Early outcomes of arthroplasty of the first carpometacarpal joint using pyrocarbon spherical implants

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The first carpometacarpal joint (CMC) is the most common hand joint to develop osteoarthritis. A survey found that many hand surgeons have revisited implant arthroplasty because it preserves critical structures. However, there is currently no implant with an ideal design and material composition. The present study was the first to use and evaluate early outcomes of pyrocarbon spherical implants for arthroplasty of the first CMC in patients with Eaton-Littler stage II and III osteoarthritis. A single surgeon performed 24 arthroplasties (23 patients [20 women, three men] with a mean age of 56 years [range 46 to 75 years]) of the first CMC (nine right hands and 15 left hands) using pyrocarbon spherical implants from May 2010 to April 2013. All patients failed conservative management. At a mean (± SD) of 18.5±11.16 months postoperatively (range 4.3 to 38.9 months), the mean Kapandji score was 8.8 of 10 (range 7 to 10), the average pre- and postoperative values on the visual pain scale were 8.96±0.64 of 10 (range 8 to 10) and 1.13±1.22 of 10 (range 0 to 4), respectively. All patients were either very satisfied (score = 5) or satisfied (score = 4) with the procedure, with a mean satisfaction score of 4.76±0.44 of 5.00 (range 4 to 5). The mean postoperative Disabilities of the Arm, Shoulder and Hand (DASH) score was 11.79±14.29 (range 0 to 49.17). The most recent radiographic evaluations confirmed that all implants were stable with no erosion of nearby cancellous bone. There were no implant subluxations, dislocations or revisions. Early outcomes show promising results and support continued use of this implant for arthroplasty. However, longer-term follow-up will be needed to confirm these results.

Key Words: *Arthroplasty; Carpometacarpal osteoarthritis; Pyrocarbon; Spherical implant*

Les résultats cliniques précoces d'une arthroplastie de la première articulation carpométacarpienne au moyen d'implants sphériques en pyrocarbone

La première articulation carpométacarpienne (CMC) est l'articulation de la main la plus touchée par l'arthrose. Une enquête a révélé que de nombreux chirurgiens de la main ont revu l'arthroplastie avec implant parce qu'elle en préserve les structures essentielles. La présente étude était la première à utiliser et à évaluer les résultats cliniques précoces d'implants sphériques en pyrocarbone pour l'arthroplastie de la première CMC chez des patients atteints d'arthrose de stades II et III selon la classification d'Eaton-Littler. Un seul chirurgien a effectué 24 arthroplasties de la première CMC (neuf de la main droite et 15 de la main gauche), au moyen d'implants sphériques en pyrocarbone, chez 23 patients (20 femmes, trois hommes) d'un âge moyen de 56 ans (plage de 46 à 75 ans) entre mai 2010 et avril 2013. Tous les patients ont échoué à une prise en charge prudente. Après une moyenne (± ÉT) de 18,5±11,16 mois après l'opération (plage de 4,3 à 38,9 mois), l'indice de Kapandji moyen était de 8,8 sur 10 (plage de 7 à 10), les valeurs préopératoires et postopératoires moyennes sur l'échelle visuelle de la douleur s'établissaient à 8,96±0,64 sur 10 (plage de 8 à 10) et à 1,13±1,22 sur 10 (plage de 0 à 4), respectivement. Tous les patients étaient soit très satisfaits (indice = 5) ou satisfaits (indice = 4) de l'intervention, et leur indice de satisfaction moyen s'élevait à 4,76±0,44 sur 5,00 (plage de 4 à 5). Le score DASH moyen d'incapacité du bras, de l'épaule et de la main était de 11,79±14,29 (plage de 0 à 49,17). Les évaluations radiographiques les plus récentes ont confirmé la stabilité de tous les implants, sans érosion de l'os spongieux avoisinant. Il n'y avait pas eu de subluxation, de dislocation ou de révision de l'implant. Les résultats cliniques précoces donnent des résultats prometteurs et appuient l'utilisation de cet implant en cas d'arthroplastie. Cependant, un suivi à plus long terme s'impose pour confirmer ces résultats.

The thumb is regarded as the most important digit of the hand and is responsible for 50% of its workload. It enables the hand to provide the grip and pinch function crucial for activities of daily living (1). As a result, the first carpometacarpal joint (CMC) is the most common hand joint to develop osteoarthritis (OA) (2). OA of the first CMC can lead to severe pain, decreased range of motion, diminished function and strength of the thumb (3). First-line treatment consists of nonsurgical options including activity restriction, nonsteroidal anti-inflammatory medications and corticosteroid injections. Failing these conservative approaches can warrant surgical management.

Common surgical procedures include arthrodesis, trapeziectomy with or without ligament reconstruction and tendon interposition (LRTI), and implants composed of silicone and ceramic. A survey found that trapeziectomy with LRTI is the most popular choice among hand surgeons; however, many have recently revisited implant arthroplasty (4). There is, however, currently no implant with an ideal design and material described in the literature. To be considered an ideal implant, it must be adequately stable when implanted, provide an adequate functional range of motion, evenly distribute stress across the joint, and be biocompatible and durable (5). The majority of the current implants reported in the literature fail to meet these criteria. However, the pyrocarbon (pyrolytic carbon) spherical implant does satisfy these criteria as an ideal implant for arthroplasty of the first CMC.

The spherical shape of this implant provides heightened advantages over current implant designs. During implantation, two bony concavities are created to cradle two-thirds of the implant, increasing its stability. The concavities are also ball-in-socket joint articulations to best reflect the wide range of motion of the thumb (6). Compared with materials used in other implants, pyrocarbon has an elastic modulus most similar to cortical bone, dampening the stress imposed by the implant at the prosthetic-bone articulation to enhance biological fixation (1). This prevents the erosion of cancellous bone apparent in numerous other implant materials. The pyrocarbon material is also well known for its biocompatibility and has been used in numerous prostheses, including heart valves.

In our opinion, the unique shape and material of the pyrocarbon spherical implant makes it the implant of choice for arthroplasty of

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Figure 1) *A pyrocarbon spherical implant for arthroplasty of the first carpometacarpal joint (Integra LifeSciences Corporation, USA)*

the first CMC in patients with Eaton-Littler stage II and III OA. To our knowledge, the present study was the first to use and evaluate the early outcomes of the pyrocarbon spherical implant for arthroplasty of the first CMC.

METHODS

The pyrocarbon spherical implant (Health Canada license number 74584) is available in five sizes (10 to 50), corresponding to a range of 10.2 mm to 16.6 mm (Integra LifeSciences Corporation, USA) (Figure 1). Ethics approval was obtained from the authors' institutional review ethics board and informed patient consent was obtained.

All patients failed conservative management consisting of activity restriction, nonsteroidal anti-inflammatory medications and a minimum of two corticosteroid injections. Inclusion criteria included clinical findings of a positive grind test, persistent tenderness in the first CMC region, dorsal-radial prominence (subluxation) of the base of the first metacarpal bone, decreased range of motion and pinch strength. Radiographic findings included Eaton-Littler stage II or III OA of the first CMC. Exclusion criteria included patients with rheumatoid arthritis, osteoporosis, scaphotrapezial arthritis and dislocation of the base of the first metacarpal bone. The senior author believed that with these conditions, patients may have benefitted more from other arthroplasty techniques, although this was not confirmed. One patient underwent arthroplasty using the authors' technique but was excluded from the study because he had multiple upper limb nerve compressions.

At the most recent follow-up appointment, patients were assessed clinically for thumb function and mobility; a Kapandji score was determined to quantify thumb opposition. A questionnaire package was then distributed. The package consisted of a visual pain scale (0 = no pain to 10 = worst possible pain) pre- and postoperatively, a five-point Likert scale for satisfaction (1 = very dissatisfied, 2 = dissatisfied, 3 = neutral, 4 = satisfied, 5 = very satisfied), and the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire. A plain radiograph was also obtained and evaluated. The mean, range and SD were calculated for all quantitative data.

Surgical technique

A single surgeon performed the procedure under general anesthesia with a tourniquet. Three cases were performed under intravenous regional anesthesia (Bier block) as requested by the patients. Intravenous prophylactic antibiotic was administered to all patients at the time of anesthesia induction. From the radial styloid process, a longitudinal incision was made over the extensor pollicis brevis and the abductor pollicis longus tendons, terminating 1.5 cm distal to the base of the metacarpal bone (Figures 2A and 2B). The superficial radial nerve branches were identified and protected throughout the surgery. The fascia between the extensor pollicis brevis and the abductor pollicis longus was opened. The deep branch of the radial artery was identified, freed and protected with a vessel loop (Figure 2C). The capsular

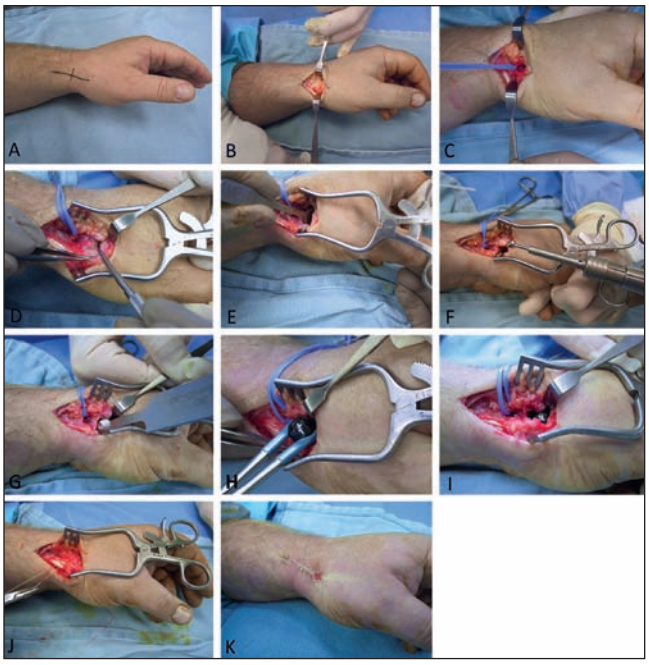

Figure 2) *Surgical technique of arthroplasty of the first carpometacarpal joint (CMC) using pyrocarbon spherical implants.* **A** *Marking the incision over the first CMC joint of the left hand.* **B** *From the radial styloid process, a longitudinal incision was made over the extensor pollicis brevis and the abductor pollicis longus tendons, terminating 1.5 cm distal to the base of the metacarpal bone.* **C** *The deep branch of radial artery was identified, freed and protected with a vessel loop.* **D** *The capsular periosteal flaps were elevated to expose the joint.* **E** *Following the resection of the distal surface of the trapezium and the base of the first metacarpal bone with a sagittal saw, the implant sizer was placed flat on the surface of the trapezium.* **F** *A round bur was used on the two resected surfaces to produce a cup in the centre.* **G** *A Broach (raspatory) was used to polish the surface of the cups.* **H** *and* **I** *The pyrocarbon spherical implant was inserted into position using an implant retriever.* **J** *Closure of the joint capsule using 2-0 undyed TiCron (Covidien, USA) sutures.* **K** *Closure of the skin using 4-0 Monocryl (Ethicon, USA) sutures*

periosteal flaps were elevated to expose the joint (Figure 2D). Using a sagittal saw, 2 mm of the first metacarpal base and the distal surface of the trapezium were resected, producing a 4 mm gap. The metacarpal base was resected first, followed by the distal trapezium because it enabled better visualization of the trapezium for resection. Care was taken to preserve the flexor carpi radialis tendon as it passes through the groove in the trapezium. A Rongeur bone cutter was used to remove thickened soft tissues and osteophytes around the joint.

The implant sizer was then placed flat against the distal surface of the trapezium (Figure 2E) and the appropriate implant size was determined from the five available sizes. If two implant sizes could fit, then the smaller implant was chosen. A round bur was then used on the two resected surfaces to produce a cup in the centre followed by the appropriate Broach (raspatory) to polish the surface of the cups (Figures 2F and 2G). The cups were prepared so that a cortical rim of bone was maintained and so that one-third of the implant sizer could fit inside each cup when it was placed perpendicular to the cups. This allowed the cups to cradle two-thirds of the implant, one-third by the trapezium and one-third by the metacarpal bone. The implant can then be inserted into position by using an implant retriever and/or finger pressure (Figures 2H and 2I).

The capsule was closed with 2-0 permanent sutures (undyed TiCron, Covidien, USA) with the thumb abducted at the CMC and flexed at the metacarpophalangeal joint (Figure 2J). The subcutaneous tissue and skin were closed using 4-0 dissolvable sutures (Monocryl,

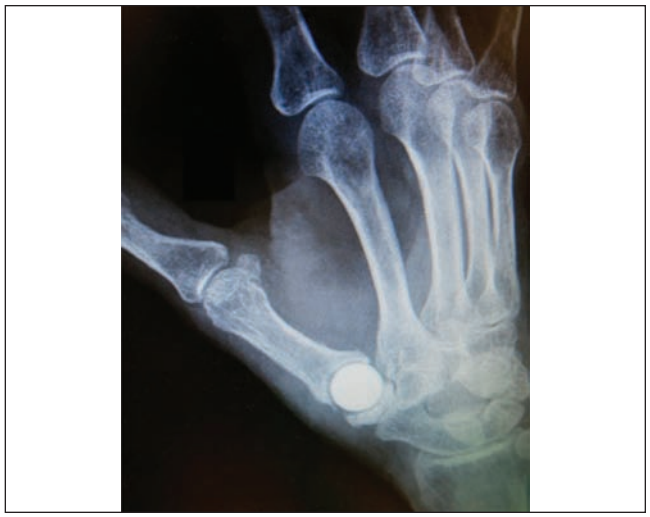

Figure 3) *Plain radiograph of the right hand following arthroplasty of the first carpometacarpal joint using a spherical pyrocarbon implant*

Ethicon, USA) (Figure 2K). A dorsal plaster splint was applied to hold the thumb abducted and the metacarpophalangeal joint flexed. This was followed by radiographic evaluation in the operating theatre.

One week postoperatively, the patient was placed in a cast with the interphalangeal joint free for five weeks. After week 6, the patient was referred to the hand therapist and was advised to avoid forceful pinching and excessive opposition (ie, opposing the thumb to the base of the fifth digit) for an additional four weeks as a precaution. All other movements were allowed as tolerated.

RESULTS

From May 2010 to April 2013, 24 arthroplasties (nine right hands and 15 left hands) of the first CMC were performed by a single surgeon. Twenty-three patients (20 women, three men) with a mean age of 56 years (range 46 to 75 years) were included in the present study. At a mean (± SD) of 18.5±11.16 months postoperatively (range 4.3 to 38.9 months), all patients exhibited improved thumb function and range of motion. Patients were able to fully flex and extend their thumb without discomfort. The mean Kapandji score was 8.8 (range 7 to 10). The mean pre- and postoperative values on the visual pain scale were 8.96±0.64 of 10 (range 8 to 10) and 1.13±1.22 of 10 (range 0 to 4), respectively. All patients were either very satisfied (score = 5) or satisfied (score = 4) with the procedure, with a mean value of 4.76±0.44 of 5.00 (range 4 to 5). The mean postoperative DASH score was 11.79±14.29 (range 0 to 49.17). There were no implant subluxations, dislocations or revisions. The most recent radiographic evaluations confirmed all implants were stable with no erosion of nearby cancellous bone (Figure 3).

Early in the study, there were two cases of suture granuloma; however, this was remediated by changing the suture material from Prolene (Ethicon) to TiCron (Covidien). Two patients reported tendinitis postoperatively and were successfully treated with cortisone injections. Three patients complained of mild wrist pain following the procedure, with visual pain scores ranging from 1 to 3 postoperatively. The pain was localized to the dorsal aspect of the wrist in the midline just proximal to the third metacarpal base. However, the pain in one of these patients subsided spontaneously and the remaining two patients showed improvement with time.

DISCUSSION

Arthroplasty of the first CMC using pyrocarbon spherical implants provides several advantages over current implant designs and materials. The spherical shape of this implant enhances its ability to remain stabilized due to the two bone concavities created. These concavities require minimal bone removal and manipulation, preserving the trapezium to maintain thumb height and critical soft tissues to allow a pathway for future revisions if needed. The concavities also produce two ball-in-socket articulations enabling a broad range of motion that best reflects the normal thumb (6). Clinically, patients were able to perform a broad range of thumb motion without discomfort at the most recent follow-up appointment. This was quantified using the Kapandji score. At a mean of 18.5 months postoperatively, the lowest score was 7 of 10, indicating that all patients could at least touch the distal interphalangeal crease of the fifth digit with their thumb. The highest Kapandji score was a 10 of 10, in which the thumb could touch the distal volar crease of the hand (Figure 4). The mean Kapandji score was 8.8 of 10, which meant that the average opposition was between an 8 (touching the proximal interphalangeal crease of the fifth finger) and 9 (proximal crease of the fifth finger).

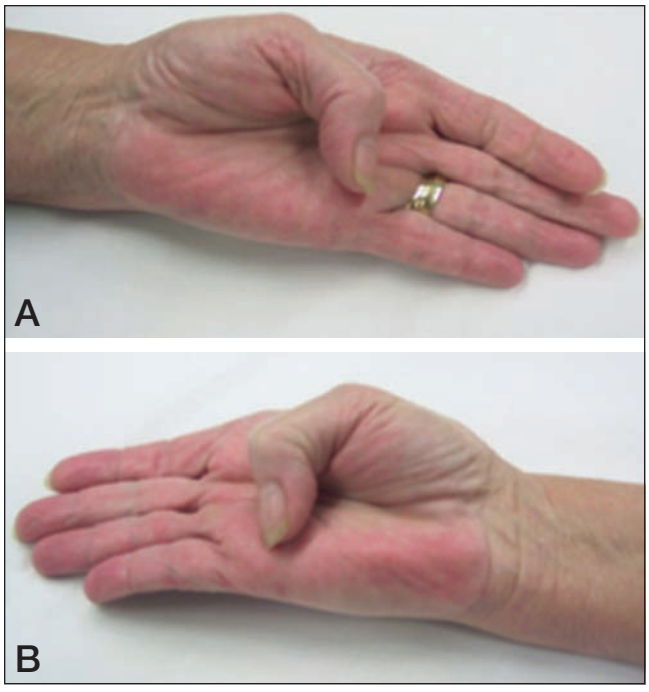

Figure 4) *A 62-year-old woman with a Kapandji score of 10 of 10 for the left thumb (***A***) and right thumb (***B***), 29.6 and 17.3 months postoperatively, respectively*

There were no implant subluxations, dislocations or revisions noted at the latest follow-up. All patients were very satisfied or satisfied with the procedure. On examination, their thumb function, range of motion, grip and pinch strength had significantly improved. Pain relief was excellent in all 23 patients, with a mean decline of 7.83 points on the visual pain scale, which enabled them to return to activities of daily living. There were three cases of wrist pain proximal to the third metacarpal base following the procedure. Whether the pain was caused by OA of other carpal bones that became noticeable following the alleviation of the more severe pain of the first CMC or due to the pressure of the implant on adjacent bones is not known.

The pyrocarbon material is highly biocompatible (1,5,7). Its elastic modulus is 29.4 GPa, which is more comparable with cortical bone (23 GPa) than other materials. This creates significantly less cortical bone wear and resorption in comparison to other implant materials such as titanium (105 GPa) and ceramic zirconium (210 GPa) (8-10). Another added benefit of the pyrocarbon material is the potential adherence of joint lubrication molecules to its surface, which reduces wear and inflammatory synovitis (11).

The DASH questionnaire measures disability of the upper limb, with a range of 0 indicating least disability to 100 indicating most disability. It is a validated questionnaire that has been shown to best discriminate patients with localized hand OA (12). In our study, the mean DASH score at a mean of 18.5 months postoperatively was 11.79. Compared

with the combined mean preoperative DASH score from five previous studies (DASH score 51.87, range 43 to 61), this was a mean decrease of 40.08 points (13-17). When compared with the normative value from an American population (n=1700) studied by the American Academy of Orthopedic Surgeons (18) (10.1±14.68), our average DASH score was only slightly higher. This suggests that postoperatively, our patients are similar to the general population in terms of upper limb disabilities. When comparing our technique with the gold standard used by hand surgeons for arthroplasty of the first CMC, trapeziectomy with LRTI, our mean DASH score was less than those reported in the literature (19). In a study performed by Naidu et al (13), 39 patients underwent complete trapeziectomy and LRTI with a postoperative DASH score of 12, with a minimum follow-up period of 24 months. Davis and Pace (20) performed the procedure on 46 patients with an average DASH score of 37 at one year postoperatively. In another study evaluating an institution's 10-year experience, the mean DASH score was 19.26±12.94 (21).

At a mean of 18.5 months postoperatively, our results demonstrated that patients had high satisfaction, minimal hand pain and upper limb disability, similar to the general population. The early outcomes of the present study support our opinion that the pyrocarbon spherical implant is ideal for arthroplasty of the first CMC joint. We believe that this is the result of the unique combination of an ideal implant design and material that other implants fail to capitalize. However, longer-term follow-up will be needed to ensure that these implants remain ideal.

CONCLUSIONS

The biocompatibility of pyrocarbon and the wide range of motion of the first CMC make the spherical-shaped pyrocarbon implant the implant of choice when performing arthroplasty of the first CMC in patients with Eaton-Littler stage II and III OA. Early outcomes show promising results and support the use of this implant for arthroplasty. However, longer-term follow-up will be needed to confirm these results.

DISCLOSURES: The authors have no financial disclosures or conflicts of interest to declare.

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