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Articular Fragment Detachment and Separate Fixation for the Treatment of Comminuted Patellar Fractures with Coronal Split Articular Fragments: Articular Detachment Technique

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Background: Treatment of comminuted patellar fractures accompanied by coronal split articular and inferior pole fragments is a challenge. To treat this difficult fracture, we perform articular fragment detachment and separate fixation for coronal split articular and inferior pole fragments. We aimed to evaluate the radiological and clinical outcomes of our technique in comminuted patellar fractures at least 1 year after surgery.

Methods: Between January 2019 and June 2022, 15 patients diagnosed with comminuted patellar fractures accompanied by coronal split articular and inferior pole fragments based on preoperative computed tomography underwent surgery using the articular detachment technique. The key point of this technique was anatomical reduction and subchondral fixation of the coronal split articular fragment to the superior main fragment after complete detachment of the coronal split fragment from the inferior pole. The remaining inferior pole was fixed using a separate construct. Postoperative articular gap, articular step-off, and complications, including resorption, reduction loss, and avascular necrosis of fixed articular fragments, were evaluated as radiological outcomes. Range of motion and the Lysholm scores were used to evaluate clinical outcomes.

Results: Among the 15 patients, the coronal split articular fragments were fixed using Kirschner wires in 13 patients and headless screws in 2 patients. The inferior poles were fixed using separate vertical wiring in 13 patients and tension-band wiring in 2 patients. A postoperative articular gap was noted in 7 patients, with an average articular gap of 1.0 mm (range, 0.7–1.6 mm). No articular step-off was observed. Bone union and normal range of motion were achieved in all patients. On the 1-year postoperative lateral radiograph, resorption of the articular fracture site was seen in 5 patients. There was no loss of reduction or avascular necrosis of the coronal split articular fragments. The average postoperative Lysholm score at 1 year was 89.3 ± 4.1 (range, 82–95).

Conclusions: The technique would be a reliable and safe option for the surgical treatment of comminuted patellar fractures accompanied by coronal split articular and inferior pole fragments in terms of anatomical reduction and stable fixation of articular fragments without risk of avascular necrosis.

Keywords: *Comminuted patellar fracture, Coronal split articular fragment, Inferior pole, Articular fragment detachment*

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Patellar fractures account for 0.5%–1.5% of all skeletal injuries, and comminuted fractures comprise 55% of all surgically treated patellar fractures.[1-3] Direct impact of the kneecap with the ground frequently results in a comminuted fracture of the patella, consisting of a main superior fragment, intercalary-type coronal split articular frag-

ments, and an inferior pole. While fixation of the inferior pole of the patella is possible using a plate, a separate vertical wiring technique, a tension-band method, and the inherent weakness of the inferior pole fragment makes it difficult to achieve sufficient stability and sound restoration of the extensor mechanism of the knee joint with allowance for early range of motion (ROM).[4-13] Although various surgical methods have been reported for the treatment of comminuted patellar fractures, stable fixation of the coronal split articular fragment is still challenging, even after open reduction.

A recent study analyzed the pattern of fracture lines in 66 multifragmentary patellar fractures using 3-dimensional computed tomography (CT) mapping and reported that coronal split fragments and inferior pole fractures occurred simultaneously in most cases.[14] Cases with small coronal split articular fragments may be managed as inferior pole fractures. In cases with substantially large fragments, achieving both anatomical reduction and stable fixation is mandatory. However, it is challenging to handle the coronal split articular fragment because it is an intercalary fragment between the superior and inferior poles and is usually attached to the inferior pole (Fig. 1).

To address this difficulty, we perform an articular detachment technique; open reduction of the articular surface by detaching the coronal split articular fragment from the inferior pole fragment. The fragment is then fixed to the superior main fragment. After that, the complex fracture pattern is converted into a simple pattern (inferior pole fracture). The remaining inferior pole is subsequently fixed with a separate fixation construct, such as separate vertical wiring or a modified tension-band technique. However, a concern exists about avascular necrosis of the coronal split articular fragment due to the possibility of damaging the remaining blood supplies during the detachment procedure. The purposes of this study were to introduce the articular detachment technique for the treatment of comminuted patellar fracture and to evaluate the radiological and clinical outcomes of the technique in comminuted patellar fractures at least 1 year after surgery. This technique was inspired by the on-table reconstruction technique of comminuted radial head fractures.[15]

METHODS

The study was approved by the Institutional Review Board of Gangnam Severance Hospital (IRB No. 3-2023-0119) and was conducted in accordance with the Declaration of Helsinki. The requirement for informed consent was waived due to the retrospective nature of the study. From January 2019 to June 2022, we included 15 consecutive patients diagnosed with comminuted patellar fractures (AO/Orthopaedic Trauma Association [OTA] classification 34C3) accompanied by a coronal split articular fragment based on preoperative CT who underwent the articular detachment technique. The inclusion criteria were age 18 years or older, an acute displaced patellar fracture, and a minimum follow-up duration of 1 year. Exclusion criteria included pathological fracture, a preexisting stiff knee before recent trauma, and revisional surgery for failed patellar fracture fixation. Additionally, patients with total knee arthroplasty or severe patellofemoral cartilage defect due to degenerative osteoarthritis were excluded.

Surgical Method

Under general anesthesia, the patient was positioned on a radiolucent table in the supine position with the affected knee at 30° of flexion. A conventional midaxial-longitudinal approach was used. The main transverse fracture line between the superior and inferior poles was identified, and the fracture site was cleaned. The coronal split articular fragment was detached from the inferior pole. With

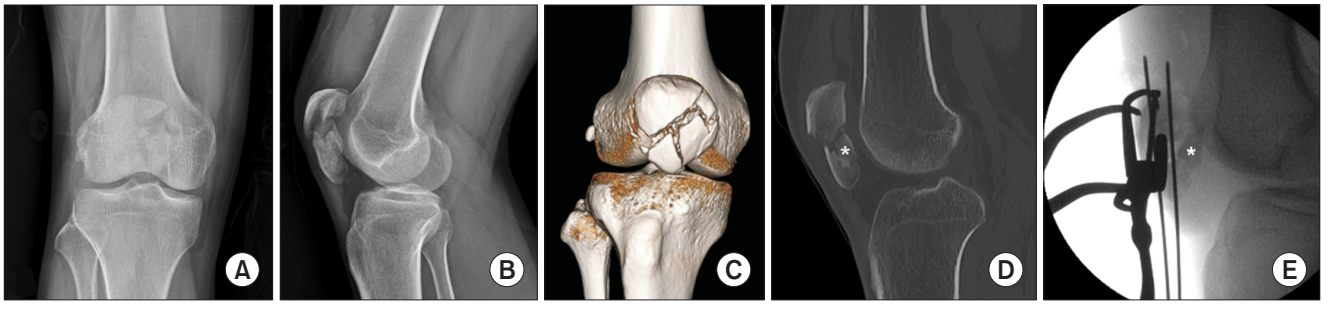

Fig. 1. (A-C) A 34-year-old man had a comminuted patellar fracture. (D) Preoperative computed tomography (CT) sagittal image. The impacted coronal split fragment is shown on the preoperative sagittal CT image. The white asterisk indicates the coronal split fragment. (E) Two parallel K-wires are inserted using tension-band wiring. Longitudinal compression of the fracture with a Weber clamp causes displacement of the coronally split articular fragments (white asterisk).

the knee fully extended, the superior main fragment was everted, and the articular surface of the coronal split fragment was reduced to the superior pole under direct vision. If this was not possible, the retinaculum on the superior pole was partially incised, as required. After anatomical reduction of the articular surface, compression was applied to both fragments using a Weber clamp. Based on the fracture pattern of the inferior pole, we determined the implant insertion points for subsequent fixation of the inferior pole beforehand and avoided these points when performing fixation of the articular fragment. Subchondral fixation of the superior pole and coronal split articular fragment was performed using Kirschner wires (K-wires) or headless screws (Fig. 2). The number of K-wires or screws used was determined based on the width of the coronal split articular fragments. When inserting 2 or more K-wires, we aimed for a slightly divergent fixation rather than parallel if possible. The remaining inferior pole and other comminuted satellite fragments were fixed using separate fixation constructs (Fig. 3). In all cases, a stable fixation status was confirmed by fully flexing the knee before wound closure.

Allowing for an ROM of up to 90° of flexion, isometric quadriceps strengthening exercises and partial weight-bearing ambulation with a full extension brace were initiated immediately after the operation. Tolerable weight-bearing ambulation without a brace (up to full weight) and full ROM of the knee joint were allowed after a postoperative period of 6 weeks. Patients were followed up at 2, 6, 12, and 24 weeks postoperatively and then at 6-month intervals thereafter.

Radiological and Clinical Assessments

Electronic medical records and radiographs were reviewed

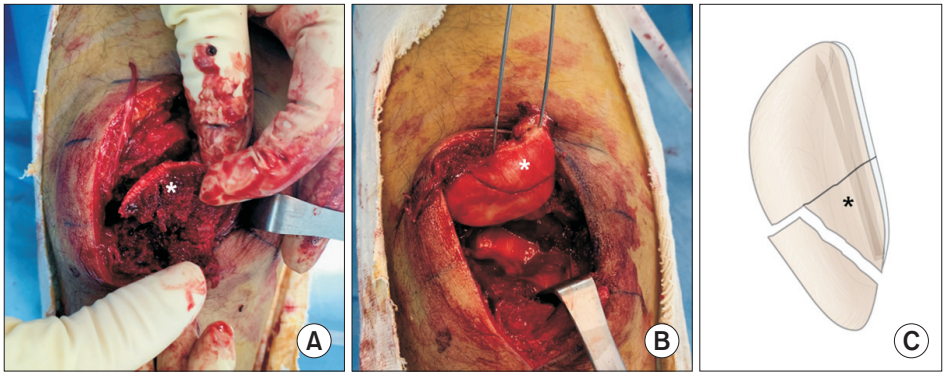

Fig. 2. Fixation of the coronal split articular fragment after complete detachment from the inferior pole fragment. The patient is identical to the one described in Fig. 1. The asterisks indicate the coronal split fragment. (A) Coronal split articular fragments detached from the inferior pole fragment. (B) Under visibility of the articular surface, the coronal split articular fragment is reduced and fixed to the superior pole using 2 Kirchner wires. (C) Surgical method.

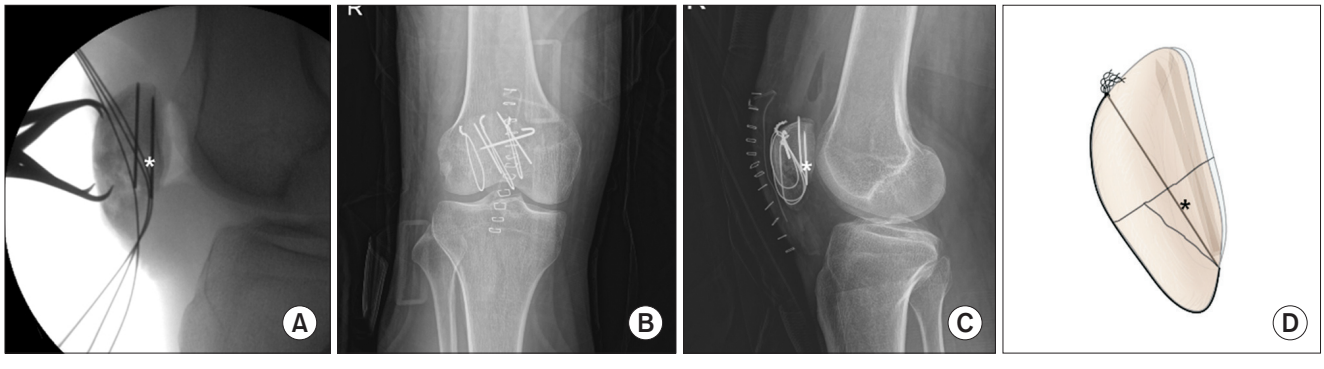

Fig. 3. Fixation of the remaining inferior pole and satellite fragments. This case is identical to those described in Figs. 1 and 2. The asterisks indicate the coronal split fragment. (A) Intraoperative fluoroscopic lateral knee images. The remaining inferior pole fragment is fixed to the superior main fragment using a separate vertical wiring technique. (B, C) Postoperative radiographs show anatomical reduction and stable subchondral fixation of the coronal split articular fragment. (D) Surgical method.

for the following data: age, sex, injury mechanism, open fracture, type of coronal split articular fragment (impacted or nonimpacted), proportional ratio of the size of the coronal split articular fragment to the total articular surface, and operative methods for the articular fragment and the inferior pole. The proportional ratio of the coronal split articular fragment size to the total articular surface size was measured on the sagittal CT image with the largest coronal split articular fragment size. Postoperative articular gap and step-off were measured using immediate postoperative lateral radiographs of the knee. Bone union was defined as the absence of fracture lines and the presence of continuous bony trabecular patterns on plain radiographs.[4] We investigated clinical complications such as surgical site and wound problems. Radiological complications, including resorption, reduction loss, and avascular necrosis of the articular fragment, were assessed on all serial radiographs until the final follow-up. All radiological measurements were performed by an orthopedic surgeon who did not participate in the treatment (DK) and were calibrated using a known implant size. The ROM and Lysholm scores were evaluated postoperatively for clinical outcomes after 1 year.

RESULTS

All patients were followed up for a minimum of 1 year (range, 12–18 months). The average age was 62.2 ± 12.3 years (range, 34–80 years), and the cohort comprised of 4 men and 11 women. Of the 15 patients, 4 sustained high-energy injuries, while 11 had low-energy injuries. One patient had an open fracture.

The type of coronal split articular fragments on preoperative CT scans were of the impacted type in 10 patients and the nonimpacted type in 5 patients. The average proportional ratio of the size of the articular fragment to the total articular surface was 44.9% ± 5.6% (range, 36.5%–54.2%). Coronal split articular fragments were fixed using 1 K-wire in 2 patients, 2 K-wires in 8 patients, 3 K-wires in 3 patients, and 2 headless screws in 2 patients. The inferior pole was fixed using a separate vertical wiring technique in 13 patients and a modified tension-band wiring method in 2 patients. Other satellite fragments on the lateral and medial sides were fixed with additional K-wires as needed. On immediate postoperative lateral knee radiographs, postoperative articular gaps were observed in 7 patients, with a mean articular gap of 1.0 mm (range, 0.7–1.6 mm) (Fig. 4). No postoperative articular step-off was observed.

Radiological union was achieved 12 weeks postoperatively in all patients except 1. This patient had uncontrolled diabetes mellitus, and union was confirmed 24 weeks postoperatively. Full ROM was achieved in all the patients within 12 weeks of surgery. No clinical complications, such as surgical site infections or wound problems, were noted in all patients. At the 1-year postoperative follow-up, resorption of the articular fracture site was seen in the lateral radiographs of 5 patients (range, 0.7–2.8 mm). No loss of reduction or avascular necrosis was observed in the coronal split articular fragments. Three patients had patellar elongation due to mild displacement of the inferior pole without extension lag. The average Lysholm score at 1 year postoperatively was 89.3 ± 4.1 (range, 82–95), with 7 patients, 7 patients, and 1 patient having excellent, good, and fair scores, respectively.

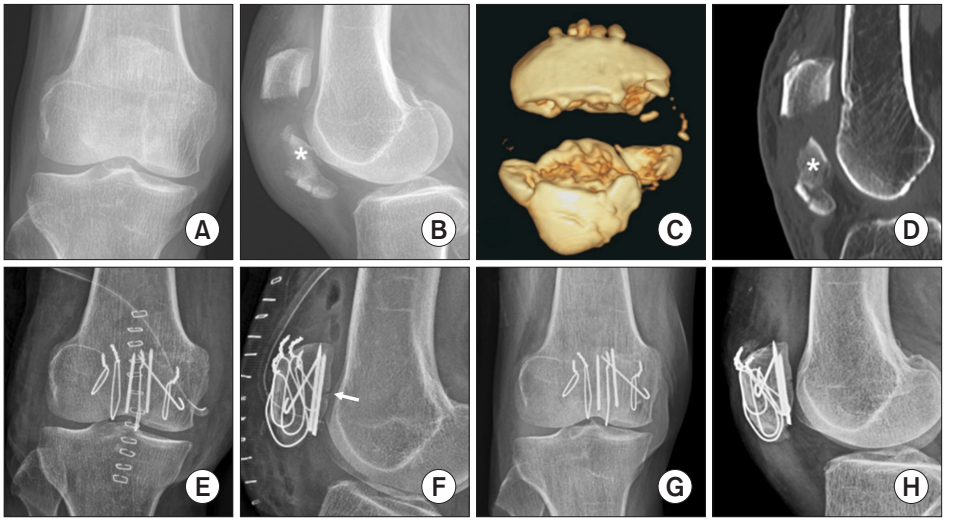

Fig. 4. Postoperative articular gap. (A-D) A 80-year-old woman had a comminuted patellar fracture accompanied by a coronal split articular fragment. The white asterisk indicates the coronal split fragment. (E, F) Separate fixation of the coronal split articular fragment and inferior pole. Immediate postoperative radiographs showing a minimal articular gap (white arrow). (G, H) On the 1-year postoperative radiographs, the articular gap was still visible, but bone union was achieved without loss of reduction or avascular necrosis of the articular fragment.

DISCUSSION

The strengths of our technique are the ability (1) to achieve anatomically stable fixation of articular fragments under direct vision and (2) to simplify the complex fracture pattern. In addition, the technique is simple because it is performed using a conventional approach for patellar fracture. After anatomical reduction and fixation of the articular surface, the inferior pole of the patella (nonarticular portion) can be attached to the main fragment using a separate fixation construct such as separate vertical wiring, modified tension-band wiring, or plating. In the current study, there were no signs of avascular necrosis of the coronal split articular fragment at the minimum follow-up period of 1 year after surgery. Bone union and full ROM were observed in all patients.

Coronal split articular fragments are usually attached to the inferior pole fragment, and some cases show bony impaction between the fragments. Each fragment has a separate goal. The coronal split articular fragment is an intra-articular fragment, and both anatomical reduction and stable fixation should be performed, whereas the inferior pole fragment is associated with the extensor mechanism of the knee joint. To address these complicated fractures, we treated both fragments separately using a simple midline approach. Detachment of the coronal split articular fragment from the inferior pole is easily performed in most cases. Subchondral fixation with embedded K-wires or headless screws is performed to fix the coronal split articular fragments. Embedded K-wire fixation is effective in treating free articular fragments in comminuted intra-articular fractures.[16,17] Owing to the visibility of the articular surface, implants were safely inserted into the subchondral area without articular penetration. Additionally, considering the subsequent fixation of the inferior pole fragment, it is important to determine the implant insertion location. Two embedded K-wires with slight divergent angles are preferred to achieve greater stability and reduce interference. In our study, fixation of the inferior pole fragments was conducted with separate vertical wiring in most cases, and it is an efficient and inexpensive method. The separate vertical wiring technique has been used to fix comminuted fractures of the inferior pole of the patella in our clinic for more than 20 years.[12] The number of vertical wires depends on the severity of inferior pole fragment comminution. Augmentation with a cerclage wire or nonabsorbable suture is recommended for highly comminuted fractures, especially in older patients, to achieve stable fixation and early ROM exercise.[9]

Interestingly, although the articular cartilage was perfectly reduced without any apparent gap during surgery, postoperative radiographs revealed a minimal articular gap in 7 patients. This is presumed to be the result of partial bone loss at the fracture site during injury and no step-off was observed in all cases. The inferior pole fragment has a dual blood supply from the midpatellar and polar vessels that enter the bone posterior to the origin of the patellar ligament.[18] Therefore, the inferior pole has a lower necrosis rate than the superior pole. However, after complete detachment of the coronal split articular fragment from the inferior pole, there is a possibility of injury to the interosseous blood supply from the polar vessels, resulting in a risk of avascular necrosis. In the current study, one-third of the patients had minimal resorption of the articular fracture site. We believe that this was not clinically significant because bony resorption at the articular fracture site is not unusual following fixation for simple transverse patellar fractures. In addition, no signs of avascular necrosis in the coronal split articular fragment were observed at the minimum follow-up of 1 year after surgery. However, additional studies with larger sample sizes are required to confirm the safety of this technique in terms of the risk of avascular necrosis.

This study has some limitations. First, the study was retrospective in nature and had a small sample size owing to the rarity of this fracture type. However, all consecutive patients who underwent this technique performed by a single trauma surgeon during the study period were included. Second, the follow-up period was only 1 year; therefore, medium-to-long-term outcomes were not available.

In conclusion, the articular detachment technique can be a reliable and safe option for the surgical treatment of comminuted patellar fractures accompanied by coronal split articular and inferior pole fragments in terms of anatomical reduction and stable fixation of articular fragments without risk of avascular necrosis.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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