Trapezium Prosthetic Arthroplasty (Silicone, Artelon, Metal, and Pyrocarbon)

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KEYWORDS

• Thumb • Trapezial-metacarpal (TM) joint • Silicone • Artelon • Pyrocarbon • Total joint arthroplasty

KEY POINTS

- Trapezium prosthetic arthroplasty has been used to treat basal joint arthritis for nearly 5 decades.
- Implant arthroplasty seeks to preserve joint biomechanics, avoid metacarpal subsidence, and provide immediate stability.
- There has been rapid development of trapezial prosthetic implants, including synthetic interposition materials, metal total joint arthroplasties and pyrocarbon trapezial arthroplasties.
- While many recently available implants have been shown to have short-term success, determining the medium- to long-term outcomes require further study.

INTRODUCTION

The basal joint of the thumb is the second most commonly affected joint by arthritis.¹ Degenerative disease of this joint can result in significant pain, stiffness, weakness, and disability. Conservative measures, such as nonsteroidal anti-inflammatory drugs, splinting, and intra-articular corticosteroid injections, can provide relief for some patients; for those with severe disease in whom nonoperative measures fail, many surgical methods are available, with successful outcomes reported in the literature. These procedures include trapeziectomy alone,²⁻⁴ trapeziectomy and ligament reconstruction with or without tendon interposition,^{2,5-9} arthrodesis,^{4,10} arthroscopic resection, 11-15 metacarpal extension osteotomy,16-19 and a variety of methods of prosthetic implant arthroplasty. To date, no single method has emerged superior, although each method has specific advantages and disadvantages for the surgeon to consider.

In contrast to ablative resection and joint fusion procedures, which sacrifice function of the basal joint in an effort to provide pain relief, prosthetic arthroplasty offers the theoretic advantages of preservation of normal anatomy and biomechanics. This could be accomplished without subsidence of the thumb metacarpal, with preservation of normal motion at the trapezialmetacarpal (TM) joint, prevention of metacarpophalangeal joint hyperextension, and immediate stability. Although the results of different joint replacement procedures of the TM joint have been variable with regards to these goals, this review summarizes the history of implant arthroplasty, evolution of prosthetic designs, and outcomes of implants available for use.

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Overview/Classification of Trapeziometacarpal Implant Arthroplasty

There is a bewildering array of implants currently available for use in thumb TM implant arthroplasty. The authors propose the following classification scheme in an attempt to bring some order into the assessment and understanding of available options.

Total Replacement

Separate trapezial and metacarpal components

- de la Caffinière (Benoist Girard et Cye, Baguaux, France)
- Braun-Cutter prosthesis (Small Bone Innovations/Avanta Orthopaedics, San Diego, California)
- Avanta Surface Replacement (SR) TM prosthesis (Avanta Orthopaedics)

Hemiarthroplasty

Anatomic

• PyroCarbon Saddle (Integra Life Sciences, Plansboro, NJ)

Nonanatomic

- CMI Carpometacarpal Implant (BioProfile/ Tornier, Edina, Minnesota)
- NuGrip (Integra Life Sciences, Plansboro, NJ)
- PyroHemiSphere (Integra Life Sciences, Plansboro, NJ)

Interposition

Partial trapezial resection

- Unconstrained
 - PyroSphere (Integra Life Sciences, Plansboro, NJ)
 - Pyrocardan (BioProfile/Tornier)
- Constrained
 - Artelon (Small Bone Innovations, Morrisville, Pennsylvania)
 - PyroDisk (Integra Life Sciences, Plansboro, NJ)

Total trapezial replacement

- Silicone (eg, Swanson [Wright Medical Technology, Arlington, Tennessee])
- Metallic (eg, TrapEZX [Extremity Medical, Parsippany, New Jersey])
- Pyrocarbon
 Pi2 (BioProfile/Tornier)

 Modified PyroDisk (Integra Life Sciences, Plansboro, NJ)

Silicone

The history of trapezial implant arthroplasty began in the 1960s, when Swanson and colleageus²⁰ proposed trapeziectomy and silicone arthroplasty to replace a degenerative TM joint. Silicone arthroplasty of the trapezium has been extensively studied over the past 5 decades, and silicone elastomer implants, such as the Swanson endoprosthesis (Wright Medical Technology) have the longest track record of any of the implant arthroplasties for the basal joint (Fig. 1).20 Results have generally been limited by silicone synovitis, secondary instability of the joint, and long-term implant failure.²¹⁻²⁴ On a histologic level, this has been confirmed by the examination of failed silicone implants of the fingers, wrist, and elbow: billions of silicone particles smaller than 15 μm were found in the inflammatory debris surrounding these implants.²⁵ Furthermore, there have been recent experimental data demonstrating oxidation of silicone elastomer finger metacarpophalangeal and interphalangeal arthroplasty in vivo, which may lead to implant fracture.²⁶

The prevalence of silicone synovitis, in the trapezium, specifically, however, has been less common a problem than that reported with carpal and small joint implants in general, although the outcomes have been mixed. In 1986, Pellegrini and Burton published their results of a series of 72 procedures in 53 patients with basal joint osteoarthritis.⁶ In a subset of 32 silicone arthroplasties at an average of 3.2-year follow-up, there was



Fig. 1. Posteroanterior radiograph of a TM joint silicone arthroplasty at 5 years postoperatively. (*From* Bezwada HP, Webber JB. Questions regarding the Swanson silicone trapezium implant. J Bone Joint Surg Am 2002;84(5):872; with permission.)

early pain relief but a 50% loss of height and subluxation of the metacarpal, with an average of 35% of the width of the prosthesis. They reported a 25% failure rate and reactive silicone giant cell synovitis with adjacent bone resorption in several cases. The investigators concluded that silicone arthroplasty was not a viable option for osteoarthritis of the basal joint, even though silicone hemiarthroplasty of the trapezium could result in satisfactory outcomes in the low-demand rheumatoid patient. Amadio and colleagues²⁷ reported on a comparison of a trapezial silicone spacer in 25 patients versus trapeziectomy alone in 25 patients and showed superior results with fewer complications in those with resection arthroplasty at a follow-up, ranging from 1 to 9 years. Lanzetta and Foucher²⁸ conducted a retrospective study of 85 patients with 98 surgical procedures divided into 3 groups-those receiving Swanson arthroplasties, patients receiving Ashworth-Blatt hemiarthroplasties, and, lastly, patients receiving trapeziectomy with ligament reconstruction and tendon interposition (LRTI). At 5 years, 15% of patients receiving Swanson arthroplasties required surgical revision, and radiographic evidence of silicone synovitis was common with one case requiring surgery secondary to this reaction. Overall, however, the results of both Swanson arthroplasty and LRTI were superior to those of the Ashworth-Blatt hemiarthroplasty.

Lehmann and colleagues²⁹ compared 27 patients treated with silicone arthroplasty with 75 patients treated with LRTI and found no differences in pain relief, range of motion, or strength between groups, although there was less radiographic subsidence of the thumb metacarpal in the group with silastic interposition. The investigators concluded that given the complication rate reported in other series, silicone arthroplasty should be limited to patients with rheumatoid arthritis in whom maximal preservation of bone stock is desirable. In 1999, Lovell and colleagues³⁰ retrospectively compared 58 cases of Swanson silicone arthroplasty with 56 cases of LRTI at an average follow-up of 5.2 years. Significantly better results were reported for pain at 1 year as well as patient-reported performance on specific tasks and overall function in those receiving Swanson arthroplasties; patients requiring further surgery or removal of the implant (8 in each group) were, however, excluded from the analysis, a major methodologic flaw, which excluded the worst results from the analysis.

Contemporary series with more rigorous outcome assessments have generally found comparable or poorer results with silicone arthroplasty compared with alternative surgical treatments. In 2002, Tagil and Kopylov³¹ reported a prospective, randomized trial of Swanson versus trapeziectomy and abductor pollicis longus (APL) suspension arthroplasty in 26 patients with osteoarthritis of the TM joint with an average follow-up of 3.6 years. There was no incidence of clinically evident silicone synovitis, but bone cysts developed in the metacarpal and the scaphoid and 2 silicone prostheses dislocated early. All 13 patients in the silicone group and 11 of 13 in the APL arthroplasty group reported that they were satisfied, and pain relief was equivalent in both groups, although half of the patients in each group had pain with heavy but not light work. Five of 13 patients in the silicone arthroplasty group had subluxation during stressed pinch. In the same year, Bezwada and Webber³² reported on the long-term results of 90 silicone arthroplasties of the TM joint in 85 patients at an average of 16.4 years of follow-up. Of the 58 patients available for follow-up (62 implants), 84% of thumbs had satisfactory results with good to excellent pain relief and function. Grip, key pinch, and tip pinch strengths increased on average. Nineteen percent of cases, however, had radiographic subluxation, and implant fracture occurred in 6% requiring revision. The investigators reported that no patients had frank silicone synovitis. In 2003, MacDermid and colleagues²² reported a series of 26 patients after silicone arthroplasty in which 88% had improvement in pain but with a 20% incidence of revision surgery and 90% rate of radiographic periprosthetic lytic changes at 6.5 years.

In 2005, Minami and colleagues³³ described unsatisfactory long-term results in 12 patients treated with silicone arthroplasty. They reported palmar abduction limited to 23°, with grip strength limited to 9.5 kg, and all but 2 patients had mild to severe pain with a high complication rate, including 2 dislocations and 5 implant failures at an average follow-up period of 15.3 years. Later that year, Taylor and colleagues¹¹ reported the results of fusion of the TM joint in 36 cases, LRTI in 25 cases, and silastic trapezial replacement in 22 cases. There were no differences in patient satisfaction, pain, range of motion, or tip and key pinch between groups, but there was a higher rate of complications and reoperations in the fusion group.

A cadaveric study of the biomechanical properties of ligament reconstruction with or without tendon interposition compared with a recently developed one-piece silicone elastomer trapezium with fixation into the canal of the metacarpal was reported by Luria and colleagues³⁴ in 2007 (Tie-In Trapezium Implant, Wright Medical Technology). They showed that the silicone implant had decreased axial and radial displacement and better maintenance of the trapezial space compared with LRTI. This implant did, however, have significant rotation in biomechanical analysis, and no clinical data are yet available.

In addition to trapeziectomy and silicone spacers designed to occupy the entire trapezial space, thin silicone hemiarthroplasty interpositional implants have been available since the 1970s, and these implants have generally been abandoned due to poor results. Ashworth and colleagues³⁵ studied the use of a modified neuro-surgical burr-hole cover as a TM interpositional arthroplasty, but results were poor with some failures due to fracture of the device. Kessler and colleagues³⁶ later reported on a stemless silicone disc, which was placed between the trapezium and metacarpal and reported several cases with implant dislocation and persistent pain.

Artelon

Artelon (Small Bone Innovations, Morrisville, Pennsylvania) is a T-shaped biodegradable polycaprolactone-based polyurethraneurea material proposed for use in isolated thumb TM arthritis. It was designed to work as both a joint interposition spacer with the vertical spacer portion of the device being placed between the thumb metacarpal base and distal trapezium and as a ligament stabilizer with 2 T-shaped wings of the implant being placed horizontally along the joint to augment the dorsal capsule and prevent dorsoradial migration of the proximal metacarpal (**Fig. 2**). The wings of the implant are typically fixed with 2 2.0-mm cortical screws. In vitro degradation



Fig. 2. Artelon spacer in the TM joint in a model. (*From* Nilsson A, Liljensten E, Bergström C, et al. Results from a degradable TM joint Spacer (Artelon) compared with tendon arthroplasty. J Hand Surg Am 2005;30A:380–90; with permission.)

studies have shown that complete hydrolysis of Artelon takes approximately 6 years.³⁷ Initial reports with this implant showed promise and compared favorably to LRTI. In 2005 Nilsson and colleagues³⁸ described their initial experience with this implant in 15 patients – 10 treated with the Artelon spacer and 5 treated with trapeziectomy and APL stabilization. At 3 years, all patients in both groups were pain-free, and patients treated with the Artelon spacer demonstrated increased key pinch and tripod pinch. A pathologic specimen from one patient at 6 months postoperatively revealed incorporation of the spacer into adjacent bone without signs of foreign body reaction.

The use of Artelon has been described by Badia¹⁶ as a spacer in conjunction with arthroscopic debridement of the trapezium in a level V surgical technique. The investigator purported possible benefits of a minimally invasive technique with potentially less pain and faster recovery as well as trapezial preservation. A 1.9-mm arthroscope is used for visualization, a 2.9-mm burr is used to remove 3 mm of subchondral bone, and then the Artelon spacer is folded and introduced into the TM joint via extension of the portal longitudinally or via insertion through a rigid cannula. The TM joint may be fixed with a Kirschner wire, which the investigator speculated may prevent micromotion and assist in fibrous ingrowth of the implant. No attempt was made to assess patient outcomes or complications.

In more rigorous investigation of patient outcome, longer-term results of Artelon arthroplasty have not been favorable. Jorheim and colleagues³⁹ reported the results of a matched cohort study of 53 patients comparing 13 patients treated with Artelon arthroplasty versus 40 patients treated with trapeziectomy and LRTI (using APL) in patients with Eaton stages I to III disease. At 13 months, there were no significant differences in the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire or pain scores between groups. Those treated with Artelon were 4 times less likely to be satisfied than those treated with LRTI, and 2 patients in the Artelon group were revised to LRTI, with another 2 having revision surgery for screw removal secondary to pain. Additionally, those treated with Artelon had a lower median grip and pinch strength compared with the LRTI group, which the investigators propose would likely have reached significance with a sufficient sample size.

As a follow-up to a pilot study, a randomized, controlled multicenter trial published in 2010 by Nilsson and colleagues⁴⁰ studied 109 patients with osteoarthritis of the basal joint treated at 7 different centers in Sweden. Seventy-two patients

were treated with the Artelon spacer, and 37 patients were treated with trapeziectomy and LRTI (using either APL, extensor carpi radialis longus, or the Burton procedure). Pain and postoperative swelling were more common in patients treated with Artelon than those treated with LRTI. Additionally, 8% of patients treated with Artelon had subsequent removal of their implants. In contrast to the initial results, there was no increase in key pinch or tripod pinch strength. Although both groups experienced significant improvement in DASH scores and pain relief, those treated with LRTI had significantly better pain relief than those treated with Artelon arthroplasty.

Several case reports have emerged from the literature describing foreign body reactions with use of Artelon in the TM joint, and this reaction may be more common than reported in initial studies. Choung and Tan⁴¹ described a patient with swelling, pain and radiographic osteolysis 10 weeks after an Artelon arthroplasty mimicking infection, with the end result implant removal and multiple surgical synovectomies and a biopsy revealing acute and chronic inflammatory synovitis with multinucleated giant cells. Giuffrida and colleagues⁴² similarly reported a patient with painful synovitis and trapezial erosion after implantation of the Artelon spacer into the scaphotrapezial-trapezoidal joint, requiring removal of the implant and revision to LRTI. Biopsy of the soft tissue and synovium revealed a granulomatous foreign body giant cell reaction to the Arte-Ion implant (Fig. 3). Additionally, Robinson and



Fig. 3. Histopathologic specimen demonstrating a granulomatous reaction to Artelon with numerous foreign body giant cells in the trapezium bone. Bony trabeculae are shown at left (*arrows*), and the foreign material is shown in the inset under polarized light (hematoxylin-eosin stain, \times 200 magnification). (*From* Giuffrida AY, Gyuricza C, Perino G, et al. Foreign body reaction to artelon spacer: case report. J Hand Surg Am 2009;34(8):1388–92; with permission.)

Muir.⁴³ reported on 3 cases of persistent pain after Artelon TM implant arthroplasty, all requiring removal of the implant and trapeziectomy to resolve symptoms.⁴³ In all 3 cases, biopsy specimen revealed a foreign-body type reaction with giant cells containing material that was presumed to be Artelon.

Metallic

Numerous metal total joint implant designs have been devised for the treatment of prosthetic replacement of TM arthritis, including various combinations of metal and polyethylene components. The earliest implant was designed by de la Caffinière and Aucouturier, which is a cemented ball-and-socket implant with a polyethylene cup inserted into the trapezium and a cobaltchromium stem in the metacarpal (Benoist Girard et Cye S.A., Baguaux, France). These investigators reported their early results in 1979, which showed that outcomes were not as good for patients with a primary complaint of stiffness preoperatively but superior outcomes in patients who were indicated for pain and instability.⁴⁴ There has been extensive experience with this prosthesis reported in the European literature since this initial study, with overall good clinical results, although there have been several cases of asymptomatic radiographic loosening seen in the trapezial component.45-50

Other data, however, brought use of this prosthesis into question because some series have found unacceptably high rates of implant loosening, which did eventually require revision, particularly in younger patients and in men who may put more stress on the prosthesis. van Cappelle and colleagues⁴⁸ examined the results of 77 de la Caffinière prostheses implanted for osteoarthritis of the TM joint. At 16 years, the survival rate of the implant was 72%, and the overall loosening rate was 44% (Fig. 4). Half of the cases of loosening (more common in men and younger women) were treated with revision, and these patients did significantly poorer. De Smet and colleagues⁵¹ conducted a retrospective survey on 43 de la Caffinière prostheses in 40 patients. Although patients had a 70% satisfaction rate, good range of motion, and increased postoperative grip and pinch force, there was an alarmingly high rate of loosening for this prosthesis (44%). There was a relationship between loosening and younger age. De Smet and colleagues⁵² also compared key pinch strength between 26 patients treated with de la Caffinière prosthetic total joint arthroplasty versus 27 patients treated with LRTI with the hypothesis that total joint arthroplasty would



Fig. 4. Posteroanterior radiograph of de la Caffinière prosthesis at 15 years postoperatively revealing loosening of both cup and stem with dislocation. Note the vertical position of the metal ring of the cup, indicating migration and rotation of the cup and dislocation of the components. Despite the radiographic appearance this patient had excellent clinical and subjective scores. (*From* van Cappelle HG, Elzenga P, van Horn JR. Long-term results and loosening analysis of de la Caffinière replacements of the trapeziometacarpal joint. J Hand Surg Am 1999;24(3):476–82; with permission.)

provide better pinch strength; there was, however, no difference between the 2 procedures in key pinch at an average of 2.1 years after surgery, failing to provide support for one of the purported benefits of joint arthroplasty, and there was a 51% loosening rate in this series.

Similar ball-and-socket prosthetic designs were independently devised by Steffee and Nahigian.^{53,54} The Steffee prosthesis was a cemented prosthesis with a cobalt-chromium-molybendum alloy metacarpal stem, which articulates with a trapezial ultra-high-molecular-weight polyethylene cup (Laure Prosthetics, Portage, Michigan). Ferrari and Steffee⁵³ retrospectively reported on the first 45 cases in 38 patients with a follow-up ranging from 2 to 6.5 years. The investigators reported a 93% rate of pain relief and restoration of range of motion and strength, but 30% of cases had asymptomatic radiolucent lines around the trapezial component (Fig. 5). There were 3 cases of symptomatic loosening. In 1999, Hannula and Nahigian⁵⁴ described a retrospective report of a different cementless ball-and-socket total joint implant for the TM joint designed with a titanium alloy coated stem and trapezium with a cobalchrome ball articularting with a polyethylene socket (Techmedica, Camarillo, California). The results of this prosthesis were reported in 42 cases in 36 patients with an average 4-year follow-up (Fig. 6).⁵⁴ They reported 78% good to excellent results. Five cases, however, required revision surgery, and radiolucent lines were also noted in 52% of patients (12 of 13 in the trapezial component), confirming the results by Ferrari and Steffee. Neither of these implants is currently available today.

The GUEPAR (Benoit-Gerrard et Cye S.A., Baguaux, France) prosthesis is a French-designed cemented cobalt-chrome on polyethylene total joint implant with several positive reports in the French and German literature.55-58 The stem is a smooth monobloc component that is conical in profile and triangular in cross-section with a collar that rests against the metacarpal surface. Masmejean and colleagues⁵⁷ showed good clinical midterm results for the second generation of this implant and found that radiolucent lines had no impact on outcome. In 2009, Lemoine and colleagues⁵⁹ described the results of the second generation of this prosthesis in 72 patients at a mean follow-up of 4.2 years (Fig. 7). There was only a 1.3% revision rate in this series, and 60% of patients were pain-free, with another 18% having pain only with significant activity.

The Elektra prosthesis (Small Bone Innovations, Péronnas, France) is a ball-and-socket semimodular, unconstrained, cementless hydroxyapatitecoated prosthesis (Fig. 8). In 2006, Regnard reported on the first 100 patients at an average follow-up of 4.4 years.⁶⁰ There were good outcomes documented by improvements in strength, range of motion, and pain relief; 15% of patients, however, had loosening of the cup, and some patients sustained subsidence of the distal component and dislocation. These early results have been attributed to the first generation of implant design and an early technique, which did not involve fixation of the cup or intraoperative fluoroscopy to verify cup orientation. A subsequent prospective study published in 2008 by Ulrich-Vinter and colleagues⁶¹ comparing the Elektra prosthesis with trapeziectomy and APL tendon interposition followed 98 patients at 3, 6,



Fig. 5. Posteroanterior (*A*) and lateral (*B*) radiographs of the right thumb of a 73-year-old woman with osteoarthritis 9 years after a Steffee TM prosthesis. (*From* Ferrari B, Steffee AD. Trapeziometacarpal total joint replacement using the Steffee prosthesis. J Bone Joint Surg Am 1986;68(8):1177–84; with permission.)



Fig. 6. Preoperative (A) Bett's view of a 58-year-old female patient with primary osteoarthritis of the TM joint, and postoperative (B) view with a well-positioned titanium total joint prosthetic arthroplasty 25 months postoperatively. (*From* Hannula TT, Nahigian SH. A preliminary report: cementless trapeziometacarpal arthroplasty. J Hand Surg Am 1999;24(1):92–101; with permission.)



Fig. 7. Posteroanterior radiograph showing GUEPAR prosthesis with complete radiolucent line around trapezial cup in an asymptomatic patient. (*From* Lemoine S, Wavreille G, Alnot JY, et al. Second generation GUEPAR total arthroplasty of the thumb basal joint: 50 months follow-up in 84 cases. Orthop Traumatol Surg Res 2009; 95(1):63–9; with permission.)

and 12 months postoperatively and showed excellent results of this prosthesis. The group receiving the total joint arthroplasty had faster and better pain relief, stronger grip strength, improved range of motion, and faster convalescence than the tendon interposition arthroplasty group. At 1 year, osteolysis was evident in the proximity of 2 cups but there were no signs of implant loosening. There was no difference in complications between the 2 groups.

The Braun-Cutter prosthesis (Small Bone Innovations/Avanta Orthopaedics) is a cemented prosthesis with a titanium collarless stem and a polyethylene cup designed for use in Eaton stages III and IV basal joint disease (**Fig. 9**). Braun reported in 1982 his initial experience in 22 patients with 29 involved TM joints with acceptable results,⁶² but there have been significant changes in implant design, cementing techniques and surgical techniques since then, prompting a study by Badia and Sambandam⁶³ to re-evaluate this



Fig. 8. Elektra total joint prosthesis seen on Posteroanterior radiograph at 1-year follow-up. Osseous integration and fixation of the prosthetic component appear without periprosthetic osteolysis or subluxation of prosthesis. (*From* Ulrich-Vinther M, Puggaard H, Lange B. Prospective 1-year follow-up study comparing joint prosthesis with tendon interposition arthroplasty in treatment of trapeziometacarpal osteoarthritis. J Hand Surg Am 2008;33(8): 1369–77; with permission.)

implant. The investigators reported in 2006 on 26 Braun-Cutter TM arthroplasties in a patient cohort with an average of 71 years of age at an average of 3.8 years of follow-up.⁶³ The results were encouraging, with 96% of patients pain-free at follow-up. Excellent range of motion of 60° of radial abduction and improved pinch (85% of contralateral thumb) were observed. One patient was revised due to posttraumatic loosening, and radiographic analysis at final follow-up did not show any subsequent atraumatic implant loosening. The investigators concluded that this implant is reliable for use in elderly, low-activity patients with advanced TM disease.

The Ledoux prosthesis (Dimso, Marmande, France) is a Belgian design consisting of an uncemented ball-and-socket with the trapezial component having a cylindrical exterior shape and conical interior with a cylindrical polyethylene



Fig. 9. Well-seated Braun-Cutter total joint prosthesis seen on lateral radiograph at final follow-up without evidence of implant loosening. (*From* Badia A, Sambandam SN. Total joint arthroplasty in the treatment of advanced stages of thumb carpometacarpal joint osteoarthritis. J Hand Surg Am 2006;31(10):1605–14; with permission.)

inlay. The trapezial component is secured both by a screw and boney ingrowth. Although initial reports were encouraging, reports of implant failure prompted a multicenter study by LeDoux⁶⁴ where the investigator identified 24 failed prostheses in 188 cases (12.7% failure rate) among 11 surgeons. The investigator sought to determine the cause of failure in these cases. There were 10 cases of improper cup orientation, which caused loosening of the trapezial component. Five cases had subsidence of the stem into the metacarpal medullary canal, and there were 2 cases of stem malalignment. Three cases had a stem that was deemed to be too small. Once case was a septic loosening and 3 dislocations were seen. Twentythree of the 24 cases were revised, and metallosis of the periprosthetic tissues was seen in 6 of these cases. Ledoux described some modifications to the initial design of the prosthesis to avoid these modes of failure, including treatment of the prosthesis head with ionic nitrogen to prevent metallosis and increasing the range of motion in the prosthesis to compensate for improper cup orientation. Wachtl and colleagues⁴⁹ performed a retrospective review on 88 total metal arthroplasties of the RM joint in 84 patients with either the cemented de la Caffinière prosthesis (43 joints) at a mean follow-up of 63 months versus the revised design cementless Ledoux prosthesis (45 joints) at a mean follow-up of 25 months (Fig. 10). Kaplan-Meier analysis revealed that the de la Caffinière prosthesis had a 66.4% survival at 68 months and the Ledoux prosthesis had a 58.9% survival at 16 months, with similarly high rates of both stem and cup components in both designs. The investigators concluded that the currently available contrained ball-and-socket TM prostheses studied at that time were not suitable for use.

Cooney and colleagues⁶⁵ developed another TM total joint prosthesis, which was a cemented implant in which the trapezial metal component was a pedestal with a sphere to articulate with a polyethylene-stemmed metacarpal socket (**Fig. 11**); the investigators described this as a surface replacement arthroplasty. This design is a reversed ball-and-socket arrangement, and was developed based on biomechanical studies with 3-D motion analysis using a magnetic lsotrak system comparing the normal TM joint with excision arthroplasty and surface replacement.^{66,67} Biomechanical analysis showed that the total joint surface replacement best duplicated thumb



Fig. 10. Posteroanterior radiograph of a Ledoux cementless prosthesis at 3 years postoperatively. (*From* Wachtl SW, Guggenheim PR, Sennwald GR. Cemented and non-cemented replacements of the trapeziometacarpal joint. J Bone Joint Surg Br 1998;80(1):121–5; with permission.)



Fig. 11. The Cooney TM resurfacing joint prosthesis represented a saddle joint with biconcave reciprocating articular surfaces and a limited degree of internal joint stability. The trapezial component is made of Co-Cr alloy and the metacarpal stem is made of high-density polyethylene. (*From* Uchiyama S, Cooney WP, Nieber G, et al. Biomechanical analysis of the trapeziometacarpal joint after surface replacement arthroplasty. J Hand Surg Am 1999;24(3):483–90; with permission.)

kinematics whereas trapeziectomy altered the moment arms and center of rotation. Initial clinical data by Cooney and colleagues⁶⁵ showed excellent motion and pinch strength but noted that 36% of their implants developed heterotopic bone postoperatively, which had an adverse impact on outcome. They reported that preoperative heterotopic bone, adjacent joint fusion or adjacent joint disease, and poor bone stock all resulted in poor outcomes in their experience, and, as a result, these are contraindications to total joint arthroplasty.

Another surface replacement design is the Avanta SR TM prosthesis (Avanta Orthopaedics), which consists of trapezial and thumb metacarpal base resurfacing articulations. The trapezial component is made of a cobalt chrome alloy with a peg centered in the trapezium, and the metacarpal component is made of ultra-high-molecularweight polyethylene (Fig. 12). Each component has pegs that are cemented into the medullary canal of its bone. In contrast to the ball-andsocket designs, this implant better replicated the surface anatomy of the normal saddle joint. The first study with this implant by Pérez-Úbeda and colleagues⁶⁸ in 20 cases had a high rate of complications at an average of 2.8 years of follow-up, with a 55% rate of loosening and 15% rate of ankylosis secondary to periprosthetic calcifications (Fig. 13). Twenty percent of patients needed revision to a salvage procedure, and only 40% of patients had good to excellent results at the end of the study. A recent series by van Rijn and Gosens⁶⁹ published in 2010, however, re-evaluated this prosthesis and revealed encouraging results. In 15 cases of prosthetic replacement with the Avanta SR TM implant with an average follow-up of 3 years, the investigators found significantly decreased pain during activitiy and significantly improved function with both hands after surgery as assessed by the sequential occupational dexterity assessment and the Michigan Hand Outcomes Questionnaire. There was no sign of radiographic implant loosening, but there was one implant failure in this series. There was no improvement in range of motion, strength, or function of the operated hand used alone.

In contrast to the metal total joint prosthetic designs, hemiarthroplasty titanium implants have also been used, first devised by Swanson in 1985. In 1997, Swanson and colleagues⁷⁰ published the results of 105 Swanson titanium condylar hemiarthroplasty prostheses (Wright Medical Technology) with an average follow-up of 5 years. They reported improvements in motion and strength at 6 months, bone remodeling radiographically, and stability of the implant. There was

Fig. 12. The Avanta SR TM prosthesis consists of 2 components whose saddle-like articular surfaces have slightly greater curvature than the anatomic surfaces to increase the stability of the articulation. The trapezial component is a Co-Cr alloy with a rounded peg to be seated in the center of the trapezium and the metacarpal component is made of ultra-high-molecular-weight polyethylene. (*From* van Rijn J, Gosens T.





Fig. 13. Posteroanterior radiograph showing an Avanta SR TM replacement in which ankylosis developed after 26 months secondary to periprosthetic calcifications. Despite the radiographic appearance and decreased range of motion, the patient was reported to have complete pain relief. (*From* Pérez-Úbeda MJ, García-López A, Marco Martinez F, et al. Results of the cemented SR trapeziometacarpal prosthesis in the treatment of thumb carpometacarpal osteoarthritis. J Hand Surg Am 2003;28(6):917–25—image originally published by the American Society for Surgery of the Hand; with permission.)

no sign of wear at 5 years, although other investigators have not been able to reproduce these excellent results. In 2003, Phaltankar and Magnussen reported on 19 titanium hemiarthroplasties in 18 patients at 2.9 years of follow-up, with good pain relief in only 13 cases.⁷¹ Radiographic loosening was seen in 5 cases and trapezial wear was seen in 10 cases, although neither radiographic finding correlated with clinical outcome. One case required revision to trapeziectomy. Naidu and colleagues⁷² recently reported on titanium hemiarthroplasty in a 2-part study consisting of a biomechanical finite element analysis and a clinical study in 47 patients with 2 years of follow-up. In the finite element analysis, they showed pistoning behavior with maximum stress concentration in the midmetacarpal shaft and with rotation of the convex sphere of the implant out of the trapezial crater. The clinical analysis had strict inclusion criteria of patients with Eaton stage III arthritis and good bone stock without contractures at the TM or metacarpophalangeal joint. Despite these narrow indications, they showed failure in 10 patients at 9 months, all converted to LRTI. Implant settling occurred mainly in 2 patterns-varus drift and axial subsidence (Fig. 14). Titanium is approximately 1000 times stiffer than host bone, and the investigators hypothesized that the modulus mismatch between titanium and host hone was responsible for the high localized stresses seen at the distal tip of the implant. Those without implant failure had



Fig. 14. Posteroanterior radiograph showing titanium TM hemiarthroplasty with typical varus drift of the implant pistoning loose within the metacarpal shaft. (*From* Naidu SH, Kulkarni N, Saunders M. Titanium basal joint arthroplasty: a finite element analysis and clinical study. J Hand Surg Am 2006;31(5):760–5; with permission.)

significant improvements in DASH scores, although there was still persistent weakness at 2-year follow-up and the operated thumbs never reached the strength of the contralateral thumbs. All patients who had an LRTI on the contralateral side definitely preferred the side treated with LRTI rather than titanium hemiarthroplasty. The investigators concluded that although titanium arthroplasty may have a role in low-demand patients with sufficient bone stock, high failure rates have prompted them to stop using this prosthesis.

In 2009 a new anatomic metal trapezial replacement called the TrapEZX (Extremity Medical) was designed in conjunction with Amy Ladd, Peter Weiss, and John Faillace. It combines anatomic design with potential for soft tissue ingrowth and suture anchor stabilization (**Fig. 15**). The device has been implanted in more than 100 patients. Although early results have been encouraging (Ladd & Weiss, personal data, 2010-2012), no published data are available for this prosthesis and further evaluation is required.

Pyrolytic Carbon

Pyrolytic carbon is another material that has more recently been developed for use in TM arthroplasty. This is a synthetic material formed by pyrolysis of a hydrocarbon gas. Unlike silicone, Artelon, and titanium, the modulus of elasticity of pyrolytic carbon is similar to that of cortical bone, which theoretically may prevent subsidence and better mimic the native biomechanical properties of the



Fig. 15. Posteroanterior (A) and lateral radiographs (B) of TrapEZX anatomic metallic trapezial total replacement. (Personal image courtesy of Mark Ross.)

native TM joint. An additional benefit of pyrolytic carbon may be the potential adherence of certain joint boundary lubrication molecules to its surface, specifically phospholipids, which have been identified as a significant component of synovial fluid lubrication.^{73–75} In 1989, Cook and colleagues⁷⁶ published a canine hip hemiarthroplasty study, which demonstrated significantly superior acetabular cartilage preservation when articulating against a pyrolytic carbon femoral head compared with a metal femoral head. Early data in primates have revealed no evidence of wear or wear debris or inflammatory synovitis.⁷⁷

Although the use of pyrocarbon has been extensively studied in other small joints of the hand and wrist,^{78–87} there are fewer published data describing trapezial arthroplasty. Pyrolytic carbon anatomic interposition arthroplasty has been described by Bellemère and colleagues.⁸⁸ The Pyrocardan implant (BioProfile/Tornier) is indicated for Eaton stage I or II disease. The biconcave implant is inserted free into the TM joint with minimal bone resection (Fig. 16). Prospective review of a continuous series of 27 implants with follow-up of 12 to 27 months (mean 16.6 months) demonstrated excellent improvements in pain and subjective scores. All implants remained in situ and no complications or revision surgery were reported.88

The PyroDisk (Integra Life Sciences) pyrolytic carbon nonanatomic interposition implant is

a biconcave disk with a central hole to allow stabilization with a tendon. Early unpublished results as part of an investigational device trial showed promise. There has been mixed experience with the device in Europe. The PyroDisk has also been implanted as an interposition with complete trapeziectomy. This modified technique has been reported by Stabler.⁸⁹ It involves complete trapeziectomy and implantation of the PyroDisk combined with ligament reconstruction and stabilization using the flexor carpi radialis tendon (**Fig. 17**). In a large series of 109 implants, excellent results have been described, although follow-up remains short and further study is required.

A further pyrolytic carbon interposition in association with complete trapeziectomy has also been reported by Ardouin and Bellemère.⁹⁰ The Pi2 (BioProfile/Tornier) prosthesis is an oval spacer designed to replace the excised trapezium (Fig. 18). Unlike the PyroDisk technique of Stabler, the Pi2 is not stabilized, because the philosophy is to have a free moving adaptive implant. This involves some additional technical requirements in terms of capsuloplasty and/or ligamentoplasty to stabilize the implant. A prospective study of 42 implants in 39 patients demonstrated excellent pain relief and patient satisfaction. Although there were 2 subluxations, none of the implants had been revised at a mean follow-up of 63 months. Another recent



Fig. 16. Preoperative (*A*) and postoperative (*B*) radiograph of Pyrocardan pyrolytic carbon anatomic interposition implant. (*Courtesy of* Philippe Bellemère, Nantes Assitance Main, Clinique Jeanne D'Arc, Nantes, France; with permission.)

study by van Aaken and colleagues⁹¹ reported on 41 patients (45 joints) with at minimum 1-year follow-up. They found that the 73% of patients who were very satisfied with their results and had improved pinch strength and Kapandji scores postoperatively. There was, however, a high failure rate of the prosthesis, with 27% having undergone subsequent removal of the prosthesis at a mean of 11 months postoperatively.

The currently available pyrolytic carbon hemiarthroplasty prosthesis, called the NuGrip (Integra Life Sciences), is a partial trapezial resurfacing implant with a stem that seats in the proximal metacarpal and insets into the trapezium, which is reamed to accept the spherical proximal surface of the implant (Fig. 19). The first generation of this prosthesis, which was called the PyroHemi-Sphere, was the proximal component of the pyrocarbon metacarpophalangeal joint implant (originally manufactured by Ascension Orthopedics) used as a TM prosthesis, but the more recently designed implant (NuGrip, Integra Life Sciences) has been designed specifically for TM arthroplasty. In contrast to metal total joint implants with a constrained trapezial component subjected to high stresses, which may contribute to high loosening rates in clinical series, this implant instead articulates with a hemisphere of subchondral trapezial bone. This obviates the trapezial component loosening, which can lead to revision with total joint prostheses. Ligament stability is crucial to avoid subluxation of the implant, and significant ligamentous instability is a contraindication to use of this implant. This implant is indicated for Eaton stages II and III disease. Scaphotrapezial-trapezoidal joint arthritis is another contraindication to its use. A series from the Mayo Clinic reported in 2009 early outcomes of patients treated with pyrolytic carbon hemiarthroplasty of the TM joint.⁹² Fifty-four TM joints in 49 patients were treated, with underlying diagnoses of osteoarthritis in 44 thumbs, rheumatoid arthritis in 8 thumbs, psoriatic arthritis in 1 thumb, and juvenile rheumatoid arthritis in 1 thumb. At 1.8 years, the overall survival rate was 80%. There were 10 patients with metacarpal subluxation, and 7 of these were salvaged by revision surgery to deepen the trapezial cup. Overall there was a high reoperation rate, with 15 reoperations in this series due to dislocation and/or persistent



Fig. 17. Posteroanterior radiograph of modified PyroDisk nonanatomic interposition implant with complete trapeziectomy and ligament stabilization. (Personal image *courtesy of* David Stabler, Gold Coast, Queensland, Australia.)

pain. Satisfaction was 81%, and 71% of patients were pain-free whereas 12% reported mild to occasional pain with repetitive activities. Grip strength recovered to 86%, key pinch to 92%, and opposition pinch strength to 95% of the contralateral side. The investigators concluded that, although there was a high complication rate

with subluxation attributed to a shallow trapezial cup in some cases performed early in the learning curve, this may be an acceptable option for treatment of TM arthritis because loosening and subsidence were not seen in this series.

Another recent prospective cohort comparative study of trapeziectomy alone versus trapeziectomy and pyrocarbon hemiarthroplasty by Colegate-Stone and colleagues93 assessed outcomes in 38 consecutive patients with primary TM joint arthritis. Patients were evaluated with the Quick-DASH and a visual analog pain scale, and objecincluded tive measures grip strength measurements. They found no significant difference between the 2 groups at 6 or 12 months postoperatively but did find a higher complication rate in the pyrocarbon group, 7 of which sustained complications.

Other Implants

There are several other implants recently been reported in the literature with either limited clinical experience or poor performance limiting widespread use. Use of the ceramic sphere implant called Orthosphere (Wright Medical Technology) manufactured of zirconia ceramic as a spacer between the thumb metacarpal and trapezium was reported by Athwal and colleagues⁹⁴ with subsidence in 6 of 7 cases and 1 case with implant dislocation requiring revision to trapeziectomy (Fig. 20). This implant was again recently reviewed by Adams and colleagues.⁹⁵ In their series of 50 patients, trapezium fracture was evident in 15, erosion of the implant into the trapezium in 11, and other complications in 10 over a 3-year follow-up. Gore-Tex (polytetrafluoroethylene) synthetic interposition arthroplasty (W.L. Gore



Fig. 18. Posteroanterior (*A*) and lateral (*B*) radiographs of the Pi2 pyrocarbon prosthesis in a patient 3 years postoperatively. (*Courtesy of* Philippe Bellemère, Nantes Assitance Main, Clinique Jeanne D'Arc, Nantes, France; with permission.)



Fig. 19. A pyrolytic carbon hemiarthroplasty seen on posteroanterior radiograph at 17 months postoperatively. (From Martinez de Aragon JS, Moran SL, Rizzo M, et al. Early outcomes of pyrolytic carbon hemiarthroplasty for the treatment of trapezial-metacarpal arthritis. J Hand Surg Am 2009;34(2):205–12; with permission.)

and Associates, Flagstaff, Arizona) has also been tried with poor results.⁹⁶ Greenberg and associates⁹⁶ studied the outcomes of a Gore-Tex interpositional arthroplasty in 34 cases with 3.4 years of follow-up. Although there were good results in terms of pain relief and subjective outcomes, there was a high prevalence of radiographic osteolysis leading the investigators to recommend against the use of this material due to concerns of particulate synovitis (**Fig. 21**).

In contrast, an acellular dermal matrix allograft called Graftjacket (Wright Medical Technology) has been used as an interpositional arthroplasty with some favorable results. Adams and colleagues¹² described an arthroscopic technique for débridement and interposition with Graftjacket in the TM joint in patients with Eaton stages II and III disease (**Fig. 22**). This series reported generally good results with some symptom relief in all patients. 94% of patients were partially or completely satisfied, and 70% had no or only mild difficult in performing activities of daily living.



Fig. 20. Posteroanterior radiograph showing subsidence of Orthosphere prosthesis into the trapezium in a patient with symptoms of pain, weakness, and stiffness. (*From* Athwal GS, Chenkin J, King GJ, et al. Early failures with a spheric interposition arthroplasty of the thumb basal joint. J Hand Surg Am 2004;29(6): 1080–4; with permission.)



Fig. 21. Posteroanterior radiographs of a 65-year-old woman 46 months after a Gore-Tex interposition arthroplasty. The arrows highlight extensive osteolysis of the distal scaphoid, trapezium, capitate, hamate, and metacarpal base. (*From* Greenberg JA, Mosher JF Jr, Fatti JF. X-ray changes after expanded polytetra-fluoroethylene (Gore-Tex) interpositional arthroplasty. Hand Surg Am 1997;22(4):658–63; with permission.)



Fig. 22. Preoperative (*A*) and postoperative (*B*) posteroanterior radiographs of the TM joint after Graftjacket interposition, revealing increased TM joint space after interposition. (*From* Adams JE, Merten SM, Steinmann SP. Arthroscopic interposition arthroplasty of the first carpometacarpal joint. J Hand Surg Eur Vol 2007;32(3):268–74; with permission.)

SUMMARY

The optimal treatment of TM arthritis remains controversial, with no one technique proved superior. Prosthetic replacement arthroplasty of the trapezium has been available for approximately 5 decades. The most long-standing technologysilicone prosthetic trapezial spacers-may have a role in the treatment of low-demand rheumatoid patients, but overall outcomes have been poor and limited by silicone synovitis, implant failure, and loosening. Recent data on Artelon interpositional arthroplasty have shown inferior results compared with trapeziectomy and LRTI; given many case reports of foreign body reactions, the data lead to recommending against the use of this implant. Initial reports on metal total joint replacement of the TM joint were variable, with failures related to the significant forces across the base of the thumb, leading to loosening of the trapezial component in ball-and-socket designs and resurfacing implants devised in Europe and the United States. Recent studies, however, have shown that newer total joint prosthetic designs may have a better outcome than trapeziectomy with LRTI, at least in the short term. When compared with earlier studies, they were shown to have smaller rates of implant failure as well as superior pain relief, with better range of motion and grip strength.^{59,61,63} Although pyrolytic carbon hemiarthroplasty has historically had higher complication rates than alternative procedures, this prosthesis may hold promise in the treatment of TM arthritis. Future research is needed to determine the longterm outcomes of the latest generation of pyrolytic carbon prostheses. Although the ideal implant may not be currently available today, the theoretic advantages for prosthetic trapezial arthroplasty

should stimulate continued innovation in implant design and more rigorous prospective, controlled trials to better determine the role of any joint replacement of the TM joint.

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