Reconstruction of the proximal phalanx head with a costal osteochondral graft for a comminuted fracture of the proximal interphalangeal joint

Running title: Reconstruction with rib cartilage graft

Yoshihiko Satake¹,²), Mitsuhiko Nanno²), Norie Kodera¹), Shinro Takai²)

¹)Department of Orthopaedic Surgery, International University of Health and Welfare Hospital, Tochigi, Japan

²)Department of Orthopaedic Surgery, Nippon Medical School, Tokyo, Japan

Address correspondence to:

Yoshihiko Satake

Department of Orthopaedic Surgery, International University of Health and Welfare Hospital, 537-3 Iguchi, Nasu-shiobara, Tochigi 329-2763, Japan

Tel: +81-287-37-2211, Fax: +81-287-39-3001, E-mail: y-satake@nms.ac.jp
Abstract

We herein report a case involving a 41-year-old male carpenter who underwent costal osteochondral grafting with a pins and rubbers traction system (PRTS) for a complex cartilage defect of the proximal interphalangeal (PIP) joint. He had inadvertently cut his finger incompletely off with a power saw. The skin laceration extended to the dorsal aspect of his ring finger, and he had incomplete loss of the ulnar condyle and comminution of the radial condyle of the proximal phalanx of the PIP joint. He was diagnosed with an intra-articular PIP joint open fracture of the left ring finger with a 60% defect of the proximal phalanx joint surface. PIP joint reconstruction was performed with a costal osteochondral graft 3 weeks after the injury. The graft was harvested at the osteochondral junction of the fifth rib. The volar side of the proximal phalanx cortex and the condyles of the proximal phalanx on each side, which included the origin of the collateral ligaments, were preserved. The graft was shaped to match the defect, and biplane fixation with three miniscrews was subsequently performed. Finally, a PRTS was attached. At 6 months postoperatively, the patient returned to his job; at 12 months postoperatively, he had a stable, pain-free joint. This technique enables preservation of the joint stabilizers and rigid fixation of the graft, resulting in a good outcome. Our modified costal osteochondral graft with a PRTS is useful for severe
intra-articular fractures of the PIP joint and should be considered prior to salvage procedures.

**Key words:** costal osteochondral graft, proximal interphalangeal joint, fracture, external fixation, surgery
**Introduction**

Severely comminuted intra-articular finger fractures with a cartilage or bone defect are among the most difficult to treat. Many therapeutic procedures have been described to repair the defects of the articular surface of the proximal interphalangeal (PIP) joint in such cases, including joint transfer\(^1\), arthrodesis\(^2,3\), prosthesis implantation\(^4\), and arthroplasty\(^5-8\). The joint surface is severely damaged with fragments that are often too small for internal fixation, generally resulting in pain and sustained restriction of the range of motion. A costal osteochondral graft was recently recommended for anatomical reconstruction with satisfactory outcomes\(^9\). However, in patients with a collateral ligament injury or lack of primary rigid fixation, active range-of-motion exercises cannot be started immediately after surgery. As a result, these patients tend to have poor outcomes. In this report, we propose a modified technique for rigid biplane fixation of a costal autograft using three miniscrews to enable early rehabilitation.

**Case report**

A healthy 41-year-old right-handed male carpenter was referred to our department because of persistent pain and reduced range of motion in the fourth proximal PIP joint of his left hand. One week earlier, he had inadvertently cut his finger incompletely off
with a power saw. At the time of the injury, the skin laceration extended to the dorsal aspect of the ring finger. A radiograph revealed a fracture of the PIP joint with incomplete loss of the ulnar condyle and comminution of the radial condyle of the proximal phalanx. During the emergency surgery performed on the same day as the injury, both collateral ligaments of the PIP joint and the origins of the collateral ligaments were found to be intact; however, the central slip was ruptured (Figure 1). Given the soft tissue damage and severe comminution of the articular surface, osteosynthesis was abandoned. To prevent the infection, radical surgical debridement and irrigation was performed. The wound was closed temporary after only repairing the central slip. In addition, antibiotic therapy with a first generation cephalosporin was started as soon as possible in the emergency room. Two grams of cephazolin was administered intravenously every 8 hours for two days, and then switch a pill of 250mg cefalexin every 8 hours for one week.

At the patient’s initial examination in our hospital, tenderness was found on palpation around the PIP joint of the left ring finger. The patient demonstrated a painful active range of motion from −12 degrees of extension to 32 degrees of flexion. A standard radiograph and computed tomography showed a comminuted intra-articular fracture with a 60% defect of the proximal phalanx head of the ring finger without an
intact dorsal cortex (Figure 2). To preserve the mobility of the joint, we decided to reconstruct the proximal phalanx head using a costal osteochondral graft.

After confirming soft tissue healing and no infection, we performed the PIP joint reconstruction 3 weeks after the injury. A dorsal approach was used through the original wound, exposing the PIP joint by a longitudinal incision through splitting of the extensor. Macroscopic examination revealed devitalized cartilage with subchondral bone destruction of the proximal phalanx head, with preservation of the origin of the collateral ligament and the cortex of the volar aspect of the proximal phalanx. A box-shaped slot was made throughout the height of the proximal phalanx head. We preserved approximately 2 mm of the condyles on each side, including the origin of the collateral ligaments.

According to the technique described by Sato et al.\textsuperscript{10}, the graft was harvested from the osteochondral junction of the fifth rib. The cartilage in the graft was then trimmed with a scalpel to match the articular surface of the middle phalanx until a smooth range of motion was achieved. The osseous component was shaped to match the defect and subsequently fixed in a biplane manner with three miniscrews; two screws were inserted through the axial plane, and one screw was inserted through the sagittal plane (Figure 3). Finally, the pins and rubbers traction system (PRTS) described by Suzuki et al.\textsuperscript{11} was
attached, and a single rubber band on each side of the finger was wrapped around the wires twice (Figure 4).

A light dressing was used around the Kirschner wires to avoid any disturbance of active motion. Active passive motion of all fingers was started immediately after the surgery under the control of a hand therapist. The traction device was removed 7 weeks postoperatively. At 9 weeks, we obtained radiographic confirmation of fracture union. The patient was able to perform all activities of daily living after 3 months, and he resumed his job after 6 months.

At 1 year after surgery, the patient demonstrated a stable, pain-free 0- to 60-degree range of motion in the reconstructed PIP joint compared with a 0- to 90-degree range of motion on the contralateral side. The range of total active motion was 185 degrees; therefore, the clinical result was good according to the evaluation method established by Ishida and Ikuta. There was no donor site morbidity. Radiographic examinations of the hand revealed a homogeneous configuration of the implanted graft with a slight bone resorption and joint space narrowing (Figure 5). Magnetic resonance imaging was performed to check the morphology of the transplant; however, quantitative assessments of the cartilage were impossible because of the inserted metal screw’s artifacts.
Discussion

In this case, we modified two points of the technique to obtain a good clinical result. First, both collateral ligaments of the PIP joint and the volar plate were preserved intact to save the joint stabilizers. Second, the graft was rigidly fixed with three screws in two different dimensions by preserving the cortical bone on the volar aspect and both lateral sides of the recipient bone. These modifications allowed for an earlier start of range-of-motion exercises, and a good clinical outcome was thus achieved.

Treatment of unstable comminuted intra-articular fractures of the PIP joints is generally considered problematic and difficult because these injuries can easily lead to pain, joint stiffness, instability, and degenerative arthritis. To avoid these problems, two important elements are required: preservation of the joint-stabilizing complex and initial rigid fixation for early rehabilitation. Most investigators recommend early active motion to prevent tendon adhesion and joint contracture. Immobilization also contributes to joint stiffness and osteoarthritis. Early mobilization is necessary not only to prevent joint stiffness but also to help repair the damaged articular cartilage.

The primary stability of the PIP joint is provided by its bony articular surface, the collateral ligament, and the volar plate. To ensure an optimal outcome, Seno et al. emphasized the importance of the stability and joint congruity achieved by open surgery.
with anatomical reduction of the articular surface, primary rigid internal fixation, and bone grafting if necessary. The volar plate resists joint hyperextension\textsuperscript{19}, while the collateral ligaments are the primary restraints to motion in the coronal plane\textsuperscript{20}. Conversely, Caravaggi et al.\textsuperscript{21} suggested that loss of bony restraint plays a much larger role than does the collateral ligament. Although controversy remains regarding how much articular involvement leads to instability, there is a general consensus that more than 50\% articular involvement indicates joint instability\textsuperscript{20,22}. In previous reports of costal osteochondral grafts\textsuperscript{10}, joint stabilizers such as the collateral ligament and/or volar plate were cut, a single screw was inserted through one direction (axial or sagittal plane only), and the injured joint stabilizers were finally repaired. These procedures may be associated with a risk of remaining joint instability. Thomsen et al.\textsuperscript{23} focused on the disadvantage of joint instability and reported a new technique involving a mortise in 2014. Their method preserved the condyles with the collateral ligament origins, but the technique seemed to lack primary bone fixation because the graft was fixed in only one plane. Our new technique improves the disadvantages described in previous reports and is thus more reliable than earlier methods.

We believe that additional use of a PRTS is desirable, especially in patients with an old complex intra-articular fracture or cartilage defect. Most previous reports\textsuperscript{11,15,16} on
the indications for a PRTS have focused on unstable, fresh intra-articular fractures of the PIP joint. Suzuki et al.\textsuperscript{11} reported that a PIP joint intra-articular fracture can be difficult to treat with conservative treatment or open reduction and internal fixation alone, and joint contracture may readily occur. In the present case, good clinical results were obtained with a PRTS according to the evaluation method described by Ishida et al.\textsuperscript{12} despite the presence of an old severely comminuted fracture and cartilage defect in the proximal phalanx condyle. Nanno and Sawaizumi\textsuperscript{24} also demonstrated good results with use of a PRTS for unstable intra-articular fractures of the PIP joint. The PRTS is recommended because it is widely effective for various unstable fractures of the PIP joint. Therefore, we believe that the PRTS is capable of treating complex intra-articular fractures of the PIP joint.

There are some limitations to this study. First, this was a case report, and did not include a control group for analysis of the effectiveness of our method. Second, a weakness of the current report was relatively short follow-up, which is an insufficient expanse of time to assess possible osteoarthrosis.

In conclusion, we have herein reported a modified technique of costal osteochondral grafting with a PRTS for a complex cartilage defect of the PIP joint with a favorable short-term outcome. Our technique enables preservation of the origins of the
collateral ligament and rigid biplane fixation of the costal autograft with three miniscrews, enabling early rehabilitation. A costal osteochondral graft with a PRTS should be considered prior to performing salvage procedures such as arthrodesis or implant prosthesis, especially in young individuals with articular cartilage defects.

**Conflict of Interest**

The authors declare no conflict of interest.

**Acknowledgment**

We thank Angela Morben, DVM, ELS, from Edanz Group (www.edanzediting.com/ac), for editing a draft of this manuscript.
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**Figure legends**

**Figure 1.** Initial photograph of the right ring finger.

*Attachment of the bone fragment with the radial collateral ligament*

The left ring finger had a soft tissue defect over the dorsum of the PIP joint and a severe fracture of the PIP joint with complete loss of the ulnar condyle and comminution of the joint surface of the radial condyle of the proximal phalanx. Both collateral ligaments of the PIP joint were intact.

**Figure 2.** Radiographs and computed tomography of the left ring finger before the second surgery. (a) Posteroanterior view. (b) Lateral view. (C) Three-dimensional computed tomography.

A standard radiograph and computed tomography showed a comminuted intra-articular proximal interphalangeal joint fracture with a 60% defect of the proximal phalanx head of the ring finger without an intact dorsal cortex.

**Figure 3.** Surgical procedure with a costal osteochondral graft for the condylar osteochondral bone defect of the proximal interphalangeal joint.

(a) Costal osteochondral graft. Costal osteochondral bone was harvested from the fifth
right rib, and the cartilage in the graft was trimmed with a scalpel to match the articular surface of the proximal interphalangeal joint. The shape of the costal osteochondral graft was similar to the head of the proximal phalanx.

(b) Photograph after graft fixation. The graft was inserted into the osteochondral bone defect in the proximal phalangeal head and rigidly fixed from two directions with three miniscrews.

(c) Schematics of photograph after graft fixation.

CL, collateral ligament; G, graft; S, screw.

**Figure 4.** Radiographs of the left ring finger immediately after surgery. (a) Posteroanterior view. (b) Lateral view. Postoperative radiographs of the left ring finger showed that the costal osteochondral graft was fixed in two different dimensions with three screws and that the pins and rubbers traction system was attached.

**Figure 5.** Radiographs of the left ring finger 1 year after surgery. (a) Posteroanterior view. (b) Lateral view.

Postoperative radiographs of the left ring finger showed union of the costal osteochondral graft and good congruity of the injured proximal interphalangeal joints.
Fig. 1
Fig. 2
Fig. 3

(a) Front and Lateral views of the surgical site.

(b) Detailed view of the surgical procedure with labels CL, G, and S.

(c) Diagram illustrating the surgical approach with annotations CL, G, S.
Fig. 4
Fig. 5

(a)  

(b)