb arthritis: the utility of suture-button suspensionplasty. Hand. 2019;14(1):66–72.
22. Avisar E, Elvey M, Wasrbrout Z, Aghasi M. Long-term follow-up of trapeziectomy with abductor pollicis longus tendon interposition arthroplasty for osteoarthritis of the thumb carpometacarpal joint. J Orthop. 2013;10(2):59–64.
23. Vermeulen GM, Slijper H, Feitz R, Hovius SER, Moojen TM, Selles RW. Surgical management of primary thumb carpometacarpal osteoarthritis: a systematic review. J Hand Surg. 2011;36(1):157–69.
24. Vandenberghe L, Degreef I, Didden K, Fiews S, de Smet L. Long term outcome of trapeziectomy with ligament reconstruction/tendon interposition versus thumb basal joint prosthesis. J Hand Surg Eur Vol. 2013;38(8):839–43.
25. Spekreijse KR, Vermeulen GM, Kedilioglu MA, Slijper HP, Feitz R, Hovius SE, et al. The effect of a bone tunnel during ligament reconstruction for trapeziometacarpal osteoarthritis: a 5-year follow-up. J Hand Surg. 2015;40(11):2214–22.
26. Lerebours A, Marin F, Bouvier S, Egles C, Rassineux A, Masquelet AC. Trends in trapeziometacarpal implant design: a systematic survey based on patents and administrative databases. J Hand Surg. 2020;45:223–38.
27. Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. Lancet. Elsevier. 2007;370:1508–19.
28. de La Caffiniere JY, Aucouturier P. Trapezio-metacarpal arthroplasty by total prosthesis. Hand. 1979;11(1):41–6.
29. Degeorge B, Dagneaux L, Andrin J, Lazerges C, Coulet B, Chammas M. Do trapeziometacarpal prosthesis provide better metacarpophalangeal stability than trapeziectomy and ligamentoplasty? Orthop Traumatol Surg Res. 2018;104(7):1095–100.
30. Poulter RJ, Davis TRC. Management of hyperextension of the metacarpophalangeal joint in association with trapeziometacarpal joint osteoarthritis. J Hand Surg Eur Vol. 2011;36(4):280–4.
31. Toffoli A, Teissier JMAÏA. Trapeziometacarpal joint arthroplasty: clinical and radiological outcomes of 80 patients with more than 6 years of follow-up. J Hand Surg. 2017;42(10):838.e1–8.
32. Miller NJK, Davis TRC. Palmar plate capsulodesis for thumb metacarpophalangeal joint hyperextension in association with trapeziometacarpal osteoarthritis. J Hand Surg Eur Vol. 2014;39(3):272–5.
33. Robles-Molina MJ, López-Caba F, Gómez-Sánchez RC, Cárdenas-Grande E, Pajares-López M, Hernández-Cortés P. Trapeziectomy with ligament reconstruction and tendon interposition versus a trapeziometacarpal prosthesis for the treatment of thumb basal joint osteoarthritis. Orthopedics. 2017;40(4):e681–6.
34. Robert M. The classic: radiography of the trapeziometacarpal joint. Degenerative changes of this joint. Clin Orthop Relat Res. 2014;472(4):1095–6.
35. Wolf JM, Oren TW, Ferguson B, Williams A, Petersen B. The carpometacarpal stress view radiograph in the evaluation of trapeziometacarpal joint laxity. J Hand Surg Am. 2009;34(8):1402–6.
36. Saltzherr MS, van Neck JW, Muradin GSR, Ouwendijk R, Luime JJ, Coert JH, et al. Computed tomography for the detection of thumb base osteoarthritis: comparison with digital radiography. Skelet Radiol. 2013;42(5):715–21.
37. Eaton R, Glickel S. Trapeziometacarpal osteoarthritis. Staging as a rationale for treatment. Hand Clin. 1987 [cited 2020 Apr 17];3(4):455–71.
38. Dell PC, Brushart TM, Smith RJ. Treatment of trapeziometacarpal arthritis: results of resection arthroplasty. J Hand Surg. 1978;3(3):243–9.
39. Ladd AL, Messana JM, Berger AJ, A-PC W. Correlation of clinical disease severity to radiographic thumb osteoarthritis index. J Hand Surg Am. 2015;40(3):474–82.
40. Kennedy AM, Barker J, Estfan R, Packer GJ. The use of the RegJoint™ implant for base of thumb osteoarthritis: results with a minimum follow-up of 2 years. Hand Surg Rehabil. 2020;39(1):53–8.
41. Vitale MA, Taylor F, Ross M, Moran SL. Trapezium prosthetic arthroplasty (silicone, artelon, metal, and pyrocarbon). Hand Clin. 2013;29(1):37–55.
42. Clarke S, Hagberg W, Kaufmann RA, Grand A, Wollstein R. Complications with the use of Artelon in thumb CMC joint arthritis. Hand. 2011;6:282–6.
43. van Royen K, Kestens B, van Laere S, Goubau J, Goorens C. Short-term results after total trapeziectomy with a poly-L/D-Lactide spacer. J Wrist Surg. 2018;07(05):394–8.
44. Smeraglia F, Barrera-Ochoa S, Mendez-Sanchez G, Basso MA, Balato G, Mir-Bullo X. Partial trapeziectomy and pyrocarbon interpositional arthroplasty for trapeziometacarpal osteoarthritis: minimum 8-year follow-up. J Hand Surg Eur Vol. 2020;175319342090680:27.
45. Oh W-T, Chun Y-M, Koh I-H, Shin J-K, Choi Y-R, Kang H-J. Tendon versus pyrocarbon interpositional arthroplasty in the treatment of trapeziometacarpal osteoarthritis. Biomed Res Int. 2019;2019:1–10.
46. Swanson AB. Disabling arthritis at the base of the thumb: treatment by resection of the trapezium and

flexible (silicone) implant arthroplasty. J Bone Joint Surg Am. 1972;54(3):456–71.
47. Krukhaug Y, Lie SA, Havelin LI, Furnes O, Hove LM, Hallan G. The results of 479 thumb carpometacarpal joint replacements reported in the Norwegian Arthroplasty Register. J Hand Surg Eur Vol. 2014;39(8):819–25.
48. Phaltankar PM, Magnussen PA. Hemiarthroplasty for trapeziometacarpal arthritis - A useful alternative? J Hand Surg Br. 2003;28B(1):80–5.
49. de Aragon JSM, Moran SL, Rizzo M, Reggin KB, Beckenbaugh RD. Early outcomes of pyrolytic carbon hemiarthroplasty for the treatment of trapezial-metacarpal arthritis. J Hand Surg Am. 2009;34(2):205–12.
50. Caudwell M, Bayne G, Page RS. Anatomic pyrocarbon hemiarthroplasty for thumb carpometacarpal osteoarthritis in patients under 65 years: mid term results. J Hand Surg (Asian-Pac Volume). 2018;23(04):469–73.
51. Pritchett JW, Habryl LS. A promising thumb basal joint hemiarthroplasty for treatment of trapeziometacarpal osteoarthritis. Clin Orthop Relat Res. 2012;470(10):2756–63.
52. Marinello PG, Shreve M, Evans PJ. Outcomes of a cementless thumb basal joint hemiarthroplasty for the treatment of trapeziometacarpal osteoarthritis. Oral Presentation at AAHS Annual Meeting. 2016.
53. Van RJ, Kimmenade D, Bullens PH, Raven EE. Short term results of the Ascension® Nugrip™ Cmc implant for thumb carpometacarpal osteoarthritis. Internet J Orthop Surg. 2014;22(1):1–7.
54. Florez GB, Rubio F. Carpometacarpal hemiarthroplasty. Oper Tech Orthop. 2018;28(1):43–8.
55. Klahn A, Nygaard M, Gvozdenovic R, Boeckstyns MEH. Elektra prosthesis for trapeziometacarpal osteoarthritis: a follow-up of 39 consecutive cases. J Hand Surg Eur Vol. 2012;37(7):605–9.
56. Thorkildsen RD, Johansson CB, Hogmalm J, Johansson PH, Røkkum M. Early cup loosening after metal-on-metal total joint replacement of the trapeziometacarpal joint: a retrieval study. J Hand Surg. 2020;45(3):213–22.
57. Goubau J, Goubau L, Goorens C, van Hoonacker P, Kerckhove D, Vanmierlo B, et al. De Quervain tenosynovitis following trapeziometacarpal ball-and-socket joint replacement. J Wrist Surg. 2015;04(01):035–42.
58. Giddins G. Functional outcomes after surgery for thumb carpometacarpal joint arthritis. J Hand Surg Eur Vol. 2020;45(1):64–70.
59. Ganhewa AD, Wu R, Chae MP, Tobin V, Miller GS, Smith JA, et al. Failure rates of base of thumb arthritis surgery: a systematic review. J Hand Surg. 2019;44(9):728–741.e10.
60. Huang K, Hollevoet N, Giddins G. Thumb carpometacarpal joint total arthroplasty: a systematic review. J Hand Surg Eur Vol. 2015;40(4):338–50.
61. 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 Vol. 2019;44(2):151–8.
62. Ulrich-Vinther M, Puggaard H, Lange B. Prospective 1-year follow-up study comparing joint prosthesis with tendon interposition arthroplasty in treatment of trapeziometacarpal osteoarthritis. J Hand Surg. 2008;33(8):1369–77.
63. Thorkildsen RD, Røkkum M. Trapeziectomy with LRTI or joint replacement for CMC1 arthritis, a randomized controlled trial. J Plast Surg Hand Surg. 2019;53(6):361–9.
64. Vissers G, Goorens CK, Vanmierlo B, Bonte F, Mermuys K, Fils JF, et al. Ivory arthroplasty for trapeziometacarpal osteoarthritis: 10-year follow-up. J Hand Surg Eur Vol. 2019;44(2):138–45.
65. Tchurukdichian A, Guillier D, Moris V, See LA, Macheboeuf Y. Results of 110 IVORY® prostheses for trapeziometacarpal osteoarthritis with a minimum follow-up of 10 years. J Hand Surg Eur Vol. 2020;0(0):1–7.
66. 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. 2017;42(8):630–8.
67. 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 Vol. 2014;39(8):826–32.
68. Dumartinet-Gibaud R, Bigorre N, Raimbeau G, Jeudy J, saint Cast Y. Arpe total joint arthroplasty for trapeziometacarpal osteoarthritis: 80 thumbs in 63 patients with a minimum of 10 years follow-up. J Hand Surg Eur Vol. 2020;0(0):1–5.
69. Johnston P, Getgood A, Larson D, Chojnowski AJ, Chakrabarti AJ, Chapman PG. De la Caffinière thumb trapeziometacarpal joint arthroplasty: 16-26 year follow-up. J Hand Surg Eur Vol. 2012;37(7):621–4.
70. Duerinckx J, Perelli S, Caekebeke P. Short report letter: cortical contact is unnecessary to prevent stem subsidence in cementless trapeziometacarpal arthroplasty. J Hand Surg Eur Vol. 2018;43(1):98–9.
71. Brauns A, Caekebeke P, Duerinckx J. The effect of cup orientation on stability of trapeziometacarpal total joint arthroplasty: a biomechanical cadaver study. J Hand Surg Eur Vol. 2019;44(7):708–13.
72. Yuan F, Aliu O, Chung KC, Mahmoudi E. Evidence-based practice in the surgical treatment of thumb carpometacarpal joint arthritis. J Hand Surg. 2017;42(2):104–112.e1.
73. Jager T, Barbary S, Dap F, Dautel G. Analyse de la douleur postopératoire et des résultats fonctionnels précoces dans le traitement de la rhizarthrose. Étude prospective comparative de 74 patientes trapézectomie-interposition vs prothèse MAIA®. Chir Main. 2013;32(2):55–62.
74. Barrera-Ochoa S, Vidal-Tarrason N, Correa-Vázquez E, Reverte-Vinaixa MM, Font-Segura J, Mir-Bullo X. Pyrocarbon interposition (PyroDisk) implant for

trapeziometacarpal osteoarthritis: minimum 5-year follow-up. J Hand Surg Am. 2014;39(11):2150–60.
75. Lenoir H, Erbland A, Lumens D, Coulet B, Chammas M. Trapeziectomy and ligament reconstruction tendon interposition after failed trapeziometacarpal joint replacement. Hand Surg Rehabil. 2016;35(1):21–6.
76. Kaszap B, Daecke W, Jung M. Outcome comparison of primary trapeziectomy versus secondary trapeziectomy following failed total trapeziometacarpal joint replacement. J Hand Surg. 2013;38(5):863–871.e3.
77. Lussiez B, Atlan F. Analyse radiologique de deux types de cupules de prothèse trapézo-métacarpienne. À propos de 50 cas Chirurgie de la Main. 2012;31(6):395.
78. Duerinckx J, Caekebeke P. Trapezium anatomy as a radiographic reference for optimal cup orientation in total trapeziometacarpal joint arthroplasty. J Hand Surg Eur Vol. 2016;41(9):939–43.
79. D'Agostino P, Dourthe B, Kerkhof F, Vereecke EE, Stockmans F. Impact of osteoarthritis and total joint arthroplasty on the kinematics of the trapeziometacarpal joint: a Pilot study. J Hand Surg. 2018;43(4):382.e1–382.e10.
80. D'Agostino P, Dourthe B, Kerkhof F, Harry Van Lenthe G, Stockmans F, Vereecke EE. In vivo biomechanical behavior of the trapeziometacarpal joint in healthy and osteoarthritic subjects. Clin Biomech. 2017;49:119–27.
81. Lussiez B. Prothèses trapézométacarpiennes à double mobilité – principes biomécaniques. Chir Main. 2015;34(6):388–9.
82. Tchurukdichian A, Gerenton B, Moris V, See LA, Stivala A, Guillier D. Outcomes of double-mobility prosthesis in Trapeziometacarpal joint arthritis with a minimal 3 years of follow-up: an advantage for implant stability. Hand. 2019;0(0):1–7.
83. di Laura A, Hothi H, Battisti C, Cerquiglini A, Henckel J, Skinner J, et al. Wear of dual-mobility cups: a review article. Int Orthop. 2017;41(3):625–33.
84. Boyer B, Neri T, Geringer J, di Iorio A, Philippot R, Farizon F. Long-term wear of dual mobility total hip replacement cups: explant study. Int Orthop. 2018;42(1):41–7.
85. Yousef S. Polymer nanocomposite artificial joints. In: Carbon nanotubes - current progress of their polymer composites: IntechOpen, London, UK; 2016. p. 253–73.
86. Benaiss S, Dunaud J-L, Gueriat F, Henry L, Hornstein S, Laterzaleroy C, et al. La prothèse trapézo-métacarpienne rubis 2 : résultats à plus de dix ans à propos de 61 implantations. Chir Main. 2011;30(6):435.
87. Dehl M, Chelli M, Lippmann S, Benaissa S, Rotari V, Moughabghab M. Results of 115 Rubis II reverse thumb carpometacarpal joint prostheses with a mean follow-up of 10 years. J Hand Surg Eur Vol. 2017;42(6):592–8.
88. Semere A, Vuillerme N, Corcella D, Forli A, Moutet F. Results with the Roseland® HAC trapeziometacarpal prosthesis after more than 10 years. Chir Main. 2015;34(2):59–66.