Outcomes of Surface Replacement Proximal Interphalangeal Joint Arthroplasty Using the Self Locking Finger Joint Implant: Minimum Two Years Follow-up

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Abstract

Background: The Self Locking Finger Joint (SLFJ) implant is a new type of surface replacement implant. The purpose of this study was to evaluate midterm clinical outcomes of the proximal interphalangeal (PIP) arthroplasty with the SLFJ implant. **Methods:** We retrospectively studied 26 PIP joint arthroplasties using the SLFJ implant in 17 patients with osteoarthritis or posttraumatic osteoarthritis. Preoperative and postoperative range of motion, grip strength and key pinch, radiographic findings, and complications were evaluated. The Disabilities of the Arm, Shoulder, and Hand (DASH) score, visual analog scale (VAS) score, course of pain, and patient satisfaction were obtained. **Results:** The mean follow-up time was 44 months (range, 24–76 months). The average active PIP joint arc of motion improved from 36° before surgery to 44° after surgery. Grip strength and key pinch showed no statistical difference between preoperative and postoperative assessments. The average DASH score and VAS score improved from 40 to 15 and from 5 to 1, respectively. Overall patient satisfaction was 94%. Ninety percent of implants showed osteointegration, and there were no radiographic signs of migration and loosening. Three joints (12%) showed abnormal heterotopic bone formation. Four joints (15%) had secondary surgery—I joint needing joint head and socket replacement and 3 joints needing contracture release. **Conclusions:** Our minimum 2 years of follow-up evaluation of the SLFJ implant PIP joint arthroplasty demonstrated good pain relief and good overall patient satisfaction while maintaining joint range of motion. The SLFJ implant showed good osteointegration. Further longer-term prospective studies with various types of currently available implants are needed.

Keywords: surface replacement arthroplasty, proximal interphalangeal joint, Self Locking Finger Joint implant, osteointegration, osteoarthritis

Introduction

To date, the ideal implant that consistently preserves proximal interphalangeal (PIP) joint motion and stability with long-term durability has yet to be developed. Over the last 4 decades, silicone implants have been the gold standard for PIP joint arthroplasty. However, studies with long-term follow-up have demonstrated problems with implant fracture, silicone synovitis, deformity, and overall complication rates as high as 32%.^{1,11,17,19} In the last 2 decades, surface replacement implants have been introduced.^{9,12,20,22} These implants have anatomically similar design to a finger joint and have the theoretical advantage of preserving joint stability.^{12,22} Some studies have shown these implants have characteristic disadvantages, such as loosening and subsidence. The revision rates of surface replacement implants range from 8% to 48%.^{2,9,10,18}

Self Locking Finger Joint (SLFJ) implant (Teijin Nakashima Medical Co, Okayama, Japan) is an uncemented surface replacement implant. The titanium joint anchor has a tapered self-tapping screw and 2 legs, which spread in the intramedullary canal to obtain firm fixation without cement. The implant is designed to preserve the collateral ligaments and allow appropriate tensioning. Implant setting with a

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Table 1. Patient Demographics.

Patient demographics	
Patients	17
Male	3
Female	14
Diagnosis	
OA	15
PA	2
Joints	26
Index	2
Middle	9
Ring	9
Small	6
Mean age, y (range)	63 (51-79)
Mean follow-up, mo (range)	44 (24-76)
OA	45 (24-76)
PA	38 (32-43)

Note. OA = osteoarthritis; PA = posttraumatic arthritis.

tapered screw allows the surgeon to adjust the position of the implant. The SLFJ implant has been in clinical use in Japan since 1999. To date, more than 1000 joints have been implanted in more than 200 institutions.

Short-term outcomes after PIP joint arthroplasty with the SLFJ implant have shown promising results. The purpose of this study was to evaluate the effectiveness of the SLFJ implant with a minimum of 2 years of follow-up.

Materials and Methods

Patients' Demographics

Institutional review board approval was obtained prior to initiating this study. A retrospective review of medical records was conducted. Inclusion criteria were patients who presented with late-stage degenerative PIP joint osteoarthritis and posttraumatic PIP joint arthritis, who had persistent pain and loss of motion and who failed to respond to nonoperative treatments, and a follow-up period of greater than 2 years. Patients with rheumatoid arthritis and inflammatory arthritis were excluded.

Between January 2005 and December 2010, 17 patients with 26 PIP joints, who had a PIP joint arthroplasty using the SLFJ implant with a minimum of 2 years of follow-up, were identified. The preoperative diagnosis was degenerative osteoarthritis in 15 (24 joints) and posttraumatic osteoarthritis in 2 (2 joints). Patient demographics are shown in Table 1.

Implantation of the SLFJ Implant

The SLFJ implant was used in all cases, and the surgery was performed by the senior author (Figures 1a-1c). Two certi-

fied hand therapists were responsible for the postoperative rehabilitation and evaluation of all subjects. Two different surgical approaches for implantation were utilized. A dorsal approach was performed in 11 joints and a volar approach was performed in 15 joints. The decision of whether a dorsal or volar approach is used depended on the amount of dorsal osteophyte that is present. In the dorsal approach, a distally based flap of the extensor mechanism is elevated to approach the PIP joint. The dorsal osteophytes are removed by a rongeur as necessary. In the volar approach, a Bruner incision is used and an incision is made in the flexor sheath between A2 and A4 pulley. The volar plate is incised at its insertion on the middle phalanx. The entire flexor sheath and flexor tendons are reflected to expose the PIP joint. After PIP joint is exposed, SLFJ implantation is then performed. The proximal phalanx is prepared by resecting the head of proximal phalanx using a micro sagittal saw 1 mm distal to the attachment of the collateral ligaments. The middle phalanx is then prepared by first burring cartilage and subchondral bone from the articular surface. A starter awl and reamer are used to prepare the intramedullary canal, and then the joint anchor is screwed into both proximal and middle phalanges. The collateral ligaments are fully preserved and left attached to both proximal and middle phalanges. Every 90 degrees of rotation, clockwise or counterclockwise, the joint anchor inserts or elevates the joint anchor 0.2 mm in the intramedullary canal (Figure 1c-1). Care is taken that the joint anchor is placed parallel to the long axis and perpendicular to the flexion/extension axis of the PIP joint with every 90° degree of rotation. The locking screw is tightened to expand the legs of the joint anchor in the medullary canal (Figure 1c-2 and 1c-3). The square recess of the joint anchor and the square projections of the head/socket component are designed to connect those components in the proper alignment after adjusting the optimal joint anchor setting (Figure 1b). A trial head/socket component is inserted and the PIP joint is reduced and evaluated. Based upon the joint tightness/stability, placement of the joint anchor is adjusted. The size of head/socket component is changed as required. Postoperative protocols are described in the online Appendix.

Evaluation

Functional assessment. Active range of motion, grip strength, and key pinch strength were recorded preoperatively and at the time of the final follow-up postoperatively (minimum 24 months). Active range of motion was measured using a goniometer (SAKAI Medical, Tokyo, Japan) by a certified hand therapist. Grip and key pinch strength were also measured using a grip meter and a pinch gauge (SAKAI Medical).

Patient-rated assessment. The Japanese Society for Surgery of the Hand version of the Disabilities of the Arm, Shoulder,

Figure 1. The Self Locking Finger Joint (SLFJ) implant for proximal interphalangeal joints. (a) Overviews of the implant. Surface replacement type implant with bicondyle anatomical joint congruity. (b) The SLFJ implant has 6 components. Joint anchors: shot-blasted titanium alloy (Ti-6Al-4V alloy). Locking screws: titanium alloy (Ti-6Al-4V alloy). Joint head: cobalt-chrome alloy (Co-Cr-Mo alloy). Joint socket: UHMWPE (ultrahigh-molecular-weight polyethylene). (c-1) The joint anchor has tapered self-tapping screw. It is designed that 1 pitch (360°) of rotation inserts the joint anchor 0.8 mm into the intramedullary canal. (c-2 and c-3) Tightening of the locking screw component will spread 2 legs of joint anchor inside the intramedullary canal.

and Hand questionnaire (DASH-JSSH)⁷ was obtained preoperatively and postoperatively (at final follow-up). It consists of a disability/symptom (DASH-DS) scale, and 2 optional modules, the work (DASH-W) and the sport/music (DASH-SM) modules. The patient's disability is calculated and the score converted to a scale from 0 to 100, with 0 being the best result.

A 10-point visual analog scale (VAS) score (0, no pain; 10, intolerable pain) was used to assess the degree of pain for all patients at the final follow-up. The patient's description of pain was also evaluated for all patients. The level of the patients' satisfaction was categorized as very satisfactory, satisfactory, or not satisfactory.

Radiographic assessment. Radiographic results were assessed preoperatively and postoperatively (at final follow-up). SLFJ implants were evaluated for signs of loosening, migration, subsidence, implant deformation (angulation), and implant fracture. We assessed implant loosening and migration, comparing radiographs of immediate postoperative radiographs and final follow-up.

Osteointegration was assessed based on an evaluation of the length and width of resorption zones around the implant. Using a modification of a previously published scoring system,¹⁴ the osteointegration of both distal and proximal implant components was assessed with scores from 0 to 3 (Figure 2).¹⁴ Because of the specific structure of joint anchor in the SLFJ implant, osteointegration extending to the inner surface of the legs of the joint anchor in the intramedullary canal was also assessed and scored.

The degree of heterotopic bone formation around the implant was also evaluated and classified into 4 grades using a previously published grading system.^{6,19} Grade 1 indicated slight bone formation, grade 2 mild, grade 3 moderate, and grade 4 severe with bony ankylosis. Abnormal heterotopic bone formation was defined as presence of moderate or severe bony formation (grades 3 and 4) in this study.

Clinical Complications and Secondary Surgery

Postoperative complications, including contracture/stiffness, "squeaking," and joint deformation due either to

Figure 2. Osteointegration scoring system with representative radiographs.

Note. 0, Obvious implant loosening, with a wide irregular resorption zone extending around the joint anchor with or without implant subsidence. 1, Slight to moderate bone resorption with an irregular resorption zone extending at least half of the joint anchor length. 2, Osteointegration at bone-metal attachment (outer surface of joint anchor). 3, Complete osteointegration with covering both outer and inner surfaces of the legs of joint anchor. Note that score 0 is defined as either implant loosening or migration and scores 2 to 3 correspond to osteointegration.

implant dislocation or implant fracture, synovitis, infection, and wound healing problems, were recorded. In this study, we defined postoperative joint contracture as a PIP joint with less than a 35° arc of motion or more than 50% of loss of motion compared with preoperative range of motion.¹ A PIP joint angulation of greater than 10° in the coronal plane was considered as a deformity. Revision surgery was defined as removal of the SLFJ implant for any reason.

Statistics

Statistical analysis was carried out by paired *t* tests to assess range of motion and grip/key pinch strength. Unpaired *t* tests were performed to assess DASH and VAS scores. A *P* value <.05 was used to judge statistical significance.

Results

Follow-up

The average follow-up period was 44 months (range, 24-76 months; mean, 44 months; median, 44 months) (Table 1).

Functional Assessment

Range of motion. Range of motion for the PIP joints and distal interphalangeal (DIP) joints was available in all patients preoperatively and postoperatively (at final follow-up; Table 2). The average active PIP joint arc of motion went from 36° before surgery to 44° after surgery. The average active DIP joint arc of motion went from 17° before

surgery to 22° after surgery. The average active PIP joint arc of motion for the volar approach was 9° versus 6° for the dorsal approach. Nine joints (35%) showed clinical signs of joint stiffness.

Grip strength and key pinch. There was no significant change in grip strength and key pinch during the follow-up period (Table 2). The average grip strength was 16 kg preoperatively and 19 kg postoperatively. Key pinch strength was slightly improved from 5 kg preoperatively to 6 kg postoperatively.

Patient-Rated Assessment

The mean DASH disability module (DASH-DS) score improved from 32 (range, 19-54) before surgery to 15 (range, 0-29) after surgery (Table 3). The mean DASH work module (DASH-W) score improved from 32 (range, 13-75) before surgery to 15 (range, 0-50) after surgery, and the mean DASH sports/music module (DASH-SM) score improved from 56 (range, 25-69) before surgery to 16 (range, 13-63) after surgery. Score improvements in both work and disability module were statistically significant (*P* < .05). The average preoperative VAS pain score of 4.4 (range, 1.2-7.0) was significantly improved to an average of 0.7 (range, 0-4.3) postoperatively (*P* < .05). Patient satisfaction revealed that 11 patients (65%) were very satisfied, 5 were satisfied (29%), and 1 was not satisfied (6%). In terms of pain, 15 patients (88%) described their pain as better, 1 patient (6%) described their pain as unchanged, and 1 patient (6%) described their pain as worse.

Table 2. Range of Motion, Grip, and Key Pinch.

	Preoperative		Postoperative		Average change gained	P value
	Average joint range of motion (extension/flexion), degrees	Average arc of motion (range), degrees	Average joint range of motion (extension/flexion), degrees	Average arc of motion (range), degrees		
All patients (26 joints)						
PIP joints	–21/57	36 (11-63)	–23/67	44 (20-78)	8	<0.05 (0.048)
DIP joints	–16/33	17 (0-50)	–13/35	22 (0-60)	5	(0.09)
Dorsal approach (11 joints)						
PIP joints	–22/60	38 (11-65)	–20/64	44 (20-64)	6	(0.24)
Volar approach (15 joints)						
PIP joints	–21/55	34 (15-64)	–20/69	49 (21-78)	9	<0.05 (0.031)
Grip strength, kg (range; % of nonsurgical side)	16 (10-24; 75%)		19 (12-23; 87%)		3	(0.608)
Key pinch, kg (range; % of nonsurgical side)	5 (3-9; 83%)		6 (3-11, 100%)		1	(0.310)

Note. PIP = proximal interphalangeal; DIP = distal interphalangeal.

Radiographic Assessment

Each of distal and proximal components among total 52 components in the 26 arthroplasties was assessed. Radiographic assessment of osteointegration showed there were total 20 implants in score 3 (38%), 27 implants in score 2 (52%), 5 implants in score 1 (10%), and no joint in score 0 (26 arthroplasties—proximal/distal components) (Table 3). There were no obvious signs of loosening, migration, or subsidence in this series. Forty-seven implants out of 52 implants showed osteointegration (scores 2 and 3).

Heterotopic bone formation assessment revealed that there were 11 joints in grade 0, 6 joints in grade 1, 7 joints in grade 2, 2 joints in grade 3, and 1 joint in grade 4, which had a bony ankylosis. There was dislocation of 1 joint. There were no episodes of implant fracture or deformation.

Clinical Complications

There was no instance of intraoperative implant fracture. There were no complaints of joint squeaking (Table 3). One joint dislocated and subsequently underwent revision surgery. Joint head and socket change and soft tissue modifications were performed in this case. Among joints with stiffness, 3 joints (12%) had a tenolysis of the extensor apparatus (release of contracture). There were no revision surgeries due to joint anchor loosening or fracture. One case showed clinical signs of superficial wound infection and was successfully treated by oral antibiotics.

Case Reports

Representative clinical cases of the SLFJ implant PIP joint arthroplasty are shown in Figures 3 and 4.

Discussion

Our clinical result of minimum 2 years of follow-up demonstrates that the SLFJ implant for osteoarthritis or posttraumatic arthritis relieves pain and demonstrates good osteointegration while maintaining joint range of motion.

In previously published studies using various types of finger joint implants, the most common reasons for revision were implant-related problems, such as loosening, subsidence, migration, and implant fracture.^{12,18,19} The revision rate for various implants reported in previous studies ranges from 19% to 39% in pyrocarbon implants,^{2,3,19} from 18% to 33% in SR-PIP implants (titanium),^{3,9,10,12} and from 11% to 14% in silicone implants.^{3,19} In the present study, one joint dislocated, which subsequently was revised by changing implant head and socket to larger size. No revision surgeries for joint anchor loosening fracture or deformity was needed in this series.

We believe this finding is related to the strong fixation feature of the SLFJ. In the present study, radiographic assessment showed 90% of implants had osteointegration. Both proximal and distal components showed a similar score distribution, indicating that the SLFJ fits well in the intramedullary canal of both proximal and middle phalanges. Screw-type implants have been introduced previously.^{14,15} Moller et al introduced titanium-threaded stem implants and had a 93% rate of osteointegration in PIP joints at an average of 41 months of follow-up.¹⁴

It is well documented that the material property of an implant also plays an important role in rigid fixation. Daecke et al reported that titanium showed superior osteointegration over pyrocarbon.⁴ This seems to be supported by recent clinical studies of pyrocarbon implants showing rates of radiographic loosening as ranging from 40% to 57%.^{2,3,16,18} Daecke et al have also reported 31% rate of implant subsidence and 39% rate of osteointegration in press-fit SR-PIP implants (titanium).³

Table 3. DASH Score, VAS Score, Patients Satisfaction, Course of Pain, Radiographic Findings, and Complications.

DASH score, VAS score, patients satisfaction, and course of pain	Preoperative	Postoperative	P value
DASH score (range)			
Work	32 (13-75)	15 (0-50)	<0.05 (0.039)
Sports	56 (25-69)	16 (13-63)	
Disability	32 (19-54)	15 (0-29)	<0.05 (0.001)
Average	40	15	
VAS score (range)	4.4 (1.2-7.0)	0.7 (0-4.3)	<0.05 (0.001)
Patients satisfaction, % of total patients			
Very		65 (11/17)	
Fair		29 (5/17)	
Not		6 (1/17)	
Patient's description of pain, % of total patients			
Better		88 (15/17)	
Unchange		6 (1/17)	
Worse		6 (1/17)	

Radiographic findings	No. of joints			%
	Proximal	Distal	Total	
Osteointegration				
Score 0	0	0	0	0
Score 1	2	3	5	10
Score 2	12	15	27	52
Score 3	12	8	20	38
Loosening		0		0
Migration		0		0
Heterotopic bone formation				
Grade 0		10		38
Grade 1		6		23
Grade 2		7		27
Grade 3		2		8
Grade 4		1		4
Dislocation		1		4
Implant deformation (angulation)		0		0
Implant fracture		0		0
Coronal deviation		0		0
Clinical complications and secondary operation	No. of joints			%
Clinical complications				
Contracture/stiffness		9		35
Squeaking		0		0
Joint deformation		1 (dislocation)		4
Particulate synovitis		0		0
Infection		1		4
Wound healing problems		0		0
Secondary operation				
Release of contracture		3		12
Soft tissue modification/implant head and socket replacement		1		4
Joint anchor replacement		0		0

Note. DASH = Disabilities of the Arm, Shoulder, and Hand; VAS = visual analog scale.

Figure 3. A 64-year-old right-hand-dominant female presents with a long-standing history of degenerative osteoarthritis affecting the proximal interphalangeal (PIP) joint of left middle finger. Preoperative radiographs of the hand (a), anteroposterior (AP; b), and lateral (c) views of middle finger PIP joint. Forty-nine months after Self Locking Finger Joint PIP joint arthroplasty. Postoperative radiographs of the hand (d), AP (e), and lateral (f) views of middle finger PIP joint. Good osteointegration in both components was observed (score 0). Neither implant subsidence nor migration was observed. She developed dorsal osteophyte at dorsal edge of middle phalangeal bone (grade 2). Postoperative clinical finding showing extension (left, g) and flexion (right, h) views. The patient was pleased with good pain relief and increased range of motion (ROM; preoperative ROM: 0°/60°, postoperative ROM: 0°/86°, arc of gain: 26°).

Those studies suggest that excellent osteointegration observed in the SLFJ implant is likely due to its specific structural features than its titanium material property.

From the radiographic analysis, we recorded changes of increased heterotopic bone formation that might lead to the limitation of the joint motion. Three joints had abnormal bone formation (grades 3 and 4), and 1 showed complete ankylosis. The majority of heterotopic bone formation was seen in association with the dorsal aspect of the implant. In the study by Daecke study, there was a 39% rate of heterotopic bone formation and 8% complete ankylosis seen in SR-PIP implants and 28% heterotopic bone formation and 6% ankylosis seen in pyrocarbon implants.³ The molecular mechanism of heterotopic bone formation has not yet been elucidated.^{5,21} Basic research has demonstrated mechanical stimuli or biochemical stimuli or both could play a role in development of heterotopic bone formation.^{13,21} Takigawa et al postulated in their study of silicone arthroplasty that abnormal heterotopic bone formation might be related to noncoverage of the resected faces of both proximal and

middle phalangeal bone.¹⁹ We hypothesize that implanting the largest head/socket socket possible has some effect in preventing heterotopic bone development.

Ninety-four percent of patients in our study were rated as very or fairly satisfactory. In addition, the VAS score and course of pain were also improved. Most currently available implants have shown good subjective postoperative data. Jennings and Livingstone noted in their study using SR-PIP implant that 88% of patients rated their procedure as very or fairly satisfactory.⁹ Ono et al reported high patient satisfaction observed in pyrocarbon PIP arthroplasty.¹⁶ Subjective score may vary based on preoperative clinical stage of the operated finger or other involved fingers. Thus, subjective data may not help surgeons to make a clinical judgment of implant selection.

Iwamoto et al reported the initial results with the SLFJ implant.⁸ Eleven joints were evaluated with majority done for patients with rheumatoid arthritis. At mean follow-up time of 9.4 months, the average arc of motion went from 44° before surgery to 69° after surgery. Although one joint showed bone absorption, no dislocation or loosening was

Figure 4. A 68-year-old female presents with a long-standing history of degenerative osteoarthritis affecting the proximal interphalangeal (PIP) joint of right middle finger. Preoperative radiographs of the hand (a), anteroposterior (AP; b), and lateral (c) views of middle finger PIP joint. Twenty-four months after Self Locking Finger Joint PIP joint arthroplasty. Postoperative radiographs of the hand (d), AP (e), and lateral (f) views of middle finger PIP joint. Good osteointegration of both components was observed (score 0). Neither implant subsidence nor migration was observed. She developed osteophyte formation at ulnar aspect of PIP joint (grade 3). Postoperative clinical exam showing extension (left, g) and flexion (right, h) views. Although motion gained after operation was only 4° (preoperative range of motion [ROM]: $-6^{\circ}/80^{\circ}$, postoperative ROM: $-12^{\circ}/90^{\circ}$, arc of gain: 4°), her overall satisfaction was good and good pain relief was achieved.

observed in their series. They also showed good fixation in rheumatoid patients, given the typically poor bone quality and frequency of immunosuppression used in these patients. From the subjective standpoint, good pain relief and patient satisfaction were observed, which is consistent with our results. Further midterm to long-term clinical outcome studies using the SLFJ implant in a rheumatoid population are ongoing at our institutions.

The limitations of this study include a relatively small sample size and the retrospective nature of the review. The possibility of type II error would need to be considered. Nonetheless, good subjective outcomes, range of motion improvement, and good osteointegration with low radiographic adverse findings in this study are promising. We have yet to demonstrate the long-term use of the SLFJ. Similarly, we have yet to compare this implant with other surface replacement implants or silicone implants. Prospective randomized comparison with various implants is

needed to prove its efficacy and truly determine its role in the treatment of patients with osteoarthritis and posttraumatic arthritis.

Authors' Note

First author (I.K.) presented "Surface Replacement Arthroplasty of the Proximal Interphalangeal Joint for Nonrheumatoid Conditions Using the Self Locking Finger Joint Implant" at 12th Triennial Congress of the International Federation of Societies for Surgery of the Hand, March 4-8, 2013, New Delhi, India. Corresponding author (Y.M.) presented "Cement-less Surface Finger Implant Arthroplasty" on poster session at 62nd annual meeting of the American Society for Surgery of the Hand, September 27-29, 2007, Seattle, Washington.

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Ethical Approval

Institutional review board approval was obtained prior to initiating this study.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent

Informed consent was obtained from all individual participants included in the study.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: The senior author (Y.M.) receives royalties from Nakashima Medicine, Inc.

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