—Case Reports—

Use of a Costal Osteochondral Graft for Reconstruction of a Proximal Phalanx Head with a Comminuted Fracture of the Proximal Interphalangeal Joint

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We report the use of costal osteochondral grafting with a pins and rubbers traction system (PRTS) for treatment of a complex cartilage defect of the proximal interphalangeal (PIP) joint in a 41-year-old male carpenter who had inadvertently incompletely severed his finger with a power saw. The skin laceration extended to the dorsal aspect of his ring finger and resulted in incomplete loss of the ulnar condyle and comminution of the radial condyle of the proximal phalanx of the PIP joint. The diagnosis was intra-articular PIP joint open fracture of the left ring finger with a 60% defect of the proximal phalanx joint surface. Three weeks after the injury, PIP joint reconstruction was performed with a costal osteochondral graft 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. Last, a PRTS was attached. At 6 months postoperatively, the patient returned to his job; at 12 months postoperatively, the joint was stable and free of pain. This technique enabled preservation of 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 before salvage procedures.
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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 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, and fragments that are often too small for internal fixation may be present, which often results in pain and sustained restriction of the range of motion. A recent study reported satisfactory outcomes after costal osteochondral grafting for anatomical reconstruction[9]. However, patients with a collateral ligament injury or lack of primary rigid fixation cannot immediately begin active range-of-motion exercises after surgery and thus tend to have poor outcomes. In this report, we propose a modified technique that uses three miniscrews and enables early rehabilitation after rigid biplane fixation of a costal autograft.

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 incompletely severed his finger with a power saw. At the time of injury, the skin laceration extended to the dorsal aspect of the ring finger. A radiograph revealed a

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fracture of the PIP joint, with incomplete loss of the ulnar condyle and comminution of the radial condyle of the proximal phalanx. During emergency surgery performed on the day of 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 (**Fig. 1**). Because of soft-tissue damage and severe comminution of the articular surface, osteosynthesis was abandoned. To prevent infection, radical surgical debridement and irrigation were performed. The wound was closed temporarily after repair of the central slip, and 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 2 days, after which oral cefalexin 250 mg was given every 8 hours for 1 week.

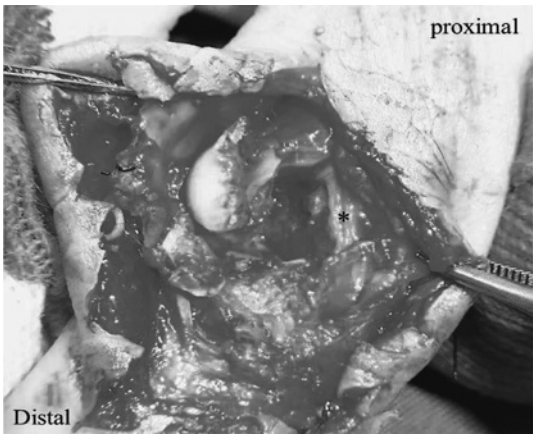

Fig. 1 Initial photograph of the right ring finger.
The left ring finger had a soft-tissue defect over the dorsum of the PIP joint and a severe fracture of the PIP joint, with complete loss of the ulnar condyle and comminution of the joint surface of the radial condyle of the proximal phalanx. Both collateral ligaments of the PIP joint were intact.
*Attachment of a bone fragment with the radial collateral ligament

The initial examination in our hospital revealed tenderness during palpation around the PIP joint of the left ring finger. The patient exhibited a painful active range of motion from –12 degrees of extension to 32 degrees of flexion. Standard radiography and computed tomography showed a comminuted intra-articular fracture with a 60% defect of the proximal phalanx head of the ring finger and a non-intact dorsal cortex (**Fig. 2**). To preserve joint mobility, we decided to reconstruct the proximal phalanx head with a costal osteochondral graft.

After confirming soft-tissue healing and absence of infection, we performed PIP joint reconstruction 3 weeks after the injury. A dorsal approach was used through the

Fig. 2 Radiographs and a computed tomography image of the left ring finger before the second surgery. (a) Posteroanterior view. (b) Lateral view. (c) Three-dimensional computed tomography image.
Standard radiography 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 and a non-intact dorsal cortex.

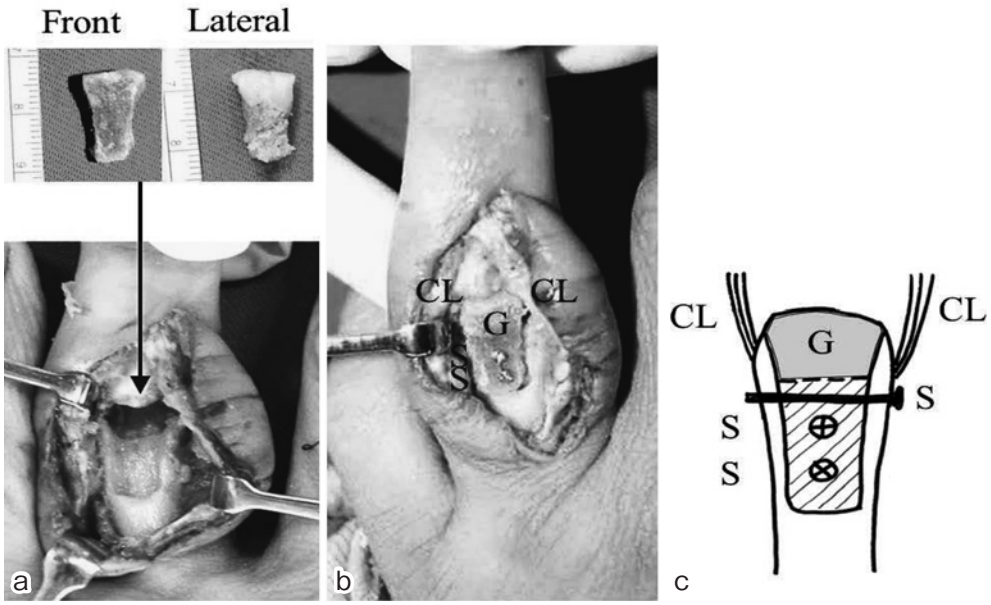

Fig. 3 Surgical procedure with a costal osteochondral graft for the condylar osteochondral bone defect of the proximal interphalangeal joint.
(a) Costal osteochondral graft. Costal osteochondral bone was harvested from the fifth right rib, and graft cartilage was trimmed with a scalpel, to match the articular surface of the proximal interphalangeal joint. The shape of the costal osteochondral graft was similar to that of 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) Schematic of photograph after graft fixation.
CL, collateral ligament; G, graft; S, screw.

original wound, and the PIP joint was exposed by a longitudinal incision through splitting of the extensor. Macroscopic examination revealed devitalized cartilage with subchondral bone destruction of the proximal phalanx head and preservation of the origin of the collateral ligament and 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.

In accordance with the technique described by Sato et al.[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 (**Fig. 3**). Last, a pins and rubbers traction system (PRTS), described by Suzuki et al.[11], was attached, and a single rubber band on each side of the finger was twice wrapped around the wires (**Fig. 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 surgery under the supervision 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 resumed his job after 6 months.

At 1 year after surgery, the patient had stable, pain-free 0- to 60-degree range of motion in the reconstructed PIP joint, as 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 classified as good according to the evaluation method established by Ishida and Ikuta[12]. There was no morbidity at the donor site. Radiographic examination of the hand revealed a homogeneous configuration of the implanted graft, with slight bone resorption and joint space narrowing (**Fig. 5**). Magnetic resonance imaging was performed to check transplant morphology; however, quantitative

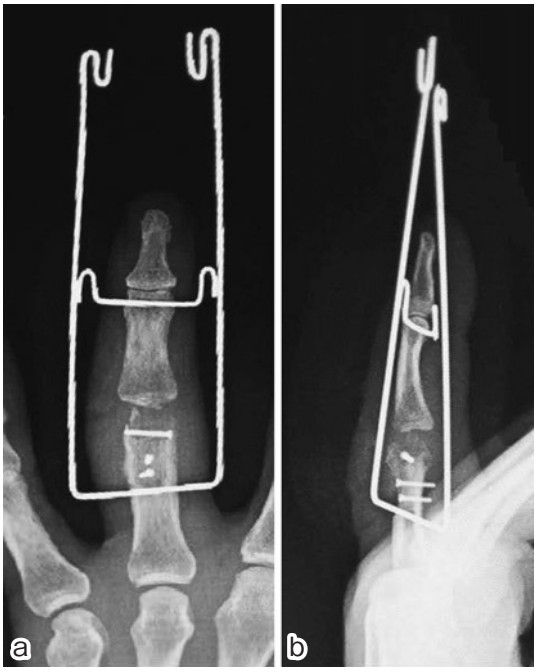

Fig. 4 Radiographs of the left ring finger immediately after surgery. (a) Posteroanterior view. (b) Lateral view.
Postoperative radiographs of the left ring finger showed that the costal osteochondral graft was fixed in two dimensions with three screws and that the pins and rubbers traction system was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

Fig. 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.

assessment of the cartilage was impossible because of artifacts attributable to the inserted metal screws.

Discussion

To obtain a good clinical result in this case, we modified two points of the technique. First, both collateral ligaments of the PIP joint and volar plate were kept intact, to save the joint stabilizers. Second, the graft was rigidly fixed with three screws in two 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, thus ensuring a good clinical outcome.

Treatment of unstable comminuted intra-articular fractures of the PIP joints is challenging because such injuries frequently 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[13]. Immobilization also contributes to joint stiffness[14] and osteoarthritis[15,16]. Early mobilization is necessary, not only to prevent joint stiffness but also to help repair the damaged articular cartilage[17].

The primary stability of the PIP joint is provided by its bony articular surface, the collateral ligament, and the volar plate. To ensure optimal outcomes, Seno et al.[18] 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[19], while the collateral ligaments are the primary restraints to motion in the coronal plane[20]. However, Caravaggi et al.[21] suggested that loss of bony restraint is much more important than the collateral ligament. Although controversy remains regarding how much articular involvement leads to instability, the consensus is that articular involvement of greater than 50% indicates joint instability[20,22]. In previous studies of costal osteochondral grafts[10], joint stabilizers such as the collateral ligament and/or volar plate were cut, a single screw was inserted through one direction (the axial or sagittal plane only), and the injured joint stabilizers were finally repaired. These procedures may be associated with increased risk of joint instability. Thomsen et al.[23] focused on joint instability and, in 2014, reported a new technique involving a mortise. 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 on previous reports and is thus more reliable than earlier methods.

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

This study has some limitations. First, it was a case report and did not include a control group for analysis of the effectiveness of our method. Second, follow-up was too short to assess possible osteoarthrosis.

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

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Conflict of Interest: The authors declare no conflict of interest.

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