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Recent advance

Pyrocarbon implants for the basal thumb arthritis

Implants en pyrocarbone pour l'arthrose de la base du pouce

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ABSTRACT

Silicone implants for the treatment of basal thumb arthritis were first proposed in the 1970's by Swanson. They became extremely popular and despite good functional results, the high rate of complications such as instability, material breakage and foreign body reactions led to them being progressively abandoned by most surgeons. Pyrocarbon implants were introduced at the beginning of the 2000's. A large range of different implant models that can be used for either hemiarthroplasty or interposition arthroplasty. For some implants, a supplemental ligamentoplasty procedure is required to avoid instability. Miniaturization of some implants provides new options for minimally invasive surgery, which is relevant in low and medium grades of osteoarthritis, especially for young, active patients. Medium- and long-term follow-up have now been reached by some pyrocarbon interpositions. Their results confirm that these implants are a reliable alternative to other techniques. This paper focuses on the surgical techniques and outcomes of pyrocarbon implants for the treatment of basal thumb arthritis. It is based on published data and the author's experience.

RÉSUMÉ

Swanson a introduit dans les années 70 le concept d'implant en silicone pour le traitement de l'arthrose de la base du pouce. En dépit de bons résultats cliniques, ces implants ont été progressivement abandonnés par la majorité des chirurgiens du fait de leur taux élevé de complications: instabilité, fracture du matériel et réactions à corps étrangers. Les implants en pyrocarbone ont été introduits au début des années 2000 avec actuellement plusieurs modèles pouvant répondre au concept d'hémiarthroplastie ou d'interposition. Pour certains implants une technique de ligamentoplastie est nécessaire pour éviter leur instabilité. Pour d'autres, leur miniaturisation permet une chirurgie peu invasive intéressante dans des atteintes arthrosiques peu sévères chez des patients jeunes et actifs. Les résultats obtenus à des reculs au moyen et long termes montrent que les arthroplasties en pyrocarbone sont une alternative valable aux autres techniques. Cet article se rapporte aux techniques chirurgicales et aux résultats des arthroplasties en pyrocarbon de la base du pouce. Il s'est basé sur les données de la littérature et l'expérience de l'auteur.

Introduction

The concept of silicone implants for arthritis at the base of the thumb was introduced by Swanson in 1968 [1]. The goal was to preserve the length of the thumb column after trapeziectomy done to treat carpometacarpal (CMC) or trapeziometacarpal (TMC) joint and/or scaphotrapeziotrapezoid (STT) joint arthritis. The implant, called a trapezium implant, was a monoblock piece of silicone with a convex base and a metacarpal stem. Its implantation required a partial trapezoidectomy and a ligamentoplasty to stabilize the implant and the metacarpal. Different silicone implant designs were proposed by Swanson (trapezium implant with a concave base, convex condylar implant, concave condylar implant) and after 1974, a high-performance elastomer was used. Silicone implants became extremely popular while other implants with a

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different shape and/or reinforcement with Dacron were also proposed by Kessler and Axer [2], Dickson [3], Ashworth et al. [4], Eaton [5], Ferlic et al. [6], O'Leary et al. [7]. Despite good functional results, a high rate of complications with silicone implants has been reported. These consisted of dislocation, instability in up to 55% of thumbs [8] and material-related complications such as breakage, wear, silicone synovitis, foreign body reaction with bone cyst formation. Due to these concerns, silicone implants were abandoned by many hand surgeons [9]. A few of them continue to use the silicone implants available on the market, the Swanson trapezium implant and the Tie-in implant which is stabilized by a tendon sling around its narrowed waist (Fig. 1). This later implant provided good functional short-term results in a retrospective series of 28 cases. There were two cases of implant dislocation requiring its removal and no cases of siliconitis at an average follow-up of 18 months [10].

Other implants made of different synthetic materials were also used (Gore-Tex, Artelon, Dacron, PLLA) for interposition arthroplasty of the CMC joint but the high rate of early complications like foreign body reactions and chronic synovitis resulted in these implants being rapidly abandoned by many surgeons and manufacturers [11–14].

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 1980's and later in the wrist [15].

This article focuses on pyrocarbon implants used in the treatment of basal thumb joint osteoarthritis (OA). The implantation techniques and the outcomes are derived from published data and the author's experience. With the authorization of the Editor in Chief (C. Fontaine) some parts of the text as well some figures come from one of my previous publications [15].

Fig. 1. Tie-in implant.

Pyrocarbon hemiarthroplasty implants for TM joint	
Name	Implant
CMI	
NuGrip	
Saddle	

Fig. 2. Hemi-arthroplasty implants.

Pyrocarbon implants

Pyrocarbon implants for basal thumb arthritis are divided into two categories:

- Hemi-arthroplasties which are metacarpal implants stabilized by an intramedullary stem: PyroHemiSpher, CMI, Nugrip, and Saddle (Fig. 2).
- Interpositions which are unconstrained implants: Pi2, Pyrodisk, Pyrospher, and Pyrocardan, some of which can be stabilized by ligament reconstruction (Fig. 3).

These implants are used as a primary treatment for TMC OA but can also be used in reoperations after total prosthesis, silicone implant, or trapeziectomy failures.

CMC hemi-arthroplasty

Pyrocarbon hemi-arthroplasties are one-piece metacarpal implants with an intramedullary stem and an articular surface that articulates with the trapezium distal surface. Stem fixation into the metacarpal shaft is made by close contact (press-fit) since pyrocarbon cannot be attached directly to the bone (no osteointegration).

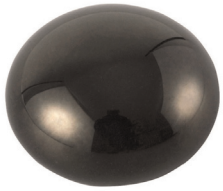
PYROCARBON INTERPOSITION IMPLANTS	
Name	Implant
Pi2	
PYROSPHER	
PYROCARDAN	

Fig. 3. Interposition implants.

Fig. 4. Nugrip implant. Courtesy of Steven Moran (Mayo Clinic, USA).

PyroHemiSpher

This is the metacarpal component of the Pyc-MCP implant. The intramedullary stem ensures press-fit fixation of the implant. It is inserted after an oblique cut is made at the metacarpal base and a hemispherical recess has been made in the trapezium surface. The only published study on this implant is that of Martinez-de Aragon et al., who reviewed 54 cases at an average follow-up of 22 months [16]. 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 three cases, aseptic synovitis was observed and attributed to diamond milling debris. Radiologically, there were two implant migrations and three cases of osteolysis.

Nugrip

This implant is the 2nd generation PyroHemiSpher implant and has been specifically designed for the CMC joint (Fig. 4). In a recent publication [17] comparing the results of 47 pyrocarbon hemiarthroplasties (24 Nugrip and 23 PyroHemiSpher) with those of 40 trapeziectomies done with Thompson's technique, Vitale et al. 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

This anatomic implant 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 et al. reported that 100% of patients experienced minimal or no pain and that no revisions were performed [18]. Caudwell et al., 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 scores of 27.56 and 48.22, respectively [19]. 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

This implant's spherical surface is offset 15° to the intramedullary stem (Fig. 5) [20]. Using a dorsoradial approach, 2 mm of 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 (ECRL) strip that is connected to the dorsal abductor pollicis longus (APL) bundle. In their 30-case series of mainly Dell-3 grade thumbs, Péquignot et al. [20] reported very satisfactory results on pain, function, mobility, and strength, with no revision at an average 5.5 years' follow-up. A 1 mm subsidence was noted in two cases and implant decentering by less than 50% of the surface area was found in 60% of cases.

Interposition implants

These small pyrocarbon spacers articulate between two bone surfaces. Depending on the type of implant used, the interposition arthroplasty can be performed after a total or partial trapeziectomy or used as an interface in the TM joint cavity. A ligamentoplasty is generally required to stabilize these implants.

Pi2

This ellipsoidal implant is 9 mm thick and two sizes are available. It was originally intended for total TM prosthesis failures but now are routinely used as a primary treatment for CMC OA as a trapezium spacer. The implant is interposed without constraints in the trapeziectomy cavity, which gives it mobility in keeping with the movements and axial stresses of the thumb column. To be stable, dorsal capsuloplasty and anterolateral ligamentoplasty are mandatory and must be performed both precisely and meticulously. For this, we recommend an anterior approach (Fig. 6) [21]. The trapeziectomy must preserve the capsuloperiosteal

Fig. 5. CMI implant. Courtesy of Jean-Louis Bovet (Bordeaux, France).

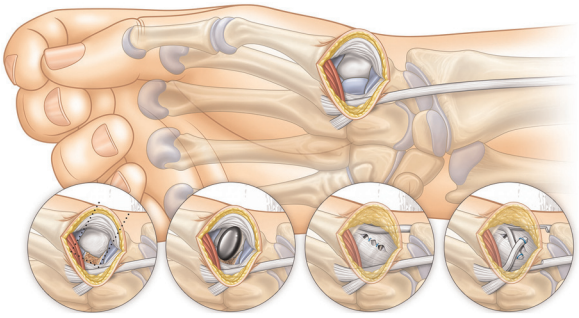


Fig. 6. Drawing of the surgical technique for the Pi2 implant after trapeziectomy. General view showing the trapeziectomy cavity from an anterior approach. From left to right: partial trapezoidectomy, Pi2 implant interposition, closure of the capsule, and ligamentoplasty with two APL and FCR tendon strips.

continuity as much as possible. A partial trapezoidectomy (one third) allows medialization of the implant, contributing to its stabilization and subsequent treatment of associated scaphotrapezial OA. A dorsal capsulorraphy by plication reduces the capsuloperiosteal redundancy pocket. Once interposed, the implant is stabilized by ligamentoplasty, performed using two tendon hemi-bands taken from the APL and flexor carpi radialis (FCR); these are crisscrossed and sutured to each other without excessive tension.

The Pi2 implant has been our technique of choice for the treatment of TMC OA. In a short-term prospective and comparative study, Alligand-Perrin et al. found earlier function recovery and better overall patient satisfaction with the Pi2 implant than with trapeziectomy-stabilization [22]. Ardouin and Bellemère's prospective study at 5 years' follow-up [23] was completed by that of Agout et al. [24] at a minimum of 10 years' follow-up. In the series

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

of 29 implants reviewed, 97% of patients were satisfied or very satisfied, pain was 1.6, QuickDASH score was 20, while grip and key pinch strength was 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 5 years' follow-up) showed bone remodeling, mainly of the scaphoid distal pole, averaging 11% (8.5% at 5 years' follow-up) of its height, without any functional repercussions (Fig. 7).

These favorable results are unusual. Many authors [25–29] 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 ours, either by the approach or the stabilization technique, if it was performed. This underlines the demanding and precise nature of this procedure, mastery of which may require a learning curve. Some surgeons use the Pi2 implant after partial trapeziectomy, but no results have been published yet.

Pyrodisk

This implant is shaped like a slightly biconvex disc of varying diameter and thickness, depending on its size. It is interposed between the metacarpal and trapezium (Fig. 8). A large opening in its center creates room for a stabilizing ligamentoplasty. The approach is dorsal. Two to 3 mm are resected from the metacarpal base and the trapezium surface is made planar. A small recess is hollowed out on the trapezium and metacarpal surfaces, and then a 3.2 mm tunnel is drilled obliquely in the middle of the cavities to allow the passage of an APL tendon strip, harvested proximally, which is then threaded through the trapezium, the center of the implant and finally the metacarpus.

Barrera-Ochoa et al.'s retrospective series included 19 patients reviewed at a minimum 5 years' follow-up [30]. Eighty-nine percent of patients were satisfied or very satisfied, pain measured 1.7 (VAS), the QuickDASH 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

Fig. 8. Pyrodisk implant after partial trapeziectomy (A) and after total trapeziectomy (B).

trapeziectomy after 1 year. A larger retrospective series (46 cases) with a longer follow-up (9.5 years) found a 93% survival rate and 6.5% complication rate [31].

The study by Mariconda et al. [32] of 27 patients reviewed at an average follow-up of 37 months had better results in terms of pain and QuickDASH score. Ninety-six percent of patients were satisfied or very satisfied. There were no complications or revisions. Radiologically, one implant was dislocated, and no bone subsidence was noted.

In indications of perfectly centered basal thumb arthritis, Odella et al. [33] generally obtained good pain relief with Pyrodisk but their results on strength (20% loss) contradicted those of Barrera-Ochoa et al. (26% gain) [30]. They reported a 3% failure rate and 3% implant dislocation rate.

A recent retrospective comparative series of LRTI (19 cases) versus Pyrodisk (20 cases) found significant 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 in complication rates [34].

The Pyrodisk implant can also be used after a total trapeziectomy (Fig. 8) as proposed by Stabler et al., Vitale et al. [35] who used the FCR to stabilize the implant, or Chaise [36] who preferred a Gore-Tex CV/0 ligamentoplasty (Fig. 8). This implant stabilization technique is simpler and less invasive than that used for the Pi2 implant. However, in our experience with more than 80 implants, the failure rate (revised by trapeziectomy) for chronic pain lasting more than 1 year was 6% and we found that the overall clinical results, especially regarding pain, seemed inferior to those of the Pi2 implant. Pain originating from the bone may be related to excessive stress peaks due to the technique used to stabilize the Pyrodisk. It makes it more constrained than the Pi2 while the ligamentoplasty is peripheral allowing it to move freely.

Pyrospher

This spherical implant is placed through a dorsal approach. Bone preparation mills two 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 [37].

Pyrocardan

The concept of this implant is a minimally invasive arthroplasty of the CMC joint by intra-articular interfacing with unconstrained interposition [38]. It is indicated in the early OA stages, Eaton's stages 1 and 2, or even in some early stage 3 cases. It is rectangular shaped with two perpendicularly opposing tubular concave faces. This geometry is intended to replicate CMC joint movements. The implant has a 1-mm central thickness regardless of size. There are 7 models ranging in width from 12 to 18 mm. Its placement requires minimal intra-articular bone resection that respects the capsuloligamentous and muscular insertions outside the joint area [39]. Stabilization ligamentoplasty is therefore not necessary.

We recommend a dorsal approach to the CMC joint with a longitudinal medial joint opening delimiting two dorsal capsular flaps prolonged with the periosteum of the metacarpal (see surgical technique on Video 1). Using a thin oscillating saw, the dorsal and palmar beaks of the metacarpal saddle are resected, thereby altering the saddle shape of the metacarpal surface (Fig. 9A). Then the lateral and medial horns of the trapezium are resected using a saw, noting that the medial horn is often more prominent than the lateral horn, due to the joint space obliquity and to the presence of a medial osteophyte (Fig. 9B). The metacarpal and the trapezium cuts must be orthogonal to the thumb column's axis. This allows metacarpal realignment in case of dislocation (one third or less). A complete joint synovectomy is then performed, preserving the continuity of the capsule. Using a burr, all irregularities of the bone cuts are removed. The metacarpal surface is remodeled into a slightly spherical convex shape (Fig. 9C), and the trapezium is remodeled into an anteroposterior cylindrical convex shape (Fig. 9D). The trial implant is then positioned and can be checked under fluoroscopy. The implant size is selected so that it completely covers the trapezium (Fig. 9E-F). After placement of the final implant, the dorsal capsuloperiosteal flaps are repositioned and sutured to one another without excessive tension, assisted by an intraosseous anchorage at the metacarpal base and reinforced with a running suture on the periosteum (Fig. 9G).

Postoperative care has been standardized and consists of immobilization with a thermoformed orthosis worn constantly for 2 weeks. Self-directed rehabilitation is then started, and the orthosis is worn overnight and occasionally during the day until the 4th week. There is no set postoperative physiotherapy protocol, and after the 6th week, there are no restrictions on thumb use.

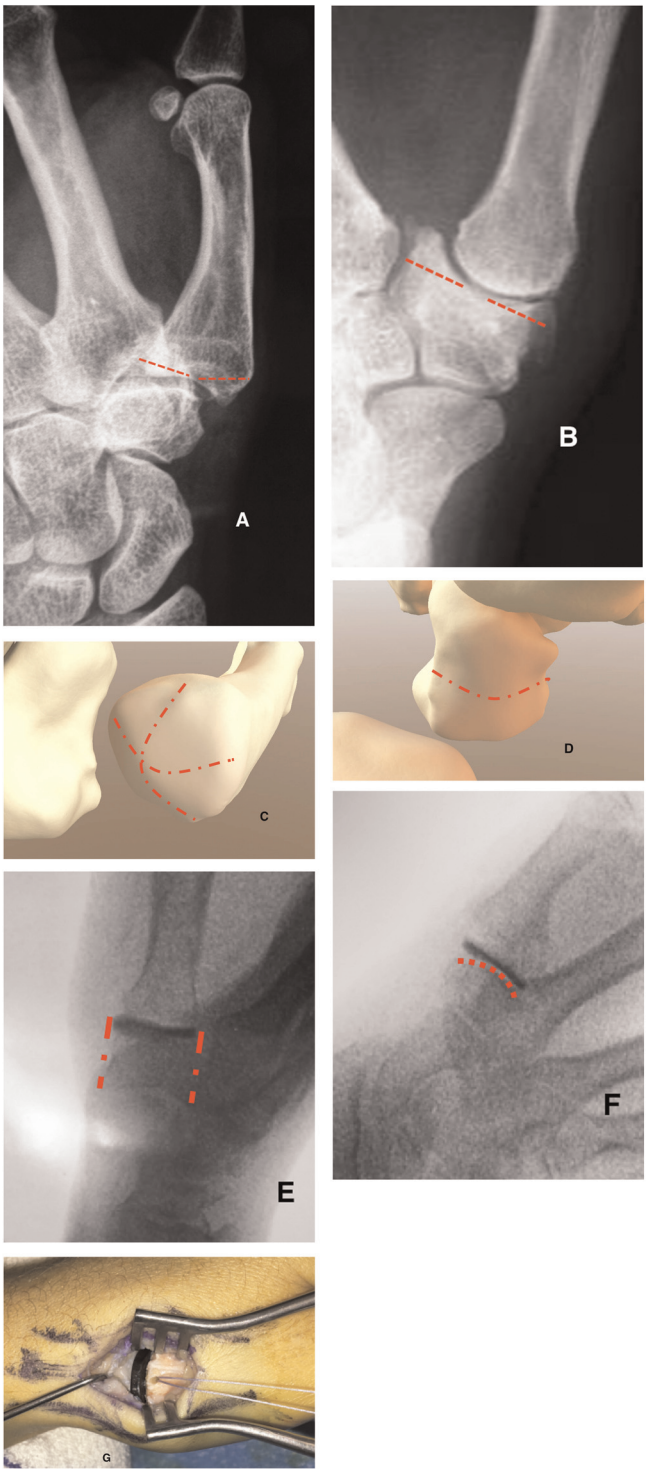


Fig. 9. Surgical technique for Pyrocardan implant in TMC joint. Bone cuts (*dotted lines*) on metacarpal (A) and trapezium (B). Remodeling of the articulating surfaces according to the orientation of the dotted lines of the metacarpal (C) and the trapezium (D). Fluoroscopic AP (E) and lateral (F) interoperative views with the implant providing perfect coverage of the trapezium. Intraoperative view before closure (E) showing the final implant in the TMC joint and the threads of a bone anchor at the metacarpal base.

The implant can also be placed through an anterior or arthroscopic approach, but we found these two approaches more difficult to perform than the dorsal one, making it more challenging to achieve perfect positioning of the implant.

In our preliminary case series of 27 patients [38], with an average follow-up of 16.6 months, 100% of patients were satisfied or very satisfied. Pain on VAS was 1.6, the QuickDASH was 10.1 with comparable mobility to the opposite side, while the grip strength of 23 kg and pinch strength of 6.4 kg were 94% and 98% of the opposite side, respectively. No revision was needed, and no radiological dislocation or loosening was found. Identical good results with similar values were found in Logan et al.'s prospective study [40] of 18 thumbs at a 2-year follow-up. In this study, the results were compared with those of a LRTI cohort. They found higher grip strength and faster recovery in the Pyrocardan® cohort.

At a minimum 5 years' follow-up, our prospective study of 103 patients [41] included 27% manual workers and 39% with permanent dislocation of the first metacarpal (Fig. 10). Fifteen patients (15%) were 50 years old or less. There was 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%. Preoperative dislocation of the first metacarpal was completely corrected in 80% of cases and remained stable throughout the follow-up. Younger patients ($\leq$50 years old) had a slightly better outcome than older patients. Overall satisfaction 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 1–3 arthritis, Odella et al. obtained better results with the Pyrodisk. However, the series was biased by the indications for the two implants, with the Pyrocardan being indicated only in cases of metacarpal dislocation and Pyrodisk only in cases of centered articulation [33].

The study by Russo et al. assessed 36 cases of stage 1–3 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 [42].

Lauwers et al. inserted 25 Pyrocardan implants by an extensive anterior approach combined with FCR ligamentoplasty. They reported an 18% failure rate at 25 months' follow-up. They explain the divergence between their results and those of our initial study [38] by the difference in surgical technique as well as the learning curve associated with this implant [43].

Erne et al. 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 [44].

Most of the patients we see in our practice for chronic and painful OA of the base of the thumb are eligible for Pyrocardan arthroplasty, which is now our treatment of choice. However, this implant is not indicated in case of severe collapse or core modification (cyst) of the trapezium or when subluxation of more than one-third of the metacarpal base is present. In these cases, trapeziectomy is required.

Pyrocarbon implants for surgical failures of TMC OA

Failed trapeziometacarpal total prosthesis

If the trapezium can be preserved, the CMI implant may be proposed even in cases where a defective trapezium is reconstructed with cancellous bone [45], or when a metacarpal corticotomy is performed to remove the metacarpal component [46].

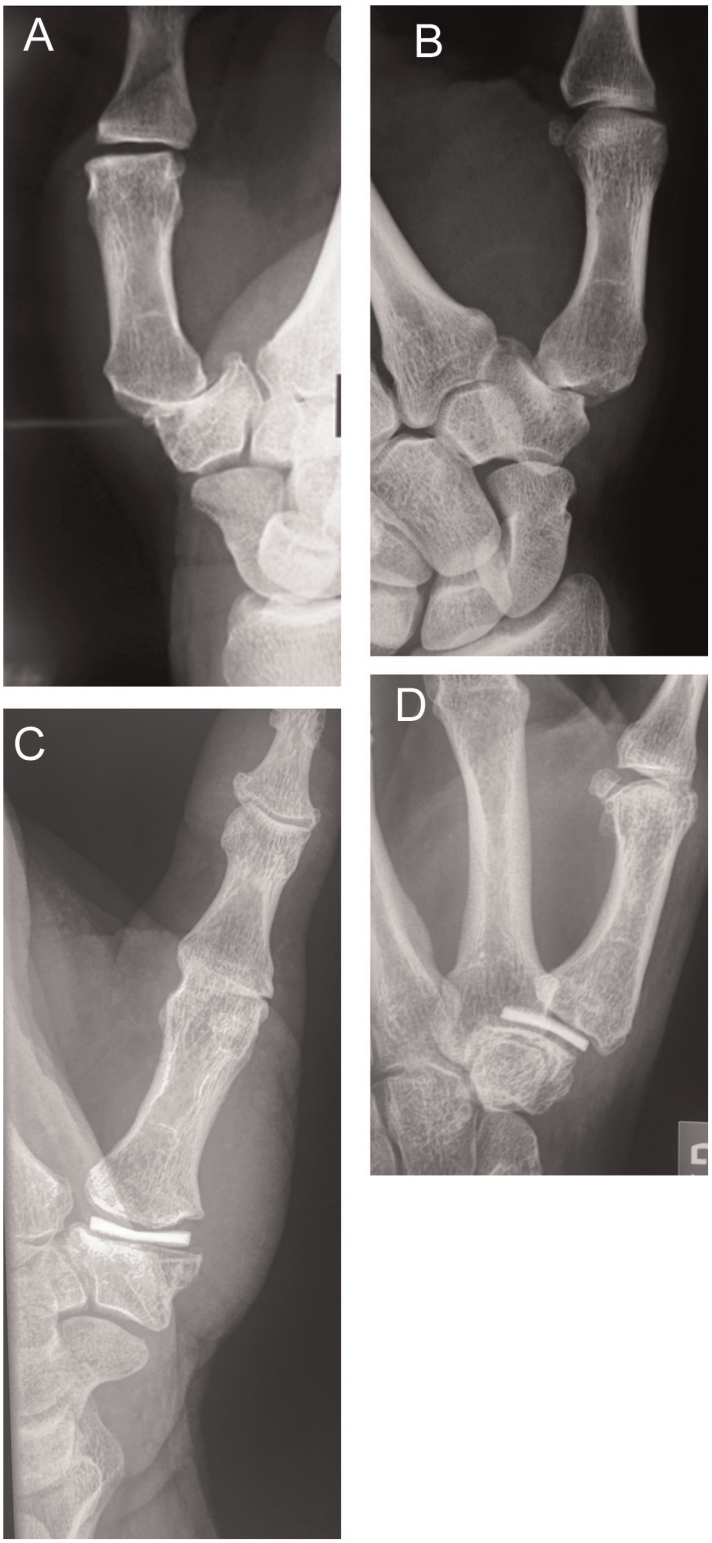


Fig. 10. TMC joint OA of the left thumb of a 47-year-old heavy manual worker (industrial logistics) treated with a Pyrocardan implant according to the standard technique. Clinical results after 7 years were VAS = 0/10, PRWE = 0/100, QuickDASH = 0/100, Tip pinch strength =8 kg, Key pinch =12.5 kg, Grip strength =38 kg. Preoperative AP (A) and lateral (B) radiographic views showing metacarpal subluxation. Postoperative AP (C) and lateral (D) radiographic views after 7 years.

If total or partial trapeziectomy is indicated, the Pi2 implant can be interposed even in cases of metacarpal medullary shaft bone grafting [47].

A comparison of total TM prosthesis failures revised by either a CMI implant (21 cases reviewed at 41 months [45]) or a Pi2 implant (25 cases reviewed at 5.5 years [47]), showed that these procedures were minimally invasive, pain relieving, and could preserve thumb function and length. Potential implant instability problems seem to have been solved by the encapsulation created by the previous arthroplasty.

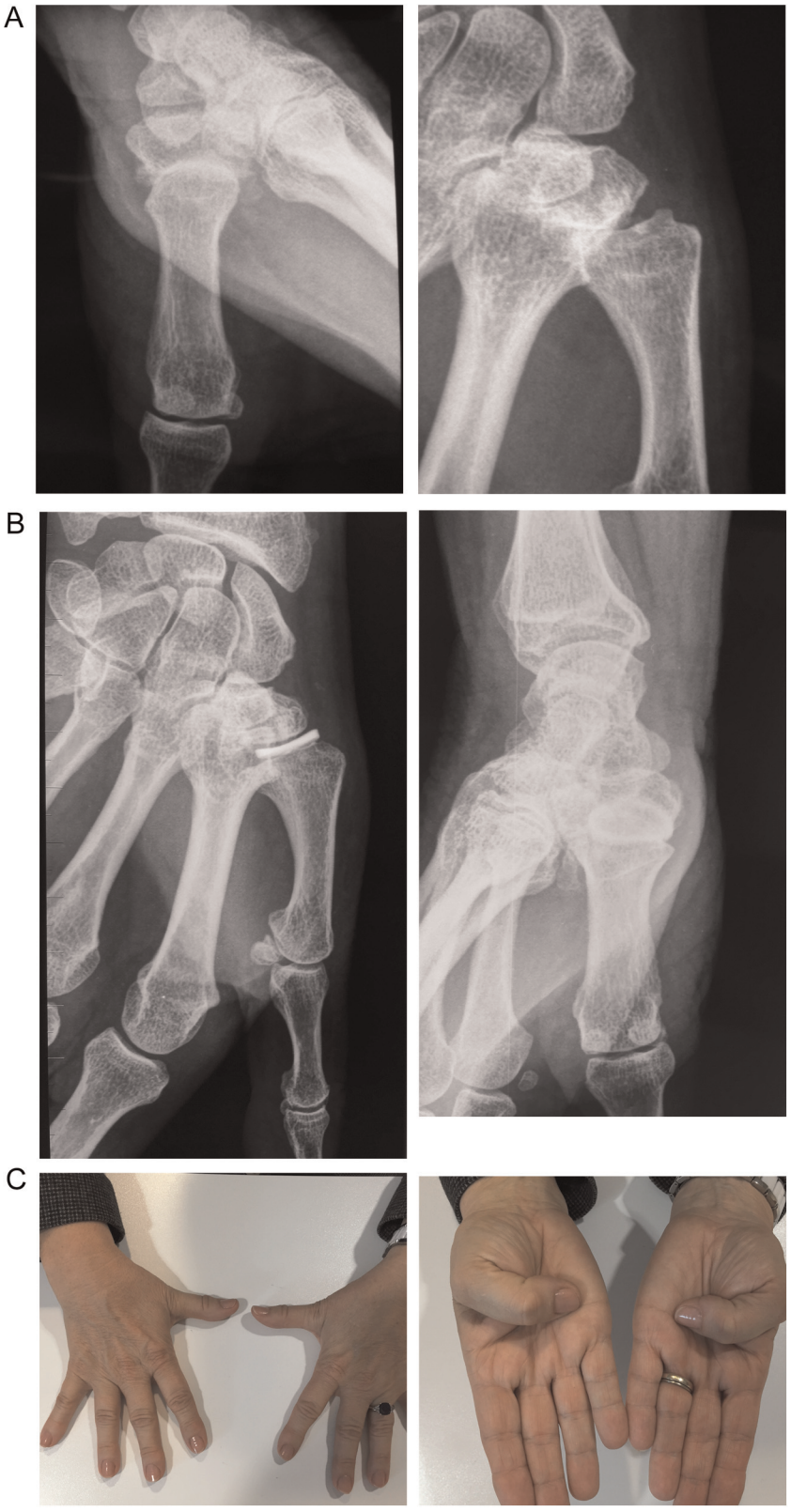


Fig. 11. Long-term results of the Pyrocardan implant in a bilateral case of TMC OA in a 57-year-old woman. Preoperative AP (A) and lateral (B) radiograph of the right side. Postoperative AP (C) and lateral (D) radiographs of the right side after more than 10 years. Clinical results after 10 years: Thumb abduction (E) and opposition (F).

Failed trapeziectomy

These are mostly related to thumb column collapse causing impingement between the metacarpal base and the scaphoid and/or trapezoid. If the scapho-metacarpal space allows it, a Pi2 or CMI interposition implant may be proposed. As is often the case, we have found that this space is very small, and the collapse is not reducible. Consequently, an interposed Pyrocardan implant, which is thinner, is a simple and effective solution (Fig. 12) [48]. Placement of a Nugrip implant has been proposed [49] but requires reaming of a cavity in the scaphoid distal pole.

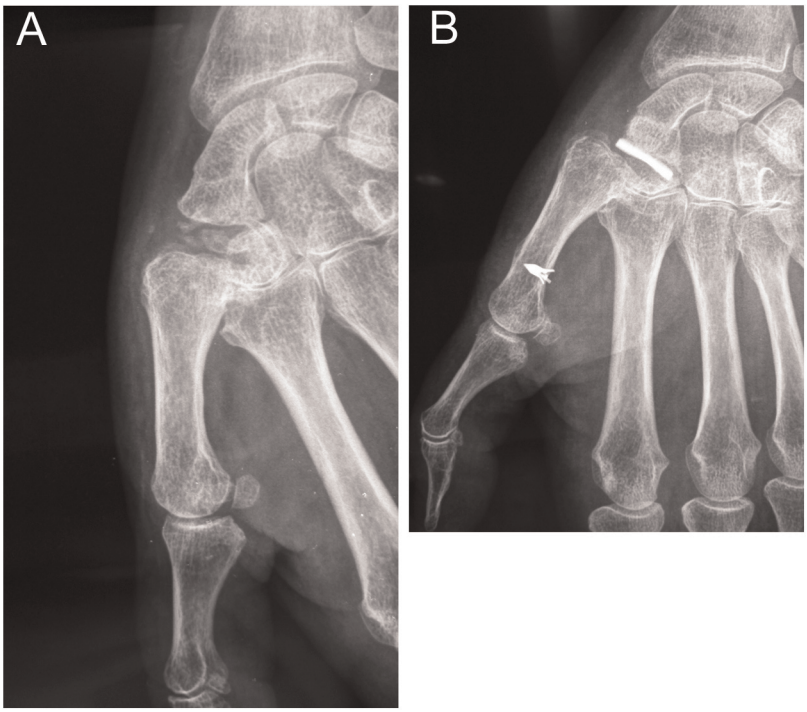


Fig. 12. Pyrocardan implant for the treatment of a failed trapeziectomy, in a patient who had painful metacarposcaphoid impingement. Preoperative lateral radiograph (A). Postoperative lateral radiograph at 66 months' follow-up (B).

Pyrocarbon implants for STT arthroplasty and peritrapezial arthroplasty

STT joint pyrocarbon arthroplasty

STT arthroplasty for the surgical treatment of STT OA seems a reasonable option to maintain scaphoid mobility and to limit intracarpal instabilities exacerbated by excessive scaphoid flexion, height loss, or conversely without ankylosis extension on the trapeziotrapezoid saddle joint.

The first pyrocarbon implant for the STT joint, called STPI, was proposed in 2000 by Péquignot et al. [50]. Its implantation requires that 3 mm–4 mm bone be resected from the scaphoid distal pole depending on the size of the implant. This circular implant has two joint surfaces, one convex for the trapeziotrapezoid surface, and the other concave for the scaphoid (Fig. 13). This shape may lead to the instability of the implant as reported in two arthroscopic studies (20% and 15% rate) [51,52] and one open surgery study (4% rate) [53]. These were attributed to technical errors such as insufficient medial scaphoid resection.

Since March 2010, we use the Pyrocardan implant in the STT joint [54] because its two concave surfaces make it more stable, its rectangular shape is closer to that of the STT joint, its 1 mm thickness reduces bone resection and its implantation conserves the scaphoid surface and its distal ligament attachments, thereby preserving its height and kinematics (Fig. 14). Using an anterior approach for implantation allows for simultaneous treatment of frequently associated FCR tendinopathy (tenosynovitis, partial or complete rupture) at the level of the STT joint (Video 2). Pain relief and functional recovery were achieved in our 22-case series of Pyrocardan implants in the STT joint reviewed at a mean follow-up

Fig. 13. STPI implant for the treatment of STT osteoarthritis at 24 months follow-up.

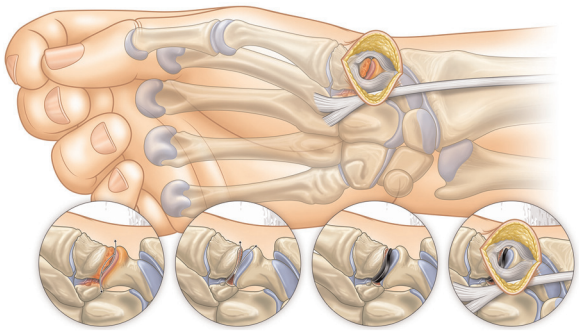


Fig. 14. Drawing of the surgical technique for STT joint arthroplasty with Pyrocardan. General view showing the anterior approach to the STT joint and from left to right, the surgical procedure with the Pyrocardan implant being inserted in the STT joint.

of 36 months (Fig. 15). Average time for functional recovery was 7.2 weeks and the patient satisfaction score was 9.5/10 [54]. No implant instability was found and the preoperative intracarpal instability was partially or completely corrected.

Peritrapezial pyrocarbon arthroplasty

In case of symptomatic early peritrapezial OA, the height and trabecular structure of the trapezium may be normal. In that case, preserving the trapezium is possible with what we call, a "burger arthroplasty", consisting of a double arthroplasty using a

Fig. 15. Pyrocardan implant for the treatment of STT joint OA with 6 years of follow-up.

Fig. 16. Radiographs showing the burger arthroplasty.

Pyrocardan implant in the TM and STT joints (Fig. 16). For each joint, we recommend the approaches described above. In order to preserve the bone's vascularization, extensive soft tissue dissection should be avoided.

The clinical and radiological scenario of peritrapezial OA for a "burger arthroplasty" is not very common; we have operated only 23 patients in the last 10 years. It may be a good alternative to other more invasive options. Our results at the midterm have shown an improvement in the QuickDASH and PRWE scores of 41 and 42 points, respectively, a better grip and pinch strength of 26 kg and 6 kg, respectively, and no MCP joint hyperextension. One patient required a revision for trapeziectomy after trapezium collapse [55]. A preoperative CT scan can be done to verify the trapezium structure in case of doubt.

Conclusion

Since the last few years, pyrocarbon implants for thumb basal joint arthritis have supplanted the use of silicone implants. They became increasingly attractive because they yield functional results that seem identical to those of other conventional surgical techniques. They have made it possible to overcome the complications (wear, debris, inflammation, allergic reaction, mechanical loosening, implant fracture, and massive bone resorption due to foreign body reaction) related to the core material of silicone implants or the metal or polyethylene of total joint replacement implants.

Pyrocarbon hemi-arthroplasties can have instability problems that are likely exacerbated by the added leverage arm that they provide to the metacarpal. They sometimes show subsidence or osteolysis around the intramedullary stem.

Interposition implants, especially convex ones, require a learning curve to master their implantation technique and/or stabilization. Advantages are their excellent medium- and long-term tolerance and the good and quickly obtained functional results, which continue to improve over time [24,31,40,41,56].

Miniaturization of some implants, such as the Pyrocardan, provides new options for minimally invasive arthroplasty. Thus, indications can be extended to low or medium grade of OA and to young, active patients. Mid-term results of this implant are promising. Furthermore, this implant can be used in the STT joint or to treat peritrapezial OA when the trapezium is healthy and not collapsed.

Lastly, pyrocarbon implants can salvage total prosthesis or trapeziectomy failures.

Conventional alternatives are always possible in case of failure with pyrocarbon implants.

We recommend not using pyrocarbon implants in case of severe Z deformity of the thumb column. The models currently available are not able to restore thumb length and correctly realign the metacarpal base. Other techniques seem preferable until new pyrocarbon implants specifically designed for this indication are developed.

Human and animal rights

The authors declare that the work described has not involved experimentation on humans or animals.

Informed consent and patient details

The authors declare that they obtained a written informed consent from the patients and/or volunteers included in the article and that this report does not contain any personal information that could lead to their identification.

Disclosure of interest

The author has a conflict of interest with Tornier Wright Medical.

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Supplemental material

This is the address online of the supplemental material: https://youtu.be/_pOgo7qW27Y.

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