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ORIGINAL STUDY

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Outcome of the MatOrtho arthroplasty for PIP osteoarthritis with a minimum follow-up of two years

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The aim of this study is to report the early results of the MatOrtho arthroplasty, a newer generation resurfacing implant of the proximal interphalangeal joint.

We performed a prospective cohort review of all MatOrtho arthroplasties implanted between 12/2013 and 05/2018 by a single surgeon at a single institution because of primary osteoarthritis, with a minimum follow-up of two years. Patient demographics, diagnosis, implant revision and other surgical interventions were recorded. Subjective and objective outcomes were evaluated, including range of motion, Patient Reported Outcome Measures and radiographic assessment. A total of 34 implants were inserted in 25 patients. Two implants were lost to follow-up.

Pain scores improved significantly (mean VAS pre-op 7, mean VAS post-op 1, $p < 0.05$). Active range of motion improved in 83% (25/30) of joints, with a mean improvement of the total arc of motion of 25 degrees. On radiographic assessment, no signs of circumferential lucency or subsidence were observed. Additional surgery was necessary for three out of 32 implants, including implant removal in two cases. 93.75% (30/32) implants survived after a mean follow-up of 33 months.

Our results confirm that at least at short term follow up, the MatOrtho PIP arthroplasty can be a successful procedure with high patient satisfaction and functional improvement.

Keywords: Proximal interphalangeal joint; PIP; osteoarthritis; arthroplasty; prosthesis; MatOrtho.

INTRODUCTION

Arthritis of the proximal interphalangeal (PIP) joint can be a painful, debilitating condition *(1-4)*. The PIP joint is the third most common location for osteoarthritis in the hand *(5-6)*. In the Framingham Offspring and Community cohort study the age standardized prevalence of radiographic osteoarthritis was 16.5% in women and 13.5% in men *(7)*. Surgical management may be indicated when conservative management fails. The options include arthrodesis and PIP joint arthroplasty *(1-5,8-12)*. Harris et al. investigated the preferences among patients with PIP joint osteoarthritis. They found that patients prefer surgical attributes characteristic of arthroplasty (ability to preserve joint motion and grip strength) relative to those associated with arthrodesis (decreased need for revision, lower costs, and shorter re-operation times). These results suggest that offering arthroplasty as a first-line

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surgical option is a highly patient-centered approach *(13)*. The primary goals of a PIP replacement are to alleviate pain, restore functional mobility and maintain adequate stability *(3-4,8-10,14-20)*. A systematic review by Adams et al. showed that a PIP joint replacement had a substantial effect on pain in the hand *(21)*. However, a high rate of complications is reported in the literature *(21-26)*.

Several implant designs are available. Silicone interposition implants have been used since the 1960s, when Swanson first introduced a hinged silicone implant that acted as a spacer *(1,4,27)*. Linscheid and Dobyns introduced the first surface replacement arthroplasty (SRA) in 1979 *(28)*, made of a proximal cobalt-chromium (CoCr) alloy component and a distal ultrahigh molecular weight polyethylene (UHMWPE) component *(4,28)*. In 2000 the prosthetic design was modified to incorporate a titanium stem *(4,29)*. Pyrocarbon-based implants were released in 2002 *(4)*. Three new generation implants have been introduced on the market. The CapFlex-PIP implant and the Tactys implant are two modular implants made of titanium and CoCr alloy *(30-32)*. The MatOrtho PIP joint arthroplasty (Mole Business Park, Leatherhead, UK) is a resurfacing implant with CoCr components, hydroxyapatite stems and a polyethylene insert. The implant design minimises the need for bone resection and preserves the collateral ligament attachments so that joint stability is not compromised. Flannery et al. reviewed 100 MatOrtho implants with a mean follow-up of 47 months and found promising results with a significant improvement in pain, function scores, and range of motion (if preoperative range of motion was > 20°). There was no radiographic evidence of loosening or subsidence *(2)*. The aim of this study is to report our clinical and radiological results with the MatOrtho PIP joint arthroplasty at a minimum of 2 years follow-up, and to confirm the results previously reported by Flannary et al. *(2)*.

MATERIALS AND METHODS

We performed a prospective cohort review of all MatOrtho PIP resurfacing arthroplasties implanted over a 5 year period with a minimum follow-up of 2 years. The study protocol was reviewed and approved by the local and regional ethics committees.

The case series included all consecutive patients treated with a MatOrtho arthroplasty because of primary PIP osteoarthritis between December 2013 and May 2018. They were all operated on by a single surgeon, in a single institution, using the same surgical technique. Informed consent was systematically obtained. A total of 34 MatOrtho PIP joint arthroplasties were implanted in 25 patients. Two implants (in two patients) were lost to follow-up, resulting in 32 implants reviewed in 23 patients.

A curved dorsal incision centered over the PIP joint is made and the joint is exposed by a longitudinal split of the extensor tendon. The central slip insertion is released and further dissected off with the periosteal tissue. After release of the capsule, synovectomy and removal of osteophytes, the joint is flexed to expose the articular surface. The central access point of the proximal phalanx is defined and a retrograde guide wire is drilled along the central axis. Correct position is confirmed by fluoroscopy. The canal is further prepared with rasps increasing in size, until a stable press-fit is achieved. If needed, a high speed burr is used to increase the cortical window. The chamfer cuts are made using the appropriate cutting block. Care is taken to remove the volar osteophytes, to achieve full flexion. A guide pin is then inserted antegrade along the central axis of the middle phalanx. The base of the middle phalanx is prepared with a convex reamer over the guide pin, preserving the surrounding cortical bone and the insertion of the collateral ligaments. The canal is further prepared with rasps. The trial prosthesis is inserted and the joint is reduced. The alignment, stability and range of motion are tested. It is essential that full passive extension is obtained without any tension. Once the correct sizing and a stable adequate range of motion are achieved, the definitive arthroplasty components are inserted and final radiographic images are obtained. The extensor tendon split is repaired with interrupted braided polyglycolic acid sutures. The skin is closed with interrupted simple nylon sutures. Our postoperative protocol consists of a splint in extension for 10 days, when stitches are removed. Hereafter, a removable extension

splint is made and active and passive range of motion exercises are initiated under the guidance of an experienced physiotherapist. Patients are advised to work on progressive flexion of the PIP joint, but it is essential that full active extension is maintained in between exercises.

Preoperative evaluations were performed by the treating surgeon. Final clinical and radiographic outcomes were assessed by a senior orthopaedic registrar as an independent observer. All patients were invited to a review clinic for the latest follow-up. Those patients unable to attend the clinic were contacted for a telephone survey. We collected the data from the medical records and through clinic assessment. Patient demographics, diagnosis and postoperative complications including secondary surgical interventions were recorded. Pain was assessed using a visual analogue scale (VAS) *(33)*, and range of motion (ROM) using a finger goniometer. The patients reported their subjective outcomes at the latest follow-up by completing 2 function scores: the Quick disabilities of the arm, shoulder and hand (QuickDASH) questionnaire and the patient evaluation measure (PEM). A lower score indicates better function. All questionnaires are reliable and valid *(34-36)*. We assessed patient satisfaction by asking whether they would have the surgery again. Anteroposterior and lateral radiographs of the affected finger were obtained at final follow-up and compared to the immediate postoperative radiographs. We chose to measure lucency and subsidence as reported by Flannery et al. *(2)* (Figure 1).

Descriptive statistics (mean, standard deviation) were performed on all the data sets. We analyzed the data using the paired t-test analysis to assess for statistical significance between the pre- and postoperative results. Results were considered statistically significant if the p-value was < 0.05, in accordance with accepted standards.

RESULTS

A total of 34 MatOrtho PIP joint arthroplasties were implanted in 25 patients. Two implants (in two patients) were lost to follow-up, resulting in 32 implants reviewed in 23 patients. The mean follow up was 33 months (ranging 24-61 months). The majority of implants were implanted in female patients. The population characteristics are summarized in Table I. Two implants (in two patients) were explanted, leaving 30 implants in 21 patients for review at final follow-up. The results are reported as individual implant based (Table II).

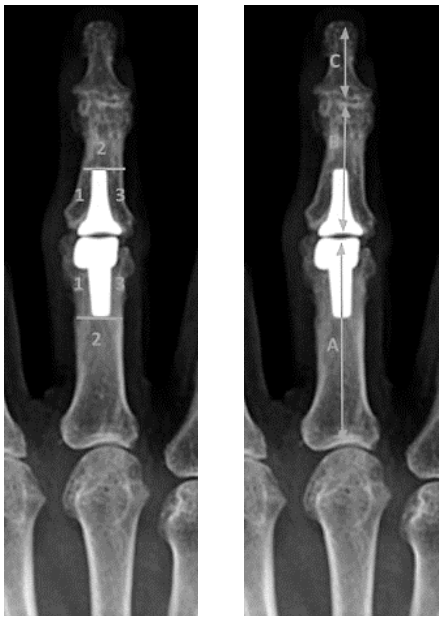

Figure 1. — Radiographic measurements
A) Lucency around the components is quantified using a zonal system on the anteroposterior radiographs. B) The length of the proximal (A) and middle phalanges (B) including the implant is measured and standardized against the length of the distal phalanx (C) to assess for subsidence of the components. The radiographic measurements were done as proposed by Flannery et al., 2016 *(2)*.

Table I. — Population characteristics

Patients	23
Joints	32
Gender	6 men (6 implants) 17 women (26 implants)
Average age	69 years (58 to 82 years)
Finger	Index: 6 Middle: 13 Ring: 11 Little: 2
Mean follow-up	33 months (24 to 61 months)

Table II. — Clinical objective and subjective outcomes

	N	Preoperative (SD)	Last follow-up (SD)	Mean difference	P value
VAS score	30	6.6 (1.3)	0.8 (1.4)	- 5.8	< 0.001
ROM (°)	30	42 (21)	60 (25)	18	< 0.001
Extension deficit (°)	29	14 (10)	9 (13)	- 6	0.04
Maximal flexion (°)	29	56 (21)	69 (23)	13	< 0.01
PEM	30	-	32 (7)	-	-
QuickDASH	30	-	14.8 (12.8)	-	-

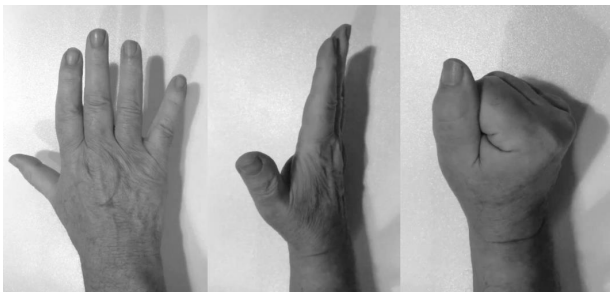

Figure 2. — Active flexion and extension following PIP arthroplasty of the ring finger.

All the patients in this study treated with the MatOrtho PIP arthroplasty experienced pain relief. The mean VAS score preoperatively was 7 (SD 1.3). This improved to a mean VAS score of 1 (SD 1.4) postoperatively. This difference was statistically significant ($p < 0.001$). Twenty cases (out of 30) reported no pain postoperatively (VAS score of 0).

The mean total arc of motion improved from 42° preoperatively to 60° postoperatively (Figure 2). This difference was statistically significant ($p < 0.001$). There was an improvement in mobility in 25 out of 30 joints. In this subgroup a mean improvement of the total arc of motion of 26° was achieved. The mobility of two joints remained status quo postoperatively. Three joints ended up stiffer than before the surgery: two joints lost 45° of their ROM, while one joint lost 5°. The extension deficit improved significantly ($p < 0.05$) from 14° preoperatively to 9° postoperatively. The maximal active flexion ameliorated significantly by 13° (Table II).

The mean postoperative PEM score was 32 (SD 7.4) and the mean postoperative QuickDASH score

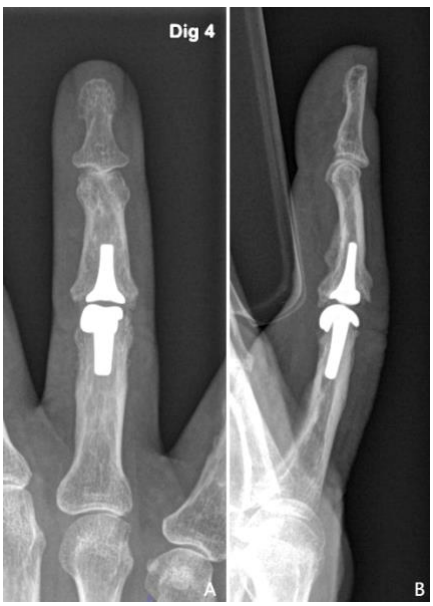

Figure 3. — Radiographic result following PIP arthroplasty of the ring finger (patient from figure 2).

was 14.8 (SD 12.8) (Table II). No preoperative data were available for comparison.

Complete radiographic data immediately post-operative and at latest follow-up were available for 22 implants (Figure 3). For an additional three implants X-rays at latest follow-up were available but there were no direct postoperative X-rays. It was not possible to include them in our evaluation for subsidence, but they were included in our assessment of lucency.

Analysis of the radiographic measurements demonstrated no subsidence of the implants at the latest follow-up (Table III). There was evidence for focal lucency in a total of 8 out of 150 zones. None

Table III. — Subsidence measurements

	Immediate postoperative	At latest follow-up
A/C	2.4 (SD 0.2)	2.4 (SD 0.2)
B/C	1.4 (SD 0.2)	1.4 (SD 0.2)

Table IV. — Incidence of lucency around implant components

Zone	P1	P2
1	1	1
2	0	0
3	2	4

of the implants showed circumferential lucency (Table IV).

Two implants (in two patients) were explanted. One implant was revised to a silicone arthroplasty in another center at 8 months postoperative due to stiffness. Three years later the patient reported that there was no change in the function of her finger. One implant was revised to an arthrodesis in our center at 42 months postoperative because of joint instability. One patient underwent two additional surgeries (soft tissue release) because of stiffness. Overall, additional surgery was necessary for three out of 32 implants.

After a mean follow-up of 33 months 30 out of 32 implants were still in situ.

Twenty out of 21 patients said that under similar conditions, they would have the surgery again

DISCUSSION

Current options for the treatment of PIP arthritis include silicone, metal, pyrocarbon and ceramic arthroplasties *(18-20)*. Silicone spacers provide reliable pain relief and patient satisfaction *(1,4,10,18-20,26)*, with an implant survivorship of 90% at average of 10 years postoperatively *(1)*. Implant fracture is a complication unique to silicone arthroplasty *(4)* with suspected fracture rates of up to 30% after 6.5 years *(19,23-24,26)*. Surface replace-ment arthroplasties aim to better anatomically re-create both components of the PIP joint to restore joint stability and mobility *(4,17)* Linscheid and Dobyns found that even in joints with limited movement, pain relief was dramatic. However, the number of complications in their series was significant *(28)*. Murray et al. reviewed 67 SR PIP implants (48 cemented, 19 press-fit) in 47 patients with a mean follow-up of 8.8 years. They found a cumulative incidence of implant failure of 3% at one year, 8% at three years, 11% at five years, and 16% at fifteen through twenty-five years. They did not find less implant failure or better radiographic results with the use of cement *(37)*. Overall, CoCr and UHMWPE SRA implants have demonstrated good pain relief but only minimal improvement in range of motion. However, complications (ranging from 21% to 40%) and revision rate remained high *(2,4,8,14-15,28,37)*. Pyrocarbon implants are successful in improving pain *(4-5,9,11-12,17,38-40)*, but improvement of range of motion has been unreliable. Some studies have demonstrated an amelioration with variable significance *(5,17)* while others have demonstrated no change *(12,38,40)* or a deterioration *(9,25)*. Loosening, subsidence and migration are common complications and high revision rates have been published *(4,9,11-12,17-21,25,38-40)*. Wagner et al. found that approximately one in five PIP pyrocarbon implants will require revision surgery by 5 years *(38)*. In a recent study, Mora et al. concluded that the use of pyrocarbon implants remains controversial. Although strength, ROM and pain relief were satisfactory, and a high implant survival (86.2%) was achieved at a mean follow-up of 6.4 years, the revision rate was substantial at 24.1% *(39)*. Interestingly, nearly all studies have described high patient satisfaction despite these complications *(12,15-17,21)*. Newer generation arthroplasties like the CapFlex-PIP implant and the Tactys implant show promising results *(30-32)*.

The MatOrtho PIP arthroplasty was first used in January 2006 at the Wrightington Hospital, UK. The design team reported their results in a retrospective review of 100 implants in 50 patients, with a mean follow-up of 47 months (range 24-77). Flannery et al. demonstrated a good survival of the PIP arthroplasty and showed a significant improvement in pain and function *(2)*. The aim of this study was to confirm the good clinical and radiological outcomes

with the MatOrtho implant previously reported by Flannery et al.

The demographics of our study population were similar to that of Flannery et al. The mean age at the time of surgery was 69 years in this study versus 64 years for Flannery et al. The majority of patients are female (26 out of 32 implants in this study versus 75 out of 100 implants for Flannery et al.). Our results show excellent pain relief, consistent with other studies *(24,14-15,28,37)*. In this study, 20 out of 30 cases reported a postoperative VAS score of 0. Flannery et al. reported that 86% of patients had no pain in rest. Our results demonstrated a statistically significant improvement in the mean total arc of motion from 42° preoperatively to 60° postoperatively. Most other studies on PIP implants showed no or minimal improvement in range of motion *(4,14-15,28,37)*. Flannery et al. found no statistical difference between preoperative and postoperative mobility. The mean arc of motion stayed 35°. Their subgroup of implants with a preoperative mobility of less than 20° experienced a significant deterioration in postoperative mobility, while the subgroup with a preoperative range of motion greater than 20° demonstrated a significant amelioration *(2)*. Contrary to these findings, our subgroup of joints with a preoperative arc of motion of less than 20 degrees showed no correlation with a postoperative decrease in ROM. In this subgroup of 4 joints the range of motion improved from an average 11° (SD 2.5) to an average 40° (SD 30), although this was not statistically significant ($p = 0.17$). Flannery et al. showed that there was a statistically significant improvement for the PEM score, but not for the QuickDASH *(2)*. If we compare our postoperative function scores to those of Flannery et al., our patients reported a mean PEM score of 32 versus 38 and a mean QuickDASH of 15 versus 34 respectively. We did not find any implant subsidence nor circumferential lucency, as consistent with the results of Flannery et al. Our results showed localized signs of lucency in 8 out of 150 assessed zones (5%) compared to 21 out of 504 zones (4%) in the study of Flannery et al. Our results show that additional surgery was necessary in three implants, including implant removal in two cases. The revision rate in this study was considerably lower than the revision rate previously reported on CoCr - UHMWPE implants *(2,14-15,28,37)*. The lower revision rate might be partially due to the introduction of an implant with hydroxyapatite coated stems, but this is certainly not the only explanation since Flannery et al. also reported a high revision rate: 13% of implants were removed and 28% had a reoperation without implant removal. Thirty out of 32 implants (93.75) survived after a mean follow-up of 33 months, compared to an implant retention of 87% after a mean follow-up of 47 months for Flannery et al *(2)*. One of the major advantages of this implant is the minimal bone resection necessary for component insertion. Specifically for the middle phalanx component, reaming over a guide pin, rather than resecting the base, allows for maximal protection of the collateral ligaments and later stability of the joint. This means the arthroplasty can be safely used for replacement of the PIP joint of the index finger (six patients in our study) while maintaining stability and pinch strength.

In concordance with other studies, we reported a high patient satisfaction. All but one patient would have the surgery again. A systematic review by Yamamoto et al. compares the outcomes of different silicone (Avanta, Swanson, Neuflex, Sutter) and surface replacement (SR, Pyrocarbon, Moje, Cap-Flex, MatOrtho) arthroplasties, and concludes that most of the patients were satisfied regardless of the implant design and surgical approach *(19)*.

This is the first independent study of the MatOrtho PIP arthroplasty. All our patients have been operated on by the same surgeon with the same surgical technique and with the same implant, for the same indication. The final outcomes were assessed by an independent observer.

However, there are also some limitations to this study. It has a smaller cohort ($n = 34$) and a shorter follow-up time (mean 33 months). There are no preoperative PEM and QuickDASH scores available.

CONCLUSION

We demonstrated excellent pain relief, functional improvement and a high patient satisfaction in

the patients operated on with the MatOrtho PIP arthroplasty. Our results showed a statistical significant improvement in the range of motion, and a considerably lower revision rate than previously reported in the literature. Thirty out of 32 implants survived after a mean follow-up of 33 months. In conclusion, the MatOrtho PIP arthroplasty can be a successful procedure, at least at short term follow-up. Longer follow-up of these patients is planned to confirm these results.

REFERENCES

1. Bales JG, Wall LB, Stern PJ. Long-term results of Swanson silicone arthroplasty for proximal interphalangeal joint osteoarthritis. J Hand Surg Am. 2014;39(3):455-461.
2. Flannery O, Harley O, Badge R, Birch A, Nuttall D, Trail IA. MatOrtho proximal interphalangeal joint arthroplasty: minimum 2-year follow-up. J Hand Surg Eur. 2016; 41(9):910-916.
3. Sauerbier M, Cooney WP, Linscheid RL. Operative technique of surface replacement arthroplasty of the proximal interphalangeal joint. Tech Hand Up Extrem Surg. 2001;5(3):141-147.
4. Zhu AF, Rahgozar P, Chung KC. Advances in Proximal Interphalangeal Joint Arthroplasty: Biomechanics and Biomaterials. Hand Clin. 2018;34(2):185-194.
5. Desai A, Gould FJ, Mackay DC. Outcome of pyrocarbon proximal interphalangeal joint replacement. Hand Surg. 2014;19(1):77-83.
6. Wilder FV, Barrett JP, Farina EJ. Joint-specific prevalence of osteoarthritis of the hand. Osteoarthritis Cartilage. 2006; 14(9):953-957.
7. Haugen IK, Englund M, Aliabadi P, et al. Prevalence, incidence and progression of hand osteoarthritis in the general population: the Framingham Osteoarthritis Study. Ann Rheum Dis. 2011;70(9):1581-1586.
8. Luther C, Germann G, Sauerbier M. Proximal Interphalangeal Joint Replacement with Surface Replacement Arthroplasty (SR-PIP): Functional Results and Complications. Hand (NY). 2010;5(3):233-240.
9. Reissner L, Schindele S, Hensler S, Marks M, Herren DB. Ten year follow-up of pyrocarbon implants for proximal interphalangeal joint replacement. J Hand Surg Eur. 2014; 39(6):582-586.
10. Swanson AB, Maupin BK, Gajjar NV, Swanson GD. Flexible implant arthroplasty in the proximal interphalangeal joint of the hand. J Hand Surg Am. 1985;10(6Pt1):796-805.
11. Storey PA, Goddard M, Clegg C, Birks ME, Bostock SH. Pyrocarbon proximal interphalangeal joint arthroplasty: a medium to long term follow-up of a single surgeon series. J Hand Surg Eur. 2015;40(9):952-956.
12. Watts AC, Hearnden AJ, Trail IA, Hayton MJ, Nuttall D, Stanley JK. Pyrocarbon proximal interphalangeal joint arthroplasty: minimum two-year follow-up. J Hand Surg Am. 2012;37(5):882-888.
13. Harris CA, Shauver MJ, Yuan F, Nasser J, Chung KC. Understanding Patient Preferences in Proximal Interphalangeal Joint Surgery for Osteoarthritis: A Conjoint Analysis. J Hand Surg Am. 2018;43(7):615-624.
14. Jennings CD, Livingstone DP. Surface replacement arthroplasty of the proximal interphalangeal joint using the PIP-SRA implant: results, complications, and revisions. J Hand Surg Am. 2008;33(9):1565.e1-e11.
15. Jennings CD, Livingstone DP. Surface replacement arthroplasty of the proximal interphalangeal joint using the SR PIP implant: long-term results. J Hand Surg Am. 2015;40(3):469-473.
16. Murray PM. Prosthetic replacement of the proximal interphalangeal joint. Hand Clin. 2006;22(2):201-206.
17. Ono S, Shauver MJ, Chang KWC, Chung KC. Outcomes of pyrolytic carbon arthroplasty for the proximal interphalangeal joint at 44 months' mean follow-up. Plast Reconstr Surg. 2012;129(5):1139-1150.
18. Herren DB. Current European Practice in the Treatment of Proximal Interphalangeal Joint Arthritis. Hand Clin. 2017;33(3):489-500.
19. Yamamoto M, Malay S, Fujihara Y, Zhong L, Chung KC. A Systematic Review of Different Implants and Approaches for Proximal Interphalangeal Joint Arthroplasty. Plast Reconstr Surg. 2017;139(5):1139e-1151e.
20. Yamamoto M, Chung KC. Implant Arthroplasty: Selection of Exposure and Implant. Hand Clin. 2018;34(2):195-205.
21. Adams J, Ryall C, Pandyan A, et al. Proximal interphalangeal joint replacement in patients with arthritis of the hand: a meta-analysis. J Bone Joint Surg Br. 2012;94(10):1305-1312.
22. Chan K, Ayeni O, McKnight L, Ignacy TA, Farrokhyar F, Thoma A. Pyrocarbon versus silicone proximal interphalangeal joint arthroplasty: a systematic review. Plast Reconstr Surg. 2013;131(1):114-124.
23. Drake ML, Segalman KA. Complications of small joint arthroplasty. Hand Clin. 2010;26(2):205-212.
24. Forster N, Schindele S, Audigé L, Marks M. Complications, reoperations and revisions after proximal interphalangeal joint arthroplasty: a systematic review and meta-analysis. J Hand Surg Eur. 2018;43(10):1066-1075.
25. Sweets TM, Stern PJ. Pyrolytic carbon resurfacing arthroplasty for osteoarthritis of the proximal interphalangeal joint of the finger. J Bone Joint Surg Am. 2011;93(15):1417-1425.
26. Takigawa S, Meletiou S, Sauerbier M, Cooney WP. Long-term assessment of Swanson implant arthroplasty in the proximal interphalangeal joint of the hand. J Hand Surg Am. 2004;29(5):785-795.
27. Foliart DE. Swanson silicone finger joint implants: a review of the literature regarding long-term complications. J Hand Surg Am. 1995;20(3):445-449.

28. Linscheid RL, Murray PM, Vidal MA, Beckenbaugh RD. Development of a surface replacement arthroplasty for proximal interphalangeal joints. J Hand Surg Am. 1997; 22(2):286-298.
29. Johnstone BR, Fitzgerald M, Smith KR, Currie LJ. Cemented versus uncemented surface replacement arthroplasty of the proximal interphalangeal joint with a mean 5-year follow-up. J Hand Surg Am. 2008;33(5):726-732.
30. Schindele SF, Hensler S, Audigé L, Marks M, Herren DB. A modular surface gliding implant (CapFlex-PIP) for proximal interphalangeal joint osteoarthritis: a prospective case series. J Hand Surg Am. 2015;40(2):334-340.
31. Athlani L, Gaisne E, Bellemère P. Arthroplasty of the proximal interphalangeal joint with the TACTYS® prosthesis: Preliminary results after a minimum follow-up of 2 years. Hand Surg Rehabil. 2016;35(3):168-178.
32. Degeorge B, Athlani L, Dap F, Dautel G. Proximal interphalangeal joint arthroplasty with Tactys®: Clinical and radiographic results with a minimum follow-up of 12 months. Hand Surg Rehabil. 2018;37(4):218-224.
33. Huskisson EC. Measurement of pain. Lancet. 1974;2(7889): 1127-1131.
34. Beaton DE, Katz JN, Fossel AH, Wright JG, Tarasuk V, Bombardier C. Measuring the whole or the parts? Validity, reliability and responsiveness of the Disabilities of the Arm, Shoulder and Hand outcome measure in different regions of the upper extremity. J Hand Ther. 2001;14(2):128-146.
35. Dias JJ, Rajan RA, Thompson JR. Which questionnaire is best? The reliability, validity and ease of use of the Patient Evaluation Measure, the Disabilities of the Arm, Shoulder and Hand and the Michigan Hand Outcome Measure. J Hand Surg Eur. 2008;33(1):9-17.
36. Sharma R, Dias JJ. Validity and reliability of three generic outcome measures for hand disorders. J Hand Surg Br. 2000;25(6):593-600.
37. Murray PM, Linscheid RL, Cooney WP 3rd, Baker V, Heckman MG. Long-term outcomes of proximal interphalangeal joint surface replacement arthroplasty. J Bone Joint Surg Am. 2012;94(12):1120-1128.
38. Wagner ER, Weston JT, Houdek MT, Luo TD, Moran SL, Rizzo M. Medium-Term Outcomes With Pyrocarbon Proximal Interphalangeal Arthroplasty: A Study of 170 Consecutive Arthroplasties. J Hand Surg Am. 2018;43(9): 797-805.
39. Mora AN, Earp BE, Blazar PE. Midterm Clinical and Radiographic Follow-Up of Pyrolytic Carbon PIP Arthroplasty. J Hand Surg Am. 2020;45(3):253.e1-253.e6.
40. Dickson DR, Nuttall D, Watts AC, Talwalkar SC, Hayton M, Trail IA. Pyrocarbon Proximal Interphalangeal Joint Arthroplasty: Minimum Five-Year Follow-Up. J Hand Surg Am. 2015;40(11):2142-2148.