



# Long-term preservation of metacarpophalangeal joint function in traumatic defects by metatarsophalangeal osteochondral transplantation

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## Abstract

**Introduction** The integrity of the metacarpophalangeal (MCP) joints is essential for finger and hand function. Preservation of range-of-motion is one of the aims in reconstruction of complex injuries to these joints. Osteochondral transplants have shown to be reliable in reconstruction of various joint defects. This series presents three patients with traumatic injuries to four MCP joints, which were reconstructed by seven avascular osteochondral transplants of metatarsophalangeal (MTP) joints. The joints were examined for radiographic signs of resorption or joint space narrowing, and if this would affect the joints' function in the long term.

**Methods** In three patients (40, 45 and 48 years) with complex injuries to their MCP joints (one milling, two saw injuries), four joints were reconstructed by three metatarsal head and four osteochondral transplants of the base of the proximal toe phalanges. Beside the joint itself, various soft tissue defects were reconstructed in each patient. The patients were clinically and radiographically examined after 9, 6, respectively, 7 years.

**Results** All patients were satisfied with the result without any pain in the MCP joints. Range-of-motion in the four affected joints rated 25, 60, 75, and 80°, DASH scores rated 13, 29, and 17, respectively. None of the patients complained of problems at their feet. Radiographic examination revealed moderate joint space narrowing in one of the four joints. In another patient, localized osteolysis was found around the screws' heads, so that the screws were removed 7 years post-op.

**Conclusions** Osteochondral transplants for reconstruction of MCP defects are able to preserve function in severely injured joints even in the long term. Joint space narrowing may occur, which is not accompanied by pain, however. Since localized osteolysis can cause screw head prominence, mid-term radiographic follow-up is necessary to prevent damage to the joint. In the long term, remaining bone stock may be adequate for total joint replacement.

**Keywords** Complex hand injury · Finger joint · Metacarpophalangeal joint · Non-vascularized graft · Osteochondral transplant · Range-of-motion

## Introduction

The interaction of the three digital joints is essential for finger movement. Thereby, with respect to finger function, the metacarpophalangeal (MCP) joint is more important than the two interphalangeal joints. And, the proximal interphalangeal (PIP) joint is in turn more important than the distal interphalangeal (DIP) joint. Littler found that within the range of a finger, the proportion of points reached by the finger-tip accounts for 77% with an unlimited range-of-motion of the MCP joint, whereas an intact range-of-motion of the PIP or the DIP joint accounts for 20% and 3%, respectively. That means that the loss of range-of-motion in the MP joint has a higher impact on finger function than the loss of

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range-of-motion in the PIP or even DIP joint [1]. Therefore, in complex injuries of the PIP or DIP joints, arthrodesis would rather be considered with the main goal to stabilize the joint. In complex injuries of the MCP joints, beside stabilization, it is in contrast essential to preserve movement of the joint.

For reconstruction of entire MCP joints, vascularized grafts of the metatarsophalangeal (MTP) joints may be used [2], whereas partial osteochondral defects of the metacarpal head, the base of the proximal phalanx or the combination of both can be reconstructed by both, vascularized or non-vascularized grafts. Non-vascularized whole joints are known to be prone to resorption with an expected loss of function [3]. Non-vascularized osteochondral grafts, however, are widely and successfully used for reconstruction of defects at different sites at the upper limb. Examples, therefore, are the hemihamate autograft for the reconstruction of the base of the middle phalanx at the PIP joint [4], grafts for reconstruction of defects of the capitellum of the humerus [5] or the radial head [6]. The purpose of this study was to examine if deterioration of joint function occurred in the long term in the patients in which traumatic defects of their MCP joints were treated by non-vascularized osteochondral grafts of the MTP joint. The hypothesis was that relevant resorption with loss of MCP joint movement does not occur.

## Materials and methods

In this retrospective study, all three patients were included in which non-vascularized osteochondral grafts of the MTP

joints were used to reconstruct defects of the MCP joint. The study protocol was reviewed and accepted by the appropriate ethics committee of the University of Würzburg, Germany. In the time period from September 2009 to January 2015, three patients were treated for complex injuries of one or two MCP joints. In these three patients, four MCP joints were treated with three osteochondral grafts of the metatarsal head for defects of the metacarpal head and with four osteochondral grafts of the base of the toes' proximal phalanx for defects of the base of the proximal phalanx of the finger. The injury patterns are described in the following. Table 1 gives a survey over the affected structures that needed reconstruction. Results are presented in a descriptive manner, and are summarized in Table 2.

Patient 1 (Figs. 1, 4a): this 45-year-old carpenter presented with a milling machine injury of the second and third ray of his dominant right hand. At the moment of injury, the patient had his fist closed, so that the machine created a defect at the dorsum of the hand with loss of skin, extensor tendon, two thirds of the second metacarpal head and half of the third metacarpal head, respectively, two thirds of the second and half of the third proximal phalanx base, leaving intact palmar soft tissue with flexor tendons, finger nerves and arteries as well as the palmar cortex of the proximal phalanx of both rays.

The two affected MCP joints were reconstructed by corresponding grafts of both third MTP joints. Thereby, the whole joints were hoisted with suturing of the deep plantar intermetatarsal ligaments. The grafts were trimmed by an oscillating saw and then screwed to the remaining palmar parts

**Table 1** Overview of injury mechanisms, affected joints and used transplants for reconstruction

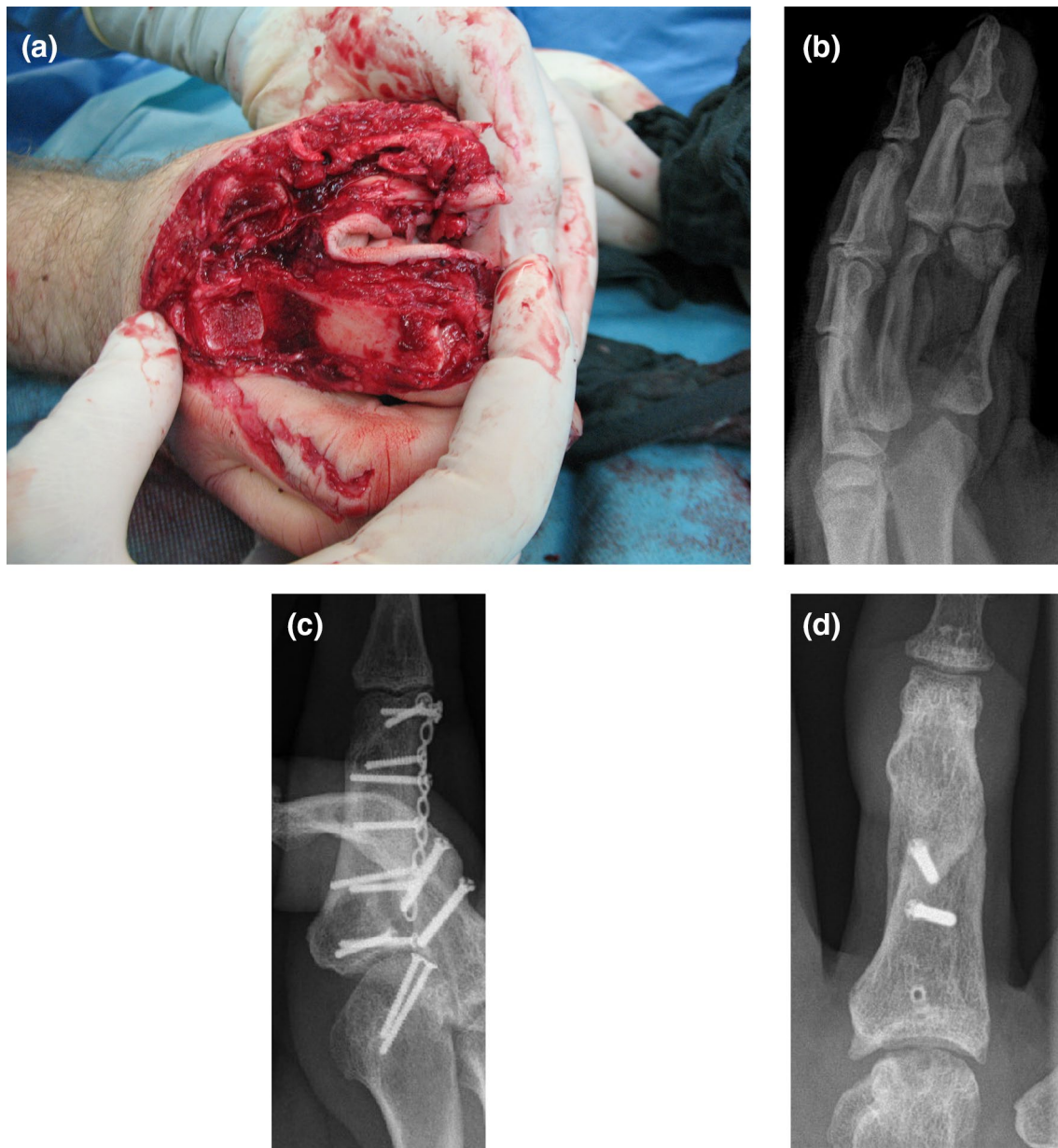
Patient	Age	Injury mechanism	Affected ray	Defect at metacarpal head	Defect at proximal phalanx base	Graft origin
1	45	Milling machine	Right index finger	2/3 dorsal	1/2 dorsal	Whole 3rd MTP joint
			Right middle finger	1/2 dorsal	2/3 dorsal	Whole 3rd MTP joint
2	41	Ribbon saw	Right index finger	–	1/2 dorsal	2nd toe proximal phalanx base
3	49	Circular saw	Right index finger	2/3 ulnar	2/3 ulnar	Whole 3rd MTP joint

**Table 2** Clinicoradiographic long-term results at the reconstructed metacarpophalangeal joint

Patient	Affected ray	Follow-up (years)	Range-of-motion (extension and flexion)	Joint space	Bone stock	Consequence
1	Right index finger	9	0-15-40°	preserved	preserved	none
	Right middle finger		15-0-45°	preserved	resorption at screws heads at proximal phalanx and metacarpal head	screw removal necessary
2	Right index finger	6	0-0-75°	preserved	preserved	none
3	Right index finger	7	0-0-90°	reduced	preserved	none

The marked grey details display relevant pathological findings

MTP metatarsophalangeal



**Fig. 1** Patient 1 with milling machine injury in a 45-year-old carpenter: clinical appearance (a) and X-rays of injury (b). Nine years post-operatively, the joint space remained intact at both MCP joints.

Osteolytic changes around the screws heads of the third MCP joint necessitated screw removal (c, d)

at the hand. Corticocancellous transplants of the iliac crest were placed on the remaining palmar cortex of the proximal phalanges including an osteosynthesis at the second ray and an arthrodesis of the PIP joint of the third ray. Free tendon grafts replaced the missing extensor tendons. Skin closure was facilitated by two pediculated abdominal flaps. A remaining defect with an adjacent scar was secondarily covered by a local insulated flap of the ring finger. Healing of the soft tissue as well as bony healing was uneventful, so that the patient was able to resume his manual work four months after the injury.

Seven years after the injury, the patient did not complain of any pain. Flexion of the index finger MCP joint rated 40° with an extension lag of 15°. Extension and flexion of the middle finger MCP joint rated 15° and 45°, respectively. Grip-strength rated 77% of the opposite hand, and with a DASH score of 13, the patient was satisfied with the result. X-rays revealed preserved joint spaces of both fingers, and only slight resorption of the third metacarpal head graft with no signs of resorption of the second metacarpal head as well as both proximal phalanx grafts. To prevent the third MCP joint from irritation by the somewhat prominent screws

heads, all screws around the third MCP joint were removed. Intra-operatively, the dorsal part of the metacarpal head graft was converted into scar, whereas the main part of the graft remained intact with healthy cartilage. Nine years after the injury, the clinical findings were unchanged. The patient still was satisfied with the results. Radiographically, no further osteolysis or joint space narrowing was noticed.

With except to the need for broader working shoes for both feet, the patient did not complain of any problems at the feet. The shortening of the third toe rays did not affect his subjective aesthetic impression.

Patient 2 (Figs. 2, 4b): this 40-year-old butcher presented with a ribbon saw injury to the index finger of his right dominant hand. Beside the transverse cut of the extensor tendon, the dorsal third of the proximal phalanx base was missing, leading to an unstable MCP joint with subluxation.

The defect of the proximal phalanx was replaced by a graft of the second toes' proximal phalanx base. Therefore, the base was completely resected, and the graft was shaped

by the use of an oscillating saw. The graft was then screwed to the remaining palmar part of the fingers' proximal phalanx base. Tendon and skin were primarily closed. Healing of bone and soft tissue was uneventful.

Two years later, the patient suffered a subtotal amputation of his middle finger of the same hand and at the same saw with successful replantation.

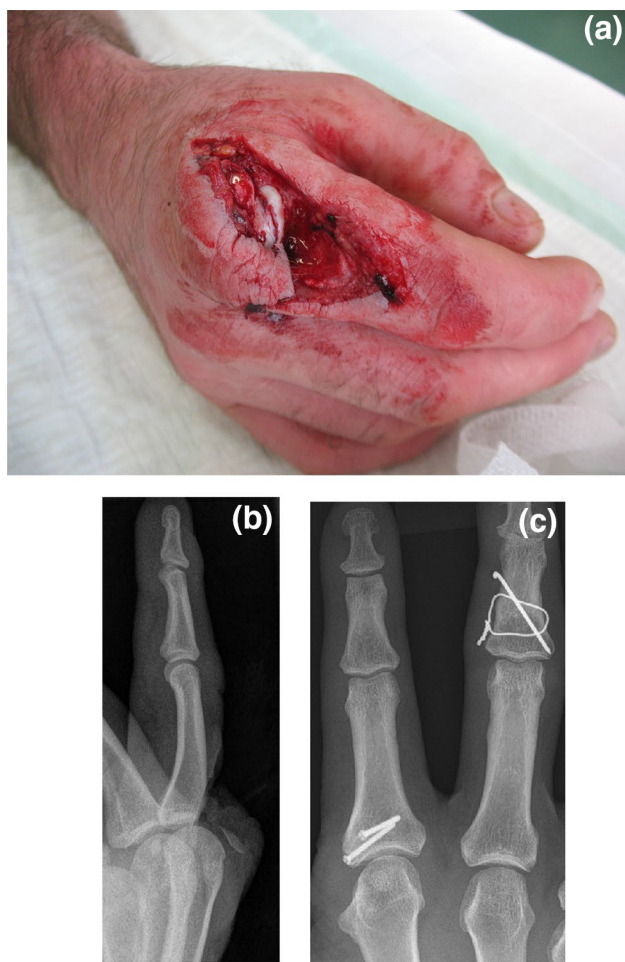
Six years after the injury to his index finger, the patient was satisfied and denied any pain. Flexion rated 75° with no extension lag. The grip-strength rated 68% of the opposite hand. The DASH score was limited to 29, mostly due to the remaining impairment by the revascularized middle finger. X-rays revealed a preserved joint space with no signs of resorption and no screw prominence.

The patient did not complain of any problems at the donor site of his right foot. The slight shortening of the second toe was not relevant to him.

Patient 3 (Figs. 3, 4c): this 48-year-old technician suffered a circular saw injury to the index and middle finger of his dominant right hand. The saw blade came from distal ulnar to proximal radial, affecting his middle finger resulting in a loss of his middle phalanx including the PIP joint and a laceration of the extensor tendon and the radial neurovascular bundle. The index finger was hit at the level of the MCP joint with loss of two third of the proximal phalanx base as well as of the metacarpal head, including a laceration of both flexor tendons, the extensor tendon and the ulnar neurovascular bundle.

Reconstruction of the MCP joint was facilitated by grafts from the third MTP joint of the foot in the way that the whole joint was taken. The metatarsal head and the proximal phalanx base were shaped by the use of an oscillation saw, respectively, and were then screwed to the remaining parts at the MCP joint. The injury pattern at the index finger necessitated reconstruction of both flexor tendons, as well as of the extensor hood and the ulnar neurovascular bundle. At the adjacent middle finger, bony reconstruction necessitated a corticocancellous transplant with primary PIP joint arthrodesis. Reconstruction of the radial neurovascular bundle and of the extensor tendon was performed. In the following, the critical soft tissue condition necessitated three further procedures including coverage of the defect by a free lateral arm flap. Bony healing was uneventful at the index finger, but was delayed at the middle finger, necessitating periodic radiographic follow-ups.

7 years after the injury, the patient was satisfied with the result of the operation without any pain in the MCP joint. Range-of-motion of the MCP joint was unlimited with a flexion of 80° and without lag of extension. DASH score rated 17. Periodic X-rays including a CT scan revealed early joint space narrowing with little osteolysis around the screws' heads as early as 1 year after the injury, however, without any further signs of resorption neither of the metacarpal



**Fig. 2** Patient 2 with ribbon saw injury in a 40-year-old butcher: clinical appearance (a) and X-rays of injury (b). Radiographic result 6 years post-operative (c)



**Fig. 3** Patient 3 with circular saw injury in a 47-year-old technician: radiographic presentation of injury (a). Early narrowing of joint space at 1 year (b). Seven years post-operatively, the joint space narrowing remained stable with no further progress (c)

head nor of the proximal phalanx base. Seven years after the injury, despite the obvious osteoarthritis, bone stock still was preserved with no signs of osseous resorption.

At the donor site of his right foot, the patient did not complain of any problems. The moderate shortening of the third toe did not cause any functional deficit.

## Discussion

Complex injuries to finger joints are even more challenging when they are accompanied by loss of bone, joint surface or both. Depending on the extent of bone defect, arthrodesis may only be possible with shortening of the affected ray or with additional autologous bone transplant. Alloplastic joint replacement was found to be safe even in the setting of

acute trauma, however, if ever possible, may not always be desired [7]. With respect to the MCP joint, however, preservation of range-of-motion should be aimed, when treatment is planned. Thereby, reconstruction of the joint with the use of osteochondral transplants of the MTP joints is one possible option. In the three patients of this series, reconstruction of the affected MCP joints preserved a satisfying mean range-of-motion of  $60^\circ$ , ranging from  $25$  to  $80^\circ$ , and a mean grip-strength of 82% of the opposite side, allowing all three patients to resume their manual work after healing of bone and soft tissue. Thereby, radiographic follow-up revealed preserved bone stock in all of the reconstructed transplants with only one demonstrating moderate osteolysis around the screws' heads with the need for screw removal. In one additional joint, moderate joint space narrowing was found in the early months after the injury, however, without any clinical consequence and with no further progress in the long term that would necessitate further treatment. And, since bone stock remained intact, an eventual prosthetic joint replacement would potentially be possible if necessary.

For the reconstruction of metacarpophalangeal joints, osteochondral grafts may be harvested from the femur condyle [8] or the ribs [9]. For that, the cartilage needs to be contoured to fit into the new joint. Zappaterra et al. [9] reported a mean range-of-motion of  $33^\circ$ , ranging from  $30^\circ$  to  $40^\circ$ , when costal transplants were used for defects accounting for at least half of the metacarpal head. Their follow-up ranged between 9 and 25 months. Grafts harvested from the MTP joints, instead, originally have the same size and shape, so that their insertion into the defect is facilitated easier and faster. In complex injuries, when reconstruction of different anatomic structures is required, this advantage may be of great value. Boulas et al. reported on five patients, in which MCP joint defects were reconstructed with MTP joint transplants. After an average of 33 months, full extension and a mean flexion of  $74^\circ$  was achieved, ranging from  $60^\circ$  to  $85^\circ$  [10]. If the greater range-of-motion in their cohort as well as in the presented cohort is based on this advantage is not clear, since functionality of a joint depends not only on the congruity of the joint, but also on its surrounding soft tissue. In any of the reported cases, associated soft tissue lesions were treated to a variable extend leaving scars and adhesions with consecutive limitation of function.

Reconstruction of whole joint defects is preferably done with vascularized joint transplants, as non-vascularized joints are prone to resorption [3]. Donor site may be an adjacent finger ray that may be redundant when amputated. In such situations, the tissue bank concept of Chase should always be applied [2, 11]. Thereby, not only a MCP joint, but also a PIP joint may be used to replace a missing MCP joint [2]. However, microvascular joint replacement is time consuming and may not be desired in the acute setting, when multiple anatomical structures are violated.



**Fig. 4** Cosmetic and functional results at the feet: relevant shortening of the donor rays was found in patient 1 (a) and 3 (c), when both, metatarsal head and proximal phalanx base was harvested. No rel-

evant shortening of the donor ray was found in patient 2, when only the proximal phalanx base of the second toe was harvested (b)

Nevertheless, microsurgical reconstruction is inevitably necessary for defects of nerves, vessels or skin defects.

Reports on reconstruction of defects at the MCP joint are rare when compared to defects of the proximal interphalangeal (PIP) joints. This may be due to the circumstance, that PIP joints are more often involved in fracture dislocations that necessitate joint reconstruction. Frequently, results from hemihamate osteochondral transplants are found in the literature [4, 12], since the grafts resemble well the geometry of the palmar aspect of the middle phalanx' base. Other defects may be filled by grafts harvested from the knee [13], or the ribs [9, 14] with the need for trimming of the gratuitous cartilage. Accordingly, to our series dealing with MCP joint defects, resembling grafts for PIP joint defects may be harvested from other PIP joints from fingers or toes with excellent results for PIP joint flexion averaging  $93^\circ$  after 4 years [15].

The main limitation of this series is the low number of patients. Nevertheless, since functionality of all four involved MCP joints remained intact even in the long term,

osteochondral transplants proved to be a reliable treatment option for reconstruction.

Harvesting the graft from the MTP joint was not accompanied by a relevant functional impairment in this cohort of patients. However, when the defect at the apex of the metatarsal head is to be avoided, the graft may be harvested from the plantar part, as long as a correct fitting into the metacarpal head is guaranteed. In cases when excessive shortening of the toes' ray is feared by harvesting of both, the metatarsal head and the base of the proximal phalanx, then a surgically created syndactyly to the adjacent toe may be considered [16].

## Conclusions

Osteochondral transplants for reconstruction of MCP defects are able to preserve function in severely injured joints even in the long term. Joint space narrowing may occur, which is not accompanied by pain, however. Since localized osteolysis can cause screw head prominence, mid-term radiographic

follow-up is necessary to prevent damage to the joint. In the long term, remaining bone stock may be adequate for total joint replacement.

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## Declarations

**Conflict of interest** The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

**Ethical approval** The study protocol was reviewed and accepted by the ethics committee of the University of Würzburg.

**Informed consent** All three patients gave their informed consent to participate in this study.

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