Early Outcomes of Pyrolytic Carbon Hemiarthroplasty for the Treatment of Trapezial-Metacarpal Arthritis

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Purpose Pyrolytic carbon implants have been successfully used in the treatment of osteoarthritis of the metacarpophalangeal and proximal interphalangeal joints. Recently, pyrolytic carbon hemiarthroplasties have been proposed for the treatment of osteoarthritis of the trapezial-metacarpal (TM) joint of the thumb. We wished to review our short-term outcomes for this device in the treatment of TM arthritis.

Methods Fifty-four arthritic TM joints in 49 patients, with a mean age of 59 years, were treated with use of a pyrolytic carbon hemiarthroplasty procedure. Underlying diagnoses included osteoarthritis in 44 thumbs, rheumatoid arthritis in 8 thumbs, psoriatic arthritis in 1 thumb, and juvenile rheumatoid arthritis in 1 thumb. The patients were followed up clinically as well as radiologically for an average of 22 months postoperatively.

Results The overall 22-month survival rate excluding scaphotrapezio-trapezoidal joint arthritis was 80% according to a Kaplan-Meier analysis. Ten metacarpal subluxations were observed. Seven of these cases were salvaged by increasing the depth of the trapezial cup. A total of 15 reoperations were required in this cohort. No complications were seen in the patients with inflammatory arthritis. Thirty-five patients were pain free at the latest follow-up, and 6 reported mild to occasional pain with repetitive activities. The overall satisfaction rate was 40 of 49 patients (81%). Grip strength recovered to 86% of that of the contralateral side. Apposition key and opposition pinch strength improved to 92% and 95%, respectively, of those of the contralateral hand.

Conclusions Pyrolytic carbon thumb arthroplasty may prove to be an acceptable option for the treatment of TM, although a high complication rate was observed in this early cohort, with many cases of subluxation attributed to the creation of a too shallow trapezial cup. Further comparative studies are warranted. *(J Hand Surg 2009;34A:205–212. © 2009 Published by Elsevier Inc. on behalf of the American Society for Surgery of the Hand.)*

Type of study/level of evidence Therapeutic IV.

Key words Arthroplasty, pyrocarbon, thumb arthritis.

THE THUMB IS the most important digit of the human hand, enabling grip and pinch function. Fifty percent of the workload in the human hand is assumed by the thumb.[1] Because of its extensive use, the trapezial-metacarpal (TM) joint is a site plagued by degenerative, posttraumatic, and other inflammatory arthritides and is the second most common joint affected by degenerative diseases.[2] Joint space erosion can result in marked pain, whereas altered joint mechanics lead to limitations in range of motion

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R.D.B. consults for Ascension Orthopedics and receives royalties from the sale of pyrolytic carbon implants.

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(ROM) and strength. The treatment of TM arthritis, however, remains challenging. Many treatment options have been reported ranging from conservative management to operative intervention.

The most common operative procedures for TM arthritis are ligamentoplasty, trapeziectomy (with or without tendon suspension or interposition arthroplasty), arthrodesis, wedge osteotomy, and arthroplasty. The potential advantages of joint arthroplasty are the preservation of thumb length and motion with pain relief and enhanced stability. TM prostheses were first developed in 1959.[3] The first successful arthroplasty used the Swanson silicon spacer, developed in 1965.[4] This was followed by several cemented and uncemented ball-and-socket polyethylene-metal designs.[5–11] A major problem with the polyethylene-metal prosthesis design was the wear of the polyethylene cup, due to the small size of the head, which would erode into the cup.[11] Steel metal-on-metal prostheses provided a good alternative, demonstrating durability; however, aseptic loosening, particulate wear, and metal allergies remained a problem.[12]

Pyrolytic carbon, in comparison with previous prostheses, is a synthetic material developed in the 1960s. Pyrolytic carbon has an elastic modulus that is similar to that of cortical bone, which aids in dampening stresses at the bone–prosthetic interface and enhances biological fixation. In addition, pyrolytic carbon has been found to have excellent long-term biological compatibility.[13,14] In this retrospective chart review study, we report the early results in 54 cases of TM osteoarthritis treated with an uncemented pyrolytic carbon hemiarthroplasty placed into the base of the thumb metacarpal.

MATERIALS AND METHODS

After institutional review board approval, a retrospective review was performed on all patients having treatment of TM arthritis with use of a pyrolytic implant (Ascension Orthopedics, Austin, Texas). Between 2004 and 2006, 54 TM joint arthroplasties were performed in 49 patients. Forty-two arthroplasties were performed in women and 12 were performed in men with a mean age of 57 years (range, 38–76 years; SD 10) and 64 years (range, 54–83 years; SD 8), respectively, at the time of surgery. Twenty-four dominant hands were treated. The mean follow-up was 22 months (range, 6–54 months; SD 14). Indications for surgery were disabling pain and difficulties in performing their current job or activities of daily living. All patients had radiographic evidence of TM arthritis, defined as an Eaton score of 2 or 3.[15] Exclusion criteria for surgery included any patient with evidence of concomitant scaphotrapezio-trapezoidal joint arthritis.

Underlying diagnoses included osteoarthritis in 44 thumbs, rheumatoid arthritis in 8 thumbs, psoriatic arthritis in 1 thumb, and juvenile rheumatoid arthritis in 1 thumb. No patient had had previous thumb surgery. The average range of symptom duration was 10 months and ranged from 1 to 100 months (SD 15).

Hand function evaluation included goniometric measurements of the metacarpophalangeal (MCP) joint extension/flexion, interphalangeal (IP) joint extension/flexion, radial abduction, and palmar abduction. Grip strength was measured with a Jamar dynamometer, and appositional (key) and oppositional pinch were measured with a pinch dynamometer. All measurements were made by a single senior nurse skilled in evaluation of thumb and hand function.

Function and radiographic measurements were made preoperatively, 12 weeks postoperatively, and at the latest follow-up. The number of available findings for each measurement is reported in Table 1 and Table 2. Eight patients (8 implants) had MCP joint arthrodesis at the time of the TM arthroplasty; these patients were not included in the MCP joint ROM evaluation. Metacarpophalangeal joint arthrodeses were performed in patients with greater than 30° of hyperextension at the MCP joint preoperatively.

The mean radiographic follow-up was 21 months (range, 5–54 months). Measurements and observations were based on the postoperative and the most recent radiographs. Radiographs were inspected for osteolysis and signs of loosening as evidenced by an increase in the normal radiolucent line surrounding the pyrocarbon prosthesis. For accuracy purposes, the prosthesis was divided into 4 zones (Fig. 1). Osteolysis and radiolucency were recorded independently for each zone.

Thumb hemiarthroplasties were performed with the proximal component of the "Ascension MCP" implant. The proximal component of the two-piece arthroplasty, originally designed for implantation within the metacarpal head of the MCP joint, is press-fit into the thumb metacarpal shaft. The prosthesis is composed of an 0.5-mm pyrocarbon layer encasing a machined graphite substrate. The graphite substrate material is impregnated with a small amount of tungsten (1 atomic percent) to be more radiopaque; however, the 0.5-mm pyrocarbon casing remains radiolucent on plain radiographs (Fig. 2). Thus, all well-seated implants should

TABLE 1. Range of Motion and Strength of the Operated Hand at Follow-Up Compared With Preoperative Measurements

	Preoperative			Last Follow-Up			
	n	Mean	SD	n	Mean	SD	*t*-Test (p)
ROM							
TM joint palmar abduction (°)	50	41	11	48	41	11	.650
TM joint radial abduction (°)	50	39	13	48	36	10	.216
MCP joint flexion (°)	38	41	20	35	35	14	.019*
MCP joint extension (°)	54	5	16	35	−1	11	.057
IP joint flexion (°)	37	49	16	44	50	17	.775
IP joint extension (°)	37	8	13	44	4	14	.130
Strength							
Grip (kg)	45	16	13	43	19	14	.254
Apposition (kg)	48	4	4	40	5	4	.496
Opposition (kg)	33	3	3	28	4	3	.602

−, degrees of extension deficit.
*Significant at $p < .05$.

TABLE 2. Range of Motion and Strength at Follow-Up Compared With the Contralateral Hand

	Operated Hand			Contralateral Hand			
	n	Mean	SD	n	Mean	SD	*t*-Test (p)
ROM							
TM joint palmar abduction (°)	48	41	11	33	44	10	.092
TM joint radial abduction (°)	48	36	10	33	39	10	.067
MCP joint flexion (°)	35	35	14	30	42	20	.056
MCP joint extension (°)	35	−1	11	30	2	15	.088
IP joint flexion (°)	44	50	17	30	47	20	.931
IP joint extension (°)	44	4	14	30	10	18	.169
Strength							
Grip (kg)	43	19	14	44	22	14	.008*
Apposition (kg)	40	5	4	40	6	3	.043*
Opposition (kg)	28	3.8	3	28	4	3	.199

−, degrees of extension deficit.
*Significant at $p < .05$.

have a uniform lucent silhouette on radiographs. This normal lucent line should not be confused with osteolysis associated with loosening.[16,17] Fixation is achieved through its press-fit design, without the need for cement. The implant is available in 5 sizes, ranging from 10 to 50. Size 30 was the most frequently used, being implanted in 27 thumbs; followed by size 20 in 17 thumbs.

Surgical technique

Through a longitudinal incision over the first dorsal compartment, the scaphotrapezio-trapezoidal joint was inspected to rule out scaphotrapezio-trapezoidal joint arthritis and the metacarpal base was mobilized. If scaphotrapezio-trapezoidal joint arthritis was present, the patient was converted to a complete trapeziectomy with ligament suspension plasty procedure. The tech-

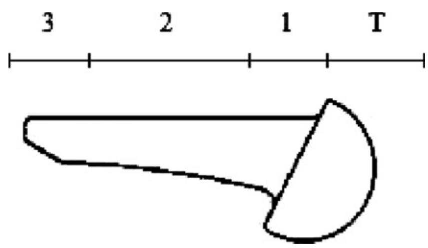

FIGURE 1: Zones of osteolysis or radiolucency. T, trapezial/implant interface; 1, proximal stem; 2, middle stem; 3, distal stem.

FIGURE 2: A pyrolytic carbon implant 17 months postoperatively. The implant shows a clear radiolucent line all around the prosthesis. This uniform lucent line should not be confused with osteolysis associated with loosening.

nique for preparation of the metacarpal is similar to that used for MCP joint arthroplasty.[16] Once the TM joint is exposed, the starter awl is used to identify the medullary canal of the metacarpal. The alignment and cutting guide is then placed within the medullary canal. An oscillating saw is placed within the saw guide and used to start the cut dorsally to the center of the guide. The angle of the cut is 28°. Once the osteotomy has been initiated, the guide is removed, and the remaining portion of the osteotomy is completed freehand.

Once the articular surface is excised, the intramedullary canal is prepared with the broaches. The canal is prepared to accept the largest implant that will fit in the metacarpal easily. Intraoperative fluoroscopy is used liberally throughout the procedure to ensure central placement of all broaches and awls within the coronal and sagittal planes. Broaching is stopped when the sized reamers are seated just below the bone edge. Final implants tend to be slightly larger than trial components.

Using a round, 8-mm or 10-mm burr, a socket is made in the center of the trapezium. Once the cup has been created, the trial implant is placed into the metacarpal, and the thumb is reduced and stability assessed. If the thumb metacarpal subluxates dorsal after initial reduction, the socket is of inadequate depth, and the trapezial cup is deepened. The trapezial cup may be safely deepened to a level equal with the distal third of the trapezium. An adequately created joint, with a trapezial cup of the appropriate depth, should remain reduced throughout circumduction maneuvers as well as 20° of radial and palmar abduction, prior to dorsal capsular closure. If deepening of the trapezial cup does not produce adequate stability, the metacarpal base may be additionally shortened. Once the trapezial cup has been created, the metal trial is exchanged for the permanent implant. The implant is gently impacted into the metacarpal base. The implant should not be completely seated flush against the metacarpal base but left 2 to 3 mm proud; this is done to avoid bony impingement of the metacarpal base against the dorsal trapezial lip during full radial abduction of the thumb.

A tight capsular closure is then performed with the thumb held in radial abduction. The abductor pollicis longus tendon was advanced dorsally and distally to reattach to the base of the metacarpal and sutured in place at the capsule. The extensor pollicis brevis was advanced and sutured to the repair, producing a tenodesis at the base of the thumb metacarpal. Once the overall construct was stable, a plaster splint was applied to maintain the thumb in wide abduction and the MCP joint in flexion. In this initial series, a cast was maintained for 4 to 6 weeks. A thumb spica splint was then worn for an additional 6 weeks, during which time range of motion exercises and hand rehabilitation was performed. The mean time of cast and splint wear within this study was 13 weeks and ranged from 2 to 45 weeks (SD 8). One patient did require extended splint wear (45 weeks) due to implant subluxation. Implant subluxation was corrected with revision surgery, but the

TABLE 3. Complications

TM Implant	Complication	Gender	Age (y)	Implant Removal	Reason for Implant Removal	Revision (Months After Surgery)	Final Treatment
1	Pain/trapezial fracture	F	67	Yes	Trapezial fracture	8	Trapeziectomy/ligament suspension
2	Pain/implant loosening	F	63	Yes	Aseptic loosening	15	Trapeziectomy/ligament suspension
3	Pain/implant loosening	F	47	Yes	Aseptic loosening	7	Trapeziectomy/ligament suspension
4	Pain/implant loosening	M	66	Yes	Aseptic loosening	8	Trapeziectomy/ligament suspension
5	Dislocation	F	61	Yes	Irreducible subluxation	19	Trapeziectomy/ligament suspension
6	Dislocation	F	65	Yes	Trapezial fracture	1	Trapeziectomy/ligament suspension
7	Dislocation	F	63	Yes	Subluxation requiring larger implant	2	Cup deepened, implant exchange
8	Dislocation	M	74	Yes	Iatrogenic coating damage during socket deepening	3	Cup deepened, implant exchange
9	Dislocation	M	54	Yes	Subluxation requiring larger implant	10	Cup deepened, implant exchange
10	Dislocation	M	53	No	N/A	1	Cup deepened/joint reduced
11	Dislocation	F	62	No	N/A	0	Cup deepened/joint reduced
12	Dislocation	F	47	No	N/A	0	Cup deepened/joint reduced
13	Dislocation	F	51	No	N/A	0	Cup deepened/joint reduced
14	Dislocation	F	62	No	N/A	6	Closed reduction
15	Pain/scaphotrapezio-trapezoidal joint arthritis	M	57	N/A	N/A	16	Trapeziectomy/ligament suspension

N/A, not applicable.

patient remained splinted after surgery for ongoing discomfort. Average follow-up for this cohort was 20 months.

Statistics

Differences within the groups were determined with Wilcoxon signed-rank tests or Student's paired *t*-tests for normally distributed data. McNemar test was used for the comparison of nonparametric values. We used the Kaplan-Meier method for the survival analysis of all 49 thumbs. All analyses were performed using statistical software (SPSS ver. 13.0; SPSS Inc, Chicago, IL). Means and standard deviations are given unless otherwise stated.

RESULTS

Fifty-four prostheses were placed in 49 patients. Nine prostheses were removed or exchanged during the follow-up period. The reasons for revision or salvage trapeziectomy were iatrogenic scuffing to the surface of the implant, necessity for a bigger implant after subluxations, particular synovitis with aseptic loosening, intolerable pain, and trapezium fracture (Table 3). The 22-month survival rate was 80% (95% CI, 0.68–0.92) (Fig. 3) according to a Kaplan-Meier analysis with revision or trapeziectomy as the endpoint.

Preoperatively, the average radial and palmar abduction were 39° and 41°, respectively, compared with

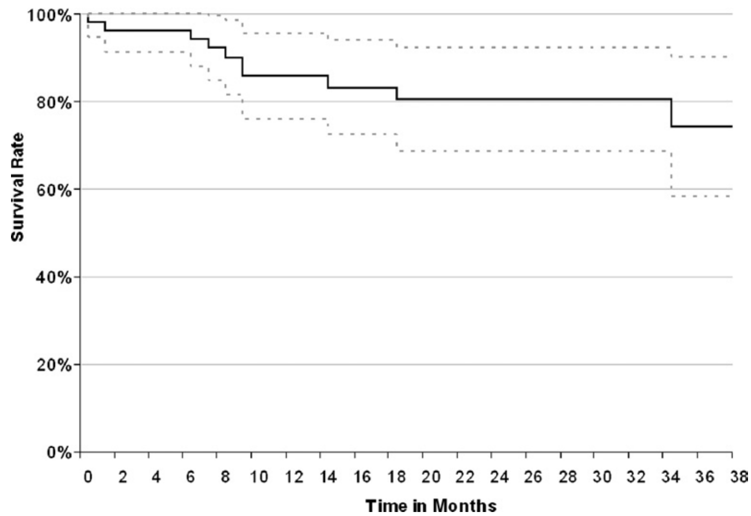

FIGURE 3: A Kaplan-Meier survival curve in which revision or trapeziectomy was considered the end point. The graph shows a 22-month survival rate of 80% (95% CI, 0.68–0.92).

those of the opposite hand, which were 44° and 46°, respectively. At 12 weeks postoperatively, an increase in palmar abduction was noted, from 41° to 44°. This was found to decrease back to 41° at the latest follow-up. At the latest follow-up, MCP joint flexion was reduced from preoperative values and this is owing most likely to the extensor policus brevis tenodesis performed to prevent MCP joint hyperextension (Table 1). All measurements, except IP flexion, were less than those of the contralateral hand, although no statistically significant differences were found (Table 2).

Strength slowly increased throughout the follow-up, including grip strength, apposition pinch strength, as well as opposition pinch strength. Strength increased from an average of 16 kg preoperatively to 19 kg for grip strength at the latest follow-up, and from 4 kg to 5 kg for apposition pinch strength and from 3 kg to 4 kg for opposition pinch strength. No statistical significance was found for this increase in strength (Table 1). At final follow-up, grip strength, apposition pinch strength, and opposition pinch strength remain 11% inferior to the measurements of the contralateral hand, with grip strength and apposition pinch strength being significantly lower ($p = .008$ and $p = .043$). Despite these decreases, patients were able to recover 86% of contralateral grip strength, 92% of contralateral appositional pinch strength, and 95% of contralateral oppositional pinch strength.

Thirty-five patients were reported to be pain free at the latest follow-up, and 6 patients had occasionally mild pain. Five patients continued to complain of pain that impeded daily functions; however, an overall satisfaction was reported by 40 of 49 patients (81%). Three patients did not answer this question.

Forty-three of the available 51 radiographs showed a stable radiolucent line consistent with a normal bone–implant interface (Fig. 2). Stem angular migration was seen in 2 cases . In addition, there was a single asymptomatic trapezium fracture observed in 1 patient. Revision was not necessary, as the joint remained stable and the patient did not have any discomfort. Osteolysis was noted in 3 patients. At re-exploration, these patients were found to have particular synovitis, aseptic loosening, and signs of implant wear with soft tissue staining. In these cases, a salvage procedure was performed with trapeziectomy and interposition arthroplasty. The particulate synovitis in these cases was associated with use of a diamond burr during the trapezial cup creation. Pathology examination of the removed trapeziums showed retained diamond particles remaining within the trapezial bone, and removed implants showed focal wear on their surfaces. It is presumed that these diamond particles resulted in wear of the pyrocarbon surface producing an aseptic synovitis.

No intraoperative complications were noted. Postoperative complications were observed in 15 implants (14 patients), occurring at an average of 8 months (range, 0.2–19 months) postoperatively. All 14 patients required a reoperation. Subluxation was the most common finding, present in 10 implants (10 patients) and recognized at an average of 6 months (range, 0.2–19 months; SD 7). Nine patients required operative reduction, and one patient was treated with closed reduction and casting. Stability was re-established by deepening the trapezial socket in 7 cases; 2 patients also required a larger prosthesis to improve stability. One prosthesis had to be revised because of iatrogenic coating damage during a socket revision. Two of the subluxations were posttraumatic, the result of a fall onto the thumb. Both of these cases required implant removal and joint salvage with trapeziectomy and ligament interposition. One patient required trapeziectomy and interposition arthroplasty after the development of scaphotrapeziotrapezoidal joint arthritis that was not amenable to medical management. Three patients, as mentioned previously, underwent implant removal for aseptic loosing and osteolysis. The majority of the subluxations occurred during the first 12 months of the study period.

Preoperative MCP joint hyperextension was not found to be a predisposing factor for subluxation. Preoperative MCP joint mean extension was 7° of hyperextension (range, 17° of flexion to 38° of hyperextension; SD 13.7) for the patients who developed subluxation and 5° of hyperextension (range, 25° of flexion to 55° of hyperextension; SD 16.9) for the remaining patients. No significant difference was found between the 2 groups ($p = .67$).

DISCUSSION

Trapeziectomy and ligament reconstruction for the treatment of TM arthritis produces good pain relief and preserves useful ROM, but postoperatively patients can suffer from thumb weakness and metacarpal subsidence. Since 1965,[4] TM joint prostheses made of different materials have been used for the treatment of TM arthritis in the hopes of better preserving joint function and thumb strength. Despite repeated attempts, thumb implant arthroplasty has failed to gain wide acceptance because of problems with implant loosening, implant failure through breakage, and bone loss producing decreasing hand function over time.[11,12,18–20] Pyrolytic carbon implants have potential advantages over previously used polyethylene and metal implants. Pyrolytic carbon has an elastic modulus that is similar to that of cortical bone, which aids in dampening stresses at the bone–prosthetic interface and enhances biological fixation. In addition, pyrolytic carbon has been found to have excellent long-term biological compatibility.[14] In addition, good short-term as well as long-term results have been reported with pyrolytic carbon implants within the MCP and proximal interphalangeal (PIP) joints.[13,14]

The short-term findings of our study produced mixed results. Overall, patients reported adequate satisfaction with the procedure. Pain relief was excellent in 35 of 49 patients, with an additional 6 of 49 patients experiencing pain only with markedly repetitive activities. Despite these subjective improvements, approximately 5 of 49 patients complained of ongoing pain, and no significant improvement in thumb motion could be shown after implantation. Grip strength and pinch strength did improve but did not reach statistical significance. The slight decrease in ROM seen 6 and 12 months postoperatively has previously been reported for pyrocarbon proximal interphalangeal joint prosthesis.[14] This is probably due to soft tissue fibrosis, which helps stabilize the joint. No complications were seen when this implant was used in patients with inflammatory arthritis, making it a potential option in these patients for whom preservation of thumb motion and strength is vital for continued hand function.

This early report suggests that pyrocarbon may provide benefits in terms of material properties when compared with other TM implant materials.[12,18–20] A commonly reported problem with TM prosthesis is the high rate of aseptic loosening. The cup component historically has produced more problems than has the stem, with loosening rates of up to 55% being reported in some studies.[18–20] In this short-term follow-up study aseptic stem loosening was observed in only 3 cases. Long-term follow-up will be required to ensure these implants do not loosen over time. In these cases, black staining from the prosthesis was encountered on the surrounding soft tissue and was believed to represent a particulate synovitis associated with use of the diamond burr. We have not encountered this problem since changing to standard metal 10- and 11-mm cutting burrs. Diamond cutting and polishing burrs should not be used when performing this procedure.

An additional concern with use of hemiarthroplasty is the possibility of joint subluxations. In our patients, 10 subluxations were seen, the majority of which occurred during our early experience with the implant. This high rate of dislocation can be attributed to difficulties in creating an adequate cup within the trapezium, as evidenced by the fact that 7 of these cases were salvaged with trapezial cup deepening. The surgeon is cautioned, however, against creating an excessively deep trapezial cup. Deeper sockets, while reducing the risk of subluxation, might weaken the trapezium, leading to fractures. We now strive to create a centralized trapezial cup of 3 to 4 mm in depth, or one third the height of the trapezium.

The risk of joint subluxation is something that must be discussed with the patient. Techniques that we have found useful in the prevention of dorsal subluxation include (1) adequate resection of the metacarpal base, (2) centralized cup placement within the trapezium, (3) use of larger implants, and (4) strong capsular plication at the time of closure. Final radiographs should always be assessed within the operating room to verify joint congruity after the postoperative dressing and splint have been secured.

Our implant failure rate was 16% and is comparable with those of previously reported TM arthroplasty studies, but further long-term follow-up is required before making any direct comparisons with previous implant designs.[11,12,18–20] The weaknesses of our study include its retrospective nature and short-term follow-up. Although a high complication rate has been observed in this cohort, our mistakes can help others who may wish to use this implant in the treatment of patients with TM arthritis. Ultimately, pyrolytic carbon hemiarthroplasty may prove to be an option for selected patients with TM arthritis. Further prospective controlled trials are needed to assess the benefits of this implant over more established surgical procedures for the treatment of TM arthritis.

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