

Does distal interphalangeal joint arthrodesis affect proximal interphalangeal joint arthroplasty outcomes in the same finger?

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Abstract

The purpose of this study was to analyse the 1-year outcomes after combining a surface replacing proximal interphalangeal joint arthroplasty and a distal interphalangeal screw arthrodesis and to compare the combined surgery with proximal interphalangeal joint arthroplasty alone. To obtain two groups with similar baseline data from our prospective registry, propensity score matching was used to match 23 fingers with the combined operations with 115 fingers with proximal interphalangeal joint arthroplasty alone. One year after surgery, the mean ranges of motion were 60° (95% CI: 53° to 67°) in the combined group and 63° (95% CI: 60° to 66°) in the control group and did not differ significantly. Grip strength, the brief Michigan Hand Questionnaire and pain also did not differ between the groups 1 year after surgery. All the proximal interphalangeal implants in patients treated with a distal interphalangeal screw arthrodesis remained in situ. Combining proximal interphalangeal joint arthroplasty with distal interphalangeal arthrodesis leads to 1-year outcomes that are similar to those achieved by proximal interphalangeal joint replacement alone.

Level of evidence: III

Keywords

Finger joint, finger implant, joint replacement, osteoarthritis, distal interphalangeal joint fusion

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Introduction

For the treatment of proximal interphalangeal (PIP) joint osteoarthritis (OA), surface replacing arthroplasty offers patients favourable 5-year results with improvements in hand function and pain and an active range of motion (ROM) of 54° (Reischenböck et al., 2021). However, the same finger is often simultaneously affected by OA of the distal interphalangeal (DIP) joint, and this condition usually needs to be addressed. The surgical procedure of choice for most patients with DIP joint OA is joint fusion.

To treat both conditions, PIP arthroplasty and DIP arthrodesis (PIP + DIP) are usually done at the same operative session. Yet there is little evidence on the effect of such a combined procedure on functional outcome after PIP replacement. One argument

against combined surgery is that the swelling from increased surgical trauma may impede rehabilitation; this can negatively affect the postoperative mobility of the replaced PIP joint. In contrast, a recent short report concluded that a combined PIP

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surface replacing arthroplasty and DIP arthrodesis results in a significantly larger ROM of the PIP joint than in fingers without DIP arthrodesis (Hamano et al., 2021); however this study was flawed by the very small ($n \leq 6$) group sample sizes.

The purpose of our registry-based study was to analyse the outcomes after combined surface replacing PIP arthroplasty and DIP screw arthrodesis (PIP + DIP) in the same finger and to compare the results of the combined technique with PIP arthroplasty alone. Our primary hypothesis was that the active ROM of the PIP joint does not differ significantly between the groups 1 year after surgery.

Methods

Patients and setting

All patients with OA at the PIP joint who receive an arthroplasty are prospectively documented in our single-centre registry using a REDCap (Research Electronic Data Capture) database (Harris et al., 2009). For this analysis, the 1-year data of two patient groups were analysed: in the PIP + DIP

group, all patients who received a combined PIP surface replacing arthroplasty and DIP screw arthrodesis at the same finger during the same surgery were included (Figure 1); the control group included matched patients with PIP surface replacing arthroplasty alone. Exclusion criteria in both groups were: rheumatoid arthritis; silicone implants at the PIP joints; revision surgery at the PIP joint; and patients who declined the use of their data. 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).

Interventions

The PIP arthroplasties were done by four hand surgeons with varying levels of expertise ranging from non-specialists (Level 1) to experts (Level 5; 91% of the surgeries) 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 either a volar (Simmen, 1993),



Figure 1. Left: baseline posteroanterior (PA) and lateral radiographs of a patient with osteoarthritis of the proximal and distal interphalangeal joints of the middle finger. Right: after combined proximal interphalangeal joint arthroplasty and distal interphalangeal joint arthrodesis, the 1-year postoperative PA and lateral radiographs indicate good alignment of the implant without any signs of loosening.

a dorsal [Chamay, 1988] or a tendon splitting approach [Schindele et al., 2017; Swanson, 1973], based on the surgeons' discretion.

The DIP screw arthrodesis was carried out using either a 2.0 mm lag screw or a 2.2 mm cannulated headless screw, depending on the preference of the surgeon. All patients followed a standardized rehabilitation protocol that involved 2 weeks of immobilization of the PIP joint followed by active mobilization. In the case of concomitant DIP arthrodesis, the DIP joint was immobilized for 6 weeks in a splint, during which time active PIP joint mobilization was undertaken as scheduled after the first 2 weeks. By 6 weeks after operation and after radiographic assessment, patients were allowed to fully use the hand in daily activities.

Outcome measures

Patients were assessed before surgery (at baseline) and at the scheduled 1-year follow-up. At each time point, patients underwent a clinical assessment and completed a set of questionnaires.

The primary outcome was active ROM of the PIP joint. Flexion and extension of the PIP joint were measured with a goniometer by a study assistant or the treating surgeon and the total ROM was calculated.

One measure of maximum grip strength was done in a standardized sitting position using a Jamar dynamometer (SAEHAN Corporation, Masan, South Korea). Hand function was measured 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. Patients rated their pain at rest and during activities on a numeric rating scale (NRS) from 0 to 10, where 0 indicates no pain and 10 maximum pain.

Revisions undertaken in the first postoperative year were analysed. These events were defined as any subsequent surgery with implant modifications such as implant removal or the exchange of one or more components.

Statistical analysis

The sample size was determined by the number of available PIP+DIP patients. Histograms and quantile-quantile plots showed that data were normally distributed. For descriptive statistics, means and 95% confidence intervals (CIs) were calculated. Propensity score matching was used to match PIP + DIP patients with suitable PIP-only patients. Matching variables of

age, sex, affected finger, surgical approach, baseline ROM, baseline pain at rest and pain during daily activities were applied as independent variables in a logistic regression model to estimate the propensity scores. The method of nearest neighbour matching without replacement was used to match five control patients with PIP arthroplasty only with each PIP+DIP patient. 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 $p \leq 0.05$. Patients in the PIP + DIP group who could not be matched were excluded from the outcomes analysis, but their revision surgeries were noted.

Results

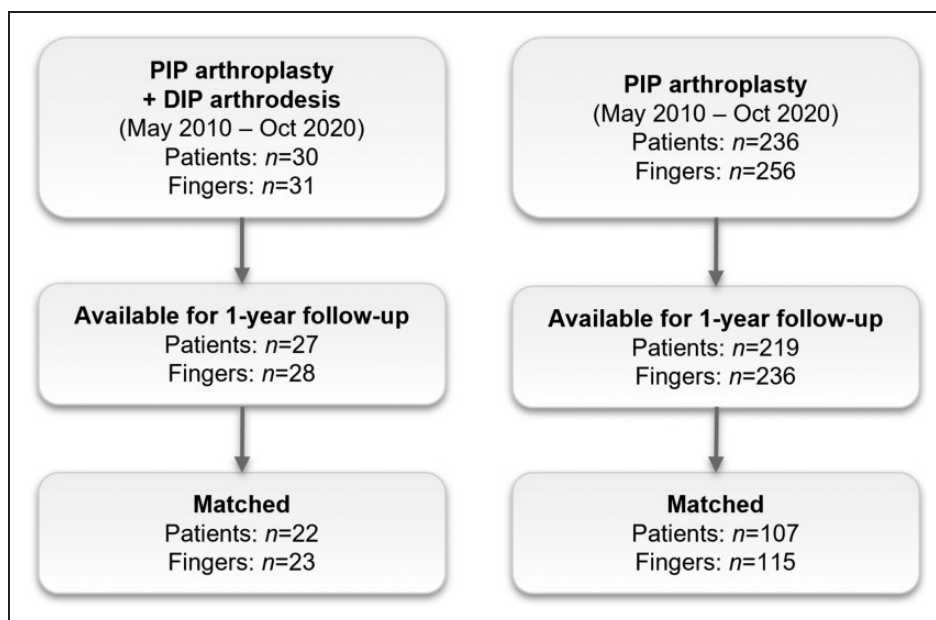
Between May 2010 and October 2020, there were 30 patients and 31 fingers in the PIP + DIP group. Twenty-two patients with 23 PIP + DIP could be matched to 115 isolated PIP arthroplasties (Figure 2). The mean age for both groups was 70 years. The PIP+DIP and control patients did not differ in the clinical or patient-reported baseline variables (Table 1). Before surgery, the mean PIP joint ROMs were 54° and 50° for the PIP + DIP and control groups, respectively. At 1 year, the mean PIP joint ROM in the PIP + DIP group increased to 60° ($p = 0.197$) and to 63° ($p \leq 0.001$) in the control group; there was no difference in this outcome between the groups ($p = 0.448$) (Table 2). All other 1-year clinical and patient-reported outcomes were also similar between the matched patients.

During the 1-year after operation, none of the surface replacing implants in the PIP+DIP group required revision. However, four DIP screws were removed because of irritation experienced at the fingertip at a mean of 9 months after operation.

Discussion

Our study revealed similar results between matched patients after simultaneous PIP arthroplasty and DIP arthrodesis versus isolated PIP joint replacement. Neither ROM nor the various clinical and patient-reported outcomes of grip strength, hand function and pain differed between the groups 1 year after surgery. Therefore, we recommend simultaneous surgical intervention in case of severe painful OA of the PIP and DIP joints of the same digit.

Based on our outcomes, it appears that the increased surgical trauma of DIP arthrodesis has no significant impact on the result of concomitant PIP arthroplasty. The mean ROM of 60° after the

**Figure 2.** Recruitment diagram.

PIP: proximal interphalangeal joint; DIP: distal interphalangeal joint.

Table 1. Baseline characteristics of the matched patient groups.

	PIP + DIP	PIP	<i>p</i> -value
Fingers [<i>n</i> (%)] ^a	23	115	0.093
Index	11 (48)	59 (51)	
Middle	10 (43)	36 (31)	
Ring	0	16 (14)	
Small	2 (9)	4 (3)	
Surgical approach [<i>n</i> (%)] ^a			1.000
Volar	1 (4)	9 (8)	
Dorsal: Chamay	1 (4)	4 (3)	
Dorsal: Tendon split	21 (91)	102 (89)	
Sex, female [<i>n</i> (%)]	17 (74)	80 (70)	0.805
Age [mean (95% CI)]	70 (66 to 74)	70 (68 to 72)	0.930
PIP range of motion (°) [mean (95% CI)]	54 (46 to 63)	50 (46 to 54)	0.383
Grip strength (kg) [mean (95% CI)]	17 (13 to 21)	18 (16 to 20)	0.620
Brief MHQ (0–100) ^b [mean (95% CI)]	42 (36 to 49)	43 (40 to 45)	0.982
Pain at rest (0–10) ^c [mean (95% CI)]	5.2 (4.0 to 6.3)	5.1 (4.6 to 5.6)	0.933
Pain during activities (0–10) ^c [mean (95% CI)]	7.2 (6.2 to 8.2)	7.1 (6.8 to 7.4)	0.821

PIP+DIP: proximal interphalangeal joint arthroplasty and distal interphalangeal joint screw arthrodesis; PIP: proximal interphalangeal joint arthroplasty only; CI: confidence interval.

^aPercentages may differ from 100 owing to rounding errors.

^bBrief Michigan Hand Outcomes Questionnaire score: 100 = best score.

^c0 = best score.

combined surgery is similar to that achieved (range 40° to 65°) for a variety of other PIP implants, such as the SR PIP system (Stryker GmbH, Selzach, Switzerland) and titanium-polyethylene (Small Bone Innovations, New York, NY, USA) or pyrocarbon surface replacement devices (Ascension Orthopaedics Inc., Austin, TX, USA) [Daecke et al., 2012; Jennings

and Livingstone, 2015; Murray et al., 2012; Yamamoto et al., 2017). Although the group difference in mobility was not significant, our PIP + DIP patients had a smaller gain in ROM between baseline and follow-up than the control group. This might be explained by several factors. Swelling after a surgical intervention at two joint levels in the same finger is greater than

Table 2. One-year postoperative outcomes for both treatment groups. Values are given as means and 95% confidence intervals.

	PIP+DIP	PIP	<i>p</i> -value
PIP range of motion (°)	60 [53 to 67]	63 (60 to 66)	0.448
Grip strength (kg)	19 [15 to 23]	22 [20 to 24]	0.155
Brief MHQ [0–100] ^a	67 [57 to 77]	72 [68 to 76]	0.234
Pain at rest [0–10] ^b	2.2 [0.9 to 3.6]	1.4 [1.1 to 1.8]	0.109
Pain during activities [0–10] ^b	3.1 [1.7 to 4.5]	2.0 [1.6 to 2.5]	0.059

PIP + DIP: proximal interphalangeal joint arthroplasty and distal interphalangeal joint screw arthrodesis; PIP: proximal interphalangeal joint arthroplasty only.

^aBrief Michigan Hand Outcomes Questionnaire score: 100 = best score.

^b0 = best score.

after surgery at only one site. Depending on the amount of swelling, the gliding resistance of the flexor tendon can also be increased. A review of in vitro and in vivo oedema studies and their implications on flexor tendon gliding found that an increase in subcutaneous tissue oedema can lead to a two- to three-fold greater gliding resistance of the flexor tendon (Wu and Tang, 2013), which causes a decrease in ROM of involved joints. Increased pain after surgery could also inhibit rehabilitation. However, an untreated osteoarthritic and painful DIP joint can have the same effect.

We were unable to confirm the preliminary findings of Hamano et al. (2021) who reported increased ROM in patients who underwent a combined procedure for treating PIP and DIP OA affecting the same finger. They argued that since the action of the deep flexor tendon is transferred to the PIP joint because the DIP joint is stiffened it adds to the strength of the superficial flexor tendon in flexing the PIP joint.

In the PIP+DIP group, the pain and brief MHQ scores at follow-up were a mean of 0.8 (pain at rest), 1.1 (pain during activity) and 5 (brief MHQ) points worse than in the control group. This may indicate that there were more symptoms in the PIP + DIP group at 1 year, but the differences were not statistically significant and the confidence intervals for both groups overlap. Furthermore, the differences do not exceed the minimal clinically important difference, which is between 1.2 and 2.0 for pain and 18 points for the brief MHQ (Marks et al., 2019; Randall et al., 2022; Stjernberg-Salmela et al., 2022).

Our study has several limitations. Although we studied a larger number of patients than has been reported previously, the number of PIP + DIP patients was still small. This leads to large confidence intervals in the data of the PIP + DIP group and limits the strength of the statistical results. Another limitation is the short follow-up of 1 year, which precludes conclusions about implant survival and long-term follow-up. Furthermore, the three

different surgical approaches used for the PIP joint arthroplasty are all known to influence ROM. Bodmer et al. (2020) concluded that the best functional outcome could be achieved with the dorsal tendon splitting approach; however, as the type of approach was one of our matching variables, its effect should be equal in both groups. Finally, the operations were carried out by surgeons with different levels of experience and the assessments were also carried out by different physicians; these varying factors can potentially influence the final clinical outcome.

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Author contributions All authors developed the protocol. XS, SS and DH treated the patients and were involved in data collection. XS and MM wrote the first draft of the manuscript. MM was involved in gaining ethical approval and analysed the data. All authors edited and approved the final version of the manuscript.

Declaration of conflicting interests The authors declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: 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.

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Ethical approval Ethical approval for this data analysis was obtained from the Cantonal Ethics Committee of Zurich, Switzerland (no. 2014-0546).

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

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