Thumb Carpometacarpal Implant Arthroplasty

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KEYWORDS

• Carpometacarpal joint • Thumb • Implant • Pyrocarbon • Arthroplasty • Total prosthesis • Osteoarthritis • Trapeziometacarpal joint

KEY POINTS

- Implant arthroplasty for thumb CMC joint has proven over time its reliability as an alternative procedure to trapeziectomy. Strength, mobility, and thumb function are more rapidly restored.
- Implant arthroplasty with total CMC prosthesis or pyrocarbon implants have reached high survival rate at medium and long-term follow-up.
- Whatever the type of implant used, implant arthroplasty requires selected indication and meticulous technique for positioning the implant.

INTRODUCTION

Implant arthroplasty is an alternative option to trapeziectomy (with or without ligament reconstruction) for the treatment of thumb carpometacarpal (CMC) osteoarthritis (OA). In 1968, Swanson introduced the concept of CMC arthroplasty with a silicone implant used as an articular spacer.[1] The goal was to preserve the thumb length after a trapeziectomy. Silicone implants became very popular, but despite good functional results, they had high rates of complications related to instability and material breakage.[2] Other implants with different types of synthetic material were also used (Dacron, Artelon, Gore-Tex, PLLA, PLDLA) for interposition arthroplasty of the CMC joint. Similarly, high rates of early complications like foreign body reactions and chronic synovitis led these implants to be rapidly abandoned by many surgeons and manufacturers.[3–5]

Currently, the most common thumb CMC implants are a total CMC prosthesis (TCP) or a pyrocarbon implant. The purpose of this article is to give an overview of these implants regarding the models, their indications, surgical techniques, and outcomes.

TOTAL CMC PROSTHESIS

Total trapeziometacarpal (TM) joint "ball-and-socket" prostheses were proposed in the early 1970s. The aim is to give a stable fulcrum between trapezium and first metacarpal, allowing conservation of centers of rotation of the joint for optimal muscular action, and conservation of first ray length.

Historical Aspects

Jean-Yves de La Caffinière,[6] a French orthopedic surgeon, designed (1971) and published (1973) the first total CMC 1 prosthesis. Initial results were disappointing, with high levels of loosening of the cup.[7] De la Caffinière[8] and others[9–12] modified this implant. In 1982, Braun analyzed the results of 29 "Braun-Cutter" implants, and later Badia[13] reviewed 26 cases with good results and recommended this technique for low-demand patients.

The second generation of the ball-and-socket prosthesis was developed in the 1990s, with modifications to the design and fixation. Some types were an evolution of same initial implant

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Hand Clin 38 (2022) 217–230
https://doi.org/10.1016/j.hcl.2021.12.006

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(GUEPAR), and others were modifications of initial implants (Maia, modification of initial Arpe, Isis evolution of GUEPAR II). Some of them disappeared for commercial failure or had high rates of complications.[14–18] Long-term follow-up of some of these prostheses[19–26] allowed accurate choice of the implants, and were followed by modifications (semiretentivity, double mobility) in the design of the prosthesis (**Fig. 1**).

Most prostheses were developed in Europe, and this may explain the difference in practice patterns around the world. Trapeziectomy (with or without ligament reconstruction) remains the most common surgical option for American surgeons—only 2% offer prostheses.[27] French and Belgian hand surgeons perform implant arthroplasty 2 to 3.5 times more often than trapeziectomy.[28]

Different Types of TCP

Implants are based on the ball-and-socket principle for replacement of the approximate center of rotation of the normal TM joint.[29,30] Most of them get the center of rotation in the trapezium, in one type (Rubis II), the center is in the base of the first metacarpal. The ball-and-socket principle is a simplification of normal anatomic kinematics (nonintersecting and nonorthogonal rotation axes). Unlike trapeziectomy, the TCP restores the point of support between the trapezium and the first metacarpal, and respects the structure of the trapezium, the tendons, and the ligaments around the thumb.

Most TCP get an anatomic design of the stem, with several sizes, several types of neck (length, orientation), several sizes and shapes of cup (hemispherical, cylindrohemispherical, conical, truncated, screw), and modular construction (stem, neck, cup, insert of polyethylene). Most types have a metal-on-polyethylene couple, some metal-on-metal couple. Some models propose semiconstrained couple, for improving the stability of the prosthesis. Osteointegration after press-fit insertion is achieved by covering of cup and stem with hydroxyapatite (HA) and/or porous coating. Some models propose fixation with cement, in first intention or for revision.

Last modifications are applications of the principle of double mobility, inspired by the hip prosthesis, on the TCP (Touch, Moovis), to improve stability.

The Models of TCP

Metal-on-metal

Elektra (Small Bone Innovations Inc, Les Bruyères, France)[31] is a modular unconstrained uncemented prosthesis with chrome-cobalt head and neck. The cup (diameter 6.5 mm) is a chrome-cobalt cone-shaped press-fit screw (**Table 1**).

Motec (Swemac AB, Linköping, Sweden)[32] is an unconstrained uncemented arthroplasty. The stem is a threaded, slightly conical component (4 sizes), coated with *Bonit*. Trapezium is threaded with HA-coated surface (1 size).

Rubis I and II (3SOrtho, Lyon, France)[20] is an unconstrained reverse prosthesis, coated with microporous titanium. Trapezial cup is a screwed circular plate.

Metal-on-polyethylene

Caffiniѐre de La (Howmedica, UK)[6] is a chromium-cobalt alloy, cemented prosthesis.

Ledoux/Carrat[33]: conical cup with 6 wings, expanded by cylindrical polyethylene liner. Anatomic stem. Arc of mobility 66°*. No commercialized anymore.*

Braun-Cutter (SBI/Avanta, Orthopedics, San Diego, CA, USA)[13]: cemented, cylindrical outer shape polyethylene cup and titanium conical stem implants (1 size).

Roseland[20]: semiconstrained noncemented implant with troncoconical cup (2 sizes) and T-shape stem (3 sizes), coating with HA in its proximal part. *No commercialized anymore*.

Arpe (Zimmer-Biomet, Warsaw, IN, USA)[19,22,26]: uncemented titanium cup and stem. Modular, straight, and offset neck, 2 head length. Stem (4 sizes). The cup is hemispherical, HA-coated (2 sizes, 9 and 10 mm), and the liner polyethylene may be retentive or not retentive.

Ivory (Stryker Corporate, Kalamazoo, MI, USA)[16,34]: anatomic HA-covered metal stem, double-coned cup, with polyethylene insert. Fixation of the neck on the stem in 3 rotations. Cup and insert are separate.

Isis (Evolutis, Briennon, France)[35]: titanium stem, triangular, porous-coated in his proximal part (5 sizes), modular neck with variable length and orientation. Semiretentive cup. 2 types of cup: cemented (2 sizes), screw (1 size).

Maia (Groupe Lépine, Genay, France)[23,24,36]: semiconstrained or unconstrained ball and socket implant, with anatomic triangular stem (4 sizes), removable PE insert, hemispherical cup (2 sizes), 2 types of neck.

Moovis (Stryker, Pusignan, France): double mobility principle, with short triangular stem (3 sizes), and conical cup.

Touch (KeriMedical, Route des Acacias, Les Acacias, Switzerland): double mobility principle, straight and offset neck, hemispherical and conical cup.[37]

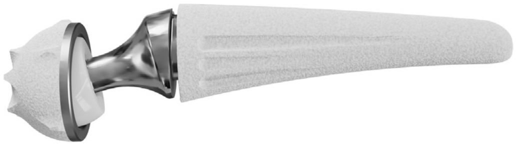

Fig. 1. Double mobility prosthesis (Touch, KeriMedical).

Ceramics

Moje Acamo: based on the principle that ceramics have the least amount of wear, and a low friction joint interface. Total ceramic implant, uncemented, coating is a glass-ceramic layer,[18] and osteointegration at the interface bone/implant is favored by roughened surface.

An other type of TCP is based on *resurfacing prosthesis*, duplicating the double-saddle anatomy of the normal joint.

Camargue: trapezial implant with saddle shape, and PE insert with saddle shape attached to the stem. *No commercialized since 2005*.

SR TMC (Avanta, San Diego, CA, USA): PE metacarpal short stem and trapezium component of chrome cobalt.[38]

Surgical Technique

The “approximative” center of rotation of the CMC 1 joint has to be restored as closely as possible during surgery. The orientation of the cup is important for the prevention of eccentric wear of polyethylene, instability of the prosthesis, and ideal physiologic range of motion of the prosthesis.[39,40]

Table 1
Main different types of TCP

1971	Caffinière (De la) (Formerly Howmedica, UK)
1982	Braun-Cutter (SBI/Avanta Orthopaedics, San Diego, CA, USA)
1985	Guepar I (Alnot) No commercialized
1986	Steffee
1987	Cooney (Mayo-Clinic prosthesis)
1989	Roseland 2 (DePuy International Ltd, Leeds, England) No commercialized
1990	Moje Acamo®
1990	Ledoux/Carrat®:1st noncemented TCP (DIMSO/Stryker) No commercialized
1991	Arpe® (Zimmer Biomet, Warsaw, IN, USA)
1994	Ivory® (Stryker Corporate Kalamazoo, MI, USA)
1996	Elektra® (formerly, SBI Inc, Morrisville, PA, USA)
1996	Avanta® (Avanta Orthopaedics, San Diego, CA, USA)
1997	Rubis II®
1999	Maia® (Lepine, Lyon, France)
1999	Nahigian prosthesis
2000	Camargue®(France) No commercialized
2003	Guepar II
2006	Isis® (Biotech, Evolutis)
2013	Moovis® (Stryker Corporate Kalamazoo, MI, USA)
2014	Touch® (KeriMedical, Geneva, Suisse)

Surgical Approaches for TCP

Laterodorsal

The incision is longitudinal (3–5 cms), distal to the first tendinous compartment (*Abductor Pollicis Longus* (APL) and *Extensor pollicis brevis* tendons) (**Fig. 2**). After visualization of sensitive branches of anterior and dorsal radial nerve, the approach of TM joint may be of 3 types: longitudinal, with a proximal capsuloligamentar flap, or with L-shape flap. Important steps are the section of the intermetacarpal ligaments, the resection of medial osteophyte and anterior calcifications, synovectomy, and optimal exposure of the trapezium surface. Advantages of this approach are the conservation of insertions of thenar muscles, and the quality of closure. Disadvantage is the technical demanding exposure of trapezium surface, especially in male-centered arthritis with strong ligaments.

Lateropalmar

It is a modification of the Gedda-Moberg approach without the proximal incurved branch. After dissection of the sensitive branch of the anterior radial nerve, a disinsertion of the APL tendon and the proximal insertions of lateral thenar muscles are done, then 2 capsuloligamentar flap are elevated for optimal exposure of the joint. The main advantage of this approach is an optimal exposure of the trapezium surface.

Steps for insertion

Whatever the model of prosthesis and the surgical approach, the quality of results depends on some essential points. First of them is the maximum shortening of the learning curve, which means exercises on cadaver pieces before the first case, and to be helped during this first case by a senior surgeon.

Then respect the following points:

Optimal exposure of trapezium surface

Section of intermetacarpal ligaments

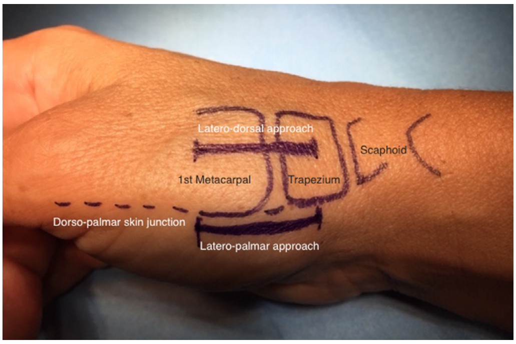

Fig. 2. Surgical approaches of thumb CMC joint. (*From* Tchurukdichian A, Lussiez B. Surgical approaches to the trapeziometacarpal joint for the insertion of implants and prostheses (non-arthroscopy). Hand Surg Rehabil. 2021;40S:S29-S32. https://doi.org/10.1016/j.hansur.2020.10.019; with permission).

Resection of medial trapezial osteophyte
Optimal centering and orientation of the cup
Intraoperative fluoroscopic control
Reinsertion of APL tendon to the APB muscle, or on the base of the first metacarpal, to minimize the risk of dislocation (in case of disinsertion).
Testing of stability of prosthesis in all sectors of mobility (research of "came-effect")
Testing of tension: not too tightened to allow mobility and decrease stress on the components, and not too loose to prevent instability. Allow a piston effect of less than half of the head.

Postoperative care

Immobilization of the thumb is the rule with cast or splint for a mean period of 3 weeks, but some surgeons authorize early return of light activity of the thumb with protection by removable splint some days after surgery. Rehabilitation may be done after this first period, to reinforce the extrinsic and intrinsic muscles groups, but usually, the patient is asked to do himself the exercises. The delay for functional recovering of the thumb is variable, around 3/8 weeks after surgery.

Results

The results of the TCP are depending on the satisfaction of the patient, the objective clinical results (pain, strength, mobility, and esthetic aspect), the radiological modifications, and the level of complications and revisions.

Results of the prosthesis

First TCP have been inserted more than 45 years ago, and during this period, there have been good and bad results.[15,17,31,41] Bad results with unacceptable high level of failure for certain types of prosthesis, essentially metal-on-metal articulations,[14–16,41] some material (ceramic),[41,42] and these models have been abandoned because of these known poor results.[14] Actually, main types of TCP have been followed with long-term follow-up[19–21,24,25,32] (see **Fig. 1**), with a high level of satisfaction of the patients up to 95% (**Fig. 3**).

Comparison with trapeziectomies

Few analyses compared the 2 techniques. In each of these comparisons, the results are better for the prosthesis: strength and delay of recovery,[11,43–47] mobility,[47] Quick-DASH, and esthetic aspect.[47]

Complications

Related to the prosthesis

Some complications have almost disappeared: related to the stem (anatomic stem), fracture of the trapezium (best ancillary), and cement fixation (press-fit/HA/porous-coated fixation). The main problems are localized around the cup: failure of fixation (radio-lucent lines/loosening, tilting, and subsidence), wear of PE, and dislocation.

The problems of fixation are various: mechanical properties of the material (elasticity), quality of bone in trapezium, quality of osteointegration, level of stress at the interface bone/cup (level of activity), design of the cup, quality of positioning of the cup at implantation.

Wear of polyethylene is frequent after several years, depending on the quality and thickness of the material, but also by penetration of the cup by the head of prosthesis.48 Double mobility and modification of the composition of polyethylene (cross-linked) should decrease the incidence of this problem.

Dislocation may occur early, due to traumatism or technical error: bad orientation of the cup, came-effect with medial trapezial osteophyte. The first results of double-mobility prosthesis show no incidence of early prosthesis dislocation.[37] Dislocation may also appear after several years, related to wear of polyethylene, and loose of stability.

Other complications are rare: De Quervain tenosynovitis is frequent with certain series, related to excessive tension of the implant. Elevated serum chrome and cobalt values for patients with metal-on-metal articulation (Elektra, Motec), without being a general health risk.[41]

Related to surgery

Other complications are uncommon: hematoma, infection, allergia, irritation of sensitive branches of the radial nerve.

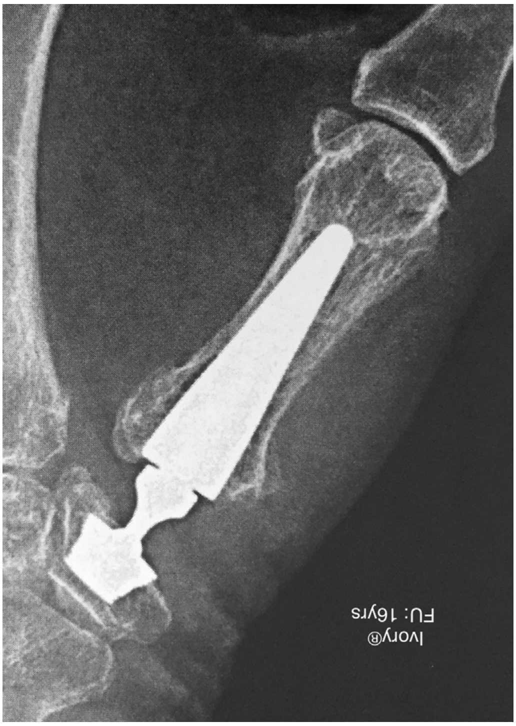

Fig. 3. Ivory prosthesis. Follow-up: 16 years. No sign of loosening, no calcifications.

Revision

Thumb CMC joint total exchange arthroplasty may be an option after failed primary arthroplasty, with or without trapezium bone grafting. Changing of the cup (larger cup), replacement of PE, trapeziectomy are other options, depending on the quality of trapezium. Stem can be left in case of trapeziectomy if no impingement.

The main reason for revision was the loosening of the trapezium component[16]; *early loosening* (1–2 years), with migration and/or tilting of the cup, related to no fixation of the cup by the absence of osteointegration or trauma; and *late loosening*, totally different, with metal-on-metal prosthesis and metal debris,[33] and metal-on-PE prosthesis with wear of PE and debris of PE at interface bone/cup.

Indications

To select the best candidate for TCP, there are first general considerations to be taken into account. Diabetes, smoking intoxication, number of infiltrations, known allergia.

Indications are first clinical: age, level of pain and its tolerance, level of impairment in daily activity: work, sports, and hobbies, decrease of strength, level of activity (low, medium, and high), loss of autonomia for elderly people, decrease of mobility. In rare cases, esthetic reason (Z deformation).

Then radiological indications depending on the classification used.[48–51] There are technical contraindications: low height of trapezium, quality of bone (mediocre quality of trapezium bone is a statistically significant factor),[38] Eaton grade III or some IV for patients with a medium-high level of functional demand,[19] and grade III and selected IV (STT painless OA) for Badia.[13] Dell stages II and III for Vissers.[21]Discrete degenerative changes in STT joint appear not to be a contraindication for using TCP. In case of more important changes in STT joint (Dell IV, Eaton IV), clinical examination of this joint determines if pain is reproduced by palpation and mobilization of this joint.

Conclusion for TCP

TM prosthesis is one of the modern options for surgical treatment of CMC 1 OA. Since first implantations, the rate of survey of the main types of actual TM prosthesis is similar to the prosthesis of the big joints.

The indications are depending on the patient, his age, his level of activity, and the impairment in his daily activities. The patient must be informed of the advantages and disadvantages of this technique. Then, the radiological aspect of his trapezium and the joints around are the technical judges.

PYROCARBON IMPLANTS

Because of the remarkable mechanical properties of pyrocarbon (elasticity, density, roughness, hardness, and resistance to wear durability) and its biocompatibility, pyrocarbon implants have been proposed as an alternative to silicone and other synthetic implants. They have been used in the hand since the 1980s and later in the wrist[52] and have proven their reliability and biotolerance over time.[53] For the basal thumb, pyrocarbon implants aim to preserve the thumb length to allow pain-free normal thumb motion and function. Different designs of pyrocarbon implant are available creating hemiarthroplasty or interposition arthroplasty of CMC joint. These implants can be used as a primary treatment for CMC OA and also for revision after failure of silicone implant, total prosthesis, or trapeziectomy.

Pyrocarbon Hemiarthroplasty

It is a one-piece metacarpal implant with an intramedullary stem and an articular surface that articulates with the trapezium distal surface (Fig. 4). Stem fixation into the metacarpal shaft is made by close contact (press-fit) because pyrocarbon

Name	Implant
CMI®	
NuGrip®	
Saddle®	

Fig. 4. Pyrocarbon hemiarthroplasty implants.

cannot be attached directly to the bone because of its lack of osteointegration.

Models, techniques, and results

PyroHemiSpher (Smith-Nephew-Integra) is the metacarpal component of the PyroCarbon MCP Total Joint implant. It is inserted after an oblique cut is made at the metacarpal base and a hemispherical recess has been made on the trapezium surface. The only published study on this implant is that of Martinez-de Aragon and colleagues, who reviewed 54 cases at an average follow-up of 22 months.[54] Eighty-one percent of patients had little or no pain, and grip and key pinch strength was 86% and 92% of the opposite side, respectively. However, there was a 26% revision rate and a 16% failure rate. Implant instability was the most common complication (18%). In 3 cases, aseptic synovitis was observed and attributed to diamond milling debris. Radiologically, there were 2 implant migrations and 3 cases of osteolysis.

Nugrip (Smith-Nephew-Integra) is the second generation PyroHemiSpher implant and has been specifically designed for the CMC joint (**Fig. 5**). The articular surface is spherically prolongated with a collar and the stem. They are 9 sizing options. In a recent publication,[55] comparing the results of 47 pyrocarbon hemiarthroplasties (24

Fig. 5. Nugrip implant. Courtesy of Steven Moran (Mayo Clinic, USA).

Nugrip and 23 PyroHemiSpher) with those of 40 trapeziectomies done with Thompson's technique, Vitale and colleagues found no significant differences in pain, strength, mobility, and QuickDASH scores at an average follow-up of more than 24 months. PyroHemiSpher had significantly better functional thumb scores (Nelson score) but also higher complication, revision, and failure rates. STT OA decompensation occurred in 23% of cases. The 30% revision rate was mainly due to STT OA; 17% were failures revised by trapeziectomy. Radiologically, 23% of cases had implant instability and 32% had radiolucent lines up to 0.5 mm around the stem.

Saddle (Smith-Nephew-Integra) is an anatomic implant that resurfaces the metacarpal base. It is inserted after a 3 mm orthogonal cut is made on the metacarpal base. No trapezium preparation is needed. In a series of 13 cases, including 4 PyroHemiSpher and 2 Nugrip implants, Woodward and colleagues reported that 100% of patients experienced minimal or no pain and that no revisions were performed.[56] Caudwell and colleagues, in a prospective series of 9 patients with a mean follow-up of 6.5 years, found significant improvement of the Wrightington score with a final DASH and PRWE (Patient Rated Wrist Evaluation) scores of 27.56 and 48.22, respectively.[57] One case had 50% implant subluxation at the last follow-up; ballooning around the stem was seen in another case. One thumb required revision with implant removal and suspensionplasty.

CMI (Stryker-Wright Medical) has a spherical surface with an offset of 15° to the intramedullary stem.[58] Using a dorsoradial approach, 2 mm of

Name	Implant
Pi2®	
PYROSPHER®	
PYRODISK®	
PYROCARDAN®	

Fig. 6. Pyrocarbon interposition implants.

the metacarpal base is resected with a 15° varus cut. The trapezium surface is milled to obtain a congruent concavity on the implant's surface. Capsule reinforcement and stabilization of the arthroplasty is performed using an extensor carpi radialis longus strip that is connected to the dorsal APL bundle. In their 30-case series of mainly Dell-3 grade thumbs, Péquignot and colleagues[59] reported very satisfactory results on pain, function, mobility, and strength, with no revision at an average follow-up of 5.5 years. A 1 mm subsidence was noted in 2 cases and implant decentering by less than 50% of the surface area was found in 60% of cases.

Pyrocarbon Interpositions

These implants are unconstrained small spacers, which articulate between 2 bone surfaces (**Fig. 6**). Depending on the type of implant they can be interposed after a total or partial trapeziectomy or used as an interface in the CMC joint cavity.

Models, techniques, and results

Pi2 (Stryker-Wright Medical) is an ellipsoidal implant, 9 mm thick, available in 2 sizes. An anterior approach is recommended for doing a trapeziectomy and partial trapezoidectomy (one-third).[59] The implant remains stable in the cavity, thank a dorsal capsulorrhaphy by plication to reduce the capsuloperiosteal redundancy pocket and a precise anterolateral ligamentoplasty using 2 tendon hemi-bands taken from the APL and flexor carpi radialis (FCR).

In a short-term prospective and comparative study, Alligand-Perrin and colleagues found earlier function recovery and better overall patient satisfaction with the Pi2 implant than with trapeziectomy-stabilization.[60] Ardouin and Bellemère's prospective study at a follow-up of 5 years[61] was completed by that of Agout and colleagues[62] at a minimum follow-up of 10 years. In the series of 29 implants reviewed, 97% of patients were satisfied or very satisfied, pain was 1.6, QuickDASH score was 20, whereas grip and key pinch strength were 24 kg and 5.9 kg, respectively. No worsening of the preoperative metacarpophalangeal (MCP) hyperextension was found and the thumb column's mobility increased. No implants were revised. Radiologically, 4% of the implants were dislocated, 48% (29% at a follow-up of 5 years) showed bone remodeling, mainly of the scaphoid distal pole, averaging 11% (8.5% at a follow-up of 5 years) of its height, without any functional repercussions (**Fig. 7**). These favorable results are unusual. Many authors[63–67] found an early implant dislocation rate between 12% and 33% and a revision rate between 4% and 33%. However, the implantation method used in those studies differed from the standard one, either by the approach or the stabilization technique, if it was performed.

PyroSpher (Smith-Nephew-Integra) is a sphere available in 5 sizes placed through a dorsal approach. Bone preparation mills 2 recesses in the metacarpal and trapezium surfaces, which each accommodate one-third of the implant's spherical surface.

The only published study reports on 24 implants reviewed at an average follow-up of 18.5 months. The results were satisfactory for pain (VAS: 1.1), function (QuickDASH score: 11.8), and overall patient satisfaction (100% satisfied or very satisfied). No thumb was revised. Radiologically, no dislocation, partial dislocation or subsidence was reported.[68]

Pyrodisk (Smith-Nephew-Integra) is a slightly biconvex disc available in 6 sizes with a central hole for the passage of a stabilizing ligamentoplasty. It is interposed between the metacarpal and the trapezium through a dorsal approach (**Fig. 8**). Two to 3 mm are resected from the metacarpal base and the trapezium surface is made planar. A 3.2 mm tunnel is drilled obliquely in the middle of the surfaces to allow the passage of an APL tendon strip, harvested proximally, which is

Fig. 7. Pi2 implant with a follow-up of 10 years.

then threaded through the trapezium, the center of the implant, and finally the metacarpal.

The Pyrodisk implant can also be used after a total trapeziectomy as proposed by Stabler in Vitale and colleagues[69] who used the FCR to stabilize the implant, or Chaise[70] who preferred a Gore-Tex CV/0 ligamentoplasty.

Fig. 8. Pyrodisk implant.

A retrospective comparative series of LRTI (19 cases) versus Pyrodisk (20 cases) found significantly better key pinch strength (1.8 kg higher) with the Pyrodisk after a minimum follow-up of 2 years. No differences were found in other functional criteria or complication rates.[71] Barrera-Ochoa and colleagues' retrospective series included 19 patients reviewed at a minimum follow-up 5 years.[72] Pain relief was achieved (VAS at 1.7), QuickDASH score was 20.2, mobility was not significantly improved, and grip strength (20 kg) increased significantly. The failure rate was 10%, associated with painful instability, revised by trapeziectomy after 1 year. In indications of perfectly centered basal thumb arthritis, Odella and colleagues[73] generally obtained good pain relief with Pyrodisk but their results on strength (20% loss) contradicted those of Barrera-Ochoa and colleagues (26% gain).[72]

The study by Mariconda and colleagues[74] of 27 patients reviewed at an average follow-up of 37 months had better results in terms of pain and QuickDASH score. There were no complications or revisions. Radiologically, one implant was dislocated, and no bone subsidence was noted. They reported a 3% failure rate and 3% implant dislocation rate. In a retrospective series of 164 Pyrodisk evaluated with a minimum 5-year follow-up, van Laarhoven et al[75] also reported good clinical and radiological outcomes. PRWHE and DASH scores were, respectively, 17 and 18, pinch and grip strength were comparable to the opposite side and the survival rate was 91%.[35] Main reasons for disc removal (15 cases, 9%) were STT arthritis, persisting pain, and disc dislocation. In a smaller retrospective series (46 cases) with a longer follow-up (minimum 8 years), Smeraglia and colleagues found a 93% survival rate and 6.5% of revision surgery for instability and pain.[76]

Pyrocardan (Stryker-Wright Medical) is rectangular shaped with 2 perpendicularly opposing tubular concave faces. The implant has a 1-mm central thickness regardless of the size (7 existing). It is an unconstrained interposition creating intra-articular interfacing of the CMC joint.[77]

Its placement requires minimal intra-articular bone resection that respects the capsuloligamentous and muscular insertions outside the joint area.[78] Stabilization ligamentoplasty is therefore not necessary. Through a dorsal approach, the dorsal and palmar beaks of the metacarpal and the lateral and medial horns of the trapezium are resected using a thin oscillating saw. The 2 articular surfaces are then remodeled into a slightly spherical convex shape for the metacarpal, and anteroposterior cylindrical convex surface. The implant size is selected so that it completely

Fig. 9. Pyrocardan implant with a follow-up of 10 years.

covers the trapezium. Join preparation allows him to be orthogonal to the long axis of the thumb (Fig. 9).

Bellemère and colleagues in a preliminary case series of 27 patients,[77] with an average follow-up of 16.6 months, reported pain on VAS at 1.6, QuickDASH score at 10.1 with comparable mobility to the opposite side, while the grip strength and pinch strength were, respectively, 94% and 98% of the opposite side. No revision was needed, and no radiological dislocation or loosening was found. Identical good results with similar values were found in Logan and colleagues' prospective study[79] of 18 thumbs at a 2-year follow-up. In this study, the results were compared with those of an LRTI cohort. They found higher grip strength and faster recovery in the Pyrocardan cohort. In a prospective series of 103 patients with a minimum 5-year follow-up, Gerace and colleagues[80] reported a significant reduction in pain postoperatively (0.6 on VAS vs 7 preoperatively), with a PRWE of 4 (60 preoperatively), QuickDASH score of 6.8 (52.3 preoperatively), tip pinch strength of 7 kg (5 kg preoperatively), and key pinch strength of 8 kg (5 kg preoperatively). There were no significant differences in pinch strength, grip strength (27 kg), and mobility compared to the opposite side (Fig. 11). Two patients had to have their implant removed and converted to a trapeziectomy after about 1 year for chronic pain. The 5-year implant survival rate was 96%. This implant's outcomes seem to be influenced by the indications and surgical technique. In a study comparing 25 Pyrocardan and 36 Pyrodisk implants, used in thumbs with stage 1 to 3 arthritis, Odella and colleagues obtained better results with the Pyrodisk. However, the series was biased by the indications for the 2 implants, with the Pyrocardan being indicated only in cases of metacarpal dislocation and Pyrodisk only in cases of centered articulation.[73] The study by Russo and colleagues[81] assessed 36 cases of stage 1 to 3 thumb basal joint arthritis and found good results at an average follow-up of 31.5 months. Two cases required implant repositioning after early dislocation, although the stage was not reported. Lauwers and colleagues[82] inserted 25 Pyrocardan implants by an extensive anterior approach combined with FCR ligamentoplasty. They reported an 18% failure rate at a follow-up of 25 months. They explain the divergence between their results and those of Bellemère and colleagues initial study[77] by the difference in surgical technique as well as the learning curve associated with this implant. Erne and colleagues[83] compared a small Pyrocardan case series with Lundborg's trapeziectomy-ligamentoplasty series. At an average follow-up of 1.5 years, the Pyrocardan cases had a significantly faster asymptomatic functional recovery time.

Indication of Pyrocarbon Implants

Patients are first selected on pain level and loss of function after failure of conventional conservative treatment of CMC OA.

Early CMC OA (Eaton Littler grade II-III)

It represents the main indication for pyrocarbon CMC arthroplasty preserving the trapezium. Hemi-pyrocarbon arthroplasties and Pyrodisk interposition require a ligamentoplasty.

Pyrocardan implant offers a new option for minimally invasive arthroplasty. Thus, indications can be extended for the low-grade or medium-grade OA and in young and active patients.

Concomitant early grade of CMC and STT OA

Symptomatic peritrapezial OA may have the height and trabecular structure of the trapezium

Fig. 10. "Burger" arthroplasty with 2 Pyrocardan implants.

preserved in the early grades. Trapezium saving is possible in such case with a double arthroplasty using Pyrocardan implant in the CMC and STT joints called ''burger arthroplasty'' (Fig. 10).

Results at the midterm of this technique have shown significantly reduced pain, significant improvement of QuickDASH and PRWE scores and of pinch strength.[84]

Severe CMC OA (Eaton Littler grade III-IV)

This condition generally requires trapeziectomy. Pi2 or Pyrodisk interposition may be used to preserve thumb length. Meticulous techniques of ligamentoplasty to stabilize these biconvex implants and the metacarpal are required.

In case of severe Z deformity of the thumb column, a biconcave implant like a thick Pyrocardan implant could be an alternative in the future (Fig. 11).

Failed CMC total prosthesis

It may be treated by the CMI or the Pi2 implants.[85,86] Metacarpal medullary shaft bone grafting is required and sometimes in the trapezium if it can be preserved.

These salvage procedures are pain-relieving, and preserve thumb function and length. Potential implant instability problems seem to have been solved by the encapsulation created by the previous arthroplasty.

Failed trapeziectomy

These are mostly related to thumb column collapse causing impingement between the metacarpal base and the scaphoid and/or trapezoid. If the scaphometacarpal space allows it, a Pi2 or CMI interposition implant may be proposed. Pyrocardan implant, which is thinner, is a simple and effective solution, especially when the collapse of the first metacarpal is not reductible (Fig. 12).[87] Nugrip implant has been proposed[88] but requires reaming of a cavity in the scaphoid distal pole.

Conclusion for Pyrocarbon Implants

Since the last few years, pyrocarbon implants have been proposed and look for reliable procedures for the treatment of CMC OA. They give promising midterm and long-term functional results that seem at least identical to those of other conventional surgical techniques. They preserve the thumb length and they have enabled to overcome complications (wear, debris, inflammation, allergic reaction, mechanical loosening, implant fracture, and massive bone resorption in reaction to foreign bodies), related to the core material of silicone implants or metal or polyethylene of total prosthesis.

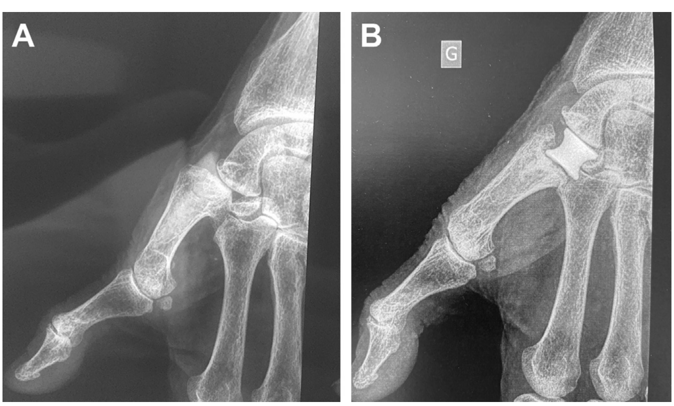

Fig. 11. Future pyrocarbon interposition (not yet available) used for severe and collapsed peritrapezium OA. Here is a failure of silicone implant. (*A*) Preoperative view. (*B*) Postoperative view after 2 years.

Fig. 12. Failed trapeziectomy treated with Pyrocardan implant.

Depending on the indication and the type of implant used, a steep learning curve may be required to master the implantation technique and/or stabilization.

Young and active patients with an early grade of symptomatic CMC OA may be indicated for pyrocarbon implants, especially the thinner ones. Conventional alternatives are always possible in case of failure of pyrocarbon implants.

CLINICS CARE POINTS

For total prosthesis:

- In case of doubt about height of the trapezium , do measure with CT scan. If it's not possible to insert à cup, change your indication for an implant.
- In case of known allergia to metals, do dermatological tests before a prosthesis.

For Implants:

- In case of hyperlaxity, consider the need of ligamentoplasty or change your indication for a total prosthesis.

DISCLOSURE

P. Bellemère and B. Lussiez have conflicts of interest with Stryker Wright Medical and KeriMedical, respectively.

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