Outcomes of Surface Replacement Proximal Interphalangeal Joint Arthroplasty Through a Volar Approach: A Prospective Study

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Abstract

Background: The dorsal approach to the proximal interphalangeal (PIP) joint provides the advantage of improved visualization of the articular surface, while the disadvantage of a dorsal approach is the disruption of the central slip and extensor mechanism requiring a delay in range of motion exercises. A volar approach keeps the central slip and extensor mechanism intact, allowing for early range of motion. The goal of this study was to evaluate patient outcomes of surface replacement (SR) PIP joint arthroplasty performed through a volar approach. **Methods:** Twenty-one patients were evaluated with primary osteoarthritis of a single PIP joint and underwent SR arthroplasty using the Stryker SR PIP joint implants. Patients included in this study were exclusively treated through a volar approach. Preoperative range of motion, coronal plan deformity, Disabilities of the Arm, Shoulder and Hand (DASH), and patient satisfaction were measured and compared with postoperative measurements using a paired Student *t* test. **Results:** The average length of follow-up was 34 months (± 9 months). Postoperative arc of motion for the PIP and distal interphalangeal (DIP) joints measured 87° ($\pm 12^\circ$) and 36° ($\pm 11^\circ$), respectively. The average improvement in PIP arc of motion was 58° , DASH score measured 14 (± 5), satisfaction measured 4 (± 1), and coronal plane deviation measured 2° ($\pm 2^\circ$). No evidence of implant subsidence was found on postoperative radiographs. Four patients required an extensor tendon tenolysis, and 1 patient suffered a superficial surgical site infection. **Conclusion:** SR arthroplasty, when performed through a volar approach, allows for early range of motion and greater improvements in arc of motion, DASH score, and patient satisfaction.

Keywords: volar approach, PIP arthroplasty, patient outcomes

Introduction

Proximal interphalangeal (PIP) joint arthroplasty is a safe and effective treatment to replace a painful, nonfunctioning, PIP joint that allows for improved pinch strength, grip strength, and arc of motion. Silicone and surface replacement (SR) implants have successfully been used for this technique with both having demonstrated improved function and quality of life.^{3,5,6} SR implants have been associated with a lower rate of joint stiffness, as well as improved implant stability, and are more desirable in patients with good bone density due to the risk of subsidence, which can be overcome with cemented implants.^{3,5,6,11}

Several studies have discussed patient outcomes for SR PIP arthroplasty. Many of these studies use a dorsal tendon splitting, or reflecting, approach, with 1 small series describing outcomes using a volar approach.^{1,4,7,8,10,13,14,16-21} Patients included in these series often reported substantial pain relief

and improvement in function; however, poor outcomes have also been reported.²⁰ The most commonly reported complication in these studies was joint stiffness which frequently required treatment with an extensor tendon tenolysis and excision of dorsal osteophytes.^{1,4,7,8,10,13,14,16-21} Reoperation rates ranged widely, from 5% to 58%, and time to reoperation ranged from 7 months to 24 months when reported.^{1,4,7,8,10,13,14,16,17,19,21}

A dorsal approach to the PIP joint does provide some advantages, particularly improved visualization of the articular

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surface.²² The disadvantage to this approach, however, is the disruption of the central slip and extensor mechanism, which requires a delay in range of motion exercises postoperatively. A dorsal approach sparing the extensor mechanism has been described, but only 16% of the articular surface can be visualized when this extensor mechanism sparing approach is used.²²

A volar approach provides the benefit of maintaining the central slip and extensor mechanism which allows for early range of motion postoperatively. However, a volar approach has several disadvantages, including increased risk of disruption of the volar plate, flexor tendon contracture, swan neck deformity, and bowstringing of the flexor tendons if the flexor pulleys are excessively released. Despite the increased risk of swan neck deformities with a volar approach, they are not unique to a volar approach, as they have also been reported following a dorsal approach.^{9,11}

The outcomes of a volar approach for silicone implants, as well as 1 small series for SR PIP implants, have been described with good patient satisfaction and well-maintained arc of motion which contrasts many long-term outcome studies using a dorsal approach for SR PIP arthroplasty which have demonstrated an eventual decrease, or no change, in the arc of motion at terminal follow-up.^{1,2,8,12,13,16-18,21}

The goal of this study is to evaluate patient outcomes following SR PIP joint arthroplasty performed through a volar approach using a cemented implant.

Materials and Methods

Between February 2011 and December 2015, we evaluated 21 patients with primary osteoarthritis of a single PIP joint for joint arthroplasty using the Stryker, Kalamazoo, Michigan, PIP joint implants. Approval by the authors' institutional review board was obtained, and each patient provided informed consent to be included in this series. Although the Stryker SR PIP arthroplasty was initially described through a dorsal approach, with the exception of patients presenting with a hyperextension deformity, the patients included in this study were exclusively treated through a volar approach. Patients with preoperative range of motion of less than 35° of active flexion of the PIP joint (patients with greater than 35° of active flexion were treated with more conservative measures before being considered for surgery) and less than 25° of deformity in the coronal plane were included in the study. Because of our experience with joint stiffness in patients who smoke or use other nicotine products, patients were not included in the study if they were actively using tobacco products as this was seen as a potential confounding variable in their outcomes. An important portion of our technique is that therapy could be started within 72 hours after the surgery, highlighting an important advantage to using a volar approach.^{4,14} Only 2 patients did not meet the inclusion criteria.

Preoperative range of motion, coronal deformity, Disabilities of the Arm, Shoulder and Hand (DASH), and patient satisfaction, measured using a numeric rating scale with 0 being less satisfied and 10 being most satisfied, were measured and compared with postoperative measurements using a paired Student *t* test. Statistical significance was set at a *P* value of less than .05.

Surgical Technique

The PIP joint was approached using a Brunner volar incision. The neurovascular bundles were identified and retracted with Ragnell retractors. A window was made in the flexor tendon sheath at the level of the A3 and C1 pulleys. The flexor tendons were retracted to both sides and the volar plate was released, dividing it close to its insertion at the base of the middle phalanx, and then creating a flap by making an incision longitudinally between the accessory collateral ligament and the volar plate.

This exposure requires a free hand cut of the condyles of the proximal phalanx using a small oscillating saw with a freer elevator placed dorsal to the condyles to protect the extensor mechanism. It is important to make the cuts completely parallel to one another. We recommend inserting a 0.045 Kirschner wire into both the middle phalangeal and proximal phalangeal medullary canal to determine the central axis, which helps to facilitate the osteotomy of the middle phalanx, and correction of any coronal plane angulation that may exist. A 2.6-mm cannulated drill is then placed over the Kirschner wires and used to ream the canals of the middle and proximal phalanx, followed by a 2 mm bur that is used to expand the canals before the hand-held broaches are used. Once the canals have been broached, an oscillating saw is used to make a free hand chamfer cut of the proximal phalanx using the trial implant as a guide. The trials can then be placed and the range of motion and position of the digit evaluated (Figure 1). The final components are then selected and cemented in place. The volar plate is repaired using 3-0 nonabsorbable sutures passed through the volar, cortical, aspect of the middle phalanx. The collateral ligaments can be reinforced, if necessary, using the same sutures that were used for the volar plate to ensure that there is no instability with radial or ulnar stress which may often occur following correction of coronal plane deviation. A stress test of the finger with the metacarpophalangeal joint in flexion should produce full PIP joint extension, ensuring that the extensor mechanism is intact. A plaster dorsal blocking splint is used after surgery. Therapy is started 72 hours after surgery. In therapy, a small dorsal block splint is made that prevents the last 10° of PIP joint extension but allows for full PIP joint flexion (Table 1).

As part of our protocol, all of the included patients had a gentle manipulation under anesthesia in the office under fluoroscopic guidance with a digital block approximately 6

Figure 1. Implantation of the Stryker surface replacement proximal interphalangeal (PIP) joint components. (a) Demonstrates the approach to the joint with the flexor tendon and neurovascular bundles retracted away from the midline using ragnell retractors. (b) The proximal phalanx exposed by hyperextension of the PIP following dissection of the volar plate. (c) A free hand cut of the proximal phalanx is made using the trial prosthesis as a guide. (d) The intramedullary canal of the middle phalanx is prepared to accommodate the final prosthesis. (e) The middle phalanx is reamed and sized with a broach to allow for passage of the distal segment of the prosthesis. (f) Trial implants in place demonstrating appropriate fit of the prosthesis, and allowing for assessment of alignment and arc of motion.

to 8 weeks after surgery. This was included as part of the postoperative protocol due to our experience with plateaus in range of motion at this point postoperatively.

Results

Twenty-one patients met the inclusion criteria; demographics and preoperative measurements of the study population are included in Table 2. Preoperative arc of motion

Figure 2. Preoperative (a) anteroposterior and (b) oblique radiographs demonstrating bone on bone osteoarthritic changes. The anteroposterior view demonstrates ulnar coronal deviation of 10.7° .

measurements for the PIP and distal interphalangeal (DIP) joints measured $29^\circ (\pm 7^\circ)$ and $37^\circ (\pm 10^\circ)$, respectively. The average preoperative DASH score measured $43 (\pm 7)$, and preoperative satisfaction, using a numeric rating scale, measured $2 (\pm 1)$. The average coronal plane deviation, whether ulnar or radial, measured $11^\circ (\pm 8^\circ)$ (Figure 2).

The average length of follow-up was 34 months (± 9 months). Postoperative arc of motion for the PIP and DIP measured $87^\circ (\pm 12^\circ)$ and $36^\circ (\pm 10^\circ)$, respectively. Postoperative improvement in PIP arc of motion was found to be statistically significant with a P value of .0001. The average postoperative DASH score measured $14 (\pm 5)$ and the postoperative satisfaction measured $4 (\pm 1)$, both were found to be statistically significant with a P value of .0001. Postoperative coronal plane deviation, whether ulnar or radial, measured $2^\circ (\pm 2^\circ)$, which also was statistically significant with a P value of .0001 (Figure 3, Table 3).

Four patients required a tenolysis of the extensor tendons, and a dorsal capsulotomy of the PIP joint combined with removal of any dorsal osteophytes between 9 and 13 months after surgery. One patient suffered a superficial infection that was treated with oral antibiotics. There were no incidences of implant failure or need for revision surgery.

Discussion

The dorsal approach for SR PIP arthroplasty has been favored because it allows for excellent joint exposure and avoids dissection of the neurovascular bundles.^{7,22} The results of this series demonstrate that the joint can be exposed well enough to allow for an SR PIP implant to be appropriately positioned through a volar approach; however, the neurovascular bundles still require identification and protection. The dorsal approach minimizes risk to the volar plate and flexor tendons, therefore decreasing the risk of a postoperative swan neck deformity, bowstringing, and

Table 1. Postoperative Therapy Protocol.

Timing after surgery	Therapy activity	Precautions
3 days	Hand-based dorsal blocking orthosis fabricated. PIP joint flexed 10°, metacarpophalangeal joint 40° of flexion. Active assisted flexion is allowed to tolerance.	Assess the integrity of the volar plate and collateral ligaments. Adjust the amount of flexion of the orthosis if any laxity of the volar plate is detected. Buddy straps to adjacent digit if there is any laxity of the collateral ligament.
2 weeks	Cohesive wrap or compressive sleeve is used for continued edema management. Convert the hand-based orthosis to a finger-based orthosis. ROM into flexion is progressed as tolerated.	Slight flexion should be applied to the orthosis if the PIP is able to be extended or hyperextended easily. The sides of the orthosis should be extended if there is laxity of the collateral ligaments.
4 weeks	If flexion is stiff a dynamic orthosis can be fabricated. If a PIP flexion contracture is developing, the dorsal orthosis can be discontinued.	
6 to 8 weeks	Protective orthosis is usually discontinued. Static or dynamic ROM can be continued until ROM goals are met. Light grip strengthening with putty can be initiated at 8 weeks.	Continue buddy straps if the collateral ligaments were repaired during the operation.

Note. This protocol was used for each participant in this series. PIP = proximal interphalangeal; ROM = range of motion.

Table 2. Patient Demographics and Preoperative Measurements.

	Age	Gender	Hand dominance	Affected digit	PIP arc of motion	DIP arc of motion	DASH	Satisfaction	Sagittal deviation	Direction of sagittal deviation
	66	F	Y	SF	25°	45°	52	1	15°	U
	71	M	N	RF	30°	30°	45	2	20°	U
	56	F	Y	IF	25°	30°	38	1	10°	R
	69	F	Y	MF	35°	20°	43	2	15°	U
	81	M	N	SF	15°	40°	35	3	0°	U
	67	F	Y	MF	35°	35°	38	2	10°	R
	74	F	Y	IF	20°	55°	39	2	10°	U
	61	F	N	MF	15°	30°	53	1	25°	U
	65	M	Y	MF	25°	40°	44	1	15°	U
	74	F	Y	IF	35°	25°	35	2	20°	U
	67	M	N	RF	20°	30°	53	1	0°	
	73	F	Y	SF	30°	45°	38	2	0°	
	66	F	Y	MF	35°	30°	43	2	15°	R
	58	F	Y	IF	25°	30°	45	1	15°	U
	77	M	Y	SF	35°	40°	53	1	20°	U
	64	F	N	SF	30°	25°	41	1	0°	
	71	F	Y	SF	35°	55°	36	3	0°	
	59	F	Y	IF	35°	40°	36	3	0°	
	66	F	N	RF	30°	35°	51	1	10°	R
	82	F	Y	RF	35°	55°	48	1	15°	U
	70	M	Y	SF	30°	50°	35	1	15°	U
Average	68.43				28.57°	37.38°	42.90	1.62	10.95°	
SD	6.98				6.73°	10.44°	6.57	0.74	8°	

Note. Demographic information of the study population, including age, sex, whether the dominant hand was affected, and which digit was affected, as well as preoperative measurement of range of motion, DASH, satisfaction, and coronal deviation. PIP = proximal interphalangeal; DIP = distal interphalangeal; DASH = Disabilities of the Arm, Shoulder and Hand; SF = small finger; RF = ring finger; IF = index finger; MF = middle finger; U = ulnar; R = radial.

flexor tendon adhesions. However, swan neck deformity is a reported complication of the dorsal approach attributed to postoperative hyperextension and possibly due to extensor

tendon adhesions depending on the stability of the joint postoperatively.^{19,22} This series demonstrated that even through a volar approach the risk of both swan neck

Figure 3. Postoperative (a) anteroposterior and (b) lateral radiographs demonstrating a well-aligned Stryker surface replacement proximal interphalangeal (PIP) arthroplasty with no subsidence at 2 weeks post-op. The anteroposterior view demonstrates minimal coronal deviation in relation to the long axis of the digit. The lateral view demonstrates full extension of the PIP. (c) Demonstration of postoperative extension at 12 weeks post-op and (d) flexion.

deformity and flexor tendon adhesions is small, as there was no incidence of swan neck deformity with repair of the volar plate and use of a dorsal blocking orthosis postoperatively, and no flexor tendon adhesions were encountered which is likely due to early range of motion.

Four patients did require reoperation for extensor tendon tenolysis and removal of dorsal osteophytes, resulting in a 19% incidence of reoperation. This rate falls within the average incidence of reoperation reported, 5% to 58%, in similar studies describing patient outcomes of SR PIP arthroplasty through a dorsal approach.^{1,4,7,8,10,13,14-17,19,21} However, one retrospective series of 294 SR arthroplasties found that 64% of the joints requiring reoperation were originally performed through a dorsal Chamay tendon-reflecting approach.¹⁵ The length of time from the initial

operation to reoperation varied, occurring anywhere from 6 months to 3 years.^{1,4,7,8,10,13,14,16,17,19,21} Patients in this series maintained an improved arc of motion of 58° at final follow-up, compared with 30° to 64° reported in similar outcome studies.^{4,7,8,10,13,16,18-20} Although this series did not directly compare the results of a volar approach using SR implants versus silastic implants, the arc of motion of silicone implants using a volar approach and 3 years of follow-up has been reported to be 39°, and this series reported better results which poses the question whether SR implants, when used with a volar approach, are superior to silicone implants.

Postoperative DASH scores from studies using a dorsal approach with similar follow-up ranged from 22 to 40.^{7,8,17-19,21} The average postoperative DASH score for this study was

Table 3. Postoperative Measurements.

	PIP arc of motion	DIP arc of motion	DASH	Satisfaction	Sagittal deviation	Direction of sagittal deviation	Follow-up months
	85°	45°	13	4	0°		37
	65°	30°	15	3	5°	U	24
	95°	25°	12	4	0°		27
	100°	25°	10	5	0°		31
	80°	35°	21	4	0°		47
	100°	30°	8	5	0°		52
	90°	55°	13	4	0°		25
	70°	30°	23	3	5°	U	29
	85°	45°	22	2	5°	U	38
	100°	30°	7	5	0°		41
	85°	25°	16	5	0°		25
	100°	45°	6	5	0°		28
	95°	25°	11	4	0°		33
	80°	25°	15	5	5°	U	29
	95°	40°	13	4	0°		45
	85°	30°	20	3	5°	R	24
	80°	50°	18	4	5°	R	35
	95°	40°	9	5	0°		28
	65°	30°	21	3	5°	R	43
	100°	55°	6	5	0°		32
	70°	50°	14	4	5°	U	39
Average	86.67°	36.43°	13.95	4.10	1.90°		33.90
SD	11.87°	10.51°	5.34	0.89	2.49°		8.19

Note. Postoperative measurements of the study population, including PIP arc of motion, DIP arc of motion, DASH score, patient satisfaction score, degree of coronal deviation, direction of coronal deviation, and length of follow-up. PIP = proximal interphalangeal; DIP = distal interphalangeal; DASH = Disabilities of the Arm, Shoulder and Hand; U = ulnar; R = radial.

14. The exact reason why the DASH score was so much improved compared with other outcome studies would require further analysis, but supports the idea of improved patient outcomes when a volar approach is used and range of motion can be started early in the postoperative period.

There were no incidences of implant failure or subsidence in this study. SR arthroplasty through a volar approach has been reported to have an increased relative risk of implant failure.¹⁴ However, the relationship between a volar approach and implant failure may be due to the preferential use of this approach in patients with more severe deformity.¹⁴ Subsidence may occur in cemented SR implants, but this is often minimal and does not require reoperation. In uncemented SR implants, subsidence has been reported to be as high as 30%; however, minor subsidence, again, does not require reoperation.^{7,11} Silastic implants have an implant failure rate as high as 50%, compared with 16% with SR implants reported in a long-term outcome study by Murray.^{3,14}

This study is limited by the fact that this is a single-surgeon series using 1 manufacturer's implant. A study with multiple surgeons would allow variables in surgical skill, technique, operative time, manufacturer systems, and

postoperative protocols and provide a greater patient population to be analyzed. By controlling for these variables, more conclusive statements could be made about the volar approach and its utility in improving range of motion, and decreasing patient reported disability. Pinch strength and grip strength were recorded by numerous providers and could not be reliably included in the final analysis. The data presented in this study, however, strongly support the utility of this approach for SR arthroplasty.

Ethical Approval

This study was approved by our institutional review board.

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. Informed consent was obtained from all patients for being included in the study.

Statement of Informed Consent

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

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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