20 Metacarpophalangeal (MCP) and Proximal Interphalangeal (PIP) Joint Arthroplasty

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20.1 Introduction

Arthritis (degenerative or inflammatory) of the small joints of the hand is a common problem. Nonsurgical treatment includes splinting, oral analgesics, and in some situations local injections. Pain is the main indication for arthroplasty and arthrodesis of small joints of the hand. Other indications are joint deformity, stiffness, and incongruity seen in degenerative and inflammatory arthritis.

Surgical treatment of arthritis of the metacarpophalangeal (MCP) and finger proximal interphalangeal (PIP) joints should be well indicated. Existing surgical options are debridement of painful osteophytes, arthroplasty, and arthrodesis. For an implant to function well, bone and soft tissue stability is essential. Therefore, the treatment of each patient will depend on the soft tissue envelope and the amount of joint destruction. In most cases arthrodesis is a better alternative to arthroplasty [1].

Silicone implant arthroplasty has been the most widely accepted and widely performed technique for the treatment of small joint deformities of the hand in patients with rheumatoid arthritis (RA). The implant is placed as a joint spacer without bony fixation to provide adequate stability and alignment until scar tissue forms. Several studies have confirmed the benefits of silicone MCP arthroplasty, including pain relief and improved functional and cosmetic appearance of the hand [2–7]. However, fractures of silicone implants are very common. This is because the implant is subjected to high stress concentrations during active flexion [8–10]. The published survival of silicone implants, considering implant fracture as the end point, is 58% at 10 years and 34% at 17 years. Although at 17 years two-thirds of the implants are ruptured on radiographs, the published survival rate considering revision surgery as the end point is 63% at 17 years [11]. The aforementioned disparity indicates that high silicone implant fracture rates are not necessarily associated with clinical failure rates. There are several silicone implants on the market. One-piece silicone implants (Swanson finger joint implants, Wright Medical Group NV, Memphis, TN, USA) have been used since the 1960s [12]. The volar hinge silicone implant (Small Bone Innovations, Inc., Avanta Orthopaedics, LLC, Morrisville, PA, USA) was introduced in 1987 [13]. Its center of flexion is palmar with respect to the longitudinal axis, unlike the Swanson type, in which the center of flexion is slightly dorsal with respect to the longitudinal axis. It has been published that the range of motion (ROM) after surgery and implant fracture rates vary depending on the type of implant used [13–17]. Several

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authors have reported that the volar hinge silicone implant is associated with better ROM than the one-piece silicone implant; however, reported fracture rates have been higher with the volar hinge silicone implant [9, 18].

Implant fracture has not been directly related to reoperation. Furthermore, it has been observed that the rate of reoperation is much lower than the rate of radiographic implant fracture [11]. However, patients with active hand use may have increased pain and deformity shortly after surgery due to implant fracture, a complication that will require a revision procedure [19]. Although prevention of early implant fracture is important to attain a satisfactory outcome and to avoid an early revision procedure, few publications have analyzed the risk factors for implant fracture [11, 18].

This chapter discusses the current controversies concerning the previously mentioned arthroplasties. Finally, it should be remembered that in most cases arthrodesis is a better alternative than arthroplasty.

20.2 Metacarpophalangeal (MCP) Joint Arthroplasty

Degeneration of the MCP joint is more often the result of rheumatoid arthritis (RA) than of OA. For this reason, MCP arthrodesis is poorly tolerated, and implant arthroplasty is the preferred surgical option [20].

20.2.1 Primary MCP Joint Arthroplasty

The most common implants used are the pyrocarbon and silicone implants, with the metal-plastic SRA a distant third [20].

20.2.1.1 Unconstrained MCP Joint Arthroplasties

Pyrocarbon MCP Joint Arthroplasty in Noninflammatory Arthritis

Due to its unconstrained design, its use is a valid option in OA. However, concerns have been raised in RA patients. Pyrocarbon implants have been associated with excellent pain relief, improved hand appearance, increased postoperative motion, and high patient satisfaction [21, 22].

In 2015, Dickson et al. published the results, complications, and survival of pyrocarbon MCP joint arthroplasty in noninflammatory arthropathy with a minimum follow-up of 5 years (level IV evidence study). They retrospectively analyzed 51 implants in 36 patients. Patient demographics, complications, subsequent surgeries, and implant revision were recorded. Objective outcomes were assessed by grip strength, ROM, and radiological assessment of alignment, loosening, and subsidence. Subjective outcomes were assessed by Patient Evaluation Measure, Quick Disabilities of the Arm, Shoulder and Hand, and Visual Analog Scale scores (0, best; 10, worst) for appearance, satisfaction, and pain. There were 35 index fingers and 16 middle fingers. The mean follow-up was 103 months. The mean ROM was 54°. There was no difference in grip strength between the operated and unoperated side. Six implants were revised, of which three required additional surgery. The average Patient Evaluation Measure and Quick Disabilities of the Arm, Shoulder and Hand scores were 27 and 29, respectively. The mean Visual Analog Scale (VAS) score for pain, satisfaction, and appearance were all 1, with ranges of 0–7, 0–4, and 0–6, respectively. The majority of the implants were Herren grade 1 lucency, while the remaining 5 proximal and 12 distal implants were grade 2. The mean subsidence was 2 mm in the proximal component and 1 mm in the distal component. The degree of loosening or subsidence did not correlate with the outcome. Implant survival evaluated by Kaplan-Meier analysis was 88% at 10 years. Ultimately, good pain relief, functional ROM, and high satisfaction were observed in most patients. All implant revisions were performed within 18 months of the initial procedure [21].

In 2017, Aujla et al. performed a systematic literature review on the outcomes of unconstrained MCP joint arthroplasty. They observed that pyrocarbon implants reduced pain by 85%, increased pinch grip by 144%, and improved ROM by 13° in both osteoarthritis (OA) and inflammatory arthritis (IA). Patients implanted with metal on polyethylene (MoP) arthroplasties showed a decrease in pinch strength. Satisfaction rates were 91% and 92% for the OA and IA groups, respectively. There were 9 failures in 87 joints (10.3%) during a mean follow-up of 5.5 years in the pyro-OA group. There were 18 failures in 149 joints (12.1%) during a mean period of 6.6 years in the pyro-IA group. Due to the heterogeneity of the studies and the limited presentation of the data, a meta-analysis was not possible [23].

Pyrocarbon arthroplasty of the MCP joint leads to better improvements in total arc motion as compared to arthroplasty of the PIP joint [24, 25], although complication rates after pyrocarbon arthroplasty tend to be greater than those after silicone arthroplasty [26, 27]. Drake and Segalman proposed that there is a well-defined patient who may benefit from this arthroplasty: young people with posttraumatic arthritis, no angular deformities, and adequate soft tissue coverage [28]. Srnec et al. considered pyrocarbon arthroplasty as the treatment of choice for OA MCP joint [20]. Generally speaking, this procedure should be avoided in RA for progressive destruction of capsuloligamentous support.

20.2.1.2 Silicone MCP Arthroplasty

Alfred B. Swanson first introduced the concept of a silicone rubber spacer for joint replacement in 1962 [29]. To this day, the Swanson finger joint silicone arthroplasty implant is the most widely used small joint arthroplasty [30].

The hinged MCP joint silicone implant is designed to maintain a joint space and alignment while relying on the formation of a capsule around the arthroplasty and proper tendon and ligament balance to maintain stability. Although silicone is generally well tolerated in the body, microscopic debris may cause pain and destruction secondary to local inflammatory response (Figs. 20.1 and 20.2).

In 2012, Chung et al. analyzed patients with rheumatoid arthritis (RA) treated with silicone MCP joint arthroplasty (SMPA). In a prospective multicenter study, 162 patients with severe subluxation and/or ulnar deviation of MCP joints were analyzed [31]. The long-term results of a group operated with SMPA ($N = 67$) were compared with those of a group of nonoperated patients ($N = 95$). Patients could choose whether to undergo SMPA or not. Results were assessed using the Michigan Hand Outcomes Questionnaire (MHQ), Arthritis Impact Measurement Scales 2 (AIMS2), grip/pinch strength, Jebsen-Taylor test, ulnar deviation, extensor lag, and ROM measurements at the MCP joints. There were no significant differences in mean age, race, education, and income at baseline between the two groups. Surgical patients had worse MHQ function and functional measurements at baseline. At 3 years, the mean MHQ global score and MHQ function, activities of daily living, aesthetics, and satisfaction scores were significantly better in the surgical group than in the nonsurgical group. Ulnar deviation, extensor lag, and arc of motion in the MCP and proximal interphalangeal (PIP) joints also improved significantly in the surgical group. No improvement in mean AIMS2 scores or grip/pinch strength was observed. Complications were minimal, and there was a fracture rate of 9.5%. Ultimately, compared with nonsurgical controls, AR patients had long-term improvement in hand function and appearance after SMPA treatment [31].

In a randomized controlled trial on silicone MCP joint arthroplasty, Chung et al. in 2015 demonstrated excellent patient satisfaction and better outcomes for the surgically treated group of RA patients with severe hand deformities [6].

Patients suffering from nonrheumatic arthritis also experience pain relief, increased ROM, and satisfaction with silicone arthroplasty [32].

Compared to PIP arthroplasties, MCP joint silicone ones show greater improvement in total range of motion [5]. Neral et al. reported a statistically significant 15° improvement in total arc of motion after MCP joint arthroplasty [32]. However, Hansraj et al. found a decrease in ROM after surgery [33] and Olsen et al. observed variable pain relief and satisfaction [34].

In 2013, Chetta et al. stated that RA patients with swan neck deformities have greater MCP joint ROM because of their need to flex the joint to make a fist, whereas the boutonniere deformity places the fingers into the flexed position, creat-

Fig. 20.1 (**a**–**d**) Rheumatic hand with metacarpophalangeal (MCP) joint subluxation operated with silicone prosthesis: (**a**) anteroposterior (AP) radiological view presurgery, (**b**) oblique radiological view presurgery, (**c**) AP radiological view 1 year postsurgery, and (**d**) oblique radiological view 1 year postsurgery

ing less demand on the joint for grip [35]. They conducted a study (level II evidence) in which they analyzed the effect of the aforementioned deformities on joint ROM and hand function. They measured the ROM of the MCP joint in 73 surgically treated patients. The data was distributed into groups according to finger and hand deformity. Functional outcomes were measured using the Michigan Hand Outcomes Questionnaire and the Jebsen-Taylor test. Nineteen fingers had boutonniere deformity, 95 had gooseneck deformity, and 178 had no deformity. The no deformity group had the lowest ROM at baseline (16 degrees) compared to the boutonniere (26 degrees) and swan neck (26 degrees) groups. The mean ROM in the no-

Fig. 20.2 (**a**–**d**) Rheumatic hand with joint metacarpophalangeal (MCP) dislocation and severe ulnar deviation operated with silicone prosthesis: (**a**) presurgical anteroposterior (AP) radiological view, (**b**) presurgical oblique radiological view, (**c**) AP radiological view 6 months postsurgery showing third-finger prosthesis dislocation, and (**d**) oblique radiological view 6 months postsurgery showing third-finger prosthesis dislocation

deformity group compared with the boutonniere group at baseline was statistically significant, but all groups had similar ROM at long-term follow-up. Only the mean Jebsen-Taylor test scores at baseline between the boutonniere and no-deformity groups were significantly different. Ultimately, the results did not support the hypothesis that swan neck deformity has a better ROM than boutonniere deformity. The boutonniere deformity had worse function at baseline, but in the long term there was no difference in function between groups [35].

Long-term results have been less satisfactory, often noting recurrence of deformity.

In 2018, Boe et al. published an analysis (level IV evidence) of 325 silicone MCP arthroplasties prospectively collected from a single institution's total joint registry over a 14-year period to assess long-term radiographic and functional outcomes [36]. Patients were followed for a mean of 7.2 years or until revision. Survival at 5, 10, and 15 years without revision was 98%, 95%, and 95%, respectively. Survival rates at 5, 10, and 15 years without radiographic implant fracture were 93%, 58%, and 35%, respectively. The 5-, 10-, and 15-year survival rates without coronal plane deformity greater than 10° were 81%, 37%, and 17%, respectively. Patients had significant improvements in postoperative pain levels and MCP joint ROM. Neither implant fracture nor coronal plane deformity >10° had a significant association with worse function. Overall, pain relief and functional improvement were reliable, although silicone implants did not protect against progression of coronal plane deformity and had a high fracture rate [36].

Implant fracture is a complication unique to silicone arthroplasty [37]. Fractures are typically caused by a tear in the implant from excessive wear from sharp bone edge. In the literature, implant fractures are reported to range from 0% to 63% [8, 11]. A fracture implant is not necessarily correlated with pain, decreased patient satisfaction, disability, or need for reoperation or revision [11].

In 2018, Morrell and Weiss set out a study to demonstrate that MCP silicone arthroplasty provides excellent long-term outcomes with a low complication rate in patients with osteoarthritis (OA) (therapeutic level IV evidence study) [38]. A group of 35 patients with OA of one or more MCP joints undergoing anatomically neutral MCP silicone arthroplasty was followed for a period of 15 years. Functional outcomes, including strength and ROM, as well as complications were recorded. All patients were available for long-term evaluation including radiographs and an outcome questionnaire. The mean follow-up of the 35 patients (40 implants) was 8.3 years. The mean age was 58 years, with 22 men and 13 women. Only one MCP joint was affected in 31 patients (middle finger, 20; index finger, 10; small finger). The dominant hand was affected in 23 patients. Seven (out of 14) patients underwent radial collateral ligament (RCL) reconstruction of the MCP joint of the index finger; no other fingers required collateral ligament reconstruction. The mean final VAS pain score was 0.3 over 10. The mean final active ROM was 4° to 73° of flexion. One patient underwent revision MCP arthroplasty with a clinical survival of 97%. Radiographs demonstrated implant fracture in 5 of 40 (12.5%) implants, but none showed instability, pain, or ROM impairment. The mean Michigan Hand Outcomes Questionnaire score was 82 (out of 100) at the end of follow-up. Ultimately, silicone arthroplasty was effective in the treatment of MCP joint OA. Long-term implant survival was 97% (clinical) and 88% (radiographic) [38].

In 2021, Iwamoto et al. attempted to identify risk factors associated with early fracture of the MCP silicone arthroplasty implant using the volar hinge silicone implant in patients with RA (therapeutic level IV evidence study) [39]. They retrospectively reviewed 113 fingers from 31 hands that underwent MCP arthroplasty, with a minimum follow-up of 3 years. An implant fracture within 3 years after surgery was considered an early implant fracture. Patient records were reviewed for possible risk factors of age, affected toes, ulnar drift angle, and ROM of the MCP joint before surgery and 1 year after surgery. Candidate risk factors were compared at the digit level and at the patient level. With implant fracture as the end point, the estimated Kaplan-Meier survival rate was 74.3% at 3 years and 67.9% at 5 years. Early implant fracture was detected in 29 fingers. Bivariate analyses showed significant associations between early implant fracture and MCP joint ROM before surgery, MCP joint flexion range 1 year after surgery, and MCP joint ROM 1 year after surgery. Multiple logistic regression analysis showed that increased MCP joint flexion range 1 year after surgery was an independent risk factor for early implant fracture. Ultimately, increased MCP joint flexion arc was associated with increased implant fractures. Iwamoto et al. proposed that the MCP joint flexion range should be restricted to less than 60° in postoperative rehabilitation. This required educating patients to avoid excessive MCP joint flexion [39].

In 2015, Squitieri et al. performed an economic evaluation of the long-term outcomes of silicone MCP arthroplasty in patients with RA [40]. In a 5-year prospective study, they analyzed 170 patients (73 surgical and 97 nonsurgical). They assessed objective functional measurements and patient-rated outcomes using the Michigan Hand Outcomes Questionnaire and the Arthritis Impact Measurement Scales 2 at 3 and 5 years. A cost-effectiveness analysis was performed using direct costs from Medicare outpatient claims data (2006–2010) to estimate incremental cost-effectiveness ratios for the Michigan Hand Outcomes Questionnaire and the Arthritis Impact Measurement Scales 2. At 5 years, a statistically significant difference in outcomes (Michigan Hand Outcomes Questionnaire) was observed between the two groups, with surgical patients having better outcomes. The costs associated with improved outcomes at 5 years after surgery ranged from $787 to $1150 when measured with the Michigan Hand Outcomes Questionnaire and from $49,843 to $149,530 when measured with the Arthritis Impact Measurement Scales 2. The incremental cost-effectiveness ratios did not increase substantially with the observed surgical revision rate of 5.5% (approximately 4% incremental cost-effectiveness ratio increase) or with previously published long-term revision rates of 6.2% (approximately 6% incremental cost-effectiveness ratio increase).

Ultimately, the short-term improvements in the outcomes of silicone MCP arthroplasty were maintained over the 5-year follow-up. Moreover, these results were achieved at a relatively low cost, even when the cost of potential surgical complications was added [40].

In 2020, Esterman et al. attempted to identify the causes of satisfaction of patients with inflammatory disease undergoing hand reconstruction with silicone MCP arthroplasty [41]. Their hypothesis was that patients taking biologic drugs would be more satisfied with the outcome. The minimum follow-up was 1 year. Patients rated their satisfaction with treatment outcome and hand appearance on a 5-point Likert scale, with a score of 5 indicating "very satisfied" and 1 indicating "very dissatisfied," and completed the brief Michigan Hand Outcomes Questionnaire (MHQ). MCP ROM, ulnar drift, and grip strength were measured. Forty-one patients with 118 operated fingers were available for follow-up after a mean of 5.6 years. Patients were satisfied with the overall treatment outcome (score 4.4), but only somewhat satisfied (score 3.3) with the appearance of their hand. The total ROM of the MCP was 61° with an ulnar deviation of 10°. Appearance and ulnar deviation were determinants of satisfaction. There was no difference in the results between patients who used biologic drugs and those who did not. The hypothesis that patients taking biologic drugs were more satisfied after surgery could not be proved. Hand appearance and ulnar deviation were the most important determinants of satisfaction after reconstruction of the MCP deformity [41]. Finally, with respect to MCP arthritis, silicone remains the gold standard for RA [20].

20.2.1.3 Surface Replacement Arthroplasty (SRA)

SRA was design to create a more anatomical joint. It tries to reproduce a physiologic articulation while preserving bone stock and collateral ligaments for stability. Preservation of collateral ligaments would decrease endosteal contact forces, minimizing osteolysis and subsidence [42]. The implant consists of a proximal cobalt chromium (CoCr) component and a distal metal-backed polyethylene-titanium component. The material properties of the implant allow better coronal plane deformity because of its modularity. However, it lacks the inherent stability of the hinged silicone implant that can be of interest in patients with poor soft tissue stabilizers.

In 2020, Claxton et al. investigated the results of surface replacement arthroplasty (SRA) in RA patients with MCP joint involvement. It was a retrospective study of 80 SRAs performed in 27 patients. The parameters analyzed were demographics, SRA revisions, reoperations, complications, pain, and ROM of the MCP joint. The mean follow-up was 9.5 years (minimum 2 years). Thirteen fingers (16%) required revision arthroplasty and 29 (36%) required reoperation. Survival rates at 5, 10, 15, and 20 years after implant revision were 95%, 85%, 80%, and 69%, respectively. Survival rates at 5, 10, 15, and 20 years from global reoperation were 80%, 65%, 55%, and 46%, respectively. MCP joint ROM, grip strength, and pain intensity were significantly improved after surgery. Ultimately, MCP joint SRA improved function and pain in patients with AR. However, the high overall reoperation rates were of concern, although most did not involve revision arthroplasty [43].

This procedure has limited use because of the high reoperation rate and its 5-year low survival rate of 67% compared to 85% for pyrocarbon and silicone implants [44].

20.2.1.4 Dorsal Capsule Interpositional Arthroplasty of the MCP Joint

In isolated MCP joint degenerative or traumatic arthritis, dorsal capsule interposition arthroplasty is a technique that provides short-term pain relief and has the advantage of preserving the bony anatomy, collateral ligaments, and volar plate, thus not excluding further implant arthroplasty.

In 2020, Walker et al. analyzed the results of a novel soft tissue arthroplasty technique that interposes the dorsal capsule, with a mean follow-up of 2 years [45]. They performed a retrospective review of 10 dorsal capsule interposition arthroplasties of the MCP joint in eight patients. Physical evaluation assessed MCP joint ROM, grip strength, and pain. The outcome tests used were the Michigan Hand Outcomes Questionnaire, Visual Analog Scale (VAS), and Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) scores. The Kellgren and Lawrence classification assessed the severity of MCP joint osteoarthritis on preoperative radiographs. The mean follow-up was 29 months. The mean VAS score was 2/10 postoperatively and the mean postoperative ROM improved 7 degrees. The mean postoperative grip strength of the operated hand was 30 kg. The mean Michigan Hand Outcomes Questionnaire final score was 70. Patients with Kellgren's grade 2 or 3 osteoarthritis scored highest on the QuickDASH and Michigan Hand Outcomes Questionnaire. All patients who were working before surgery returned to work. No patient required a second surgery. Ultimately, this technique of dorsal capsule interposition arthroplasty was considered a viable technique for isolated degenerative or traumatic arthritis of the MCP joint after a mean follow-up of 2 years. Pain relief was more intense in patients with less severe radiographic findings. The advantage of this procedure is that it preserves the bony anatomy, collateral ligaments, and volar plate, thus not excluding further implant arthroplasty [45].

20.2.2 Revision MCP Arthroplasty

The main complications of MCP arthroplasty are subsidence, osteolysis, dislocation, and implant fracture. These complications are more frequent in patients with joint deformities and loss of joint stability and do not always require revision surgery. Different materials have been used and different techniques have been developed to achieve favorable results after revision MCP arthroplasty. It should not be forgotten that the main problem of this technically complex surgery is the loss of bone tissue and soft tissue support.

In 2007, Ikavalko et al. stated that MCP arthroplasty after silicone implant arthroplasty had frequent complications, such as severe bone loss, osteolysis, and diaphyseal perforations. Also, impacted, morselized allografts were frequently used to treat bone loss in revision surgery [46]. They described a new treatment method using a bioreconstructive poly-L/D-lactic acid (PLDLA) joint scaffold and allograft bone packing, after complete removal of the original silicone implants. This method restored bone deficiencies, corrected malalignment, and improved hand function. In a prospective, nonrandomized study, the authors presented the clinical and radiographic results of 21 patients with 52 MCP revision arthroplasties using PLDLA implants and allograft bone packing, with 1-year follow-up. Recurrent volar displacement of the proximal phalanges occurred in 33 of the 52 joints. No surgical wound healing problems were encountered. Some patients suffered transient loss of tactile sensation. Bone packing appeared to be successful in restoring host bone stock and PLDLA implantation provided a bioresconstructive scaffold for fibrous tissue ingrowth that promoted adequate stability and function. However, Ikavalko et al. also mentioned that the role of the described method should be assessed in the long term [46].

In 2012, Tiihonen et al. stated that revision arthroplasty of MCP joint in patients with chronic inflammatory arthritis after silicone implants was technically challenging due to severe bone loss and existing soft tissue deficiencies [47]. In their study they evaluated the results of the revision MCP arthroplasty using poly-L/D-lactic acid 96:4 (PLDLA) interposition implant and morcelized allograft or autograft bone packing in patients with failed MCP arthroplasties and severe osteolysis. They analyzed 15 patients (15 hands and 36 joints) with a mean follow-up of 7 years. They reviewed radiographs for osteolysis and incorporation of the grafted bone. The clinical parameters evaluated were active ROM, pain, subjective outcome, and grip power. The technique provided satisfactory pain relief, but function was limited. Radiographic analysis showed complete incorporation of the grafted bone into the diaphyseal portion of the metacarpal bones and into the host phalanges in 30 of 36 joints. All patients had very limited grip strength on both the operated and nonoperated sides. Ultimately, due to soft tissue deficiencies, long-term functional and alignment problems could not be resolved with the PLDLA interposition implant [47].

In 2019, Wagner et al., in a level IV evidence study, analyzed the results of 128 revision MCP arthroplasties performed in 64 patients [44]. The mean age of the patients was 62 years. Fifty nonconstrained (31 pyrocarbon and 19 surface-replacing arthroplasty) and 78 constrained silicone implants were used for revisions. With a mean follow-up of 6 years, 20 (16%) implants required secondary revision surgery. The 5- and 10-year survival rates were 81% and 79%, respectively. Postoperative dislocation occurred in 17 (13%) MCP joints. Subgroup analysis demonstrated a 5-year survival rate of 67% in surface-replacing arthroplasties, compared with 83% for both pyrocarbon and silicone implants. Postoperatively, improvements in pain and ROM of the MCP were observed in most patients. Ultimately, MCP revision arthroplasty was a difficult procedure, with one in five patients requiring a revision procedure at 5 years and a relatively high rate of postoperative dislocations. However, most patients who did not require secondary revision surgery improved in terms of pain and ROM. The worst results were obtained in patients with a history of MCP dislocations [44].

In 2020, Notermans et al. stated that MCP silicone arthroplasty had a high revision rate and that the preoperative degree of ulnar and radial wrist deviation had been suggested to influence the duration of revision [39]. They conducted a study to evaluate what factors were associated with reoperation after MCP silicone arthroplasty. They retrospectively evaluated 73 adult patients (252 arthroplasties). The treated fingers included 66 index, 67 long, 60 ring, and 59 small fingers. The overall reoperation rate was 9.1% ($N = 23$). Indications for reoperation were implant rupture ($N = 11$), instability ($N = 4$), soft tissue complications ($N = 4$), infections ($N = 3$), and stiffness ($N = 1$). Patients operated on a single finger showed a greater tendency to have higher revision rates (19% vs. 3.5%, $p = 0.067$). Radiographic follow-up demonstrated joint incongruity in 50% of cases, bone erosion in 58%, and implant breakage in 19%. There was a tendency to have a higher revision rate in patients without preoperative MCP joint subluxation (19% vs. 6.7%, $p = 0.065$). Implant survival rates at 1, 5, and 10 years were 96%, 92%, and 70%, respectively. Revision surgery occurred at the first 14 months in 15 patients (65%) and after 5 years in 8 (35%) patients. In short, revision surgery after MCP silicone arthroplasty appeared to be bimodal. Patients with greater preoperative hand function may be at greater risk of needing revision surgery [48]. This is consistent with Iwamoto's statement that increased arc of flexion of the MCP joint is associated with increased implant fractures [39].

20.3 PIP Joint Arthroplasty

The complexity of the PIP joint makes management particularly challenging.

Treatment of the PIP joint has evolved over time and requires an understanding of the biomechanics of the joint. Normal functional range of motion is between 23° and 87°. It is important to consider functional ROM when evaluating the results of arthroplasty. The PIP joint destruction is often related to OA or posttraumatic degeneration and to a lesser extent to RA. The most common implants used are silicone arthroplasty, metal-plastic SRA, and pyrocarbon arthroplasty.

20.3.1 Emergency Arthroplasty of the PIP Joint for Complex Fractures with Silicone Implant

Silicone arthroplasty usually provides good pain relief and patient satisfaction [49–52] (Figs. 20.3 and 20.4). However, ROM improvements are less predictable than in the MCP joint. Swanson reported a 35° increase in PIP joint arc of motion [12], but in a larger study he later noticed only a 10° increase in arc of motion [53]. Other studies reported little changes in total PIP range of motion [24, 49–51]. Conolly and Rath demonstrated that preoperative contracture was inversely related to the arc of motion that could be restored [54]. Long-term survivorship has been satisfactory, between 80% and 90% at 8–10 years [51, 52, 55]. This implant has been shown to be ineffective for the correction of boutonniere and swan neck deformities, subluxation, and ulnar and radial deviation [51].

In 2020, Laurent evaluated emergency finger silicone implants in complex and comminuted fractures of the PIP joint, as well as their clinical and radiological complications [56]. In comminuted fractures, arthroplasty with a silicone implant is a controversial therapeutic option in an emergency setting. Joint destruction is often accompanied by soft tissue injuries (skin, tendons, devascularization), which makes reconstruction even more complex. In their retrospective study they analyzed 13 patients undergoing emergency surgery with a PIP NeuFlex arthroplasty 1. PIP joint reconstruction was associated with soft tissue repair at the same time (skin cover, tendons, nerves) in all patients. The mean age of the patients was 57.7 years, and there was a predominance of male sex (92%). Injuries were caused by domestic accident in 61% of cases. The mean follow-up was 4.7 years. The mean total active ROM was 183°. The mean QuickDASH score was 24. There was one case of implant rupture without functional consequences. There were no cases of infection or instability. Arthroplasty with a silicone implant was a simple, reliable, fast, and durable solution for complex PIP joint fractures when conservative treatment was impossible. This solution is a good alternative to arthrodesis or even amputation of the finger and they stated that the PIP joint was particularly vulnerable to trauma [56].

The complications of this implant are instability, implant fracture, and synovitis.

As for instability or deviation of the postoperative axis, we will discuss it later with the SRA. Implant fracture varies between 0% and 55% according to the studies [49–52, 55].

A fractured implant is not necessarily associated with disability, pain, and revision surgery. Bales et al. reviewed 21 fractures of which only 3 required revision for pain and concluded that radiographic alterations did not correlate with prognosis [52].

Silicone synovitis and granuloma formation are another clinical problems that may require implant removal due to pain and bone loss. It has been reported but is rare (0%–24%) at the PIP and MCP joint in contrast to the higher incidence after silicone total wrist arthroplasty [50–52, 57].

Silicone arthroplasty has remained a good treatment option for PIP joint arthritis, and it has the longest follow-up studies of all available implant arthroplasties.

Fig. 20.3 (**a**–**d**) Posttraumatic lesion of the proximal interphalangeal (PIP) joint third finger operated with silicone prosthesis: (**a**) presurgical anteroposterior (AP) radiological view, (**b**) presurgical oblique radiological view, (**c**) AP radiological view 1 year postsurgery, and (**d**) lateral radiological view 1 year postsurgery

Fig. 20.4 (**a**–**f**) Posttraumatic arthritis of proximal interphalangeal (PIP) joint of the fourth finger treated with silicone prosthesis: (**a**) anteroposterior (AP) radiological view before surgery, (**b**) lateral radiological view before surgery, (**c**) AP radiological view 1 year postsurgery, (**d**) lateral radiological view 1 year postsurgery, (**e**) AP radiological view 2 years postsurgery, and (**f**) lateral radiological view 2 years postsurgery

20.3.2 Surface-Replacing Implant Arthroplasty

The aim of this procedure was to create an implant with more physiological articulation and stability, particularly with laterally directed tension [42]. Linscheid et al. reported their data using the SRA PIP implant, and total pain relief was achieved in 86.1% of patients and a 12° increase in mean total ROM [42]. Jennings et al. observed good pain relief but no improvement in PIP joint ROM [58]. Daecke et al. found a 2° loss of PIP joint motion at 3-year follow-up [26]. Stoecklein et al. reported a 27° increase in total ROM using a volar approach that maintains the integrity of the extensor mechanism allowing early postoperative motion [59].

In 2020, Bodmer et al. compared the results of volar, Chamay, and tendon-splitting approaches for PIP arthroplasty using a superficial replacement implant (CapFlex-PIP) (level IV evidence study) [60]. One thousand patients were studied prospectively, with a 2-year follow-up. PIP ROM, brief Michigan Hand Outcomes Questionnaire scores, and complications were analyzed. The mean PIP joint ROM increased in the volar (53° to 54°), Chamay (38° to 53°), and tendon-splitting (40° to 61°) approaches. The volar approach produced the greatest flexion and the greatest extension deficit. The mean Michigan Hand Outcomes Questionnaire scores at baseline and 2 years were 45 and 74 (volar), 45 and 66 (Chamay), and 41 and 75 (tendon splitting), respectively. Seven patients in the Chamay group and two in the volar group required reintervention, which consisted of teno−/arthrolysis. Compared with the volar and Chamay approaches, the tendon-splitting approach showed a tendency to produce the best results, which were associated with fewer complications [60].

SRA has been used with or without cement and its results have been examined. Johnstone et al. in a long-term retrospective study found no difference in pain score or range of motion, although cemented implants had a higher revision rate (26% vs. 8%) and uncemented components had a higher rate of radiographic loosening of the implant [61]. Murray et al. reported no difference in clinical or radiographic outcomes between cemented and uncemented PIP-SRA implants [62].

Many surgeons avoid the use of cement since revisional surgery becomes more difficult and heat released during cement curing may negatively affect bone and soft tissues [42].

Other possible complications are tendon adhesions, joint instability, swan neck deformity, boutonniere deformity, intraoperative fracture, malalignment, dislocation, and infection [26, 42, 63]. Revision surgery or conversion to arthrodesis is necessary in 9.1%–27% [26, 42, 61].

20.3.3 Complications After Surface-Replacing and Silicone PIP Arthroplasty

In 2021, Helder et al. analyzed complications after surface-replacing and silicone PIP joint arthroplasty [64]. They studied complications, reoperations (subsequent intervention without implant modification), and revisions (subsequent surgery with implant modification or removal) in two groups of patients: those operated with a surface-replacing arthroplasty at the PIP joint using the CapFlex-PIP prosthesis and those operated with a PIP silicone implant. In addition, they evaluated radiographs for deviations of the longitudinal axis of the finger. They analyzed 279 surface-replacing implants and 424 silicone implants. The overall complication rate was 20% for surface-replacing implants and 11% for silicone implants ($p \leq 0.01$), with soft tissue-related events being the most frequent in both groups. Reoperations were significantly more frequent after surface replacement (5.4%) than after silicone arthroplasty (0.5%; $p \leq 0.001$); however, revision rates did not differ significantly (4.4% and 3.3%, respectively; $p = 0.542$). Postoperative axis deviations were significantly less frequent in the surface replacement group (19% vs. 58% for silicone arthroplasty; $p \leq 0.001$). Ultimately, Helder et al. recommended using a surface-replacing implant in cases with preoperative axis deviations and a correctable anatomical situation [64].

20.3.4 Lateral Stability in Healthy PIP Joints Versus Surface Replacement and Silicone Arthroplasty

In 2020, Hensler et al. attempted to quantify the lateral stability of healthy PIP joints using a three-dimensional motion capture system and to compare it to affected joints after surface replacement or silicone arthroplasty [65]. The three study groups were healthy individuals, patients with osteoarthritis of the PIP joint treated with a surface-replacing implant (CapFlex-PIP), and patients with osteoarthritis treated with silicone arthroplasty. All participants were matched for gender and digit, and the two groups of patients were also matched for duration of follow-up. An optical tracking system was used to measure lateral stability. Radial and ulnar stability of the PIP joint were measured as the maximal lateral deviation angle of the middle phalanx under loads of 40 g, 90 g, and 170 g at 0°, 20°, and 45° of PIP joint flexion. Thirty joints were evaluated (5 index and 5 middle fingers in each of the three study groups). Lateral deviation increased proportionally with the applied load. Silicone arthroplasty joints had a higher mean lateral deviation angle (5.18) than healthy joints (3.08) and surface replacement joints (3.38) at 45° flexion and under a 170-g load. After PIP joint arthroplasty, the lateral stability of the PIP joint was highly variable in both healthy participants and patients. Surface replacement PIP joint arthroplasty showed a tendency to provide better anatomical stability than flexible silicone implants [65].

Despite favorable reports with SRA implants for RA of the PIP joint, some authors prefer the use of silicone in this patient group [20].

20.3.5 Pyrolytic Carbon PIP Arthroplasty

Pyrocarbon is biologically inert, has elastic modulus similar to that of bone, and its implant stem has no bony ingrowth. PCA for PIP joint was developed to provide patients with an alternative to silicone and SRA. The primary indication for PIP arthroplasty is pain. Literature suggests that PCA has been relatively successful in improving pain, shows low complications, and presents reasonable implant survival [27, 66–70].

However, other studies have demonstrated high rates of complications and revision surgery. Pyrocarbon implant is vulnerable to dislocation, implant migration, contracture, and squeaking. Sweets and Stern found a gradual decrease in motion over time, high rate of revision surgery, dislocation, stiffness, and implant fracture [25]. Due to the lack of bony ingrowth, pyrocarbon rates of migration and loosening have been high (64%) [25, 68]. A meta-analysis reported higher rates of complications associated with the use of pyrocarbon (30%) versus silicone implant (8%) and the authors have abandoned this technique [71].

In 2020, Mora et al. stated that the use of pyrolytic carbon arthroplasty (PCA) for the proximal interphalangeal (PIP) joint is still controversial [72]. They conducted a prognostic study (grade IV evidence) to evaluate the midterm clinical and radiographic outcomes of PCA of the PIP joint. Patients were assessed after a mean of 6.4 years. Evaluation included grip and pinch strength and digital range of motion (ROM). The study included 29 PIP joint PCAs implanted in 23 hands of 19 patients. Seven implants required further surgical procedures. Three implants were removed and revised by silicone implants due to two dislocations and one implant migration. One was revised with a larger distal component. Three required soft tissue surgical revisions in which the implant was retained (one flexor digitorum superficialis tenodesis and two capsulectomies). At the end of follow-up, the survival of the original implant was 86.2%. Final radiographic review of the remaining 26 implants showed two swan neck deformities and two implant migrations. Postoperative grip strength (38.4 lb) and postoperative pinch strength (13.8 lb) were 92% and 91% of nonsurgical grip and pinch strength, respectively. The final mean ROM for the MCP joint was 82.1° and for the PIP joint was 60.6°. Mean outcome scores were visual analog scale, 1.6; Michigan Hand Outcomes Questionnaire, 71.6; and Disabilities of the Arm, Shoulder, and

Hand, 24. Ultimately, midterm follow-up (mean 6.4 years) of 29 PCA implants in 19 patients revealed a surgical revision rate of 24.1%. Of the 29 implants, 13.8% were removed after a mean of 4.6 years. Strength, ROM, and pain relief were satisfactory [72].

The indications of pyrocarbon implant arthroplasty are young patients with posttraumatic arthritis, no angular deformity, and adequate soft tissue coverage [28] and its use should be avoided in the rheumatoid hand secondary to progressive destruction of capsuloligamentous support.

20.4 Autologous Tissue for Small Joint Arthroplasty

Autologous tissue transfer affords complete biocompatibility and the opportunity for composite reconstruction. The first island, vascularized joint transfer was performed by Buncke in 1967 [73] and subsequent studies of vascularized joint transfer have shown both maintenance of hyaline cartilage and preservation of the joint space [74].

A systematic review of outcomes after vascularized toe joint transfer, silicone implant arthroplasty, and pyrocarbon arthroplasty found that vascularized joint transfer for posttraumatic PIP joint reconstruction had worse arc of motion (37 ± 11°) than either silicone (44 ± 11°) or pyrocarbon arthroplasty (43 ± 11°). Despite limited improvement in arc of motion, relatively higher major complication rates, and need for secondary surgery, vascularized joint transfer is the only procedure that allows future growth [75].

Another treatment option is perichondrium grafting. In 2020, Muder et al. compared the long-term results of perichondrium transplantation and those of two-component surface replacement (SR) implants to the MCP and PIP joints (therapeutic study with level III evidence) [76]. They evaluated 163 joints (in 124 patients), divided into 138 SR implants (in 102 patients) and 25 perichondrium transplantations (in 22 patients). The primary outcome was any revision surgery of the index joint. The mean follow-up was 6 years for SR implants and 26 years for perichondrium transplantations. Patient age at the time of surgery was 64 years for SR implants and 45 years for perichondrium transplantations. MCP joint survival was slightly better in the perichondrium group (86.7%) than in the SR implant group (75%), but not statistically significant. PIP joint survival was also slightly better in the perichondrium group (80%) than in the SR implant group (74.7%), but below the threshold of statistical significance. Ultimately, resurfacing of finger joints using transplanted perichondrium is a technique worth considering, as its low midterm revision rates were similar to those of SR implants [76].

Another technique to avoid silicone or pyrocarbon arthroplasty is to perform arthroplasty using cadaveric meniscus for osteochondral defects in hand joints. The cadaveric meniscus provides resurfacing of the affected bone and serves to maintain the articular space. Hoang et al. reported improvement in both ROM and pain relief, no complications occurred, and only two patients (14%) required postoperative revision surgery for tenolysis and capsulotomy [77].

The development of biotechnology and the application of stem cells to degenerated articular surfaces may render implant arthroplasty obsolete in the future. However, for the time being, it is necessary to continue improving the design and longevity of implants.

20.5 Prevalence of Complications and Cost of Small Joint Arthroplasty for Hand Osteoarthritis and Posttraumatic Arthritis

In 2020, Billig et al. stated that osteoarthritis of the hand is commonly treated by implant arthroplasty [78]. However, despite the increasing prevalence of hand OA, data on the complications and associated cost of patients undergoing PIP joint and MCP joint arthroplasty were lacking. Therefore, they evaluated the complications and cost of PIP joint and MCP joint arthroplasty in patients undergoing such interventions after a 2-year follow-up (prognostic study with level II evidence). They analyzed insurance claims from

2009 to 2016 using Truven MarketScan databases for adult patients undergoing PIP and MCP arthroplasty after a diagnosis of OA or posttraumatic arthritis. They analyzed 2859 patients, of whom 36% had received an MCP arthroplasty and 64% had received a PIP arthroplasty. The mean complication rate was 35%. PIP arthroplasty patients were more likely to suffer a prosthetic fracture than MCP arthroplasty patients (3.4% vs. 1.5%, respectively). Each complication resulted in an additional cost of $1076 [78].

20.6 Conclusions

Arthritis of the hand (proximal interphalangeal [PIP] and metacarpophalangeal [MCP] joints) is frequent and can result from osteoarthritis (OA), inflammatory arthritis, or posttraumatic arthritis. The main clinical presentation is pain and loss of range of motion. Initial treatment is conservative, including splinting, oral analgesics, and sometimes local injections. Cases where pain persists despite conservative treatment warrant surgery. Continued pain is considered the main indication for arthroplasty of MCP and PIP joints. Other surgical indications are deformity, stiffness, and joint incongruity. Surgical options are debridement of painful osteophytes, arthroplasty, and arthrodesis. Improvements in implant materials and developments in MCP and PIP joint arthroplasty have provided physicians and patients more options in treating these joints. Several designs of primary MCP joint arthroplasty are available: unconstrained pyrocarbon has shown good results in OA, silicone implant is the gold standard for RA, and little can be said about surface replacement arthroplasty (SRA) for the MCP joint. Primary PIP joint arthroplasty with silicone implants remains the gold standard for OA. The use of a pyrolytic carbon implant is controversial because of its high reoperation rate compared to silicone and surface-replacing implants. The SRA implant for PIP joint has shown good clinical and survival results at medium follow-up. However, silicone prostheses are often preferred for the PIP joint. Early results have demonstrated improvements in pain and ROM, but lower rates in complications and long-term follow-up studies are required. Nowadays, there is no clear consensus in the arthroplasty option.

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