

Proximal interphalangeal surface replacement in patients with severe longitudinal joint axis deviation

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Abstract

We compared the 2 year outcomes after proximal interphalangeal joint surface replacement in 68 joints with severe ($>15^\circ$) preoperative longitudinal axis deviation and 50 joints without ($<5^\circ$) preoperative deviation. Patients in both groups had a mean preoperative brief Michigan Hand Outcomes Questionnaire score of 47 and had similar 2 year scores of 72 (95% CI 68–77) (severe deviation) and 70 (95% CI 65–76) (no deviation). Pain, proximal interphalangeal joint range of motion, grip strength and complications did not differ between the groups at 2 years. Ninety per cent of the severely deviated joints had a deviation of less than 15° at follow-up. The revision rates were 5.9% and 1.8% for deviated and non-deviated joints, respectively. We recommend a surface replacing implant to correct severe preoperative axis deviations of the proximal interphalangeal joint, but the risk of revision surgery needs to be considered.

Level of evidence: IV

Keywords

CapFlex-PIP prosthesis, finger middle joint, hand surgery, implant, osteoarthritis

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Introduction

Proximal interphalangeal (PIP) joint osteoarthritis of the fingers can cause longitudinal axis deviation, which is most often observed in the radial digits owing to ulnar-directed mechanical forces created during a pinch grip with the thumb. Both the index and middle fingers are functionally important for achieving a stable pinching action with the thumb, and radial instability can lead to diminished hand function (El-Gohary et al., 2019). The standard treatment for deviating osteoarthritis of the index and middle fingers is PIP joint arthrodesis (Pellegrini and Burton, 1990; Vitale et al., 2015). Silicone implants, often used for arthritic PIP joints in the ulnar digits, are known to lack the rigidity required for ensuring a stable grip in the radial rays (Ceruso et al., 2017). Studies have shown that the use of silicone implants in joints with preoperative axis deviation leads to more complications including

postoperative instability, implant breakage and recurrent axis deviation (Bales et al., 2014; Helder et al., 2021). In contrast, surface replacement implants offer better axial stability of the joint (Hensler et al., 2020). It has been shown that preoperative deviations from the longitudinal axis can be corrected with a surface replacing implant (Herren et al., 2022; Meuser et al., 2024; Reischenböck et al., 2021). However, it is not known whether patients with

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preoperative axis deviations have similar outcomes to those with straight fingers.

The aim of this study was to compare the 2 year outcomes after surface replacement in PIP joints with a preoperative axis deviation larger than 15° with those without any preoperative deviation. We hypothesized that the postoperative hand function, as measured by the brief Michigan Hand Outcomes Questionnaire (MHQ), would be similar in both groups.

Methods

Patients and setting

All patients who receive a PIP arthroplasty are prospectively documented in a single-centre registry using a REDCap (Research Electronic Data Capture) database (Harris et al., 2009). For this retrospective data analysis, we included patients who received one primary PIP surface replacing arthroplasty and attended a 2 year follow-up. Patients were divided into two groups depending on the extent of preoperative PIP joint axis deviation, which was classified as either severe deviation ($>15^\circ$) of the longitudinal finger axis or no deviation ($\leq 5^\circ$). Patients with moderate joint axis deviation ($5\text{--}15^\circ$) were excluded from this analysis as were patients with silicone implants at the PIP joints, those who had more than one surgically treated finger, and patients who declined the use of their data. Patients who had revision surgery during the 2 year study period were also excluded from the analysis of outcomes, but the reasons for revision were noted.

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

Intervention

The PIP arthroplasties were done by hand surgeons with varying levels of expertise ranging from non-specialists (level 1) to experts (level 5; 84% of the operations) as defined by Tang and Giddins (2016). The CapFlex-PIP prosthesis (KLS Martin, Tuttlingen, Germany) was implanted as described by Schindele et al. (2015) using anterior (Simmen, 1993), dorsal Chamay (1988) or tendon splitting approaches (Schindele et al., 2017; Swanson, 1973), based on the surgeons' discretion. In joints with an axis deviation over 15° and radial instability, we tend to tension the radial collateral ligament with a non-absorbable suture.

The postoperative standardized rehabilitation protocol involved immobilizing the PIP joint for 2 weeks in straight fingers and up to 4 weeks in fingers with severe axis deviation. Afterward, active mobilization started. Six weeks after operation and radiographic assessment, patients were allowed to fully integrate their hand into daily activities.

Outcome measures

Patients were assessed before surgery (baseline) and at the scheduled 2 year follow-up. At each time point, patients underwent a clinical assessment and completed a set of questionnaires.

The primary outcome was hand function measured with the brief MHQ. This tool shows good measurement properties for patients with various hand conditions (Knobloch et al., 2012; Waljee et al., 2011; Wehrli et al., 2016), and the final score ranges from 0 to 100, with higher scores indicating better hand function.

Patients rated their pain at rest and during activities on a numeric rating scale from 0 to 10, where 0 indicates no pain and 10 indicates maximum pain. Flexion and extension of the PIP joint were measured with a goniometer and the total range of motion was calculated. One measure of maximum grip strength was done in a standardized sitting position using a Jamar dynamometer (SAEHAN Corporation, Masan, South Korea).

Standard posteroanterior and lateral radiographs of the affected finger were taken and assessed for joint axis deviation. At follow-up, radiographs were also assessed for radiolucent lines around the implant.

Throughout the 2 year postoperative period, any complications were documented in REDCap by the surgeon and an independent researcher. Complications were defined as any untoward medical occurrence (International Organization for Standardization, 2020) related to the primary PIP surgery that required treatment. The outcomes in patients who were initially included in the registry but dropped out owing to revision surgery (i.e. subsequent surgery with implant modifications such as implant removal or exchange of one or more components) were not analysed, but the reasons for revisions were described and the revision rate was calculated.

Statistical analysis

The sample size was determined based on all available patients with severe and no PIP joint axis deviation documented in the registry. Histograms and a quantile-quantile plot showed that the data were

normally distributed. For descriptive statistics, means and 95% confidence intervals were calculated. Within-group changes of interval scaled data were analysed with a paired, two-tailed *t*-test and between-group differences with an unpaired, two-tailed *t*-test. Ordinal outcomes were compared using Fisher's exact test. Significance level was set at $p \leq 0.05$.

Results

Between May 2010 and March 2022, 85 patients with a severe preoperative axis deviation and 56 patients without axis deviation underwent a PIP surface replacement arthroplasty (Figure 1). Up to 2 years after surgery, five patients with severe preoperative deviations (5.9%) underwent revision surgery because of stiffness, stiffness with rupture of the radial collateral ligament, late low-grade infection, suspected metal intolerance and recurrent, unstable axis deviation.

Two joints were revised to an arthrodesis, two received a silicone implant and in one the CapFlex-PIP implant was removed without further procedure. One patient without preoperative axis deviation (1.8%) required revision surgery with a component change because of implant luxation. The revision rates did not differ significantly between the groups ($p = 0.402$).

At 2 years, 68 (80%) patients with preoperative axis deviation and 50 (89%) patients without deviation were available for follow-up (Figure 1; Table 1). Patients in both groups had a mean preoperative brief MHQ score of 47 and similar 2 year scores of 72 (severe deviation) and 70 (no preoperative deviation) (Table 2). In addition, pain, range of motion and grip strength did not differ between the groups. All clinical and patient-reported outcomes improved significantly between baseline and 2 years after the surgery (Table 2). Radiolucent lines around the implant were seen in nine (13%) patients with

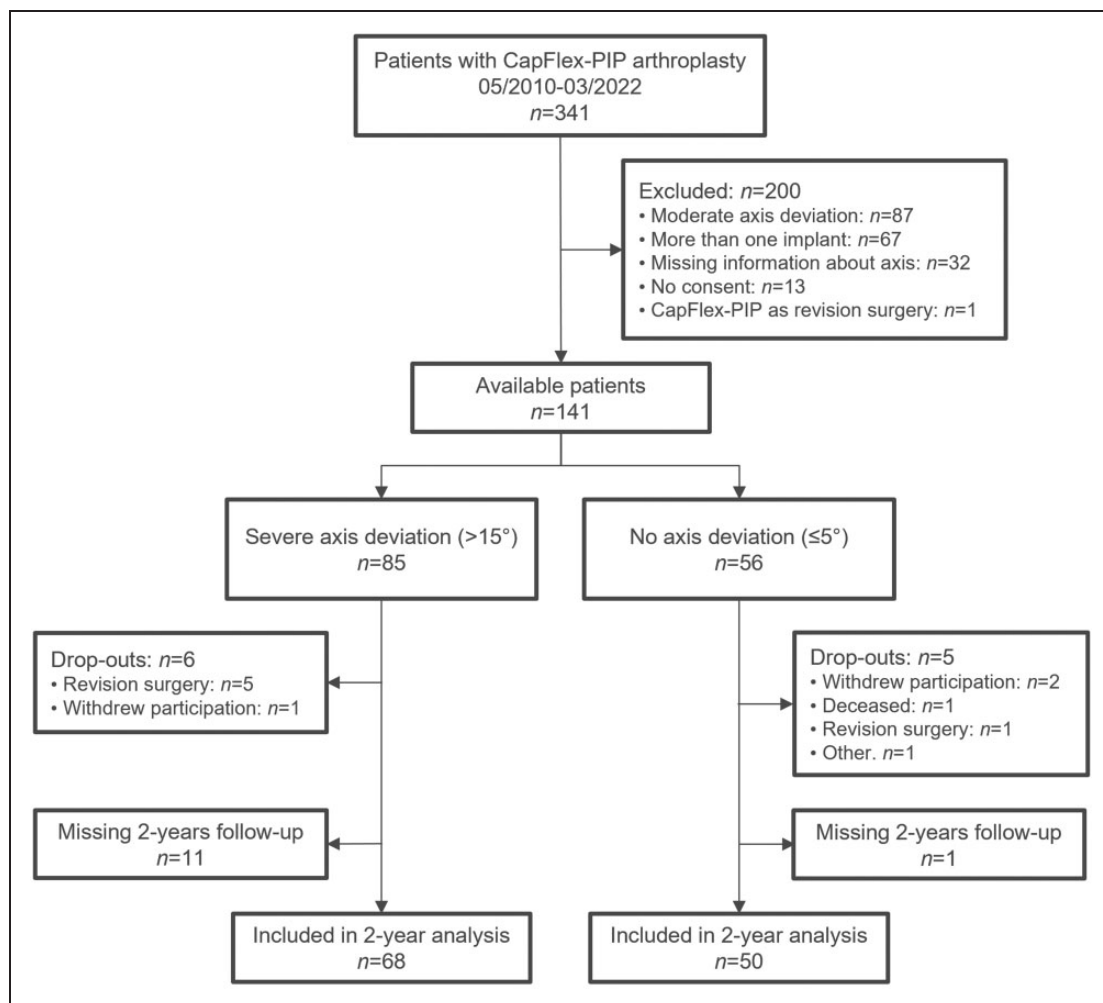


Figure 1. Patient selection diagram.

Table 1. Characteristics of patients with and without severe preoperative proximal interphalangeal axis deviation.

	Severe deviation ($>15^\circ$) ($n = 68$)	No deviation ($<5^\circ$) ($n = 50$)	<i>p</i> -Value
Age (years), mean (SD)	68 (12)	69 (12)	0.93
Female	41 (60)	39 (78)	≤ 0.05
Diagnosis*			0.483
Primary osteoarthritis	54 (79)	44 (88)	
Secondary osteoarthritis	9 (13)	4 (8)	
Inflammatory disease	5 (7)	2 (4)	
Affected finger			≤ 0.001
Index	38 (56)	15 (30)	
Middle	19 (28)	14 (28)	
Ring	4 (6)	18 (36)	
Small	7 (10)	3 (6)	

Data are presented as n (%) unless otherwise stated. Bold values indicate significant differences. SD, Standard deviation. *Percentages may differ from 100 owing to rounding errors.

Table 2. Patient-reported and clinical measures at baseline and 2 years for patients with and without severe preoperative proximal interphalangeal axis deviation.

	Baseline	2 Years	<i>p</i> -Value within-group
Brief MHQ (0–100)			
Severe deviation	47 (43–51)	72 (68–77)	≤ 0.001
No deviation	47 (42–51)	70 (65–76)	≤ 0.001
<i>p</i> -Value between-group	0.877	0.546	
Pain at rest (0–10)			
Severe deviation	5.0 (4.3–5.7)	1.1 (0.7–1.5)	≤ 0.001
No deviation	4.8 (3.8–5.8)	1.6 (1.0–2.2)	≤ 0.001
<i>p</i> -Value between-group	0.746	0.173	
Pain during activities (0–10)			
Severe deviation	6.5 (5.9–7.0)	1.9 (1.3–2.4)	≤ 0.001
No deviation	6.8 (6.1–7.5)	2.4 (1.8–3.1)	≤ 0.001
<i>p</i> -Value between-group	0.459	0.203	
Range of motion (deg)			
Severe deviation	41 (36–46)	57 (51–63)	≤ 0.001
No deviation	45 (39–51)	58 (51–65)	≤ 0.05
<i>p</i> -Value between-group	0.331	0.851	
Grip strength (kg)			
Severe deviation	21 (18–24)	26 (22–29)	≤ 0.001
No deviation	18 (15–21)	22 (18–25)	≤ 0.001
<i>p</i> -Value between-group	0.118	0.100	

Data are presented as mean (95% CI). Bold values indicate statistically significant differences. MHQ, Michigan Hand Outcomes Questionnaire.

severe deviation and six (12%) patients without preoperative deviation ($p = 1.0$). At the 2 year follow-up, only six patients still had a severe axis deviation and the majority of fingers could be corrected to a deviation of less than 15° (Table 3; Figure 2).

Complications occurred in five (7.4%) patients with severe deviation and three (6%) patients without preoperative deviation ($p = 1.0$) (Table 4).

Table 3. Axis deviation at 2 years.

Axis deviation at 2 years	Severe deviation at baseline	No deviation at baseline
$<5^\circ$	43 (73)	37 (86)
5– 15°	10 (17)	6 (14)
$>15^\circ$	6 (10)	

Data are presented as n (%). Some 2 year data are missing.

Discussion

The comparison of patients with and without preoperative deviation of the longitudinal joint axis showed similar outcomes at 2 years after PIP joint surface replacement. Therefore, our hypothesis that both



Figure 2. Standard posteroanterior radiographs showing an example of severe longitudinal finger axis deviation at baseline (left) that could be corrected to a straight finger 2 years after proximal interphalangeal joint arthroplasty (right).

groups would have similar hand function, as measured by the brief MHQ, could be confirmed.

Joint axis could be corrected with a surface-replacing implant in most of our cases. In contrast, this outcome was unattainable with silicone arthroplasty; Takigawa et al. (2004) showed that most patients with preoperative moderate or severe axis deviation who underwent Swanson silicone PIP joint arthroplasty experienced recurrent ulnar or radial axis deviation. In such cases, the deviating forces often lead to implant fracture requiring a reoperation (Takigawa et al., 2004). Consequently, PIP joint fusion in the radial digits has remained the treatment of choice for decades and provides good pain relief, high patient satisfaction and successful fusion in 92–96% of cases (Millrose et al., 2022; Pellegrini and Burton, 1990).

Despite the good outcomes of joint fusion, there is a trend towards motion-preserving arthroplasty to improve the function over that achieved with fusion (Herren, 2017). Even in the index finger, surface-replacing arthroplasty produces good results that are comparable with those achieved for other fingers (Herren et al., 2022). Therefore, we prefer a motion-preserving treatment rather than joint fusion. However, the type of implant needs to be carefully considered. Cadaver and biomechanical studies have shown that the lateral stability of surface-replacing arthroplasty is superior to that of silicone implants (Hensler et al., 2020; Minamikawa et al., 1994).

A recent retrospective analysis including 61 patients described similar clinical results to our study in that the median baseline axial deviation of 11° could be significantly corrected to 2° at 3 years after surface-replacing PIP arthroplasty (Meuser et al., 2024). The authors also described tensioning the elongated radial collateral ligament after

Table 4: Eight patients with postoperative complications after proximal interphalangeal arthroplasty that required treatment before the 2 year follow-up.

Preoperative axis deviation	Finger	Complication	Treatment	Months until treatment
Severe deviation	Middle	Boutonnière deformity	Reoperation: arthro-/tenolysis with reconstruction extensor tendons	7
Severe deviation	Middle	Suture granuloma	Reoperation: granuloma removal	23
Severe deviation	Index	Instability and axis deviation	Splint	1
Severe deviation	Middle	Stiffness	Hand therapy	1
Severe deviation	Index	Painful axis deviation	Splint; hand therapy	1
No deviation	Ring	Stiffness, swan neck deformity	Reoperation: arthro-/tenolysis	20
No deviation	Index	Painful osteophyte	Reoperation: osteophyte removal	9
No deviation	Middle	Trauma	Bandage; steroid infiltration	5

prosthesis implantation in joints with deviations over 15° to avoid recurrent deviation while adhering to the standard rehabilitation protocol (Meuser et al., 2024). We also believe that tensioning the radial collateral ligament helps to recentre the joint. In this context, we also recommend longer postoperative immobilization than is used for stable joints, as well as controlled mobilization and the use of dynamic splints.

Although there was no statistically significant difference in revision rates between the groups in our cohort, the 5.9% revision rate for deviated joints is somewhat higher than the 1.8% for those joints without any deviation. This higher revision rate is still comparable with rates that have been published for silicone arthroplasties (3.3–11%) (Helder et al., 2021; Yamamoto et al., 2017). However, the revisions rate for deviated joints is slightly higher than for CapFlex-PIP implants in general (3–4.4%) (Helder et al., 2021; Meuser et al., 2024; Reischenböck et al., 2021). In cases of persisting complaints after PIP joint arthroplasty, joint fusion remains an option for revision, with satisfactory functional and subjective results (Jones et al., 2011).

The reasons for reoperation in our cohort cannot be directly related to preoperative axis deviation. However, the main reason for postoperative stiffness, which required either additional hand therapy or surgery, could be indirectly related to axis deviation, as these joints were immobilized longer after surgery than straight fingers.

This study is limited by the registry design: the sample size in both groups differed owing to the availability of patients and there were some missing data at follow-up. In particular, in the severe axis deviation group, 11 patients missed the 2 year follow-up. In these patients, the implant is still *in situ* and missing data occurred for reasons unrelated to the PIP surgery, such as poor general health. Inclusion of those patients would produce data that differed somewhat from the current set, yet it is unlikely that the paper's overall conclusions would be altered. The operations were done by 10 different surgeons and different surgical approaches were used. Assessments were also carried out by different surgeons. Therefore, variations in the surgical techniques or assessments could have potentially affected the outcomes. Another limitation is the short follow-up of 2 years, which precludes conclusions about implant survival and long-term follow-up. In the group with preoperative deviation, a higher proportion of patients had the index finger affected or inflammatory disease. As both may be risk factors for revision surgery, this may have contributed to the higher revision rate. The study may be at risk of type 2 error (failing to detect a real difference)

because of the small sample size. However, as the confidence intervals overlap and the difference of two points in the brief MHQ score at 2 years is well below the reported minimal important change of 18 points in patients with PIP osteoarthritis (Marks et al., 2019), we consider the results to be robust.

Based on the results of this study, we recommend a surface replacing implant to correct severe preoperative axis deviations of the PIP joint, but the risk of revision surgery needs to be considered.

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Conflict of interest statement S. Schindele and D.B. Herren were involved in the development of the CapFlex-PIP prosthesis and receive royalties from KLS Martin Group, Tuttlingen, Germany. Miriam Marks has a consultancy agreement with KLS Martin Group, Tuttlingen, Germany.

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Informed consent declaration Written informed consent was obtained from all subjects before the study.

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