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ARTICLE

Partial trapeziectomy and pyrocarbon interpositional implant (Pyrodisk) for trapeziometacarpal osteoarthritis in the active working population: outcomes of a 10 years-experience

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ABSTRACT

The treatment of trapeziometacarpal (TM) osteoarthritis is still debated, as many surgical options are available, and no technique has proven to be superior. Prosthetic treatment in this context has been described since the early 60s. Recently, the use of pyrolytic carbon-based prosthesis has revolutionized arthroplasty surgery in the hand. We performed a retrospective investigation of our surgical management of TM osteoarthritis since 2010 including the study only patients treated with partial trapeziectomy and Pyrodisk implant, with at least 5 years follow-up. After the application of inclusion criteria, 26 patients (6 males and 20 females) were retained. Despite the literature suggesting that implant TM surgery is well suited for older patients, in our experience, the procedure was mainly proposed to the young manual worker, with high demands in terms of thumb strength and stability (mean age of 53 years old, range 37–65). A statistically significant improvement in post-operative DASH, Kapandji and scores was observed. As well, strength measurements, particularly pinch strength and grip strength, increased significantly after the surgery. According to our findings, the Pyrodisk implant provides satisfactory results in terms of thumb strength and stability even in young and active patients and should therefore be considered as a valuable option in selected cases. Meticulous surgical procedure is mandatory in order to avoid complications and should therefore be executed by an expert surgeon.

Abbreviation: IV: level of evidence

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Trapeziometacarpal osteoarthritis; active working population; pyrocarbon interpositional implant; Eaton–Littler classification

Introduction

The trapeziometacarpal (TM) osteoarthritis is the second most common degenerative joint disease in the human with an overall incidence that can exceed 10%, involving about one in four women over age 55 [1–3]. A wide range of symptoms is associated in those cases, including pain at the thumb base, reduced thumb range of motion (ROM) and lack of strength [4,5].

The thumb has a key role in hand ergonomy, enabling pinch and grip functions; arthritis at this level can be therefore particularly disabling, affecting the patient's ability to work and perform routine actions.

Although conservative management can be attempted in milder cases, surgery remains the only valid option for the more advanced stages [1]. Several surgical options are available, including trapeziectomy, ligamentoplasty, arthrodesis, metacarpal osteotomy and joint replacements, according to different stages of the disease and patient's needs. Each method has its own benefits and disadvantages and no technique has proven to be superior [6]. The shared goal among these procedures is to preserve the TM space, enabling strength and motion recovery.

Prosthetic treatment in such context has been described since the early 60s, using silicone implant first and polyethylene-metal joint implant, both cemented and uncemented, afterward [7–9]. However, the high rate of failure (due to dislocation, synovitis, metallosis and aseptic loosening) has limited the widespread of these techniques [1,10,11].

Recently, the use of pyrolytic carbon-based prosthesis has revolutionized arthroplasty surgery in the hand. This material is inert, with long-term biological compatibility and a module of elasticity similar to the cortical bone, reducing stresses at the bone-implant surface [12–14].

The PyroDisk (Integra LifeSciences Services, France) is a non-anatomic interposition implant made of pyrocarbon, introduced in 2005 in the US, with a biconvex disk shape and a central hole to allow implant alignment and stabilization with a tendon [1,2]. Different implants sizes are available, enabling the surgeon to select the most suitable for each patient.

Previous literature supported the validity of prosthetic treatment in the aging population, considering this surgical strategy ideal to reduce pain while being suboptimal in terms of stability and range of motion [10]. In the literature, the use of the interpositional implant in the active working population is controversial and still debated [15]. This work retrospectively reviews our experience in the surgical treatment of TM arthritis in active and demanding patients, with a grade II–III according to Eaton–Littler, using the Pyrodisk implant. Surgical technique and indications are discussed together with general and functional outcomes over a 10-year experience.

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Patients and methods

A retrospective investigation was performed on a prospectively maintained database, including all patients treated by the same senior author (A.M.) for TM osteoarthritis from November 2009 to June 2015. According to senior author experience and consistently to previous literature [1] indications for TM arthroplasty were the failure of non-operative treatment with disabling TM pain and radiographic evidence of stage II-III TM osteoarthritis according to Eaton–Littler classification. Moreover, the procedure was proposed particularly to the manual worker, young patients (40–60 years old) with high demands in terms of thumb strength and stability. Patients with scaphotrapeziotrapezoidal osteoarthritis, rheumatic disease, or previous trapeziometacarpal joint operations were considered not eligible for this procedure.

After gathering patients' data (including occupation), we analyzed only patients less than 65 years old, with active routine activities involving manual work (either occupational or hobbies). A minimum of 60 months of follow-up was required to be included in the study.

Demographics, co-morbidities and surgical-related details were collected from clinical, operative and anesthesiologic charts.

According to internal follow-up protocol, all patients underwent standard radiograph pre-operatively (postero-anterior and lateral views), in the immediate post-operative period and at the last follow-up. The implant position and alignment were evaluated according to previous experience [1], involving an independent radiologist blinded to the study.

Functional evaluations were performed preoperatively and at last follow-up in the outpatient clinic by a hand physiotherapist blinded to the study. Active range of motion (ROM) of the thumb was measured with a goniometer, while grip strength and key pinch were measured using a JAMAR hydraulic dynamometer (Baseline, White Plains, NY, USA) on both affected and unaffected sides. Three measurements were performed for each parameter, the obtained values were then averaged together. The Kapandji score (out of 10 points) was used to rate thumb opposition and abduction, with 0 indicating no opposition and 10 complete opposition. A VAS score (Visual Analog Scale, out of 10 points) was used to evaluate pain (0 no pain, 10 maximum pain) and patient satisfaction (0 no satisfied, 10 completely satisfied), while the functional outcomes were assessed according to validated score such as DASH (Disability of the Arm, Shoulder and Hand, out of 100 points). Patients' occupations and the recovery time necessary to resume previous activities were recorded.

Informed consent was obtained from all patients, including approval for photographic/video documentation.

Surgical technique

All patients were treated by the same senior surgeon (A.M., level 5 experience surgeon according to Tang et al.), under tourniquet control and axillary block anesthesia.

Prophylactic antibiotics are routinely administrated. The surgical technique is performed according to previous authors [2,15,16]. A longitudinal incision is made along the radial base of the first metacarpal, the radial sensory nerves and the radial artery are identified and protected. A transverse capsulotomy of the TM joint is performed exposing the bones; a conservative bone resection (2–3 mm) from the base of the first metacarpal and the distal part of the trapezium is carried out with an oscillating saw, carefully removing the articular surface and exposing the cortical bone on both sides. Precise control of the saw inclination is of paramount importance in this phase: the cut should be parallel to the axis of the metacarpophalangeal (MP) joint, preserving a parallel alignment between the trapezial saddle and the metacarpal base. With a specific tool, all osteophytes on the radial and ulnar aspect of the metacarpal base are removed and a complete joint synovectomy is performed. A 3.2 mm drill is used to make the first hole through the trapezium, from the scaphotrapezial joint to the center of the TM joint, and a second hole 1 cm distal to the metacarpal base on the dorsal radial aspect of the bone. The medullary canal of the metacarpal is entered with the same instrument, connecting the dorsal hole. With the help of trials implant and intraoperative fluoroscopy, the proper implant size (diameter and height) is selected: the target is to have a gentle rocking and good gliding of the implant on both the trapezium and the metacarpal base. To mirror the convexity of the implant, a reamer is used to create a mild concavity on the distal surface of the trapezium and the metacarpal base. The definitive implant is positioned and therefore stabilized with an ulnar bundle of the flexor radialis carpi: preserving an intact distal insertion, the tendon is passed through the base of metacarpal bone, in the center hole of the Pyrodisk and in the trapezium, sub-sequentially. The tendon is then sutured at the right tension to the joint capsule using interrupted braided sutures.

Post-operative care and follow-up

After the surgery, a thumb spica cast is maintained for 3 weeks; within this period, physiotherapy is started according to internal rehabilitation protocol, performing passive mobilization in flexion and extension of the fingers and thumb without removing the cast. At 3 weeks, the sutures are removed, and the implant position is checked with standard radiographies. Afterward, the cast is removed 6–8 times a day to perform active and passive mobilization gradually increasing the motion of the wrist, fingers, and thumb, together with electrostimulation of the wrist and forearm muscles.

After 6–8 weeks, depending on patient comfort, a light splint in neoprene is used and the patient is encouraged to perform daily activities with the hand. At 10–12 weeks the splint is removed, and unrestricted routine is allowed.

Statistical analysis

Preoperative functional and surgical outcomes were compared with postoperative values. Firstly, we verified the assumption of normality using the Shapiro-Wilk test. If values were normally distributed, independent non-parametric two-sided *t*-tests were used, while Mann–Whitney tests were used when values were not normally distributed.

Comparisons of range of motion, force recuperation (grip and pinch strength) and pain data (VAS) were performed among preoperative, postoperative and contralateral values using ANOVA multiple comparison tests.

Statistical significance was set at a p-value <0.05. Statistical analysis was performed using GraphPad Prism (version 8.0, GraphPad Software, La Jolla, CA).

Results

30 patients met the inclusion criteria and were retained for the study. 4 were excluded because of incomplete postoperative data collection. Finally, 26 patients were included. Patients' demographics are presented in Table 1. There were 6 males and 20 females, with a mean age of 53 years old (37–65). Dominant hand

was involved in 18 patients (70%). The mean duration of follow-up was 81 ± 24 months (128–60). Based on the pre-operative radiological staging of the TM osteoarthritis, there were 9 Eaton–Littler stage II and 17 stage III. Patients' occupations are presented in Table 2.

Table 1. Demographics and other characteristics of patients.

Characteristic	Value
Gender (male/female)	6/20
Mean age (range) in years	53 (37–65)
Mean follow-up (range) in months	81 (60–128)
Dominant hand injured	18/26
Eaton–Littler stage II/III	9/17

Table 2. Type of work and return to work after surgery.

Characteristic	Value
Patients (male/female)	6/20
Factory worker (male/female)	2/5
Sports Teachers (personal trainers, tennis teachers) male/female	2/4
Public officers (military, police) (male/female)	2/5
Housekeeper (male/female)	0/8
Return to work < 3 months (male/female)	4/14
Return to work from 3 to 6 months (male/female)	2/5
Return to work from 6 to 9 months (male/female)	0/1

Postoperative results are summarized in Table 3. No statistical differences were found comparing TM, MCP (metacarpal phalangeal) and IP (interphalangeal) motion between pre-operative and post-operative values. Strength measurements, particularly pinch strength and grip strength increased significantly after the surgery from an average of 3 and 10 kg pre-operatively to 3.8 and 21 kg at the last follow-up, respectively, ($p < 0.001$). A statistically significant improvement was seen in the DASH and Kapandji scores comparing the pre-operative and post-operative data ($p < 0.0001$). 14 patients were completely pain-free after the surgery, 14 patients had occasional mild pain (VAS 1–2) while 2 continued to complain of pain requiring painkillers (VAS 3–5). No patient described major limitation to routine activities and all patients, but one was either satisfied or highly satisfied (VAS 8–10) with the surgery (Figure 1). 18 patients could resume their previous work less than 3 months after surgery, while only in one case it required more than 9 months because of implant dislocation and reintervention.

Among complications, one implant dislocation (Figure 2) was seen in a symptomatic patient (3%) at 6 months, the patient required a trapeziectomy with tendon interposition and achieved good functional outcomes at the last follow-up.

Table 3. Pre-operative and post-operative outcomes.

Outcomes	Preoperative	Postoperative	Contralateral	*p*-Value
Range of motion (degrees)				
Flexion TM, mean (SD)	10 (4)	13 (4)	13 (4)	>0.05
Flexion MP, mean (SD)	45 (14)	49 (9)	51 (8)	>0.05
Flexion IP, mean (SD)	48 (8)	52 (9)	56 (10)	>0.05
Grip strength, mean (SD) in kg	10 (5)	21 (4)	27 (4)	0.0001
Pinch key strength, mean (SD) in kg	3 (1)	3.8 (1)	4.5 (1)	0.001
Kapandji score, median (IQR)	5 (2)	9 (2)		0.0001
VAS pain, median (IQR)	8 (2)	2 (2)		0.0001
DASH score, mean (SD)	56 (12)	17 (8)		0.0001

SD was used for normally distributed values, while IQR for the non-normally distributed. *p*-Values are related to pre- and post-op values.
SD: standard deviation; TM: trapezial-metacarpal; MP: metacarpal-phalangeal; IP: interphalangeal; IQR: interquartile range; RL: radiolunate; VAS: Visual Analogue Scale; DASH: Disability of Arm, Shoulder and Hand;.

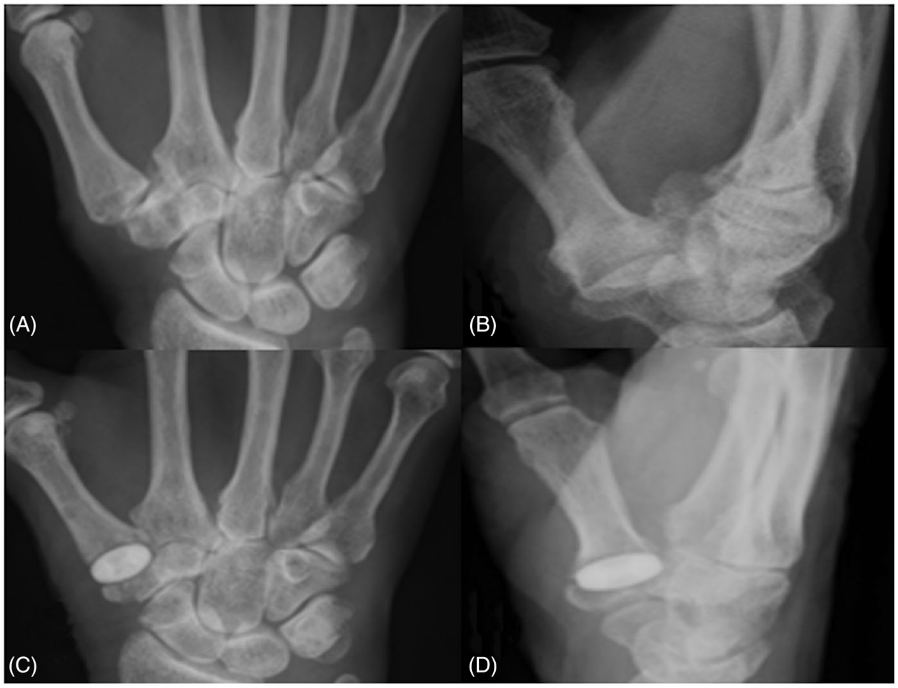

Figure 1. Sagittal (A–C) and coronal (B–D) radiographs of a stage II rizoarthrosis according to Eaton–Littler classification preoperatively and at 66 months follow-up, following a trapeziometacarpal arthroplasty with Pyrodisk. The implant is well positioned, and no sign of implant loosening are seen.

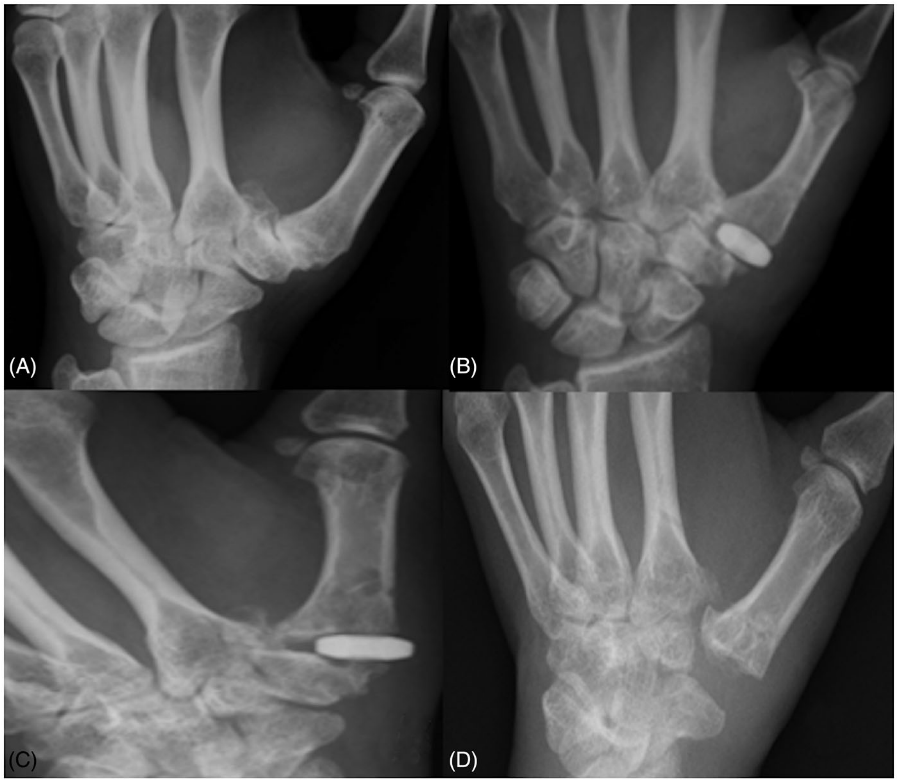

Figure 2. Pre-operative (A) and immediate post-operative (B) radiographs showing the positioning of the Pyrodisk implant in a 40 years old woman. Implant dislocation (C) occurred at 6 months and was successfully treated with the ablation of the implant and trapeziectomy with tendon interposition (D).

Table 4. Radiographic outcome implant position at the last control according to the Barrera-Ochoa classification.

	Value at last follow-up
Total implant	26
Centered	15
Mild displacement (one-fourth displaced)	8 (asymptomatic)
Moderate displacement (one-half displaced)	2 (asymptomatic)
Dislocation (more than one-half displaced)	1 (revision)

Radiographic outcomes are reported in Table 4. Among the 25 implants that were evaluated at the last follow-up (excluding the one dislocated), 15 were centered in relationship with the first metacarpal long axis, 8 presented a mild displacement and 2 a moderate displacement. As patients were asymptomatic it was not possible to determine if the incidence of implant dislocation was related to the time since surgery, however, no further revision surgeries were needed according to our follow-up. Periprosthetic osteolysis was seen in 3 patients, again those findings did not correlate with clinical symptoms or instability of the implant.

Discussion

A recent Cochrane review comparing different surgical procedures for rizoarthrosis management was not able to identify a clear superiority of one technique [6,17].

Trapeziectomy with or without soft tissue reconstruction is among the most popular technique for operative treatment of advanced TM ostheoartritis [18].

Despite the good long-term outcomes and low complications rate expected [19–21], a significant reduction in the TM space has been described, even when the trapeziectomy is associated with ligament reconstruction and tendon interposition [19].

The literature has not yet clarified the association between the residual trapezial height and functional outcome. However, the contact between the metacarpal and scaphoid can result in mechanical pain and subsequent loss of thumb function [22].

According to Imaeda et al. [13], the unique motion of the TM joint cannot be simulated by a trapeziectomy with LRTI, because of a change in the center of rotation/pivot point in the flexion/extension and abduction/adduction movements, arming the patient ability to perform the strong and stable motion.

TM arthrodesis is considered a controversial option: on one side it can provide good grip and pinch strength recuperation [23] making it useful in active patients; on the other side, a reduced range of motion of the thumb should be expected, together with a progression of degenerative change at the STT joint and an incidence of bony non-union that can be as high as 50% [24,25].

In this context, joint replacement can be attractive, because the theoretical preservation of trapezoidal space height results in greater thumb strength [23].

Regardless of the type and shape of the employed implant, a satisfactory post-operative thumb function with an acceptable long-term survival rate is described by the vast majority of recently published literature [1,2,15,26]. However, the unreliable rate of reported complications, particularly, implant dislocation, remains a big issue when referring to this technique [26].

Ball-and-socket implants have been used in TM joint replacement for more than 40 years [27]. Despite the introduction of the cement-less joint prosthesis, the aseptic loosening rate can reach an incidence of 50%. Moreover, the quality of bone in the trapezium is a major problem in establishing a stable bony fixation with high risks of traumatic fracture of the trapezium following the surgery [28].

Several implant materials have been proposed for total joint arthroplasty in TM arthritis. The pyrocarbon is gaining popularity over others because of the minimal wear and the high durability, producing slightly better outcomes, and it is routinely used as implant material in joint arthroplasty in different anatomical locations [29,30].

Among pyrocarbon implants, Colegate et al. compared the trapeziectomy (14 patients) and the PI2 (Tornier, San Diego, CA, USA) pyrocarbon interposition implant (24 patients), concluding that the implant does not significantly improve postoperative function, while it requires a longer operation with an increased rate of revision surgery.

Similarly, Martinez de Aragon et al. [12], using the Nugrip (Integra, Austin, Texas) hemiarthroplasty implant in 49 patients, described a failure rate of 16% in a two-year follow-up, being the subluxation the most common complication. Noteworthy, in the reported technique, in order to prevent MCP hyperextension, the extensor pollicis brevis and the abductor pollicis longus are advanced and sutured to the joint capsule, producing a tenodesis at the base of the thumb and thus limiting the post-operative range of motion.

Odella et al. compared the effectiveness of the Pyrocardan implant (Tornier, Montbonnot Saint Martin, France) ($n = 25$) relative to the PyroDisk ($n = 34$) in low-demanding patients. Even though both implants were effective in providing pain relief, maintaining a good range of motion and a satisfactory grasp strength, the Pyrocardan led to more revision surgery when compared to the Pyrodisk (12% and 2.8% respectively) [2].

On the other hand, promising [17,31], and our study is consistent with those findings. In our series, only one dislocation occurred, comparing favorably with the high dislocation rate described for other pyrocarbon interposition implants (Pyrocardan and Pi2) occurring in up to 30% of patients in the short term [32,33].

When using a meticulous surgical technique, Pyrodisk placement allows for a minimal resection of the articular surfaces, at the same time preventing proximal migration of the thumb and preserving first ray length [17]. Such details may be the basis to explain the strength recuperation experienced in our series.

Moreover, the implant is a little invasive, and it does not jeopardize the use of more conventional techniques in case of failure. Results are generally long-lasting if no early dislocation occurs in the first year, as previously reported [16].

Of over 300 TM osteoarthritis surgeries performed in the last 10 years, less than 10% were implant-based. This reflects the strict pre-operative patient selection, which is mandatory considering the costs of the implant and the apparent lack of benefit over other surgical techniques [1,15]. In our experience, the TM arthroplasty with Pyrodisk fits particularly young patients (usually $<$ 65 years old), with high functional requirements because of an active day life routine and manual jobs, with the intent to guarantee good strength and stability of the thumb (compared to trapeziectomy and ligamentoplasty) while preserving mobility [1,16,32]. Moreover, the quality and established durability of the new materials justifies the application of Pyrodisk implants in the younger population. This finding is consistent with what was recently described by Smeraglia et al. [15] In their long-term follow-up study (8 years) including 46 patients treated with Pyrodisk implant, they stated that because of the longevity of the implant and the good clinical outcomes it could be suited particularly for the younger patient (<60 years old).

We believe that technical details play a major role in final outcomes as implant stability relies on meticulous surgery: Pyrolitic implantation must be executed by an expert surgeon because it demands great precision in bone resection [2], it is mandatory to remove all lateral osteophytes at the base of the first metacarpal in order to avoid the dislocation of the implant and particular care should be taken in centering the tunnels for the tendon bundle for implant stabilization [1,16].

Conclusion

This study presents a 10-years' experience with the Pyrodisk implant for the treatment of TM osteoarthritis in active patients under 65 years old. The implant provided satisfactory results in terms of thumb strength and stability and should therefore be considered as a valuable option in selected cases.

We acknowledge the retrospective nature of this study and the low number of patients enrolled, together with the lack of a comparative group. Further studies with higher statistical relevance are required in order to reduce skepticism around this technique.

Ethical approval

Not applicable.

Informed consent

Written informed consent was obtained from the patient(s) for their anonymized information to be published in this article.

Authors' contributions

AM and FV researched literature and conceived the study. FV, GS and PDS were involved in protocol development, patients recruitment and data analysis. FV and GS wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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Disclosure statement

The authors declare no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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