Focus On
Anatomical Small Joint Replacement in the Hand

Introduction
This review will focus on arthroplasty in the hand using implants intended to recreate normal anatomy and biomechanics. The surgical considerations for anatomical small joint replacement are quite different to those for a silastic arthroplasty, in which the implant acts as an internal splint allowing the soft tissues to rebalance. Silastic joint replacement certainly has an important role in the management of inflammatory arthropathy in the hand. With anatomical implants attention must be paid to critical soft-tissue attachments, bone resection and implant alignment to avoid issues of instability, maximise movement and provide longevity.

Consideration will be given to the surgical anatomy, biomechanics, implant design, surgical tips, reported outcomes and complications for arthroplasty of the metacarpophalangeal joint (MCPJ), proximal interphalangeal joint (PIPJ) and first carpometacarpal joint (CMCJ). Readers are directed to the implant manufacturers’ literature for information on implantation technique.

Metacarpophalangeal Joint (MCPJ)
The most common indication for arthroplasty of the MCPJs is rheumatoid arthritis; in these cases silastic arthroplasty with soft-tissue rebalancing is most usually indicated and does well.1,2 In patients with primary and post-traumatic osteoarthritis (OA), the silastic implant fares less well. Early failure may occur as a result of the high demands placed through the implant in an otherwise normal hand.3 In these cases anatomical replacement is probably a better alternative.

Surgical Anatomy. The MCPJ is a condylar joint with a convex, cam-shaped surface on the metacarpal head and an incongruent (larger radius of curvature) concave surface on the proximal phalanx. This allows 150° of flexion/extension and up to 57° of radioulnar deviation in extension, although most activities of daily living are achieved in an arc of 10° to 70° of flexion.4,5 The primary stabilisers of the joint form a sling, whose sides are formed by the collateral ligaments which originate from the tubercle on the metacarpal head and insert onto the base of the proximal phalanx, the accessory collateral ligaments which insert into the floor of the sling, and the volar plate, which is mobile at the MCPJ.

Work from the Mayo clinic in 1984 showed that the collateral ligaments have differing actions at various positions of the joint. The ligaments are, however, at full stretch in MCPJ flexion, thereby preventing abduction and rotation but are relatively slack in full extension in order to allow these movements.6 The secondary stabilisers are the musculotendinous units that cross the joint; the long extensors (primary extensors of the MCPJ), the long flexors (primarily act on the PIPJ and distal interphalangeal joint (DIPJ)) and the intrinsic interosseous and lumbrical muscles which are the primary flexors of the MCPJs.

Biomechanics. The MCPJ is subjected to significant forces, up to 190 Newtons during a pinch manoeuvre and probably more with power grip.7 The centre of rotation is unlikely to be through a fixed point on the metacarpal head because of the latter’s cam shape. Despite this, most prostheses are designed to incorporate a fixed point of rotation.

Surgical tips. The MCPJ is best approached through a dorsal incision, orientated either longitudinally over the MCPJ or transversely if multiple joints are to undergo surgery. It is important to preserve the vascular bundles that run in the gutters between the metacarpals in order to retain venous drainage and prevent swelling. We would advocate a radial paratendinous approach, as the radial sagittal band often requires imbrication to centralise the tendon. The tendon can be elevated from the underlying capsule and a median capsulotomy performed. With anatomical joint replacement, any soft-tissue release should be limited and, in particular, care must be taken to retain the attachments of the collateral ligaments.

Implant design. Early implants were of the constrained-hinge design, but these often failed by fracture or loosening, leading to recurrent deformity. The first unconstrained “anatomical” implant was made from alumina ceramic with favourable outcomes, but the authors felt that the design could be improved by moving the centre of rotation more volarward.8,9 Other designs now use pyrocarbons and other composite materials. Pyrocarbon is a synthetic material with a high strength graphite core coated with a pyrolytic carbon layer formed by heating a hydrocarbon gas to approximately 1300 °C. Pyrocarbon was first used in mechanical heart valves, is inert and compatible with normal bone. It was initially thought that osseointegration would occur but this has been shown not to be the case.10

Reported outcomes. In 1999, Cook et al reported their experience in 53 predominantly rheumatoid patients with 151 anatomical unconstrained MCPJ implants made from pyrocarbon (Fig. 1).11 Despite the use of this material, the authors reported a revision rate of 12% with a ten-year survival rate of 81.4%. The short-term outcome of a pyrolytic carbon implant in patients with OA has also been shown to be good.12 In both rheumatoid arthritis (RA) and OA, pyrocarbon MCPJ arthroplasty has been shown to reduce pain scores and increase range of movement in the
short term. In rheumatoid patients implant subsidence has been documented.\textsuperscript{15}

Harris and Dias have reported their results using an anatomical implant with cobalt chrome on an ultra-high-molecular-weight polyethylene (UHMWPE) bearing.\textsuperscript{16} The proximal cobalt-chrome component is inserted into an UHMWPE press-fit sleeve that is itself inserted into the metacarpal with an interference fit. The authors followed up 13 joints for a mean of five years; there was one revision for infection, and evidence of loosening of two phalangeal and one metacarpal component.

**Complications.** The complications seen after anatomical MCPJ arthroplasty are different to those for silastic arthroplasty. Subluxation or dislocations of the unconstrained components, loosening of the implants, implant fracture and joint stiffness have all been described.\textsuperscript{13,17}

These complications can be a challenge to address. A loose implant may be revised to a larger prosthesis with bone grafting. If an implant is to be removed, then the surgeon may consider revision to a silastic implant or volar plate arthroplasty.

**Proximal Interphalangeal Joint (PIPJ)**

Enthusiasm for PIPJ arthroplasty has recently increased as a result of the success of MCPJ replacement, although PIPJ fusion can result in acceptable hand function and excellent pain relief. However, where there is concomitant disease of the MCPJ or DIPJ, fusion of the PIPJ will result in a stiff finger and impaired function, and a motion-retaining arthroplasty may be preferred. Equally, an adequately counselled patient may choose to accept the risk of arthroplasty in order to maintain some movement in the joint rather than opt for a fusion. The only contraindications to arthroplasty in our practice are young active patients, manual workers, and patients with significant bone loss, gross instability or previous infection.

**Surgical anatomy.** The PIPJ is a bicondylar joint with an intercondylar concavity on the proximal phalanx.\textsuperscript{18,19} On either side of the head of the proximal phalanx are pits from which the collateral ligaments originate. On the middle phalanx there are two concavities, incongruent with the middle phalanx possessing a larger radius of curvature, separated by a saddle-shaped ridge that dorsally extends into a tubercle for the attachment of the central slip. On the volar margin of the articular surface is a rough, flat area for insertion of the volar plate; this takes origin proximally from the checkrein ligaments attached to the neck of the proximal phalanx. The accessory collateral ligament takes origin close to the true collateral near the pit on the proximal phalanx and inserts into the volar plate. This completes the walls of a box made up of the articular surface, volar plate and collateral and accessory collateral ligaments.

**Biomechanics.** Movement of the PIPJ varies from 0° to 30° of hyperextension to 100° of flexion. The PIPJ is not a true hinge joint as there is a small amount of rotation and angulation of the coronal plane during flexion; the axis of rotation is centred on a fixed point on the head of the proximal phalanx. Minamikawa et al demonstrated that with a lateral stress, 5° of adduction and 9° of supination is seen at the PIPJ.\textsuperscript{20} In full extension and flexion the joint is more stable.

**Surgical tips.** Arthroplasty of the PIPJ can be performed under local anaesthetic (if only one joint), regional block or general anaesthesia. The joint may be approached through dorsal or volar approaches, or through the ulnar lateral border. The dorsal approach allows for excellent exposure and is of particular benefit where large osteophytes are present. Our preferred technique is to split the extensor hood in the midline, elevating the central slip insertion off the middle phalanx as a continuous sleeve for reattachment with a transosseous suture. Alternatively, a dorsal, distally based chevron Chamay approach may be used.\textsuperscript{21} The central slip is divided in a chevron shape with the base on the middle phalanx. The lateral bands are preserved and allowed to sublux volarward to allow the joint to be hinged open. Here too, retention of soft tissue attachments is critical to the stability of the prosthesis.

In the operation note the surgeon should document the stability of the PIPJ, and whether the joint is suitable for early active mobilisation. The finger should be splinted immediately with a volar slab, with the wrist in neutral, the MCPJ and PIPJ in slight flexion and the hand elevated to reduce swelling. Rehabilitation should begin on day two, preferably under the supervision of an experienced hand therapist. If suitable, early active mobilisation
can be commenced with a resting splint to block extension at 20° (Fig. 2). If a lateral approach has been used the collateral repair should be protected with a radial outrigger or by buddy strapping. At six weeks protective splints can be discontinued but a resting night splint should be worn for a minimum of three months.

**Implant designs.** The first anatomical resurfacing PIPJ was developed by Linscheid using stemmed unconstrained implants with a bearing of UHMWPE on cobalt chrome. The stems were fixed with polymethylmethacrylate cement. An uncemented implant with an UHMWPE on cobalt chrome bearing, the PIPr (Depuy, Warsaw, IN) (Fig. 3), is now available as well as a pyrocarbon implant (Ascension Orthopedics, Austin, Texas) (Figs. 4 & 5).

**Reported outcomes.** In 1979, Linscheid et al reported the results of 66 of their implants in 47 patients with a minimum follow-up of one year. Using their own criteria they reported 32 good, 19 fair and 15 poor outcomes. The outcomes were worst in digits with pre-existing deformity or extreme bone and/or soft-tissue loss. A more recent cohort from Australia reported excellent long-term results in 18 of 20 patients.

**Complications.** As with all implants, infection is a major concern after PIPJ arthroplasty. From our own data we estimate the risk at approximately 1%. This is best treated by excision and secondary reconstruction with a silastic implant, or volar plate arthroplasty. With unconstrained implants instability is a problem that is best avoided with careful soft-tissue balance and accurate implant alignment at the primary procedure. Early dislocations may be addressed with closed reduction and splintage. If this management fails then revision to a hinged, silastic implant is likely to provide a stable, pain-free joint. Implant loosening, a common problem with highly constrained arthroplasty, is also seen with unconstrained components. Revision with larger components and bone grafting may be successful, otherwise a silastic hinged implant can be used.

**First Carpometacarpal Joint (CMCJ)**

First carpometacarpal osteoarthritis is a very common condition, particularly among elderly females. A number of prostheses have been developed to address this problem but comparative results are limited.

### Table I. Reported outcomes of the Ascension pyrocarbon PIPJ arthroplasty (Ascension Orthopedics, Austin, TX)

<table>
<thead>
<tr>
<th>Year</th>
<th>Author</th>
<th>No.</th>
<th>m/f</th>
<th>Follow-up (mths)</th>
<th>Age</th>
<th>Increase arc</th>
<th>Re-operation</th>
<th>Revision</th>
<th>Satisfaction</th>
<th>Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>Herren</td>
<td>17</td>
<td>19</td>
<td>12-27</td>
<td>64</td>
<td>55-81</td>
<td>8</td>
<td>6%</td>
<td>6%</td>
<td>71%</td>
</tr>
<tr>
<td>2006</td>
<td>Nunley</td>
<td>7</td>
<td>2</td>
<td>12-23</td>
<td>40</td>
<td>28-56</td>
<td>2</td>
<td>28%</td>
<td>28%</td>
<td>14%</td>
</tr>
<tr>
<td>2006</td>
<td>Tuttle</td>
<td>18</td>
<td>0</td>
<td>6-30</td>
<td>62</td>
<td>52-69</td>
<td>0</td>
<td>11%</td>
<td>0</td>
<td>84%</td>
</tr>
<tr>
<td>2007</td>
<td>Branam</td>
<td>19</td>
<td>0</td>
<td>6-36</td>
<td>62</td>
<td>52-69</td>
<td>1</td>
<td>0</td>
<td>81%</td>
<td>2</td>
</tr>
<tr>
<td>2007</td>
<td>Ng</td>
<td>15</td>
<td>0</td>
<td>7-44</td>
<td>62</td>
<td>38-82</td>
<td>15.3</td>
<td>20%</td>
<td>0</td>
<td>8 to 2</td>
</tr>
<tr>
<td>2007</td>
<td>Bravo</td>
<td>50</td>
<td>15</td>
<td>27-46</td>
<td>53</td>
<td>21-73</td>
<td>7</td>
<td>28%</td>
<td>8%</td>
<td>80%</td>
</tr>
<tr>
<td>2010</td>
<td>Wijk</td>
<td>53</td>
<td>0</td>
<td>12-60</td>
<td>59</td>
<td>40-85</td>
<td>-8</td>
<td>13%</td>
<td>2%</td>
<td>3 to 0.4</td>
</tr>
<tr>
<td>2010</td>
<td>Watts (unpublished)</td>
<td>97</td>
<td>2</td>
<td>24-109</td>
<td>56</td>
<td>24-79</td>
<td>13</td>
<td>23%</td>
<td>13%</td>
<td>76%</td>
</tr>
</tbody>
</table>
studies have not demonstrated an advantage of prosthetic replacement over simple trapeziectomy with or without tendon interposition. As a result many surgeons have been reluctant to expose patients to the risks of first CMCJ arthroplasty. **Surgical anatomy.** Imaeda et al studied the surgical anatomy of the first CMCJ and described five major ligaments; the anterior oblique, ulnar collateral, first intermetacarpal, the posterior oblique and dorsal radial ligament. Of these, the anterior oblique, also known as the beak ligament, is the most important for stability of the joint and should be retained for successful joint reconstruction. The double, saddle-shaped articular surface is asymmetrical, the convex surface is an ovoid arc (similar in cross-section to an aircraft wing where the radius of curvature decreases from back to front). The opposing concave surface has a small radius of curvature centrally that is maintained on one side of the central ridge but has a gentler slope on the other. Xu et al demonstrated that the joint is incongruent, allowing flexion, extension, adduction and abduction. The contact area is small, particularly in females, which may account for the increased female susceptibility to OA of the first CMCJ. **Biomechanics.** The forces that the first CMCJ must withstand are considerable. Cooney and Chao calculated that a tip pinch of 1kg will generate 12kg of joint compression. For power grip the load may be as high as 120kg. **Surgical tips.** The surgical approach to the first CMCJ may be dorsal-radial or volar. The dorsal-radial approach is centred over the first CMCJ in line with the first extensor compartment. Care must be taken to identify and protect the branches of the superficial radial nerve as injury may result in painful neuromata. The radial artery should be mobilised and protected, any fine branches being cauterised with diathermy. A distally based T-shaped capsulotomy is performed to expose the joint. The volar approach is through a curvilinear incision on the radial border of the thenar eminence centred over the first CMCJ. Cutaneous branches of the median nerve should be protected. The thenar muscles are elevated from the underlying capsule by sharp volar-ward dissection and the abductor pollicis brevis tendon is mobilised dorsally before a longitudinal capsulotomy to expose the joint is performed. For successful arthroplasty, capsular stability is essential. If there is instability as a result of the previous pathology then ligament reconstruction may also be performed using tendon grafts such as a split flexor carpi radialis tendon graft. At Wrightington the joint is immobilised in a static splint for six weeks with the thumb abducted and the nail plate aligned at 90° to the palm. **Implant design.** As with other joints in the hand, the initial experience of first CMCJ arthroplasty was with silastic implants. Initial reports indicated increased movement, grip strength and decreased pain with these implants; however, instability was also reported. With longer follow-up there were increasing reports of implant fragmentation, silicon synovitis and continuing instability. Alternatives to silicon arthroplasty include total joint replacement with ball and socket designs, and anatomical resurfacing arthroplasty.
Reported outcomes. The SR trapezometacarpal prosthesis (Avanta Orthopaedics, CA) was the first anatomical design, with biconcave cobalt-chrome on UHMWPE-bearing stemmed implants. Initial results reported by the originators were encouraging and were supported by impressive kinematic studies.42,43 However, an independent study by Perez-Ubeda et al reported 70% failure in 20 implants followed for between 24 and 45 months, with loosening in 55% and ankylosis in 15%.44 In 1982 Braun reported the initially favourable results of a titanium metacarpal component and a polyethylene trapezial component, both cemented with PMMA cement.45 Good outcomes were also reported at a mean of 59 months with only one patient complaining of minimal pain, and one revision for post-traumatic loosening.46

A new anatomical pyrocarbon resurfacing haemiarthroplasty prosthesis for the base of the first metacarpal has now been developed (Ascension Orthopedics, Austin, Texas) (Fig. 6). At Wrightington a review of the first 19 patients to undergo pyrocarbon haemiarthroplasty with a minimum follow-up of one year presented at the British Hand Society47 indicated an improvement in pain scores but no change in function or grip strength. However, four of 19 joints were subluxed. The authors conclude that the implant may have a role in the young patient who wishes to retain strength.

Complications. Painful neuromata can be difficult to treat and are best avoided by appropriate care being taken at the initial surgery. For refractory cases some success has been seen with excision of the tender skin and a full-thickness skin graft. With more recent resurfacing implants new complications have emerged. Painful loosening of the implant can be addressed with revision to a larger prosthesis and bone grafting, or simple implant excision. Resurfacing haemiarthroplasty may be associated with trapezial erosion which, if painful, may require removal of the implant.

Further Reading: Trail IA. Arthroplasty of the Hand and Wrist. Published by Lawrencekirk, UK.

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References


