Chapter 11
Condylar Replacement Arthroplasty and Other PIP Autografts

John R. Lien and T. Greg Sommerkamp

Abstract Proximal interphalangeal (PIP) joint injuries with associated osteochondral defects are a challenging problem. Without restoration of a concentrically reduced PIP joint, post-traumatic articular degenerative changes will develop. The indications for hemihamate replacement arthroplasty (HHRA) are limited to volar defects of the middle phalanx base with an intact dorsal cortex and at least 10–20 % of the dorsal articular surface remaining on the base of the middle phalanx. Other osteoarticular PIP joint injuries include middle phalanx base sagittal defects, proximal phalanx unicondylar defects, combined proximal and middle phalangeal osteochondral defects from open injury, and isolated focal osteochondral defects. The goal of this chapter is to provide an overview of autograft options (other than HHRA) for PIP joint osteochondral defects, with a clinical vignette demonstrating reconstruction of a unicondylar injury of the proximal phalanx.

J.R. Lien, M.D.
Department of Orthopaedic Surgery, University of Michigan Health Systems, 2098 South Main Street, Ann Arbor, MI 48103, USA
e-mail: jlien@med.umich.edu

T.G. Sommerkamp, M.D. (✉)
Tri Health- Hand Surgery Specialists, Inc., 545 Centre View Blvd, Crestview Hills, KY 41017, USA
e-mail: thomas_sommerkamp@trihealth.com

J.E. Adams (ed.), *PIP Joint Fracture Dislocations*,
DOI 10.1007/978-3-319-28579-5_11

Keywords Proximal interphalangeal joint • Osteochondral arthroplasty • Proximal phalanx condyle fracture • Condylar replacement arthroplasty

Introduction

Proximal interphalangeal (PIP) joint injuries with associated osteochondral defects are a challenging problem. These injuries may present acutely, with severely comminuted and/or open articular fractures, as well as in a subacute setting with malunited or resorbed periarticular fractures. Pain, swelling, limited range of motion (ROM), angular deformity, and rotational deformity may be appreciated. Without restoration of a concentrically reduced PIP joint, posttraumatic articular degenerative changes will develop.

The hemihamate replacement arthroplasty (HHRA) is an effective tool in the management of severe dorsal PIP fracture dislocations. However, the indications for HHRA are limited to volar defects of the middle phalanx base with an intact dorsal cortex and at least 10–20 % of the dorsal articular surface remaining on the base of the middle phalanx. Other osteoarticular PIP joint injuries include middle phalanx base sagittal defects, proximal phalanx unicondylar defects, combined proximal and middle phalangeal osteochondral defects from open injury, and isolated focal osteochondral defects.

The goal of this chapter is to provide an overview of autograft options (other than HHRA) for PIP joint osteochondral defects, with a clinical vignette demonstrating reconstruction of a unicondylar injury of the proximal phalanx.

Management Options

Prior to considering autograft reconstruction, if the fracture is relatively acute and the fragments are of reasonable size, one must consider open reduction and internal fixation or other means of maintaining a stable reduction. In the setting of malunion, osteotomy with internal fixation is an option if the articular surface is preserved and there is adequate bone stock. Other tools include implant arthroplasty and joint arthrodesis. Patient factors such as activity level, age, and comorbidities are important in determining management. The ideal candidate for autograft reconstruction is a young, active patient who wishes to preserve joint motion.

Many methods of autograft reconstruction have been described, but most outcome data are limited to small case series.

Total Joint Transfer

Vascularized second toe joint transfer is useful in situations with proximal and distal articular loss, as well as composite dorsal tissue deficit [1]. Additionally, growth potential of the epiphysis may be maintained in the pediatric patient. However, it is a technically demanding microsurgical procedure not without morbidity. Additionally, joint flexion contractures and extensor lag with a limited arc of motion are common outcomes with this procedure.

Vascularized homodigital and heterodigital joint transfer may be used in traumatic situations as “spare part” surgery. As with toe joint transfer, this technique is useful in the setting of total joint destruction as well as composite tissue loss. Since the donor finger is nonsalvageable due to other injuries, these procedures carry no additional morbidity. Both island and free joint transfer, either from the PIP or distal interphalangeal (DIP) joint, have been described [2].

Partial Articular Reconstruction

Osteochondral autograft transfer utilizes osteochondral plugs from either hamate or knee donor [3, 4]. This can be performed on either the proximal phalanx or middle phalanx articular surface and may be useful in patients with focal osteoarticular defects. However, in order to maintain press-fit fixation, an intact rim of articular cartilage or cortex is necessary.

Nonvascularized hemi-toe autograft may be used to reconstruct the proximal phalanx condyle [5] as well as full-thickness sagittal defects (involving volar and dorsal cortices) in the middle phalanx base [6]. Morphometric studies show the third toe proximal phalanx distal articular surface and the medial base of the toe middle phalanx most closely approximate the PIP recipient site [7].

Costal perichondrial resurfacing may produce a fibrocartilage articular surface but cannot compensate for bony defects and concomitant angular deformity. Additionally, problems with substantial joint stiffness are recognized in follow-up [8]. Chondroperichondrial grafting has also been described, but is also reserved for salvage arthroplasty [9]. Costal cartilage autograft reconstruction provides a structural support to correct bone loss and produces hyaline cartilage [10] but also has problems with stiffness, with one series reporting a 33° average arc of motion [11]. Potential problems with this donor area during harvest, though unlikely, can be substantial.

Portions of the second and third carpometacarpal (CMC) joints can be harvested for nonvascularized osteoarticular autograft and for reconstruction of proximal phalanx condyle (capitate donor) as well as middle phalanx base (metacarpal base donor) defects [12]. In addition, a pedicled osteoarticular distal capitate flap, based on the second or third dorsal metacarpal artery, can be used for reconstruction of a unicondylar proximal phalanx defect. A theoretical advantage is the vascularity of the graft, which may help with incorporation and viability of the chondrocytes. While no avascular necrosis (AVN) was observed, 3 of 15 patients who underwent flap autograft had PIP joint space narrowing at follow-up [13].

The fourth and fifth metacarpal (MC) bases have been morphometrically compared as potential donor sites for proximal phalanx condylar replacement arthroplasty [14]. The small MC base has a radius of curvature (ROC) that more closely resembles that of the phalangeal condyles, and this correlation between donor and recipient appears to remain constant despite variations in hand size. A clinical series demonstrated reconstruction using fifth MC base osteoarticular autograft, with acceptable results at an average of 4.8-year follow-up [15].

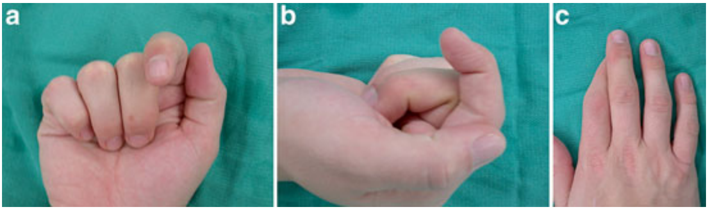

Fig. 11.1 Preoperative physical exam findings: ulnar deviation and supination deformity and limited PIP range of motion

Clinical Vignette

Clinical Problem

A 21-year-old right-hand dominant male sustained a right index proximal phalanx comminuted ulnar condyle fracture. He was initially treated with "buddy taping" of the index finger to the adjacent long finger by the initial treating orthopedic surgeon. He presented 6 months later with stiffness, loss of motion, PIP pain, and angular/rotational deformity at the PIP joint.

Examination

Active ROM upon presentation was MP +20–85°, PIP 26–56°, and DIP 4–65°. Passive ROM was MP +25–90º, PIP 20–60º, and DIP 0–70º. Deformities in ulnar deviation (20°) and supination (10°) at the level of the PIP joint were also noted (Fig. 11.1). Radiographs revealed an ulnar condyle malunion with loss of condylar height, bone resorption, and a bony flexion block deformity (Fig. 11.2a).

Procedure: Condylar Replacement Arthroplasty (CRA)

We recommended CRA using the base of the small metacarpal as the source of the osteochondral autograft. Rationale for this graft includes minimal donor-site morbidity, technical practicality, and relationship to normal condylar morphology [14].

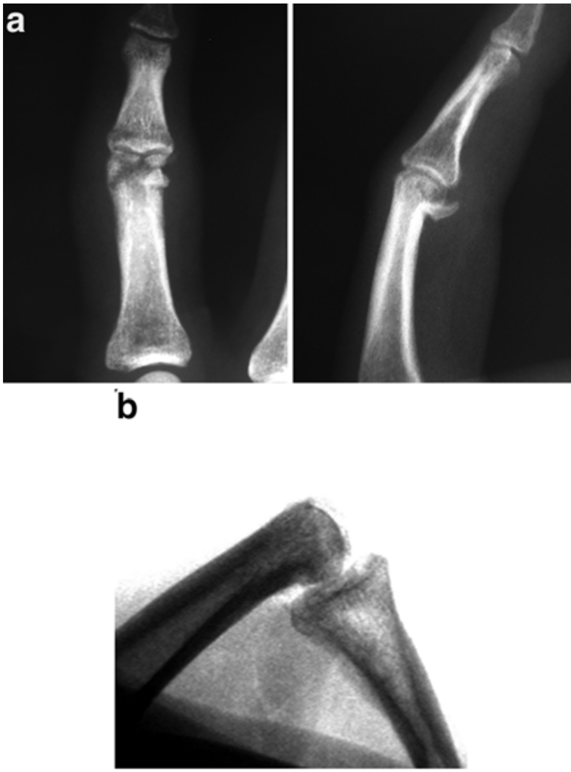

Fig. 11.2 Radiographic views of the index finger PIP joint preoperative (**a**) and intraoperative (**b**). (**a**) The preoperative films demonstrate a proximal phalangeal ulnar condyle malunion. (**b**) Intraoperative films show improved flexion following excision of the deformed ulnar condyle

The index ulnar condyle was exposed through an ulnar mid-axial approach. The transverse retinacular ligament was sharply divided just volar to the lateral band. The capsule was identified and a capsulotomy was performed. The ulnar collateral ligament (UCL) origin was subperiosteally dissected off the damaged ulnar condyle and saved for later UCL reconstruction. The PIP joint was then completely exposed by a modified "shotgun" exposure hinging the middle phalanx around the intact radial collateral ligament. Upon exposure of

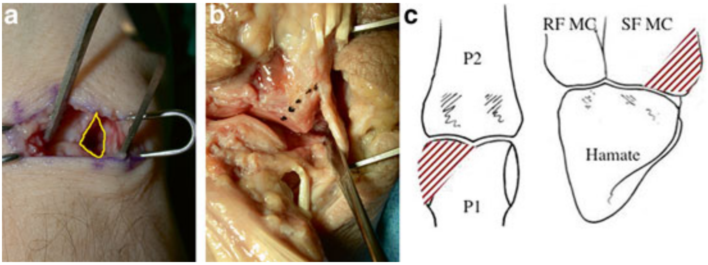

Fig. 11.3 (**a**, **b**) Harvest of small metacarpal base (cadaver on right), (**c**) illustration of small finger metacarpal base donor site and proximal phalanx recipient site

the PIP joint, the degenerative changes over the ulnar condyle were noted. In addition, the bony block to flexion was identified and removed. Intraoperative flexion improved from 60° to 90° (Fig. 11.2b), yet ulnar deviation and supination deformity persisted. The comminuted, malunited ulnar condyle was unreconstructable and removed through an oblique osteotomy which was performed in the anterior-posterior plane. An oblique osteotomy provided a maximum amount of cancellous bone surface to support and secure the graft and augment rapid revascularization.

Next, the small finger CMC joint was exposed through a transverse incision approximately 2 cm in length. The CMC joint was exposed between the extensor carpi ulnaris and extensor digiti quinti tendons. A capsulotomy was performed making sure to remove the ulnar portion of the CMC ligament from the hamate and leaving a portion of it attached to the ulnar base of the small MC to be used for later reattachment to the ulnar collateral ligament of the PIP joint. The condylar defect was measured, and the appropriate amount of graft was harvested from the ulnar aspect of the small finger MC base (Fig. 11.3a–c). The extensor carpi ulnaris tendinous insertion was partially reflected distally from its attachment when necessary to obtain adequate graft material (Fig. 11.3b). The entire dorsal-volar dimension was included in the graft, whereas only the necessary radial-ulnar dimension was obtained. Once the graft was harvested, the remaining CMC joint was tested for stability directly by grasping the remaining intact base and attempting to dislocate the joint and

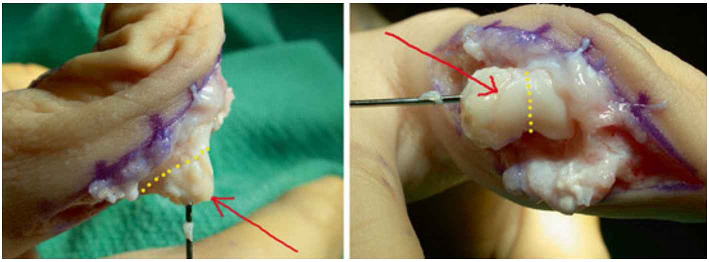

Fig. 11.4 Provisional fixation of condylar replacement autograft. *Red arrow* depicts CRA graft; *dashed yellow lines* depict osteotomy site

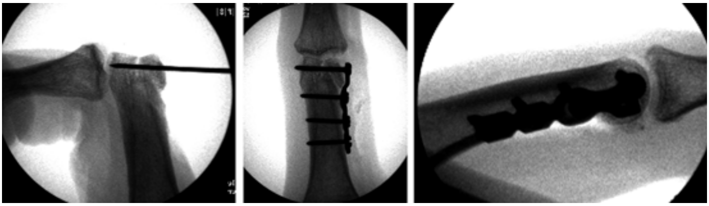

Fig. 11.5 Provisional then definitive fixation of CRA graft with A.O./Synthes 1.5 mm minicondylar plate

indirectly by flexing and extending the metacarpal and observing for subluxation, and none was present.

Following harvest, the graft was appropriately positioned in the proximal phalangeal defect and provisionally fixed with a Kirschner wire (Fig. 11.4). Definitive fixation was then performed with a 1.5 mm A.O./Synthes minicondylar plate over the provisional wire. Intraoperative radiographs revealed excellent alignment and position, and the wire was replaced with a 1.5 mm lag screw placed across the CRA graft into the radial condyle (Fig. 11.5). It is important to position the graft such that any excess in the anterior-posterior dimension is directed dorsally. Thus, if any dorsal trimming of excess graft is required, the volar articular contour of the graft is preserved, thereby allowing maximal flexion. Once positioned and trimmed, the PIP joint was reduced. The ulnar collateral ligament was then repaired to the CMC ligament remaining on the graft. Stability and ROM were tested.

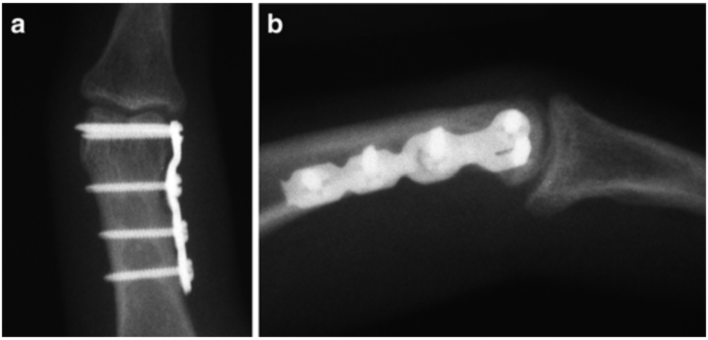

Fig. 11.6 Postoperative films demonstrate that the graft has incorporated into the host bone without evidence of AVN and maintenance of the joint space at 2 years

Postoperatively, immobilization consisted of a volar positioning splint. Full active ROM was initiated 48 h after surgery, with active-assisted ROM starting 1 week postoperatively. The index finger was well aligned with improved PIP AROM (10–90°) achieved by 10 weeks which was slightly reduced at 36 months (25–90°). Representative radiographs at 24 months postoperatively revealed complete incorporation of the graft with preservation of joint space and no evidence of avascular necrosis (Fig. 11.6). At 36 months, the patient did complain of hardware tenderness from the prominent "shoulder" of the 1.5 mm minicondylar implant and underwent successful hardware removal, tenolysis, and capsulectomy. A small cartilage punch biopsy of the peripheral articular rim of the CRA autograft obtained at the time of the hardware removal revealed viable hyaline cartilage with numerous chondrocytes (Fig. 11.7). The final active ROM at 48 months was PIP 15–95° and DIP 0–65°. X-rays at 48 months revealed the CRA graft to be well incorporated and revascularized without any plain radiographic changes of AVN or post-traumatic osteoarthritis (Fig. 11.8). There was no instability or arthrosis at the donor site.

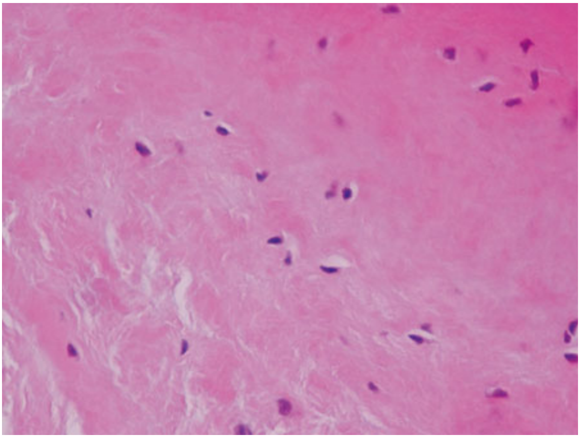

Fig. 11.7 Photomicrograph of a biopsy obtained from the most peripheral rim of the CRA graft demonstrating viable chondrocytes in the peripheral fibrocartilage

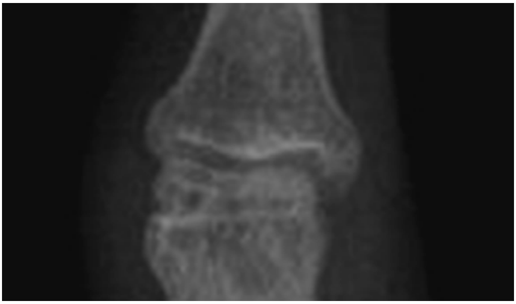

Fig. 11.8 Radiograph of PIP joint at 4 years post-op, after hardware removal. Note ulnar condyle with normal radiodensity and no sign of late segmental collapse, with well-preserved joint space

Discussion

As part of our earlier lab research [14], the base of the small and ring finger metacarpals was morphometrically assessed as potential donors to replace one of the condyles of the proximal phalanx. Of the two donor grafts investigated, only the small MC base demonstrated adequate graft material to resurface all dimensions of the phalangeal condyles. Both potential donors demonstrated adequate graft in the anterior-posterior and dorsal radial-ulnar dimensions. When assessing volar width, however, only the small MC base had more osteocartilaginous stock than the recipient condyles to assure room for adjustments. The ring MC base, on the other hand, had just enough material, which provides minimal room for error in making adjustments in the volar dimension. In addition, since all of the volar surface must be harvested, ring CMC instability is of concern. These would not be concerns for the small MC base as there is adequate material in all dimensions.

Although the ring MC base has enough stock to reconstruct some of the condyles, another confounding variable is its large radius of curvature that makes it less suited for condylar reconstruction. The small MC base, on the other hand, has a lower radius of curvature that more closely approximates that of the phalangeal condyles. In addition, regression analysis demonstrated that the relationship in ROC between donor and recipient is stronger if the small MC base is used as the donor. Thus, the surgeon can be confident that the correlation between donor and recipient will remain a constant, despite variation in hand size.

Both the ulnar as well as the radial base of the small metacarpal can be utilized; however, the ulnar base is simpler to harvest. The radial base is bordered by the ring MC base and thus makes it more difficult to harvest. Although, the ulnar base was used to resurface an ulnar condyle in both our cadaveric preparations and in the case example, the same ulnar base can also be used to resurface the radial condyle after being rotated appropriately.

In the ulnar two digits, the radial condyle is more frequently fractured than the ulnar condyle [16]. The opposite occurs for the radial two digits, i.e., the ulnar condyle is more frequently fractured than the radial condyle. Interestingly, the condyles that are frequently fractured also happen to be the larger condyles by measurements obtained in our prior studies [14]. Given that the small finger MC graft has a larger radius of curvature than any of the native condyles, it is optimal that the frequently injured condyles are of larger size. This makes those condyles that are frequently damaged a better match for the small MC donor CRA graft.

Development of osteoarthritis at the donor site is a legitimate concern following harvest. The data in the present study demonstrates that CMC stability is not altered by graft harvest. Therefore, given that the CMC joint is stable following harvest, the likelihood of developing OA is less likely than if instability was encountered. In the study by Williams et al., no donor-site morbidity was encountered in their series of hemihamate harvests for the hamate hemiarticular replacement arthroplasty (HHRA) [17] as well as in a 10-year follow-up study by Calfee et al. [18].

Another concern following autograft reconstruction is the viability of the osteochondral graft. Williams et al. demonstrated graft survivability in all patients treated with distal hamate osteochondral grafting for dorsal PIP fracture dislocations [17]. This is consistent with studies examining unicondylar grafts [19, 20]. However, grafts used to reconstruct both condyles have been met with less success [12]. The case example in this report demonstrated survivability of the unicondylar graft at latest follow-up of 48 months with normal radiographic appearance (Fig. 11.8) and viable chondrocytes on histology (Fig. 11.7).

Our studies have demonstrated that the base of the small MC is of appropriate dimensions to be suited for osteochondral donor material to resurface the proximal phalangeal condyles. In addition, the graft is simple to harvest and results in minimal morbidity with respect to CMC stability. Of the previously discussed autografts for condylar reconstruction, we believe that the base of the small MC is the optimal donor material.

The presumptive indications for condylar replacement arthroplasty using the ulnar base of the small MC include both acute and chronic conditions. In the acute situation, it is conceivable that CRA can be used for severely comminuted condyle fractures with an unreconstructable articular surface or complete condylar destruction by power saws. It can also be used in the chronic situation where malunion of the condyle fracture is associated with posttraumatic osteoarthritis where the middle phalanx base is minimally involved.

References

1. Tsubokawa N, Yoshizu T, Maki Y. Long-term results of free vascularized second toe joint transfers to finger proximal interphalangeal joints. J Hand Surg Am. 2003;28A:443–7. doi:10.1053/jhsu.2003.50087.
2. Foucher G, Lenoble E, Smith D. Free and island vascularized joint transfer for proximal interphalangeal reconstruction: a series of 27 cases. J Hand Surg Am. 1994;19A:8–16. doi:10.1016/0363-5023(94)90217-8.
3. Ozyurekoglu T. Multiple osteochondral autograft transfer to the proximal interphalangeal joint: case report. J Hand Surg Am. 2010;35A:931–5. doi:10.1016/j.jhsa.2010.02.034.
4. Yamagami N, Yamamoto S, Tsujimoto Y, Uchio Y. Osteochondral autograft transplantation for malunited intra-articular fracture of the proximal interphalangeal joint: a case report. Arch Orthop Trauma Surg. 2013;133:135–9. doi:10.1007/s00402-012-1622-4.
5. Gaul JS. Articular fractures of the proximal interphalangeal joint with missing elements: repair with partial toe joint osteochondral autografts. J Hand Surg Am. 1999;24A:78–85. doi:10.1053/jhsu.1999.jhsu24a0078.
6. Pirani AA, Rao A, Sharma S. Traumatic proximal interphalangeal joint reconstruction with an autologous hemi-toe osteochondral graft: case report. J Hand Surg Am. 2013;38A:1320–3. doi:10.1016/j.jhsa.2013.03.045.
7. Hendry JM, Mainprize J, McMillan C, Binhammer P. Structural comparison of the finger proximal interphalangeal joint surfaces and those of the third toe: suitability for joint reconstruction. J Hand Surg Am. 2011; 36A:1022–7. doi:10.1016/j.jhsa.2011.01.047.
8. Seradge H, Kutz JA, Kleinert HE, Lister GD, Wolff TW, Atasoy E. Perichondrial resurfacing arthroplasty in the hand. J Hand Surg Am. 1984;9A:880–6. doi:10.1016/S0363-5023(84)80072-6.
9. Takayama S, Nakao Y, Horiuchi Y, Itoh Y. Arthroplasty of MP and PIP joints using a chondroperichondrial graft. Tech Hand Up Extrem Surg. 1998;2(2):115–8. doi:10.1097/00130911-199806000-00005.
10. Sato K, Sasaki T, Nakamura T, Toyama Y, Ikegami H. Clinical outcome and histologic findings of costal osteochondral grafts for cartilage defects in finger joints. J Hand Surg Am. 2008;33A:511–5. doi:10.1016/j.jhsa.2008.01.003.
11. Zappaterra T, Obert L, Pauchot J, Lepage D, Rochet S, Gallinet D, et al. Post-traumatic reconstruction of digital joints by costal cartilage grafting: a preliminary prospective study. Chir Main. 2010;29:294–300. doi:10.1016/j.main.2010.07.003.
12. Ishida O, Ikuta Y, Kuroki H. Ipsilateral osteochondral grafting for finger joint repair. J Hand Surg Am. 1994;19A:372–7. doi:10.1016/0363-5023(94)90048-5.
13. Zhang X, Fang X, Shao X, Wen S, Zhu H, Ren C. Osteoarticular pedicle flap from the capitate to reconstruct traumatic defects in the head of the proximal phalanx. J Hand Surg Am. 2012;37A:1780–90. doi:10.1016/j.jhsa.2012.05.004.

14. Hernandez JD, Sommerkamp TG. Morphometric analysis of potential osteochondral autografts for resurfacing unicondylar defects of the proximal phalanx in PIP joint injuries. J Hand Surg Am. 2010;35A:604–10. doi:10.1016/j.jhsa.2009.12.041.
15. Cavadas PC, Landin L, Thione A. Reconstruction of the condyles of the proximal phalanx with osteochondral grafts from the ulnar base of the little finger metacarpal. J Hand Surg Am. 2010;35A:1275–81. doi:10.1016/j.jhsa.2010.04.013.
16. Weiss AP, Hastings H. Distal unicondylar fractures of the proximal phalanx. J Hand Surg Am. 1993;18A:594–9. doi:10.1016/0363-5023(93)90297-G.
17. Williams RM, Kiefhaber TR, Sommerkamp TG, Stern PJ. Treatment of unstable dorsal proximal interphalangeal fracture/dislocations using a hemi-hamate autograft. J Hand Surg Am. 2003;28A:856–65. doi:10.1016/S0363-5023(03)00304-6.
18. Calfee RP, Kiefhaber TR, Sommerkamp TG, Stern PJ. Hemi-hamate arthroplasty provides functional reconstruction of acute and chronic proximal interphalangeal fracture-dislocations. J Hand Surg Am. 2009;34A:1232–41. doi:10.1016/j.jhsa.2009.04.027.
19. Bury TF, Stassen LP, van der Werken C. Repair of the proximal interphalangeal joint with a homograft. J Hand Surg Am. 1989;14A:657–8. doi:10.1016/0363-5023(89)90185-8.
20. Hasegawa T, Yamano Y. Arthroplasty of the proximal interphalangeal joint using costal cartilage grafts. J Hand Surg Br. 1992;17B:583–5. doi:10.1016/S0266-7681(05)80248-7.