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Comparison of outcomes of three surgical approaches for proximal interphalangeal joint arthroplasty using a surface-replacing implant

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Abstract

The objective was to compare outcomes of the volar, Chamay and tendon splitting approaches for proximal interphalangeal joint arthroplasty using a surface-replacing implant (CapFlex-PIP). One-hundred prospectively documented patients with a 2-year follow-up were included. Range of proximal interphalangeal joint motion, the brief Michigan Hand Outcomes Questionnaire and complications were analysed. Between baseline and follow-up, mean proximal interphalangeal joint motion increased for the volar (53° to 54°), Chamay (38° to 53°) and tendon splitting (40° to 61°) approaches. The volar approach yielded the greatest flexion and the highest extension deficit. The mean brief Michigan Hand Outcomes Questionnaire scores at baseline and 2 years were 45 and 74 (volar), 45 and 66 (Chamay) and 41 and 75 (tendon splitting). Seven patients in the Chamay group and two in the volar group required a reoperation consisting of teno-/arthrolysis. The tendon splitting approach tended to result in the best outcomes that were associated with fewer complications compared with the volar and Chamay approaches.

Level of evidence: IV

Keywords

Dorsal approach, volar approach, proximal interphalangeal joint, arthroplasty, Michigan Hand Outcomes Questionnaire

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Introduction

Different surgical approaches for proximal interphalangeal (PIP) joint arthroplasty exist (Cheah and Yao, 2016; Yamamoto et al., 2017) and vary depending on the entry point used to expose the joint as well as on the handling of tendons (i.e. volar (Simmen, 1993), lateral (Bain et al., 2015; Green et al., 1991) or dorsal approach using either a tendon splitting (Swanson, 1973) or V-shaped tendon flap (Chamay, 1988)). Each technique has its advantages, potential pitfalls and possible complications. The ideal approach should be safe, technically easy and offer ample visualization of the joint. In addition, it should achieve a functional range of motion (ROM) with a low incidence of complications.

The volar approach for PIP joint surface replacement offers the advantage of maintaining the extensor tendon, which theoretically allows for more aggressive postoperative mobilization to potentially enhance the ROM. Yet collateral ligaments have to be released with risk of postoperative lateral instability, boutonniere deformity, adhesions of the flexor tendon and PIP joint contracture (Cheah and Yao, 2016; Shirakawa and Shirota, 2016; Yamamoto et al., 2017). As the dorsal approach requires

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extensor tendon release with subsequent repair, it is associated with a greater risk of extensor tendon adhesion leading to PIP joint motion restriction, possible instability in the coronal plane and ensuing swan-neck deformity. However, ROM, patient-reported outcomes and revision rates seem comparable among all approaches for surface PIP joint replacement (Yamamoto et al., 2017).

There is a lack of strong evidence advocating one specific surgical approach for PIP joint surface replacement over another. We investigated three different surgical approaches for PIP joint arthroplasty using a single surface-replacing implant (CapFlex-PIP) and compared the 2-year clinical, radiographic and patient-reported outcomes of the volar, dorsal Chamay and central tendon splitting approaches. Primary outcome parameter was active ROM with the hypothesis that the volar approach leads to better ROM, since tendons are preserved, and less scarring is expected.

Methods

Patients

All patients receiving a PIP joint arthroplasty with the CapFlex-PIP prosthesis are prospectively documented in a single-centre registry using a REDCap (Research Electronic Data Capture) (Harris et al., 2009) database. Patients are routinely assessed before surgery and 6 weeks, 3 months, 1 year, 2 years and 5 years after surgery. For this analysis, patients who had a PIP joint arthroplasty and either a clinical follow-up or a completed study questionnaire 2 years after surgery were included. Patients with a shorter/missing follow-up, arthroplasty of the thumb interphalangeal joint, more than one PIP arthroplasty implanted in one session or a revision surgery (i.e. implant removal) were excluded. For those patients excluded from the analysis due to revision surgery, the reasons and time points for revision as well as any subsequent procedures were described for the purpose of reporting on complication outcomes.

The data analysis was approved by the local ethics committee and conducted according to the 'REporting of studies Conducted using Observational Routinely-collected health Data' (RECORD) statement (Benchimol et al., 2015).

Surgical treatment and rehabilitation

The PIP joint arthroplasties were performed by one of six certified hand surgeons with levels of expertise ranging from less experienced specialists (level 2) to experts (level 5) according to the definition of Tang and Giddins (2016). They chose the surgical approach based on personal preference and expertise. The experts performed all approaches, while the less senior surgeons used only the one approach they were most familiar with. The CapFlex-PIP prosthesis, a modular metal-polyethylene surface replacement for the PIP (KLS Martin Group, Tuttlingen, Baden-Württemberg, Germany) was used (Schindele et al., 2015). For the volar approach (Simmen, 1993), a flexor tendon sleeve was prepared including the volar plate with check-rein ligaments. The dorsal Chamay approach (Chamay, 1988) included a distally based triangular extensor tendon flap. For the dorsal tendon splitting approach, the articular surface was exposed through a longitudinal split of the central slip (Swanson, 1973).

All patients followed the same standardized rehabilitation protocol involving 2 weeks of immobilization. Thereafter, patients started active mobilization exercises. Six weeks after surgery they were allowed to fully integrate their hand into normal daily activities.

Outcome measures

Outcomes were assessed preoperatively (i.e. baseline) and 2 years following surgery. At each time point, patients completed a set of questionnaires and underwent clinical assessment by the operating surgeon.

The primary outcome was total active ROM. Active flexion and extension of the PIP joint were measured with a goniometer and the total ROM was calculated. Flexion and extension deficits were analysed as secondary outcomes. Hand function was evaluated with the brief Michigan Hand Outcomes Questionnaire (MHQ), which shows good measurement properties for patients with various hand conditions (Knobloch et al., 2012; Waljee et al., 2011; Wehrli et al., 2016). The score ranges from 0 to 100, with higher scores indicating better hand function. Standard anteroposterior and lateral radiographs of the PIP joint were analysed by the surgeon for implant migration, radiolucent lines, cysts and deviations from the longitudinal joint axis.

Complications, defined as any untoward surgery-related event that potentially compromised the clinical result and/or required further intervention (International Organization for Standardization, 2011), were recorded throughout the 2-year postoperative period. Revisions, defined as implant removal, were evaluated and described based on the complete sample in the registry, regardless of the time at which these events were recorded during the postoperative follow-up period.

Statistics

Patients were allocated to one of three groups based on the surgical approach for PIP joint arthroplasty. Descriptive statistics for patient characteristics, radiological signs and complications were presented as frequencies and percentages. For age, ROM and the brief MHQ scores, means and standard deviations were calculated. Within-group changes between baseline and the 2-year follow-up were analysed with the Wilcoxon signed-rank test. Diagnostic plots (histograms, Q-Q plots, residual plots) were used to evaluate normal distribution of the data and the residuals of the regression models. These prerequisites for linear regression were met for total active ROM, PIP joint flexion and the brief MHQ. Differences at 2 years were tested with multiple linear regression models with adjustment for baseline MHQ score, age, sex and diagnosis followed by pairwise comparison. The significance level was set at $p < 0.05$.

Results

Between May 2010 and May 2018, 201 patients with 210 joints were treated. For this analysis, 116 patients met the inclusion criteria and 100 patients (86%) with 100 affected fingers were available for follow-up (Online Figure S1). Forty-two joints were approached volarly, 37 with a Chamay approach and 21 with a tendon splitting approach (Table 1).

Total ROM in the Chamay and tendon splitting group significantly increased from means of 38° and 40° at baseline to 53° and 61° at 2 years, respectively (Table 2). In contrast, patients in the volar group did not show an improvement in ROM ($p = 0.40$). There was no significant difference in the 2-year follow-up total ROM between the groups ($p = 0.47$). Furthermore, patients with the volar approach appeared to have larger extension deficits than patients who underwent either of the dorsal approaches (Table 2, Figure 1).

All patients had significantly improved hand function after surgery measured with the brief MHQ ($p < 0.01$). However, there were significantly higher 2-year scores for the volar and tendon splitting approaches versus the Chamay approach (Table 2).

Two cases of implant migration were documented, one associated with the volar approach and the other with the Chamay approach (Table 3). The most complications were documented for the Chamay group: eight patients (22%) required further treatment mainly for joint stiffness and swan-neck deformities (Table 4). Seven of these patients required teno- and/or arthrolysis. One complication of tendinitis for a patient in the tendon splitting group was successfully treated with a corticoid injection. Two patients in the volar approach group underwent teno- and arthrolysis due to stiffness.

Two volar approach implants had to be removed. The first was due to a rupture of the radial collateral ligament 1 year after the index procedure. Implant removal and arthrodesis were performed. The second was a patient with a stiff joint, who received a silicone implant 1.5 years after the primary surgery. Around 1.5 years postsurgery, an implant originally inserted via the tendon splitting approach was removed because of a low-grade local infection, and this complication did not require further treatment. Based on our entire cohort, the survival rate of the Cap-Flex-PIP prosthesis 2 years after surgery is 99% regardless of the surgical approach.

Discussion

Our study shows that all three surgical approaches led to a total active ROM of about 50°–60° 2 years after PIP surface-replacing arthroplasty. Our primary hypothesis that the volar approach would lead to a

Table 1. Baseline characteristics of 100 included patients stratified by surgical approaches.

Parameter	All	Volar	Chamay	Tendon splitting
Number of patients	100	42	37	21
Age at surgery in years [mean (SD)]	66 (11)	63 (12)	67 (9)	72 (8)
Sex, male [*n* (%)]	35 (35)	6 (14)	15 (41)	14 (67)
Diagnosis [*n* (%)][a]				
Primary osteoarthritis	85 (85)	33 (79)	34 (92)	18 (86)
Secondary osteoarthritis	6 (6)	4 (10)	1 (3)	1 (5)
Rheumatoid arthritis	1 (1)	1 (2)	0	0
Other	8 (8)	4 (10)	2 (5)	2 (10)

[a]Percentages differ from 100% due to rounding errors.

Table 2. Range of motion (ROM) and the brief Michigan Hand Outcomes Questionnaire (brief MHQ) at baseline and 2 years postsurgery stratified by surgical approaches.

	Volar[a]	Chamay[a]	Tendon splitting[a]	Volar vs. Chamay[b]	Volar vs. Tendon splitting[b]	Chamay vs. Tendon splitting[b]
Total ROM (°) [mean (SD)]						
Baseline	53 (19)	38 (17)	40 (16)			
2 years	54 (17)	53 (27)	61 (26)			
p-value	0.40	<**0.05**	<**0.01**	0.44	0.89	0.41
Flexion (°) [mean (SD)]						
Baseline	65 (13)	55 (18)	55 (13)			
2 years	76 (11)	60 (27)	69 (24)			
p-value	<**0.001**	0.21	<**0.05**	<**0.01**	0.10	0.49
Extension deficit (°) [mean (SD)]						
Baseline	13 (12)	17 (9)	14 (10)			
2 years	22 (15)	9 (15)	9 (13)			
p-value	<**0.01**	<**0.01**	0.15	<**0.01**	<**0.05**	0.84
Brief MHQ (0–100) [mean (SD)]						
Baseline	45 (14)	45 (14)	41 (14)			
2 years	74 (18)	66 (20)	75 (21)			
p-value	<**0.001**	<**0.01**	<**0.001**	<**0.01**	0.77	<**0.05**

[a]Wilcoxon signed-rank test for differences between baseline and the 2-year follow-up.
[b]Difference in 2-year scores (multiple linear regression with adjustment for baseline score, age, sex and diagnosis followed by pairwise comparison).
Significant *p* values are bold.

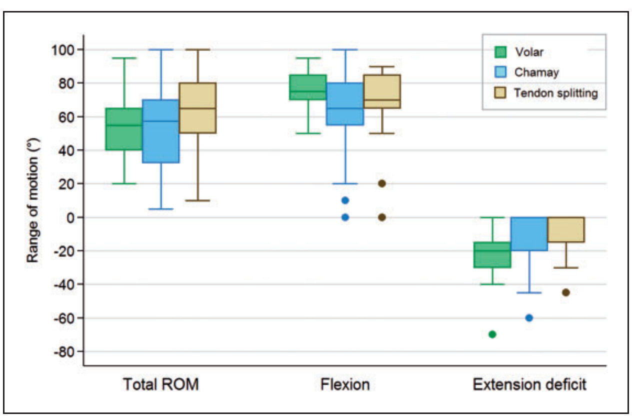

Figure 1. Total ROM, flexion and extension deficit at the 2-year follow-up stratified by surgical approach.

Table 3. Radiological signs of 89 patients with available 2-year radiographs per surgical approaches.

Radiological changes	Volar (*n* = 39)	Chamay (*n* = 30)	Tendon splitting (n = 20)
Patients with radiological sign [*n* (%)]	4 (10)	5 (17)[a]	1 (5)
Implant migration	1 (3)	1 (3)	0
Radiolucent lines	2 (5)	3 (10)	0
Cysts	1 (3)	1 (3)	0
Axis deviation >15°	0	2 (7)	1 (5)

[a]One patient showed three signs (i.e. implant migration, radiolucent lines, cysts).

better ROM is not supported by the study findings. Regarding functional outcomes, the Chamay approach yielded the worst results. In combination with the high prevalence of complications, we no longer recommend the Chamay technique. A relatively high number of complications also occurred after the volar approach. Therefore, we prefer the dorsal tendon-splitting approach because, in our hands, it is safe, has good outcomes and is easier to perform than the volar approach.

In our patient series, it seems that the volar approach provides adequate flexion but with limited extension due to volar scarring, which results from the preparation of the flexor tendon sleeve and volar plate release. In contrast, the Chamay approach is associated with more dorsal scarring, thus restricting flexion. A literature review investigating different approaches for various PIP joint implants revealed lower total ROM values for both volar (47°) and dorsal (51°) techniques compared with our study (Yamamoto and Chung, 2018; Yamamoto et al., 2017).

Table 4. Complications requiring further treatment and reoperations stratified by surgical approaches.[a] No patient experienced more than one event.

Complications and reoperations	Volar (n = 42)	Chamay (n = 37)	Tendon splitting (n = 21)
Complications (total) [n (%)]	3 (7)	8 (22)	1 (5)
Swan-neck deformity	0	3 (8)	0
Stiffness/ossification/tendon adhesion	1 (2)	4 (11)	0
Residual osteophytes	1 (2)	0	0
Residual pain	1 (2)	0	0
Tendovaginitis stenosans	0	0	1 (5)
Intraoperative unstable proximal component	0	1 (3)	0
Reoperations (tenolysis, arthrolysis)	2 (5)	7 (19)	0

[a]There were three implant removals before the 2-year follow-up and therefore not part of this analysis: two implants after the volar and one implant after the tendon splitting approach were removed due to a rupture of the radial collateral ligament, stiff joint and low-grade local infection, respectively.

Those findings might be due to the assessment of different implants. On the other hand, the extension deficit was similar to our results with 17° and 14° for the volar and dorsal approaches, respectively. A smaller study investigating the outcomes of the volar approach using different implant types reported a postoperative ROM of 56° (Duncan et al., 2018); which was similar to our volar cohort.

We observed a significant increase in the brief MHQ score for all groups regardless of the surgical approach. These results are in line with the final MHQ score, ranging from 61 to 87, from a number of smaller patient series examined after different PIP joint arthroplasties using a dorsal approach (Amirtharajah et al., 2011; Flannery et al., 2016; Ono et al., 2012; Rijnja et al., 2017).

In our patients, the worse hand function associated with the Chamay approach is in line with the observed complications of stiffness and tendon adhesions that required further surgical intervention. The V-shape Chamay flap exposes the extensor tendon surface to a greater extent than the tendon splitting approach and may contribute more scarring (Rizzo, 2014). In addition, the Chamay flap may provoke a tendon imbalance with swan-neck deformity. This can be explained again by the shape of the extensor tendon flap, which crosses the border of the central slip and lateral bands. In our series, swan-neck deformity was only documented in fingers treated with the Chamay approach (8%), although this incidence is higher than that recently reported for metal–polyethylene arthroplasties (5%) by Forster et al. (2018). We consider the three CapFlex prosthesis removals to be unrelated to the initial surgical approach because the three events were clearly associated with individual instances of joint instability, suspected metal intolerance and a low-grade infection.

One case of distal component migration observed 2 years after implantation using the Chamay approach did not require revision surgery because the patient reported minimal symptoms. Although radiolucent lines were detected around five implants, these events are unlikely related to the surgical approach. None of these implants had to be revised, but further observation is needed. Our 2-year revision rate of 1.5% is low compared with that for titanium implants reported to be up to 27%, mainly due to implant loosening (Daecke et al., 2012; Jennings and Livingstone, 2015; Luther et al., 2010).

Data collection in a routine clinical registry is a limiting factor in this study. Some data were missing and baseline parameters such as age, sex, diagnosis and ROM differed between the groups. In particular, the difference in baseline ROM might be the result of selection bias, since surgeons chose the approaches according to their preferences and experience. Due to this difference, we adjusted the analysis for baseline variables. A randomized controlled trial or a propensity score-matched study would be useful to eliminate these baseline differences. The prerequisites for linear regression (e.g. normally distributed residuals) are violated for the variable 'extension deficit'. Therefore, the results concerning this parameter should be interpreted with caution. In addition, we did not collect the data beyond postoperative 2 years for this report. The function and revision rate for the implant needs a longer follow-up period. Ideally a longer follow-up period is better, especially if overall outcomes are the main study theme. However, our follow-up for 2 years provided data for us to see differences in three surgical approaches.

Furthermore, observer bias might have occurred as ROM was assessed by each of the six participating surgeons. Although all six surgeons were experienced, variations in the surgical techniques can potentially yield different outcomes.

The learning curve associated with performing the CapFlex-PIP arthroplasty might have also influenced our results, as the first series of interventions was done using the Chamay approach. Due to the observed cases of stiffness and swan-neck deformity, we discontinued the Chamay approach in favour of the volar approach. Yet implantation of a complex prosthesis might be more difficult through a volar approach and therefore, we began using the dorsal tendon splitting approach, which is now our routine technique of choice for surface-replacing arthroplasties. Finally, our results are specific for patients who received a surface-replacing CapFlex-PIP prosthesis, and any extrapolation to patients with other implants should be made with caution.

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Supplemental material Supplemental material for this article is available online.

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