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Metacarpophalangeal Arthroplasty

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Abstract: Metacarpophalangeal (MP) arthroplasty is the most common and most successful joint replacement surgery of the hand. This paper will briefly review the anatomy of the MP joint, and the indications, technique, results, and complications of MP arthroplasty. Although MP implants are occasionally performed for post-traumatic or osteoarthritic joints, the literature focuses on patients with rheumatoid or other inflammatory arthritis. These patients can anticipate correction of deformity, improved function, and highly effective pain relief.

Introduction

The history of metacarpophalangeal (MP) joint replacement is heavily dependent on the work of Albert Swanson, which was first reported in 1966 [14]. The silicone rubber implants used in MP arthroplasty differ in their fixation, articulation, and motion from the prostheses commonly used in larger joints. The role of the implant, according to Swanson, is not to function as a true prosthesis, but to serve as a spacer to maintain the joint in alignment after a resection arthroplasty is performed [15]. Resection arthroplasty of the MP joint is a procedure that is still advocated by some authors [12,18]. Currently, most authors favor the insertion of a prosthesis. The implant provides enough stability in the early post-operative period to mobilize the joint. However, the contribution of the implant to joint motion is debated. These prostheses have been described as "dynamic spacers" [15].

The implant promotes the development of a fibrous capsule, adapted to a functional range of motion determined by the post-operative mobilization. Swanson has termed the development of this fibrous capsule the "encapsulation process" [15].

The implants are inserted without an attempt to achieve rigid fixation. The encapsulation process itself is the definitive fixation of the implant. A small amount of pistoning of the intramedullary stem of the implant occurs [3]. Attempts at more rigid fixation of these implants have resulted in early fracture and clinical failures. The pistoning or gliding of the implant within the medullary canal adds to the range of motion achieved by the arthroplasty, in addition to dispersing the forces of motion along the implant-bone interface [13,15].

Anatomy

The normal MP joint is a diarthodial, condylar-type joint. The metacarpal head has a greater surface area than the base of the proximal phalanx. The articular surface of the head is convex and has a wider palmar surface. The asymmetry of this surface accounts for the tightening of the collateral ligaments when the joint is brought into flexion. This also provides mobile center of rotation to the MP joint, which moves volarly with flexion. The normal synovial membrane of the MP joint is attached around the margins of the articular cartilage with volar and dorsal capsular reflections. The largest synovial fold is found on the dorsal neck of the metacarpal [8].

The arc of motion of the normal MP joint is described as neutral to 90 degrees of flexion, although many individuals will demonstrate variable degrees of hyperextension. Radial and ulnar deviation is maximized in extension and is decreased with flexion and the associated tightening of the collateral ligaments. The MP joint deviates slightly in the ulnar direction with flexion of the digits.

The joint is stabilized by ligamentous structures. The collateral ligaments originate on the dorsal aspect of the metacarpal head-neck junction. They insert on the volar aspect of the proximal phalanx. The collaterals are the primary stabilizers against varus, valgus and dorsopalmar stresses. The volar plate has a membranous attachment on the neck of the metacarpal and a more fibrous attachment on the base of the proximal phalanx. The volar plate is the primary stabilizer against hyperextension. The flexor tendon sheath, the intermetacarpal ligaments, and the sagittal bands of the extensor hood attach to the volar plate. The accessory collateral ligaments are located volar to the collateral ligaments and insert into the volar plate. The accessory collaterals are stabilizers of the volar plate, as well as secondary stabilizers against varus and valgus stress.

The interossei and lumbrical muscles exert a flexion force on the MP joint through their attachments into the extensor hood and proximal phalanx. The sagittal bands aid in extension of the MP joint through their insertion into the volar plate, as well as stabilizing the extensor tendons over the joint itself. The long flexor tendons can exert a flexion moment on the MP joint, but their insertions on the distal and middle phalanges require this to occur after interphalangeal joint flexion.

Pathophysiology of Rheumatoid MP Joints

The MP joint is the most common site of involvement of rheumatoid arthritis (RA). The vast majority of indications for MP arthroplasty and the focus of the literature are patients with RA. The remainder of this review will focus on this clinical scenario. Destruction of the MP joint in RA begins with a proliferative synovitis and progressively leads to a volarly subluxated proximal phalanx with ulnar deviation and destruction of the articular cartilage. The deformities of the MP joint in RA have been extensively described. Characteristic changes occur in the articular surface, soft tissue stabilizing structures, and bony supports [8,13].

The primary causative factor producing the characteristic joint deformities remains controversial. Zancolli and others have made the proposal of a dynamic deformity, which exists before articular destruction [19]. Inflammation of the carpometacarpal joints exaggerates the spread of the metacarpals and the tendency for the MP joints to move into ulnar deviation with flexion. The supination deformity of the carpus leads to a radial deviation of the metacarpals. The resulting imbalance of forces on the extensor tendons results in their subluxation off the metacarpal head. This is facilitated by synovial infiltration along the collateral ligaments and at their attachments, which results in stretching out of the radial ligaments, producing further ulnar deviation and subluxation. The synovial proliferation within the joint contributes to attenuation of the radial sagittal bands and facilitates migration of the extensor tendons [8,13].

The theory of a dynamic deformity preceding the development of MP articular changes is not universally accepted, as some authors have thought that the changes in the articular surface are primary. The initial changes seen in the articular cartilage are softening and a loss of the normal translucent appearance of articular cartilage. A gradual progression to fibrillation and pitting of the surface of the metacarpal head occurs, followed by erosions and exposed bone. Bony erosions correspond to the areas of the synovial reflections. Volar erosions tend to be shallower than the dorsal ones. Erosions in any area have the potential to penetrate through the cortical bone, although this is less common volarly. In advanced cases, the erosions can coalesce circumferentially around the metacarpal neck. Erosions of the proximal phalanx occur later in the disease and tend to involve a circumferential margin around the base of the phalanx [8].

Surgical Indications

Advanced arthritis of the MP joint requiring surgical intervention is uncommon except in the rheumatoid hand. The literature on MP arthroplasty in osteoarthritic or post-traumatic arthritis is limited, and specific indications are not published. The general indications for MP arthroplasty are pain, deformity, and loss of function refractory to conservative measures. Substantial literature exists on MP arthroplasty in rheumatoid arthritis, and surgical indications will be discussed in a general overview of the MP joint in this condition.

Clinical Assessment

Evaluation of a patient with RA of the MP joints requires an assessment of the global function of the extremity and in particular the deformities of the adjacent joints. The deformities of adjacent joints and their subsequent progression may contribute to the ultimate success or failure of any

procedure performed in the MP joints. Progressive deformity of the wrist, in particular, may predispose MP arthroplasty to early recurrent ulnar deviation. The long flexor and extensor tendons should be evaluated for synovitis and the potential for rupture. Changes in the proximal interphalangeal joints have substantial effects on global hand function, and therefore, the ultimate success of any MP procedure. Surgical intervention for these joints is frequently performed at the same time as MP arthroplasty. A severe boutonniere deformity may need to be addressed prior to the MP joint, as this deformity tends to compromise MP function. Involvement of the thumb may need to be addressed concurrently or at a separate surgery if deformity is substantial [3,13,15].

The deformities of the MP joint have been classified in stages by Nalebuff and Millender [9]. Stage I disease shows MP synovitis, the ability to fully extend the joint, and little ulnar deviation or articular changes. Typically patients are managed medically for the synovitis, with splinting and/or corticosteroid injection for symptomatic relief. Night splints that hold the MP joints in extension and correct ulnar deviation are frequently prescribed.

Stage II is marked by the development of early erosions. Pain is generally the chief complaint. The extensor tendons show a tendency to move toward the web spaces. An extensor lag commonly exists, but flexion is well preserved. Clinical intervention focuses on maximizing medical management. Surgical intervention is infrequently performed, but could include synovectomy and soft tissue balancing. Synovectomy is not thought to alter the long-term prognosis of the disease but is widely accepted for alleviating local symptoms. Before undertaking soft tissue realignment, the surgeon must consider the adjacent joints and the mechanical effects on the MP. The incision for a Stage II procedure is the same as that used for arthroplasty should further surgery be necessary. Some surgeons consider crossed intrinsic transfers to the radial lateral band for significant ulnar deviation.

Stage III disease is characterized by advancement in joint destruction and an increase in the deformity. Stage III patients frequently have substantial PIP disease. The surgical decision is whether arthroplasty or tendon centralization and synovectomy is appropriate. The patient's level of pain and the function of the affected hand typically guide this decision.

Stage IV disease is marked by fixed subluxation and destruction as seen on radiographs. By this stage, silicone implants are widely considered the treatment of choice, and decision making focuses on the options available for the other joints. However, in a young patient with a functional range of motion of the MP joint (an active arc of motion of 60 to 70 degrees), the surgeon must determine whether surgical intervention is indicated, as there is unlikely to be functional improvement. Examination of the wrist and PIP joints must be performed, as changes in these areas are more common with advanced disease and may need to be surgically addressed before performing an MP arthroplasty [3,13].

Surgical Technique

The technique for MP arthroplasty has been extensively described [2,4,5,7,15]. A dorsal transverse incision is used at the level of metacarpal head-neck junction. The dorsal veins are preserved to the extent possible. The extensor mechanism is exposed and a longitudinal incision is made in the extensor hood. Swanson and most other authors make this incision on

the ulnar aspect of the hood, although Beckenbaugh and Lindscheid recommend preserving the ulnar hood if possible and incising the radial aspect of the extensor mechanism [3,15]. The capsule is then incised longitudinally and the neck of the metacarpal is exposed. A soft tissue release is necessary to relocate the phalanx and to allow preparation of the bony structures for insertion of the component. The collateral ligaments are released at their origin and the contracted ulnar intrinsics, including the abductor digiti minimus, are released. The flexor digiti minimi is preserved, as the small finger typically has the most difficulty achieving active flexion post-operatively. Some surgeons prefer not to release the ulnar intrinsic to the index finger in an attempt to preserve the function of the first palmar interosseous muscle for pulp to pulp pinch.

The metacarpal head is then removed along with capsular attachments after transecting the neck with a saw, rongeur, or drill. The level of resection is just distal to the origin of the, now reflected, collateral ligaments. Hypertrophic synovium within the joint capsule may then be removed [3,15]. Preparation of the medullary canal of the metacarpal is performed with hand reamers. Swanson uses a specially designed burr with a smooth tip to lessen the chance of cortical perforation. There is evidence that over-reaming of the canal is associated with peri-prosthetic bone loss post-operatively, therefore, reaming is minimized in both the metacarpal and proximal phalanx. After reaming, a trial prosthesis is selected. An effort is made to fit the largest size without applying undue force. An appropriately sized prosthesis should fit snugly while the transverse midportion of the implant rests against the cut surface of the bone [15].

The proximal phalanx is prepared by making a perforation in the subchondral bone in line with the center of the medullary canal. The hole is enlarged to accept a rectangular prosthesis with a rasp or burr. The index finger may be held in a slightly supinated position while rasping to improve tip pinch. After preparation and reaming of the selected, trial prostheses are once again inserted to ensure proper fit. With placement of a properly sized trial, no subluxation of the joint should occur and the implant should fit snugly into both canals [15].

The use of implants with titanium grommets has been suggested by some authors to improve the durability of the implants. In theory, the titanium protects the silastic from wear; however, there is little clinical data documenting any benefit. The data from animal experiments is inconclusive [11]. Some surgeons reserve the use of grommets for cases with extensive erosion of the dorsal aspect of the proximal phalanx to achieve a more stable construct.

Before insertion of the actual prosthesis, soft tissue reconstruction of the radial ligament complex must be considered. This is accomplished with the proper collateral ligament, unless it is severely attenuated. It is reattached with non-absorbable suture through holes in the metacarpal neck and imbricated as necessary. If the collateral ligament is deficient, an alternative radial ligamentous reconstruction has been described with the volar capsule and half of the volar plate attached to the origin of the collateral ligament [3,13,15]. Kirschenbaum and Schneider have described good long-term results without a radial reconstruction.

The bony surfaces are then irrigated and prepared for implantation. A so-called "no-touch" technique is used with smooth forceps so as not to injure the surface of the silicone rubber, as implant fracture has been

related to propagation of surface defects. The implant is first inserted into the metacarpal and then with flexion and distraction the distal end is placed into the phalanx. The radial reconstruction is tied down after placement of the implant, and the capsule is closed. The extensor tendon is centralized and the radial sagittal bands are reefed. The skin is closed with interrupted sutures over a subcutaneous drain. A bulky dressing is applied and the hand is splinted with the MP joints in extension to protect the soft tissue reconstruction [13,15].

The post-operative therapy protocol begins within 1 week of surgery; the patient is fitted with a dynamic splint holding the MP joints in extension and neutral to radial deviation. A static resting splint is also fabricated. The patient is encouraged to actively flex the MP joints in a controlled fashion to protect the extensor realignment and prevent prosthetic dislocation. The patient is weaned from the dynamic splint at 6 weeks, but static splinting is continued at night for 3--4 months. Special attention is devoted to the small finger, which may achieve active flexion more slowly because of the release of the hypothenar intrinsics and to the index finger, which has a greater tendency toward ulnar drift [13,15,17].

Results

The results after MP arthroplasty are well-documented and function is substantially improved in appropriately selected patients. The variables reported in the literature include range of motion, ulnar deviation, pain relief, and patient satisfaction. Realistic expectations are important, as the arthroplasties are not expected to achieve a full range of MP motion. Patients with substantial extensor lag or ulnar deviation preoperatively will only have a small increase in the arc of motion, but the arc will be in a more functional position. Key and tip pinch will also be improved as the index is brought over into a radial position. Reported post-operative arcs of motion vary from 38 to 60 degrees [1,2,4--7,15]. Extension lags also vary from 9 to 22 degrees [1,2,4--7,15]. A loss of 12 degrees of active motion at an average of 5 years of follow-up was documented from an early post-operative arc of motion of 51 degrees reported by Bieber [4].

Ulnar deviation is reliably corrected, although there is a tendency for some ulnar drift to recur with long-term follow-up. The correction of deformity has been documented as one of the major contributors to patients' subjective sense of improvement. Correction within a few degrees of neutral is reported in most series. Recurrent ulnar drift has been reported in up to 43% of patients; however, the recurrent deformities reported is less than 20 to 30 degrees in most series [1,2,4--7,15].

Pain relief is inconsistently documented in follow-up studies of MP arthroplasty, although clinical experience suggests that it is consistent. Kirschenbaum reported that of 144 arthroplasties in 36 hands, none complained of pain. Bieber reported that only 20% of patients in their series reported pain as a pre-operative concern [4,7]. Beckenbaugh reported recurrence of pain in 2% of patients at an average follow-up of 32 months [2]. Patient satisfaction with the procedure is generally high, with the majority of patients in most series reporting they would undergo the procedure again.

Complications

Silicone rubber MP joint implants generally have a low rate of complications [1,2,4--6,15]. Several other types of MP prostheses have a higher rate of long-term complications [1]. Foliart has published an extensive review of the literature on complications of Swanson finger joint implants [6]. The most frequently reported complication was extensive change in the bone surrounding the implant. This complication was found in 4% of silicone rubber implants [6]. Swanson has extensively studied the changes in bone morphology [16]. Metacarpal midshaft cortical bone consistently decreased post-operatively in this study, and the length of metacarpals with implants in place decreased by an average of 9% [16]. Bones remodeling also resulted in thickening of the bony surfaces at the metacarpal and phalangeal metaphysis while maintaining the shape of the cut end of the metacarpal [16].

Foliart found implant fracture in 2% of reported cases [6]. However, the rate of implant fracture varies form 0 (Bieber) to 38% (Beckenbaugh) and may depend on how extensively the investigator looks for radiographic evidence of fracture [1,2,4,5,7,15]. Many authors report that the majority of patients with fractured implants have acceptable function and do not require revision. The low morbidity of fractured prosthesis has been related to the function of the implant as a spacer rather than as an articulated prosthesis [1,2,4,5,7,15]. Several changes have been made in the implants to address this problem. The original silicone rubber 372 has been replaced by "high performance" (HP) silicone rubber. In vitro investigation demonstrates improved resistance to fracture and tear propagation with the newer silastic. Studies of only HP implants have shown fewer fractures than earlier studies, although no controlled trials have been undertaken to our knowledge.

Infection was noted in 0.6% of reported implants by Foliart [6]. Most series, including Swanson's, report a rate between 0.1 and 1% [1,2,4,5,7,10,15]. Millender and Nalebuff have published a detailed report on infection after silicone arthroplasty in the hand. All of Millender's infections presented within 8 weeks of implantation. Staphylococcus Aureus was the most common organism isolated and most of the prostheses ultimately required removal, and an average of 2 weeks of antibiotic treatment [10].

Particulate synovitis and silicone induce lymphadenopathy have received substantial attention. Both of these complications were recorded in less than 0.1% of reported cases by Foliart [6]. Synovitis in MP implants occurred almost exclusively in fractured implants or in implants with substantial signs of wear at removal. Four patients with lymphadenopathy and silicone rubber implants have been reported who developed non-Hodgkin's lymphoma. All four were in rheumatoid patients with the concomitant a 10-fold increased risk over the general population of developing lymphoma [6].

Summary

Treatment of the arthritic MP joint, particularly in the rheumatoid hand, requires consideration of the degree of compromise, as well as a thorough understanding of the anticipated outcome of the options for intervention. Silicone MP arthroplasty is one of the more successful operations performed in these patients when it is applied at the appropriate stage. The patient can anticipate a reversal of deformity, an active arc of motion of 40 to 50 degrees in a functional position and highly effective pain relief. Although MP arthroplasty is a successful procedure, problems do exist. Recurrence of a mild, ulnar drift deformity occurs in a substantial percentage of patients.

Implant fracture remains a concern, although the incidence of this problem has probably been reduced. In addition, longevity and reliable function beyond 10 years has yet to be documented. Silicone rubber arthroplasty provides an important method for the hand surgeon to improve the function of patients with severe MP disease. Future advances in implant technology and surgical technique will need to address these problems to allow MP arthroplasty to become a more successful and more widely applicable operation.

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