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A Systematic Review of Different Implants and Approaches for Proximal Interphalangeal Joint Arthroplasty

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Abstract

Background—Outcomes after implant arthroplasty for primary degenerative and posttraumatic osteoarthritis (OA) of proximal interphalangeal (PIP) joint were different according to the implant design and surgical approach. The purpose of this systematic review was to evaluate outcomes of various types of implant arthroplasty for PIP joint OA with emphasis on different surgical approaches.

Methods—The authors searched all available literature in the PubMed and EMBASE databases for articles reporting on outcomes of implant arthroplasty for PIP joint OA. Data collection included active arc of motion (AOM), extension lag, and complications. We combined the data of

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Author Contributions

Yamamoto & Chung had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Chung, Yamamoto, Malay.

Acquisition of data: Yamamoto, Fujihara.

Analysis and interpretation of data: Yamamoto, Fujihara.

Drafting of the manuscript: Yamamoto, Malay.

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various types of surface replacement arthroplasty into one group to compare with silicone arthroplasty.

Results—A total of 849 articles were screened, yielding 40 studies for final review. The mean postoperative AOM and the mean gain in AOM of silicone implant with volar approach were 58° and 17° respectively which was greater than surface replacement implant with dorsal approach as 51° and 8°, respectively. The mean postoperative extension lag of silicone implant with volar approach and surface replacement with dorsal approach was 5° and 14° respectively. The revision rate of silicone implant with volar approach and surface replacement with dorsal approach was 6% and 18% at the mean follow-up period of 41.2 and 51 months, respectively.

Conclusions—Silicone implant with volar approach showed the best AOM with less extension lag and fewer complications after surgery among all the implant designs and surgical approaches.

Keywords

Approach; implant arthroplasty; proximal interphalangeal joint; systematic review

Introduction

The age standardized prevalence of radiographic osteoarthritis (OA) of the proximal interphalangeal (PIP) joint was 16.5% in women and 13.5% in men in the Framingham Offspring and Community cohorts.¹ The frequency of symptomatic PIP joint OA ranged from 0.7 to 2% (approximately 2.3 million using United States Standard Population data in 2000 among the same cohorts).¹ Nonsurgical treatment may reduce the symptoms such as pain, swelling, stiffness, and decreased grip and pinch strength in the early stages.^{2,3} However, with the progression of symptoms, surgical intervention is indicated. Numerous techniques were in practice to restore a stable, painless, and mobile finger. To achieve the most stable and powerful pinch and grip, arthrodesis has been a standard, especially for radial finger.^{4,5} Successful arthroplasty for degenerative or posttraumatic PIP joint OA is an elusive goal of reconstructive hand surgery for many years. To maintain the mobility of the joint, current treatment options include arthroplasty using silicone, metal, pyrocarbon, and ceramic implants with volar, lateral or dorsal approach. Substantial effort has been invested for more than half a century towards the development of small joint prostheses.

After the introduction of silicone spacer to treat primary degenerative OA, posttraumatic OA, and inflammatory arthritis of the PIP joint of the finger, its surgical indications and techniques have been well established.⁶ Ninety-eight % of the patients experienced good pain relief. Arc of motion (AOM) increased after surgery except in the patients with rheumatoid swan-neck deformities.⁷ Although the complications associated with silicone implants were relatively low, implant fracture necessitating revision surgery was the major complication reported as 13% with an average follow-up period of 6.5 years.⁸ Formerly, most studies reported the use of the dorsal approach. However, recently, favorable outcomes using the volar approach were published.^{9–12} The volar approach offers the advantages of maintaining the integrity of the extensor mechanism, resulting in a complete restoration of extension in the AOM. The volar approach permits early postoperative exercise to prevent extensor tendon adhesion and joint contracture. Although the dorsal approach enables wide

exposure and easy access to the joint, it risks joint contracture owing to extensor tendon adhesion causing extension lag. The lateral approach needs to divide the capsule and collateral ligaments of PIP joint at their proximal insertion to expose the joint, its outcome is uncertain because articles reporting on lateral approach are few.^{13–15}

The first anatomical surface replacement arthroplasty developed by Linscheid and Dobyns is a novel cobalt-chrome proximal component and high-molecular-weight polyethylene distal component PIP joint surface replacement implant.¹⁶ Both components are designed to fit the internal contours of the medullary canal of the bone. The low-profile of the implant preserves the bone stock and the integrity of the collateral ligaments.¹⁶ Complication rate after surgery is different according to the approach used. SR PIP (Small Bone Innovations, Inc., Morrisville, PA, USA) prosthesis implanted via a volar approach failed more often than those implanted via a dorsal approach.¹⁷ PyroCarbon implant, (Ascension Orthopedics, Inc., Austin, Texas, USA) one of the latest technologies in this field has an elastic modulus similar to bone with an assumed higher durability and wear resistance, making it a better option for younger patients.¹⁸ However, high complication rate with implant dislocation and subsidence, and eventual poor outcomes were observed.^{19–21} Although the volar approach to PIP joint arthroplasty was suggested recently,²² the dorsal approach to PIP joint was commonly used for these surface replacement arthroplasties.^{23,24} Various surface replacement arthroplasty designs were introduced that have a concept of anatomical reconstruction unlike silicone spacer, in which the implant acts as an internal splint that requires the soft tissues to rebalance.²⁵ However, there is no comparative study for outcomes of silicone spacer and nonconstrained surface replacement PIP arthroplasty with different approaches.

Evidence on outcomes of implant arthroplasty for PIP joint OA is limited because most study designs were retrospective case series of a single implant design and had small sample size.^{26–29} Only one study was a prospective, randomized, multicenter comparison of 3 types of PIP joint arthroplasty with all using dorsal approach.²¹ A systematic review is needed to summarize all the available evidence regarding the type of approach and type of implant design that will have most favorable outcomes for reconstruction of a PIP joint OA. The purpose of this study is to conduct a rigorous evaluation of the available literature for silicone and various types of surface replacement arthroplasty for PIP joint OA with emphasis on different surgical approaches. We aim to analyze the outcomes and complication rates in the implant arthroplasty treatment for PIP joint OA.

Materials and Methods

Literature Search

Applying the Preferred Reporting Items for Systematic Review and Meta-Analysis guidelines, we performed a systematic literature search of the PubMed and the EMBASE databases with the key words ((arthroplasty OR “joint replacement” OR implant) AND (finger OR digit OR hand)) AND (“proximal interphalangeal” OR pip).³⁰ We included articles from January 1st, 1970 to December 31st, 2015. The title and abstract of each article were checked according to the predetermined inclusion and exclusion criteria (Table 1). Because our target conditions for this review were primary degenerative OA and

posttraumatic OA of finger PIP joint, we excluded the studies that reported inflammatory arthritis only. But we included the papers with combined inclusion criteria for primary degenerative OA, posttraumatic OA, and inflammatory arthritis.

Articles were screened thoroughly for redundant papers. We included data from the latest version of articles from papers that had the same authors and came from same institution to avoid duplication of data from the same subjects. We set postoperative AOM gained and revision rate as our primary outcomes in this systematic review.

Data Extraction and Analysis

For all inclusive articles, we assessed study characteristics (type of approach, year of publication and country of origin), patient and finger demographic data (female/total ratio, mean age, OA ratio, type of implant, type of approach, and finger distribution), number of fingers, mean follow-up period, active AOM, extension lag, subjective findings (pain, patient-reported outcomes, and satisfaction), and grip and pinch strength. Complications were assessed as revision rate. Data for extension lag are important for comparing volar and dorsal approach, because we hypothesized that volar approach causes less extension lag than the dorsal approach. We combined the data of various types of nonconstrained surface replacement arthroplasty into one group to compare with silicone implant, because of the low number of articles with each of the different types of surface replacement arthroplasty.

Statistical Evaluation

Overall mean pre and postoperative active AOM, gain in AOM, extension lag, and the number of revisions and rate were calculated for each subgroup of patients (silicone implant arthroplasty with volar approach, lateral approach, and dorsal approach, and surface replacement arthroplasty with volar approach, and dorsal approach). Because most of the articles did not present individual patients' data or standard deviation value, we could not compare subgroups statistically. Instead, we ordered the subgroups from small to large or vice versa for outcomes as appropriate.

Results

Study Retrieval and Characteristics

Eight hundred and forty-nine citations were identified through the PubMed and the EMBASE databases. A flow chart diagram of our study selection was outlined in Figure 1. Of the 148 relevant titles that underwent abstract and full text review, 40 studies were eligible for final review. Seventeen studies reported on using silicone arthroplasty, 14 studies reported on PyroCarbon arthroplasty, nine studies used SR arthroplasty, two articles reported on Moje arthroplasty (MOJE ceramic implants, Petersburg, Germany) one article used CapFlex-PIP arthroplasty (KLS Martin Group, Tuttlingen, Germany), and one article presented MatOrtho arthroplasty (MatOrtho Limited, Leatherhead, Surrey, UK). Two articles contained both volar and dorsal approach with separately extractable data.^{31,32} One article contained silicone, PyroCarbon, and SR arthroplasty with separately extractable data.²¹ Finally; we arrived at 44 studies from 40 articles according to the type of implant and surgical approach.

Study characteristics are listed in Table 2. Twenty-seven studies including silicone and surface replacement arthroplasty were reported from Europe and 13 studies were published from the United States. Most surface replacement arthroplasties were performed with dorsal approach. Only two articles reported on surface replacement arthroplasty of PIP joint with volar approach. Whereas for silicone arthroplasty, there were six articles with volar approach, three articles with mainly lateral, and eight articles with dorsal approach. There was no article included older than 1980 because of the inclusion/exclusion criteria of this systematic review.

Patient, implant, and finger characteristics

We presented patient, implant, and finger demographic data in Table 3. Although the percentage of females was high in general, for posttraumatic OA, female/total ratio was low and ranged from 13 to 40%.^{15,33–36} Long and ring fingers were commonly operated with not only silicone but also surface replacement arthroplasty. Mean age at surgery for patients with posttraumatic OA only was less (33–40 years) compared with patients of other types of PIP joint OA (47–68 years).^{15,33–36} Twenty-three studies included more than one indication for arthroplasty such as rheumatoid arthritis and psoriatic arthritis except for primary degenerative or posttraumatic OA.

Arc of motion

The mean follow-up period of silicone arthroplasty with volar approach, dorsal approach, and surface replacement arthroplasty with dorsal approach was 41.2, 57.6, and 48.6 months, respectively. The mean postoperative AOM and the mean gain in AOM of silicone with volar approach were 58° and 17° respectively which were greater than silicone with dorsal approach as 51° and 12°, and also larger than surface replacement with dorsal approach as 51° and 8° respectively. The order of the mean gain in AOM from large to small was silicone volar (17°), silicone lateral (16°), silicone dorsal (12°), surface replacement volar (9°), and surface replacement dorsal (8°) (Table 4). Because the standard deviation could not be extracted from the articles, statistical testing for significance was not possible.

Extension lag

Pre and postoperative extension lag were not reported in all included articles. The mean postoperative extension lag of silicone implant volar approach and surface replacement arthroplasty with dorsal approach was 5° and 14°, respectively. The order of the extension lag from small to large was silicone volar (5°), silicone dorsal (8°), silicone lateral (12°), surface replacement dorsal (14°), and surface replacement volar (17°) (Table 5).

Complication

Silicone arthroplasty with volar approach had the lowest revision rate (all revisions including minor and salvage procedures) as 6%. The revision rate of surface replacement with dorsal approach was 18%. The mean follow-up period of silicone arthroplasty with volar approach, dorsal approach, and surface replacement with dorsal approach was 41.2, 17, and 51 months, respectively. The order of revision rate from low to high was silicone volar (6%), silicone lateral (10%), silicone dorsal (11%), surface replacement volar (17%), and surface

replacement dorsal (18%). Among the surface replacement dorsal, the most common types of revision surgery were revision to silicone implant (23%), arthrodesis (14%), revision with or without cement to original implant (11%), explantation of the implant (10%), amputation (4%), and other procedures (38%) (Table 6).

Patient reported outcomes (PROs)

Most articles reported improvement of pain in patients after surgery. Visual analogue scale (VAS 0–10; pain free is 0, maximum pain is 10) was used in 23 articles. Postoperative pain was 0–4.0 regardless of the type of implant and surgical approach. The Disabilities of the Arm, Shoulder and the Hand (DASH) or the quick DASH questionnaires were used in 16 articles. The postoperative mean DASH scores of patients with silicone implants were significantly better than those of patients with PyroCarbon implants ($P = .006$).²¹ The Michigan Hand Outcomes Questionnaire (MHQ) was used in 4 articles. Patient Evaluation Measure (PEM) was used in 3 articles, and Canadian Occupational Performance Measure (COPM) was used in 2 articles. Improvement of the PROs scores after surgery was found in all but one study.³⁶ Sixty-six percent of articles reported on the satisfaction of patients after surgery. Most of the patients were satisfied regardless of the implant design and surgical approach (See Supplemental Digital Content 1, Appendix A, which shows the Subjective Findings (Pain, Patient-Reported Outcomes, and Satisfaction) before and after Proximal Interphalangeal Joint Implant Arthroplasty, [INSERT LINK](#)).

Grip and Pinch strength

Data on grip and pinch strength before and after surgery were sparse (See Supplemental Digital Content 2, Appendix B, which shows the Grip and Pinch Strength before and after Proximal Interphalangeal Joint Implant Arthroplasty, [INSERT LINK](#)). Postoperative grip and pinch strength improved regardless of the type of implant and surgical approach,^{13,20,33,36–41} however, one study reported a decrease in grip strength from preoperative 21 kg to 17 kg at 10 years follow-up.⁴²

Discussion

We hypothesized that silicone arthroplasty with volar approach has less extension lag and better gain in AOM compared with other approaches and implant designs. In our systematic review, silicone implant with volar approach showed better outcomes in terms of gain in AOM, extension lag, and revision rate compared with a different approach and surface replacement arthroplasty.

Implant arthroplasty for PIP joint is indicated when patients do not recover after nonsurgical treatment such as self-management, behavioral changes, joint supports, adjunct pharmacological treatments and/or topical non-steroidal anti-inflammatory drugs, and intra-articular corticosteroid injections.⁴³ However, revision rates after arthroplasty range from 6 to 18 % at the mean follow-up period ranging from 17 to 80 months.

Various types of implant design for finger PIP joint surface replacement have been developed so far. PyroCarbon and SR arthroplasties are currently the most commonly used and reported implants. In addition, the use of ceramic unconstrained two-component implant

(MOJE), a modular prosthesis (CapFlex-PIP), and a cobalt-chromium metal-on-polyethylene mobile-bearing surface replacement arthroplasty (MatOrtho) was reported recently.^{39–41} Moje ceramic implant is coated by hydroxyapatite to advance bony ingrowths and to preclude loosening of the prosthesis.³⁹ CapFlex was designed to improve lateral stability with press fit fixation because collateral ligaments are preserved and minimize the bone resection.⁴⁰ MatOrtho is a cementless prosthesis with hydroxyapatite coating to hasten bony integration. It also preserves the collateral ligament attachments.⁴¹ These anatomical unconstrained implants have a risk of joint instability. Careful soft tissue balance and appropriate alignment of the finger are necessary for success with surface replacement arthroplasty.²⁵

Nearly half a century passed after Swanson first reported silicone implants for replacement of degenerated or damaged joints in the hand.⁶ Swanson et al. reported favorable, long-term, and rewarding results for PIP joint with dorsal approach.⁷ Most authors favored a dorsal approach for silicone implants because of ease of joint exposure despite the use of other approaches.^{4,33,34} Dorsal approach uses a dorsal incision over the PIP joint, longitudinal division of the central slip of the extensor apparatus or Chamay's technique by lifting the central dorsal aponeurosis.^{21, 50} Although the dorsal approach enables easy access to the joint and is used widely, it possesses the risk of joint contracture due to extensor tendon adhesion causing extension lag. On the other hand, after Schneider first reported volar approach for PIP joint OA in 1991, beneficial outcomes have been reported using this approach more recently.^{9,12,44} Volar approach consists of a volar zigzag incision over the PIP joint crease, release of the A3 pulley, volar plate, and partial collateral ligaments. Volar approach does not always require postoperative splinting and enables range of motion exercises immediately after surgery.⁴⁴ Therefore, we hypothesized that silicone implant arthroplasty with volar approach has the best gain in arc of motion, and less extension lag after surgery. An 8-years follow-up study of silicone arthroplasty for PIP joint with volar approach demonstrated their durability with only one revision surgery (3%) performed.¹⁰ Although a comparative study of dorsal and volar approaches showed no significant difference in the two groups in terms of postoperative arc of motion, the authors preferred the volar approach for silicone arthroplasty of PIP joints in cases for which no dorsal bony or extensor tendon correction was necessary because volar approach enabled early active and more aggressive rehabilitation.³¹ Minamikawa et al. reported on the greater lateral laxity of silicone implants compared with surface replacement prosthesis in their cadaveric anatomical study.⁴⁵ Silicone implant becomes encapsulated, and with appropriate surgical procedures, including reattachment of collateral ligament, stability of the joint can be restored.⁴⁶ In our systematic review on finger characteristics, not only ulnar little and ring fingers had silicone arthroplasty, silicone spacers were implanted in the index and the long fingers even though lateral stability of pinch was a concern.

A randomized study comparing silicone and 2 types of surface replacement arthroplasty for degenerative PIP joint OA showed that implant explantations were required in 11%, 27%, and 39% of patients respectively. Silicone arthroplasty had fewer complications among the three groups.²¹ In this systematic review, the subgroup of silicone arthroplasty with volar approach had the lowest rate of revision (6% at the mean follow-up period 41 months) among all the subgroups. Comparing silicone volar approach with dorsal, 47 revisions (44%)

due to stiffness or extensor tendon adhesion were reported among silicone with dorsal approach subgroup. There was no tenolysis reported in silicone with volar approach subgroup. This difference could be attributed to their approaches. Furthermore, surface replacement arthroplasty with dorsal approach had the highest rate of revision including tenolysis (18% at the mean follow-up period 51 months) among all the subgroups. Thirty-six (23%) revision surgeries after surface replacement arthroplasty with dorsal approach were conversions to silicone implant. There is a clear difference in the number of revisions between silicone arthroplasty with volar approach and silicone or surface replacement arthroplasty with dorsal approach.

Sixty-six percent of articles reported higher satisfaction after surgery regardless of the approach and implant design. Among the articles that reported on pain status, the authors found general improvement of pain after surgery. These results suggest there is a definite need of implant arthroplasty for degenerative or posttraumatic PIP joint OA.

Postoperative grip and pinch strength improved regardless of the type of implants and surgical approach. However, most articles failed to report on grip and pinch strength. We found a tendency that recent papers published in the 21st century reported on grip and pinch strength more rigorously compared with previous papers. These data variables must be included in future studies because grip and pinch strength are one of important factors to evaluate functional status.

Our study has several limitations as with any systematic review. The quality of available literature influenced our review because most articles were retrospective case series which may have selection bias. We attempted to reduce this bias with strict inclusion and exclusion criteria. We also included both English and non-English articles to collect data on more number of patients from 1970. Most articles failed to report preoperative arc of motion, pain status, PROs, and grip and pinch strength. Furthermore, most articles did not report standard errors or deviations. Therefore, it was difficult to analyze statistically when complete data reporting is lacking. We recommend the comprehensive reporting including clear inclusion and exclusion criteria, patients and finger characteristics, and individual data of pre and postoperative outcomes using subjective and objective evaluation such as arc of motion, extension lag, complication, grip and pinch strength, pain status, PROs, satisfaction with appropriate follow-up period in future publications.

In conclusion, we found that silicone implant arthroplasty with volar approach showed the best gain in arc of motion, less extension lag, and had fewer complications after surgery among all the implant designs and surgical approaches. This volar approach using the silicone implant is the preferred technique adopted by the senior author because of lower revision rate, ease of revision if necessary, minimal extension lag and best arc of motion. Level-1 evidence using prospective randomized controlled trials for PIP joint arthroplasty with different implant designs and surgical approaches is required. But most importantly, the future for this critical joint is to develop an anatomic implant that will osteointegrate by critically evaluating current and past implants designed for continued refinement.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Flow chart of database search, including number of citations identified at each level of search. *Two articles contained both volar and dorsal approach, and †one article contained Silicone, Pyrocarbon and SRA arthroplasty with dorsal approach.

Table 1**Inclusion and Exclusion Criteria for Literature Search of PIP Joint Arthroplasty**

Inclusion Criteria	
Studies that included adult patients with degenerative or posttraumatic PIP joint osteoarthritis of the finger	
Implant with silicone or surface replacement arthroplasty	
Studies that reported the primary outcome (arc of motion of the PIP joint and complication) and follow-up period	
Original articles and published from January 1, 1970 to December 31, 2015	
Exclusion Criteria	
Inflammatory arthritis only	
Immediate reconstruction after trauma or complexed trauma lesion	
Animals or cadaveric studies	
Without implant arthroplasty	
Use of currently unavailable implant	
Studies with mixed surgical approach of volar and dorsal	
Failure to report the type of implant, surgical approach, primary outcome, and follow-up period	
Data duplication from the same author or the same institution	
Lacking extractable data in the study	
Review article	
Surgical technique article	
Single case report	

PIP- proximal interphalangeal.

Table 2

Study Characteristics of Proximal Interphalangeal Joint Implant Arthroplasty Review

	Silicone volar	Silicone lateral	Silicone dorsal	Surface replacement volar	Surface replacement dorsal	Total
Period during which studies were reported						
1970–1979	0	0	0	0	0	0
1980–1989	0	0	1	0	0	1
1990–1999	2	1 [#]	4 [†]	0	0	7
2000–2009	1 [*]	1 [#]	2 [*]	0	6	10
2010–2015	3	1	1 ^{**}	2	19 ^{*,**,††}	26
Study location						
United States	2	0	3	2	6	13
Asia	0	0	0	0	2	2
Europe	4 [*]	3 ^{#, #}	4 ^{*,**}	0	16 ^{**,††}	27
Other	0	0	1 [†]	0	1 ^{††}	2

* One study included Silicone arthroplasty with volar or dorsal approach.

** The other study included Silicone and two types of surface replacement arthroplasty.

† Study performed in Brazil.

†† Study performed in South Africa.

lateral or dorsal approach.

Table 3
Patient and Finger Characteristics of Proximal Interphalangeal Joint Implant Arthroplasty Review

Authors	female ratio (%)	mean age	OA ratio (%)	implant	approach	index	long	ring	little
Silicone with volar approach									
Proubasta et al. ⁹	77	60	100	Avanta	volar	0	10	24	2
Lautenbach et al. ¹⁰	80	66	100#	Swanson	volar	10	14	8	3
Bouacida et al. ¹²	86	66	57	NeuFlex	volar	3	11	11	3
Herren et al. ³¹	N/A	65.7	61	Swanson	volar	N/A			
Lin et al. ¹¹	64	52	70	Swanson	volar	10	26	24	9
Schneider ⁴⁴	N/A	N/A	N/A	Swanson	volar	N/A			
Total						23	61	67	17
Silicone with lateral approach									
Merle et al. ¹³	74	61	100	NeuFlex	lateral	9	15	20	7
Stahlenbrecher et al. ¹⁴	81	64	96	Swanson20, NeuFlex33	lateral41, dorsal12	15	14	15	9
Hage et al. ¹⁵	33	34	100##	Swanson	dorsal or lateral	4	5	7	0
Total						28	34	42	16
Silicone with dorsal approach									
Daecke et al. ²¹	81#	64.9	100	Swanson	dorsal	3	7	5	3
Namdari et al. ⁵⁴	64	63	100	NeuFlex	dorsal	N/A			
Herren et al. ³¹	N/A	65	61	Swanson	dorsal	N/A			
Mathoulin et al. ³³	29	38	100##	Sutter	dorsal	6	9	3	3
Silva et al. ³⁴	13	39	100##	Swanson	dorsal	0	16	7	0
Cesari et al. ³⁵	60	36 [*] , 55 ^{**}	100	Swanson	dorsal	3	7	6	2
Pellegrini et al. ⁴	88	58	96	Swanson	dorsal	0	14	11	1
Swanson et al. ⁷	N/A	N/A	48	Swanson	dorsal	87	133	121	83
Total						99	186	153	92
Surface replacement with volar approach									

Authors	female ratio (%)	mean age	OA ratio (%)	implant	approach	index	long	ring	little
Jennings et al. ³²	100	51.2	95 [†]	SR	volar	0	5	1	0
Stoecklein et al. ²⁶	40	60	100	SR	volar	1	3	2	0
Total									
Surface replacement with dorsal approach									
Jennings et al. ³²	92	63.4	95 [†]	SR	dorsal	14	9	9	4
Lawson-Smith et al. ⁵⁵	73	64	96	SR	dorsal	N/A			
Vogt et al. ³⁶	75	62	92	SR	dorsal	14	18	23	11
Daecke et al. ²¹	81#	64.9	100	SR	dorsal	8	11	5	2
Amirharajah et al. ²⁷	67	59	82	SR	dorsal		6	4	1
Luther et al. ⁵⁰	52	47	100	SR	dorsal	2	13	5	4
Johnstone et al. ⁵¹	75	54	77	SR	dorsal	10	16	11	6
Dickson et al. ²³	71	57	76	Pyrocarbon	dorsal ^{††}	24	31	32	10
Tagil et al. ³⁷	86	59	85	Pyrocarbon	dorsal	N/A			
Reissner et al. ⁴²	79	64	94	Pyrocarbon	dorsal	7	7	3	0
Daecke et al. ²¹	81#	64.9	100	Pyrocarbon	dorsal	7	3	7	1
Desai et al. ⁵²	64	61	71	Pyrocarbon	dorsal	7	8	3	2
Heers et al. ²⁸	N/A	61	100	Pyrocarbon	dorsal	4	3	5	1
Ono et al. ²⁰	85	57	85	Pyrocarbon	dorsal	5	10	5	1
McGuire et al. ⁵³	78	61	98	Pyrocarbon	dorsal	11	25	12	9
Mashhadi et al. ⁵⁴	94	60	88	Pyrocarbon	dorsal	N/A			
Hutt et al. ²⁹	73	61	100	Pyrocarbon	dorsal	5	5	3	2
Sweets et al. ¹⁹	94	64	100	Pyrocarbon	dorsal	7	14	8	2
Meier et al. ⁵⁵	60	61	95	Pyrocarbon	dorsal	6	10	4	0
Bravo et al. ³⁸	57	53	60	Pyrocarbon	dorsal	15	18	10	7
Nunley et al. ³⁶	40	40	100##	Pyrocarbon	dorsal	0	2	4	1
Wesemann et al. ⁵⁶	80	61	100	Moje	dorsal	7	6	5	3
Pettersson et al. ³⁹	60	55	70	Moje	dorsal	2	10	6	2

Authors	female ratio (%)	mean age	OA ratio (%)	implant	approach	index	long	ring	little
Schindele et al. ⁴⁰	30	68	100	CapFlex-PIP	dorsal	5	2	2	1
Flannery et al. ⁴¹	75	64	74	MatOrtho	dorsal	29	29	32	10
Total									
						189	256	198	80

[#] Patients with inflammatory arthritis were excluded from review.

^{##} Only patients with posttraumatic osteoarthritis were included.

^{*} median age of patients with posttraumatic arthritis.

^{**} median age of patients with degenerative arthritis.

[†] OA ratio includes volar and dorsal approach.

^{††} This study includes 6 (6%) lateral approach. N/A, not available.

Avanta, Swanson, NeuFlex, Sutter, PyroCarbon, SR, Moje, CapFlex-PIP, and MatOrtho – different brands of implants.

Table 4

Arc of Motion (AOM) for the Proximal Interphalangeal Joint

Authors	Number of fingers	Mean follow-up period (months)	Mean preop AOM	Mean postop AOM	Gained AOM
Silicone with volar approach					
Proubasta et al. ⁹	36	18	37	72	35
Lautenbach et al. ¹⁰	35	104	44	81	37
Bouacida et al. ¹²	28	39	29	58	29
Herren et al. ³¹	38	28.2	52.5	52.6	0.1
Lin et al. ¹¹	69	41	44	46	2
Schneider ⁴⁴	29	14	N/A	48	N/A
Total	235	41.2	42*	58	17*
Silicone with lateral approach					
Merle et al. ¹³	51	36	38	63	25
Stahlenbrecher et al. ¹⁴	53	34	45.6	52.7	7.1
Hage et al. ¹⁵	16	48	N/A	25.6	N/A
Total	120	36.7	42**	54	16**
Silicone with dorsal approach					
Daecke et al. ²¹	18	35	48	56	8
Namdari et al. ⁴⁷	16	49	N/A	61.1	N/A
Herren et al. ³¹	21	51.4	50.7	53.3	2.6
Mathoulin et al. ³³	21	46	15	55	40
Silva et al. ³⁴	23	30	N/A	40	N/A
Cesari et al. ³⁵	18	64	26	33	7
Pellegrini et al. ⁴	26	44.9	N/A	56	N/A
Swanson et al. ⁷	398	62	40	51	11
Total	541	57.6	39#	51	12#
Surface replacement with volar approach					
Jennings et al. ³²	6	125	60	50	-10

Authors	Number of fingers	Mean follow-up period (months)	Mean preop AOM	Mean postop AOM	Gained AOM
Stoecklein et al. ²⁶	6	35	33	60	27
Total	12	80	47	55	9
Surface replacement with dorsal approach					
Jennings et al. ³²	36	95	57	54	-3
Lawson-Smith et al. ⁴⁸	48	18	55	81	26
Vogt et al. ⁴⁹	66	29	N/A	72	N/A
Daecke et al. ²¹	26	35	67	65	-2
Amirtharajah et al. ²⁷	11	39.6	33	61	28
Luther et al. ⁵⁰	24	27	33	54	21
Johnstone et al. ⁵¹	43	60	43	52	9
Dickson et al. ²³	97	118	25	35	10
Tagil et al. ³⁷	59	12	53	54	1
Reissner et al. ⁴²	15	116.4	36	29	-7
Daecke et al. ²¹	18	35	56	61	5
Desai et al. ⁵²	20	42	40	70	30
Heers et al. ²⁸	13	99.6	46	58	12
Ono et al. ²⁰	21	44	43	39	-4
McGuire et al. ⁵³	57	27	30	66	36
Mashhadi et al. ⁵⁴	24	48	36	46	10
Hutt et al. ²⁹	18	74.4	40	45	5
Sweets et al. ¹⁹	31	55	57	31	-26
Meier et al. ⁵⁵	24	15	N/A	50	N/A
Bravo et al. ³⁸	50	37	40	47	7
Nunley et al. ³⁶	7	17	32	30	-2
Wesemann et al. ⁵⁶	21	13	N/A	18.5	N/A
Pettersson et al. ³⁹	20	12	43	60	17
Schindele et al. ⁴⁰	10	12	42	51	12

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Authors	Number of fingers	Mean follow-up period (months)	Mean preop AOM	Mean postop AOM	Gained AOM
Flannery et al. ⁴¹	100	47	36	34	-2
Total	859	48.6	41[†]	51	8[‡]

* n=206.
** n=104.
n=476.
† n=748. N/A, not available. Preop-Preoperative; postop-Postoperative

Table 5

Extension Lag for the Proximal Interphalangeal Joint

Authors	Number of fingers	Mean follow-up period (months)	Preop extension lag	Postop extension lag
Silicone with volar approach				
Proubasta et al. ⁹	36	18	18	0
Lautenbach et al. ¹⁰	35	104	13	4
Bouacida et al. ¹²	28	39	14	5
Lin et al. ¹¹	69	41	17	8
Total	168	48.9	16	5
Silicone with lateral approach				
Merle et al. ¹³	51	36	N/A	12
Total	51	36	N/A	12
Silicone with dorsal approach				
Namdari et al. ⁴⁷	16	49	N/A	0
Mathoulin et al. ³³	21	46	20	10
Cesari et al. ³⁵	18	64	19	15
Pellegrini et al. ⁴	26	44.9	N/A	3.2
Swanson et al. ⁷	398	62	22	8
Total	479	60	22[*]	8
Surface replacement with volar approach				
Jennings et al. ³²	6	125	16	21
Stoecklein et al. ²⁶	6	35	22	13
Total	12	80	19	17
Surface replacement with dorsal approach				
Jennings et al. ³²	36	95	12	7
Lawson-Smith et al. ⁴⁸	48	18	15	4
Amirtharajah et al. ²⁷	11	39.6	22	13
Dickson et al. ²³	97	118	N/A	18
Tagil et al. ³⁷	59	12	14	19
Reissner et al. ⁴²	15	116.4	20	19
Nunley et al. ³⁶	7	17	18	52
Wesemann et al. ⁵⁶	21	13	N/A	20.4
Pettersson et al. ³⁹	20	12	17	9.5
Schindele et al. ⁴⁰	10	12	18	9
Flannery et al. ⁴¹	100	47	21	13
Total	424	56.8	17[#]	14

*
n=437

n=306. N/A, not available. Preop-Preoperative; postop-Postoperative

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Table 6

Number and Rate of Revision after Proximal Interphalangeal Joint Implant Arthroplasty

Authors	Number of fingers	Mean follow-up period (months)	Number of revision (%)	Complications
Silicone with volar approach				
Proubasta et al. ⁹	36	18	0	2 implant fractures, but no revision surgery
Lautenbach et al. ¹⁰	35	104	1 (3)	1 revision because of painful instability
Bouacida et al. ¹²	28	39	1 (4)	1 revision among 3 implant fractures
Herren et al. ³¹	38	28.2	0	no implant fracture and no infection
Lin et al. ¹¹	69	41	9 (13)	3 revisions due to implant fractures, 2 arthrodesis, 1 amputation, and 3 others
Schneider ⁴⁴	29	14	2 (7)	revision due to I fracture and 1 persistent deformity
Total	235	41.2	13 (6)	
Silicone with lateral approach				
Merle et al. ¹³	51	36	5 (10)	3 lateral instabilities, 1 implant fracture, and 1 volar plate repair
Stahlenbrecher et al. ¹⁴	48	34	5 (10)	5 implants were removed due to infection or implant break
Hage et al. ¹⁵	16	48	2 (13)	2 revisions to arthrodesis or amputation
Total	115	36.8	12 (10)	
Silicone with dorsal approach				
Daecke et al. ²¹	18	36	2 (11)	2 implants were removed due to implant fracture
Namdari et al. ⁴⁷	16	49	0	1 implant fracture by X-ray
Herren et al. ³¹	21	51.4	4 (19)	4 reoperations due to excessive bony reaction
Mathoulin et al. ³³	21	46	8 (38)	5 secondary tenolysis, 1 osteophyte resection, 1 arthrodesis and 1 revision due to implant fracture
Silva et al. ³⁴	23	30	1 (4)	1 implant rupture to arthrodesis
Cesari et al. ³⁵	18	64	4 (24)	3 implants changed and 1 extensor tenolysis
Pellegrini et al. ⁴	26	44.9	0	27% of joints showed asymptomatic periarticular erosion on X-ray
Swanson et al. ⁷	812	12	88 (11)	41 stiffness or deformity, 11 lipid retrieval studies, 31 implant fracture, 3 infections, 1 dislocation, 1 pain with a minimum 1 year follow up
Total	955	17	107 (11)	
Surface replacement with volar approach				
Jennings et al. ³²	6	125	2 (33)	2 revisions to Swanson implant
Stoecklein et al. ²⁶	6	35	0	only non-cemented joint demonstrated progressive subsidence of both components
Total	12	80	2 (17)	
Surface replacement with dorsal approach				
Jennings et al. ³²	32	95	9 (28)	6 revisions with cement, 2 fusions, and 1 revision to Swanson implant
Lawson-Smith et al. ⁴⁸	48	18	3 (6)	3 reoperations due to contracture
Vogt et al. ⁴⁹	66	29	7 (11)	5 tenarthrolysis, 1 swan-neck correction, and 1 implant revision

Authors	Number of fingers	Mean follow-up period (months)	Number of revision (%)	Complications
Daecke et al. ²¹	26	35	11 (42)	7 implants were removed, 4 secondary surgeries without explantation of implant
Amirtharajah et al. ²⁷	11	39.6	1 (9)	1 tenolysis and 7 showed some subsidence
Luther et al. ⁵⁰	24	27	14 (58)	9 tenoarthrolysis, 1 tenodesis, and 4 infection
Johnstone et al. ⁵¹	43	60	16 (37)	2 amputations, 5 revisions, 7 extensor tenolysis, and 2 swan-neck correction
Dickson et al. ²³	97	118	14 (14)	10 revisions to silicone and 4 arthrodesis
Tagil et al. ³⁷	89	60	10 (11)	2 revisions, 3 fusions, 1 explantation, and 4 others
Reissner et al. ⁴²	15	116.4	1 (7)	1 revision to fusion
Daecke et al. ²¹	18	35	7 (39)	7 explantations due to loosening or dislocation
Desai et al. ⁵²	20	42	1 (5)	1 amputation due to stiffness
Heers et al. ²⁸	13	99.6	2 (15)	2 early revisions for stiffness
Ono et al. ²⁰	21	44	0	complication rate 43%, but no revision surgery
McGuire et al. ⁵³	57	27	5 (9)	4 revisions to silicone and 1 revision to large component
Mashhadi et al. ⁵⁴	24	48	3 (12)	3 tenoarthrolysis
Hutt et al. ²⁹	18	74.4	4 (22)	1 amputation, 1 arthrodesis and 2 surgical mobilizations
Sweets et al. ¹⁹	31	55	6 (19)	4 arthrodesis, 1 revision to silicone, and 1 excision exostosis
Meier et al. ⁵⁵	24	15	3 (12)	3 arthrodesis due to 1 infection and 2 dislocations
Bravo et al. ³⁸	50	37	14 (28)	2 revisions to PyroCarbon, 1 revision to silicone, 2 amputations, 1 arthrodesis and 8 others
Nunley et al. ³⁶	7	17	2 (29)	1 amputation and 1 revision to silicone
Wesemann et al. ⁵⁶	21	13	9 (43)	9 revisions to silicone
Pettersson et al. ³⁹	20	12	0	no reoperation during the follow-up period
Schindele et al. ⁴⁰	10	12	2 (20)	2 secondary tenolysis
Flannery et al. ⁴¹	100	47	13 (13)	9 revisions to NeuFlex, 3 arthrodesis, and 1 revision to MatOrtho
Total	885	51	157 (18)	