Archives of Orthopaedic and Trauma Surgery
https://doi.org/10.1007/s00402-019-03301-9

HANDSURGERY

Non-vascularized partial joint transfer for Finger Proximal Interphalangeal joint reconstruction: a series of 9 patients

Franck M. Leclère[1] · Luzian Haug[1] · Rahel Meier[1] · Carsten Surke[1] · Frank Unglaub[2] · Esther Vögelin[1]

Received: 28 July 2019

Abstract

Introduction Finger proximal interphalangeal joint (PIP) reconstruction after the destruction of parts of the joint remains challenging. Surgical techniques include implant arthroplasty, arthrodesis, free vascularized joint transfer, and non-vascularized bone and joint transfer. This study analyzes our experience after non-vascularized transfer in terms of range of motion, postoperative rehabilitation, and patient satisfaction.

Materials and methods Between 2009 and 2014, ten patients underwent non-vascularized partial joint transfer for PIP joint reconstruction. One of them was lost to follow-up. Included patients had osteochondral partial joint transplants of 25–50% of the toes ($n=4$) and the hand ($n=5$). Range of motion (ROM), grip-, and pinch-strength were measured at the last follow-up control and compared to the healthy side. Patients were asked to score the pain at rest/ on load on a visual scale (VAS: 0 = no pain; 10 = excruciating pain). Satisfaction self-assessment was evaluated by asking the patients to grade their postoperative result as excellent, very good, good or poor.

Results Mean follow-up period was 4.0 years (range 1.2–7.9 years). Mean PIP joint flexion was $93 \pm 26°$ at the last follow-up control. Mean grip- and pinch-strength of the operated side at the last control were, respectively, 43 ± 18 kg and 8 ± 5 kg, close to the healthy side values (45 ± 15 kg and 9 ± 4 kg). Mean pain at rest/on load measured on a visual scale was, respectively, 0.3 ± 1 and 1.8 ± 2. Eight patients (89%) rated their operation as excellent, and one as poor.

Conclusion In this study, non-vascularized partial joint transfer provides a mobile and stable PIP joint 4 years after reconstruction. The surgical technique presented herein is complex depending on additional injuries but results in great patient satisfaction.

Keywords Non-vascularized transfer · Joint transfer · Hemi-hamate arthroplasty · PIP reconstruction

Introduction

Finger proximal interphalangeal joint (PIP) reconstruction after destruction of parts of the joint, additional soft tissue, extensor tendon and ligament injuries, remains challenging [1–8]. Surgical techniques include implant arthroplasty [9–16], arthrodesis [17–20], non-vascularized bone and joint transfer [21–23], and free vascularized joint transfer [24, 25].

Arthrodesis is one of the surgical options but has the major drawback of immobile reconstruction [17]. Joint arthroplasty may be an alternative technique in selected cases but is no option in destroyed joints and simultaneous ligament injury and instability. Furthermore, these lesions are very common in younger patients and therefore arthroplasties are not the first choice. Arthroplasties are associated with significant complications including infection, implant loosening, joint contractures, and dislocation resulting in high revision rates [9, 10]. Reconstruction with free vascularized transfer of the PIP joint from second toe or banked finger becomes one of the major alternatives especially for young and active patients [24]. It has sufficient stability and range of motion (ROM); however, it remains subject to donor site morbidity, extensor lag, flap loss, and contraindication to microsurgery [24]. Non-vascularized partial joint transfer includes transfer of parts of the PIP joint from

✉ Esther Vögelin
esther.voegelin@insel.ch

[1] Department of Plastic und Hand Surgery, Bern University Hospital, Inselspital, University of Bern, Freiburgstrasse, 3010 Bern, Switzerland

[2] Department of Hand Surgery, Vulpius Klinik GmbH, Vulpiusstraße 29, 74906 Bad Rappenau, Deutschland

Published online: 05 November 2019

second toe including extensor tendon, homo- or heterotransfer of the DIP or PIP joint, or hemihamate arthroplasty [26, 27].

This study analyzes our experience after non-vascularized partial joint transfer for complex dorsal joint defects of the head of the proximal phalanx and or the base of the middle phalanx in terms of the range of motion, postoperative rehabilitation, and patient satisfaction.

Materials and methods

Study inclusion criteria of this retrospective study were patients with partial dorsal or palmar destruction of the PIP joint including soft tissue and or extensor mechanism and or collateral ligaments, aged 18 years or older, operated on between January 2009 and December 2014. The defects were reconstructed with non-vascularized partial joint transplants of the same patient from the foot or the hand. Exclusion criteria included lack of patient consent and patient lost to follow-up. 324 patients who sustained proximal interphalangeal joint trauma were treated during this study. Ten patients met the study inclusion criteria. One patient was lost to follow-up.

Surgical technique

A dorsal approach with the extension of the already injured skin was performed. The extent of injury of skin, extensor tendon and collateral ligament was assessed as well as the destruction of the dorsal and palmar part of the head of the proximal phalanx and/or the base of the middle phalanx. With a small saw the exposed subchondral bone was smoothened. Usually, there were defects of cartilage and subchondral bone between 25 and 50%. A template of the missing tissue was made on paper. In case of multiple digital injuries, we tried to determine whether the missing parts of tendon and cartilage with bone could be harvested from another finger or the same hand (carpometacarpal IV joint). In case of a single digital injury, the ipsi- or contralateral foot was always prepared depending on the wish of the patient. A longitudinal incision over the second or third metatarsophalangeal or interphalangeal joint was performed. In case of reconstruction of the central slip, the required amount of the base of proximal phalanx including extensor tendon was harvested according to template measurements. The extensor tendon was harvested long enough to be moved and weaved into the extensor tendon of the involved finger. In case of ligament reconstruction, another partial extensor tendon graft was harvested to augment or reconstruct the collateral ligament. According to the defect of the head of the proximal phalanx, a matched piece of osteochondral graft was harvested from the head of the metatarsophalangeal or interphalangeal joint. The parts of the harvested joints were then provisionally fixed with 0.8 mm k-wires used as a joystick, to place the graft in the best position. A second 0.8 mm K-wire was used to fix the graft. If possible one of the K-wires was removed and replaced by one 1.0 mm screw. The definitive fixation was performed with 2–3 1.0 mm unicortical screws to restore the head and the base of the PIP joint. Extensor tendon and or collateral ligaments were augmented with tendon strips or harvested tendon by weaving the tendon into the original tendon or ligament. Tendon fixation of osseous avulsion was performed with a 1.0 mm screw or inserted by a micro anchor (Mitek®, DePuy Synthes Sports Medicine, Raynham, MA, USA). The longitudinal split of the extensor tendon was sutured using a PDS 4-0. In case of a skin defect, local flaps or an intermetacarpal flap were harvested. The skin was usually closed by resorbable stitches.

Post-operative rehabilitation

Post-operative rehabilitation was started immediately after surgery. A dorsal splint was used to keep the joint in extension. In case of dorsal skin flap, a volar splint in extension was used. For exercising, a palmar flexion block in 40° allowed only a small amount of flexion to start with. Apart from the five exercises per day, the finger was held in extension. Active and passive mobilization of the joint was carried out depending on the edema. A splint holding the finger straight was used at night. Every week more flexion of the PIP joint was allowed, depending on the capability of active and passive extension. Dynamic extension splints were only used in due course when no active extension was possible or a trend toward a flexion deformity over 25° had developed. Four weeks after the procedure, the patients were assessed clinically and radiologically apart from the weekly visits in Handtherapy. The splints were removed if recovery was adequate or altered if there was PIP flexion deformity. No activities requiring forceful movement of the operated finger were allowed until the fourth month after surgery.

Intraoperative assessment and complications

Patient charts and follow-up examination were used to assess complications. Complications were divided into minor, which did not require surgery, and major. Regarding major complications, special attention was given to infection, local hematoma, required re-osteosynthesis, and arthrodesis.

Objective assessment

Active and passive motion of the PIP joints were measured with a goniometer at the last follow-up control and compared to the healthy side. The reconstructed PIP joints were manually evaluated for tenderness as well as coronal and sagittal

stability. Bilateral grip- and pinch-strength measurements were made with a dynamometer (Jamar, Boling Brook, IL) at the last follow-up control and compared to the healthy side.

Radiological assessment

Reconstructed PIP joints were imaged with plain radiographs in two planes (posteroanterior and lateral). The reconstructed PIP joints were evaluated for coronal and sagittal stability with dynamic X-ray.

Subjective assessment

Patients were questioned regarding residual pain, cold intolerance, and the sensation of instability in the affected hand and digit. Visual analog scale (VAS) ratings (0–10) was used to explicite pain on load and at rest, with higher numerical rating indicating poorer outcome (VAS: 0 = no pain; 10 = excruciating pain). Satisfaction self-assessment was evaluated by asking the patients to grade their postoperative result as excellent, very good, good or poor.

Measured parameters

The retrospective study includes nine patients. All the parameters measured are reported in Table 1. Data analysis was performed using the spss program (SPSS v. 22.0, SPSS Inc., Chicago, IL, USA). Data are presented as mean. Student's test (two samples) is used to calculate the p values, and $p < 0.05$ is considered to be statistically significant. Data are presented as mean ± standard deviation of the mean. $p < 0.05$ was considered to be statistically significant.

Table 1 Our series of nine patients with non-vascularized partial joint transfer for finger proximal interphalangeal joint reconstruction

N	Non-vascularized osteochondral joint graft	Reconstruction	Pain at rest/on load	ROM MCP PIP DIP	Grip-strength right/left (kg)	Pinch-strength right/left (kg)
1	PIP III left foot	30% head P1 DII left hand + extensor tendon reconstruction (PL)	3/6	80–0–0 110–10–0 70–0–0	36/32	8/4
2	Amputate P2 DIP D V right hand	50% head P1 D IV right hand, central slip, radial collateral ligament, radial artery and nerve	0/2	80–0–20 100–10–0 70–0–0	60/58	15/16
3	PIP II right foot	90% head P1 DII right hand + extensor tendon reconstruction, collateral ligament repair, 2 local flaps	0/5	100–0–30 90–50–0 40–0–0	44/53	9/10.5
4	MC IV left hand	30% base P2 DII left hand + extensor tendon reconstruction (PL), artery + nerve reconstruction, intermetacarpal flap	0/2–3	95–0–20 110–0–0 70–45–0	26/12	4/3
5	CMC IV left hand	25% head P1 DII left hand	0/1	90–0–0 100–0–0 60–10–0	52/48	
6	Hemihamate left hand	50% head P1 DV right hand + extensor tendon reconstruction (PL), collateral ligament repair, local flap	0/0	100–0–30 95–40–0 30–0–0	52/48	11/10
7	PIP III right foot + extensor tendon	50% base P2 DV right hand + extensor tendon reconstruction (tendino-osteocartilaginous graft)	0/0	106–0–10 25–0–0 65–35–0	56/56	12/10
8	MC II (amputate) right hand	30% head P1 DIV right hand	0/0	92–10–0 108–0–20 Arthrodesis	20/18	2/3
9	PIP II right foot	40% radial head and 30% ulnar head P1 D II right hand, extensor tendon reconstruction (PL), collateral ligament reconstruction, local flap	0/0	80–0–15 100–30–0 30–0–10	60/62	11/12

MTP metatarsophalangeal joint, *D* digit, *p1* proximal phalanx, *P2* middle phalanx, *DIP* distal interphalangeal joint, *PIP* proximal interphalangeal joint, *CMC* carpometacarpal joint

Results

Between 2009 and 2014, ten non-vascularized transfers were performed in our university hand center. One patient was excluded from the study. There were no intraoperative complications. Descriptions of each reconstruction and bone graft used are presented in Table 1.

Objective assessment

Mean follow-up period was 4.0 years (range 1.2–7.9 years). Patient outcomes are presented in Table 1: Mean PIP joint flexion was 93 ± 26° at the last follow-up control. Mean grip- and pinch-strength of the operated side at the last control were, respectively, 43 ± 18 kg and 8 ± 5 kg, close to the healthy side values [45 ± 15 kg ($p < 0.001°$) and 9 ± 4 kg ($p < 0.001°$)].

Radiological assessment

Plain radiographs in two planes showed consolidation in all but one case (Figs. 1, 2, 3). In three cases, osteolysis could be seen around the screws head.

Subjective assessment

None of the patients complained about cold intolerance or a sensation of instability in the affected hand and digit. Mean pain at rest/on load measured on a visual scale was, respectively, 0.3 ± 1 and 1.8 ± 2. Eight patients (89%) rated their operation as excellent, and one as poor.

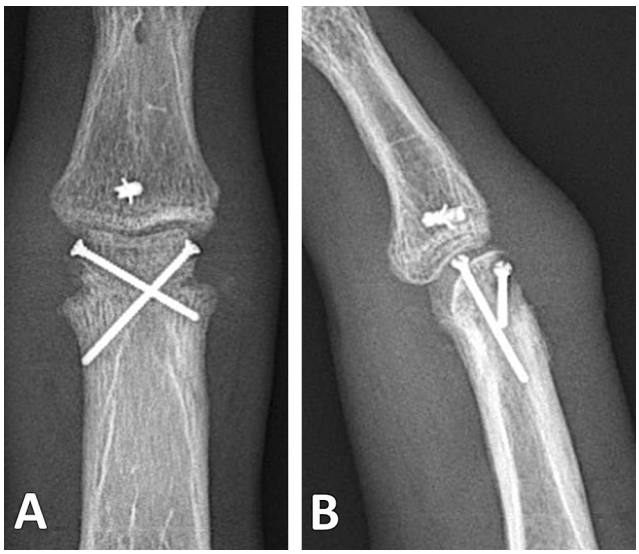

Fig. 1 Radiological results 3 years after reconstruction of 90% of the proximal phalanx head of the right index finger with the PIP joint of the second right toe (Table 1, Patient 3): anteroposterior view (**a**) and lateral view (**b**) of PIP joint of the third finger of the right hand

Fig. 2 Radiological results 6 years after reconstruction of 30% of the proximal phalanx head of the left index finger with the PIP joint of the third left toe (Table 1, Patient 1): anteroposterior view (**a**) and lateral view (**b**) of PIP joint of the third finger of the right hand

Discussion

In this study, nine non-vascularized transfers were performed for finger proximal interphalangeal joint reconstruction. No major complications were reported. Mean PIP joint flexion was 93° at the last follow-up control. Mean grip- and pinch-strength of the operated side at the last control were, respectively, 43 kg and 8 kg, close to the healthy side values. Mean VAS at rest/on load were, respectively, 0.3 and 1.8. Eight patients (89%) rated their operation as excellent, and one as poor.

The goal of the PIP reconstruction is to provide a painless, stable and useful joint that allows powerful pinch/grasp and range of movement [2, 5]. Arthrodesis is one of the surgical options but has the major drawback of immobile reconstruction [17]. Joint arthroplasty is not an alternative technique during primary reconstruction in these cases, because the patients are usually young, and the joints are unstable due to additional extensor tendon and collateral ligament injuries. Reconstruction with free vascularized transfer of the PIP joint from the second toe or banked finger has become one of the major alternatives especially for young and active patients: A recent review performed by Chen et al. [14] showed that an overall ROM after vascularised toe-to-finger PIP joint transfer ranged from 31.8° to 69.2°. Transferred toe PIP joints can reach the maximal flexion limits of their native position, with

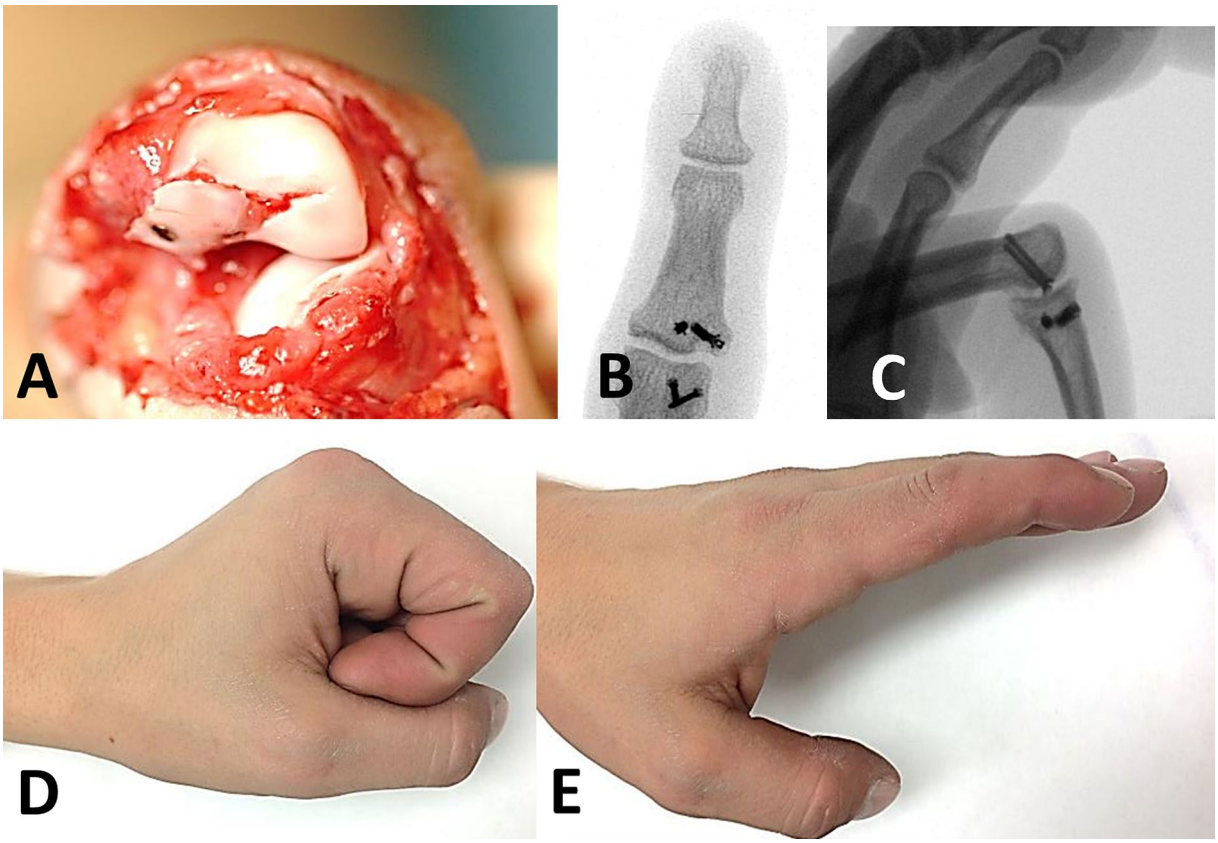

Fig. 3 Outcome 6 years after reconstruction of 25% of the proximal phalanx head of the left index finger with MC joint of the fourth left finger (Table 1, Patient 5): intraoperative findings (**a**): the definitive fixation of the parts of the harvested joint was performed with 2×1.0 mm screws; anteroposterior view (**b**) and lateral view (**c**); active flexion of 100° (**d**) and 0° extension of PIP joint (**e**) (10° extension lag at DIP joint) at the 6-year control

an average of 69.2. Reconstruction with free vascularized transfer has sufficient stability and range of motion (ROM), however it remains subject to donor site morbidity, extensor lag, flap loss, and contraindication to microsurgery. In our series only few patients had a defect of the proximal phalanx head of more than 50%. Therefore, these defects would not justify a vascular whole joint transplant. Non-vascularized partial joint transfer includes transfer of parts of the PIP joint from second toe including extensor tendon, homo- or heterotransfer of the DIP or PIP joint, or hemihamate arthroplasty [11, 12]. Recently Calfee et al. [15] underlined the paucity of literature dealing with late outcomes after PIP joint reconstruction with non-vascularized transfer. In our series, compared to a few other reports [21, 27], we mostly report defects of the head of the proximal phalanx. After a mean follow-up of 4 years, we could identify four advantages of this surgical technique: (i) First, the method uses off-the-shelf reconstruction. In other words, if a non-vascularized joint transfer fails or needs to be revised, another more sophisticated surgical technique is always possible. (ii) Moreover, this technique allowed a better bone stock and a stable joint. In other words, in case of arthrosis, arthroplasty may be performed later on. (iii) Additionally, compared to other surgical techniques, our postoperative protocol allowed early mobilization. As a consequence, we observed not only unexpected joint salvage in some instances but also a satisfactory restoration of function, even in combination of extensor tendon reconstruction and/or collateral ligament repair. (iv) Finally, the surgical technique presented herein has the advantage of great patient satisfaction.

Despite the promising outcomes, our series presents both methodological and technical limits: (i) First, the diversity of surgeons and bone defects makes the series non- homogeneous, although this is offset by the standardization of the technique of the same surgical school, as confirmed by the overall good results in terms of range of motion. (ii) Moreover, with the small number of cases in this series, the development of post-traumatic arthritis in the reconstructed joint remains unclear. (iii) Finally, the absence of a control group did not allow us to compare the outcomes of our technique with other approaches.

Conclusion

In this study, non-vascularized partial joint transfer provides a mobile and stable PIP joint 4 years after reconstruction. The surgical technique presented herein is complex depending on the additional injuries but results in great patient satisfaction.

Funding There is no funding source.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with animals performed by any of the authors.

References

1. Khan W, Agarwal M, Muir L (2004) Management of intra-articular fractures of the proximal interphalangeal joint by internal fixation and bone grafting. Arch Orthop Trauma Surg 124:688–691
2. Yamagami N, Yamamoto S, Tsujimoto Y, Uchio Y (2013) Osteochondral autograft transplantation for malunited intra-articular fracture of the proximal interphalangeal joint: a case report. Arch Orthop Trauma Surg 133:135–139
3. Tekkis PP, Kessaris N, Gavalas M, Mani GV (2001) The role of mini-fragment screw fixation in volar dislocations of the proximal interphalangeal joint. Arch Orthop Trauma Surg 121:121–122
4. Caggiano NM, Harper CM, Rozental TD (2018) Management of proximal interphalangeal joint fracture dislocations. Hand Clin 34:149–165
5. Unglaub F, Langer MF, Hahn P, Müller LP, Ahrens C, Spies CK (2016) Fractures of the proximal interphalangeal joint: Diagnostic and operative therapy options. Unfallchirurg 119:133–143
6. Strohl AB, Teplitsky SL, Gandhi SD, Kane PM, Osterman AL (2017) Dorsal versus lateral plate fixation of finger proximal phalangeal fractures: a retrospective study. Arch Orthop Trauma Surg 137:567–572
7. Park JH, Park GW, Choi IC, Kwon YW, Park JW (2019) Dorsal transosseous reduction and locking plate fixation for articular depressed middle phalangeal base fracture. Arch Orthop Trauma Surg 139:141–145
8. Quadlbauer S, Pezzei C, Hintringer W, Hausner T, Leixnering M (2019) Percutaneous treatment of unstable fractures of the base of the middle phalanx : Technique according to Hintringer and Ender. Oper Orthop Traumatol Epub Jul 25.
9. Wagner ER, Luo TD, Houdek MT, Kor DJ, Moran SL, Rizzo M (2015) Revision proximal interphalangeal arthroplasty: an outcome analysis of 75 consecutive cases. J Hand Surg [Am] 40:1949–1955
10. Moran SL, Rizzo M (2018) Medium-term outcomes with pyrocarbon proximal interphalangeal arthroplasty: a study of 170 consecutive arthroplasties. J Hand Surg [Am] 43:797–805
11. Squitieri L, Chung KC (2008) A systematic review of outcomes and complications of vascularized toe joint transfer, silicone arthroplasty, and PyroCarbon arthroplasty for posttraumatic joint reconstruction of the finger. Plast Reconstr Surg 121:1697
12. Bravo CJ, Rizzo M, Hormel KB (2007) Pyrolytic carbon proximal interphalangeal joint arthroplasty: results with minimum two-year follow-up evaluation. J Hand Surg [Am] 32:1–5
13. Schindele SF, Altwegg A, Hensler S (2017) Surface replacement of proximal interphalangeal joints using CapFlex-PIP. Oper Orthop Traumatol 29:86–96
14. Rijnja JP, Kouwenberg PPGM, Ray S, Walbeehm ET (2017) Robert Mathys Finger prosthesis of the proximal interphalangeal joint: a retrospective case series of 19 joints in 17 patients. Arch Orthop Trauma Surg 137:1155–1160
15. Hohendorff B, Zhang W, Burkhart KJ, Müller LP, Ries C (2015) Insertion of the Ascension PyroCarbon PIP total joint in 152 human cadaver fingers: analysis of implant positions and malpositions. Arch Orthop Trauma Surg 135:283–290
16. Schindele SF, Sprecher CM, Milz S, Hensler S (2016) Osteointegration of a modular metal-polyethylene surface gliding finger implant: a case report. Arch Orthop Trauma Surg 136:1331–1335
17. Newman EA, Orbay MC, Nunez FA Jr, Nunez F Sr (2018) Minimally invasive proximal interphalangeal joint arthrodesis using headless screw: surgical technique. Tech Hand Up Extrem Surg 22:39–42
18. Hohendorff B, Franke J, Spies CK, Müller LP, Ries C (2017) Arthrodesis of the proximal interphalangeal joint of fingers with tension band wire. Oper Orthop Traumatol 29:385–394
19. Millrose M, Zach A, Kim S, Güthoff C, Eisenschenk A, Vonderlind HC (2019) Biomechanical comparison of the proximal interphalangeal joint arthrodesis using a compression wire. Arch Orthop Trauma Surg 139:577–581
20. Spies CK, Hohendorff B, Löw S, Müller LP, Oppermann J, Hahn P, Unglaub F (2017) Arthrodesis of the distal interphalangeal joint using the headless compression screw. Oper Orthop Traumatol 29:374–384
21. Capo JT, Hastings H Jr, Choung E, Kinchelow T, Rossy W, Steinberg B (2008) Hemicondylar hamate replacement arthroplasty for proximal interphalangeal joint fracture dislocations: an assessment of graft suitability. J Hand Surg 33A:733–739
22. Tyser AR, Tsai MA, Parks BG, Means KR Jr (2015) Biomechanical characteristics of hemi-hamate reconstruction versus volar plate arthroplasty in the treatment of dorsal fracture dislocations of the proximal interphalangeal joint. J Hand Surg [Am] 40:329–332
23. Pillukat T, Kalb K, Fuhrmann R, Windolf J, van Schoonhoven J (2018) Reconstruction of the middle phalangeal base of the finger using an osteocartilaginous autograft from the hamate. Oper Orthop Traumatol Epub Sep 14.
24. Kuzu İM, Kayan RB, Öztürk K, Güneren E (2018) Functional improvement with free vascularized toe-to-hand proximal interphalangeal (PIP) joint transfer. Plast Reconstr Surg Glob Open 6:e1775
25. Chen HY, Lin YT, Lo S, Hsu CC, Lin CH, Wei FC (2014) Vascularised toe proximal interphalangeal joint transfer in posttraumatic finger joint reconstruction: the effect of skin paddle design on extensor lag. J Plast Reconstr Aesthet Surg 67:56–62
26. Calfee RP, Kiefhaber TR, Sommerkamp TG, Stern PJ (2009) Hemi-hamate arthroplasty provides functional reconstruction of acute and chronic proximal interphalangeal fracture-dislocations. J Hand Surg Am 34:1232–1241
27. Williams RM, Kiefhaber TR, Sommerkamp TG, Stern PJ (2003) Treatment of unstable dorsal proximal interphalangeal fracture/dislocations using a hemi-hamate autograft. J Hand Surg 28A:856–865