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Reconstruction of large bone defect using autogenous fibular strut and iliac bone graft for revision total elbow arthroplasty

Yoon Min Lee, MD, PhD, Soo Hun Son, MD, Yoo Joon Sur, MD, PhD, Seok Whan Song, MD, PhD*

Abstract

The stability and longevity of the prosthesis after revision total elbow arthroplasty (TEA) are greatly influenced by the reconstruction of bone defects around the distal humerus and proximal ulna. This study evaluated the clinical and radiological results of reconstruction of a large bone defect using an autogenous fibular strut and iliac bone graft in revision TEA.

This retrospective study reviewed 10 patients who underwent revision TEA with autogenous fibular strut and iliac corticocancellous bone graft between March 2007 and May 2016. Range of motion (ROM), Visual Analog Scale (VAS), and Mayo Elbow Performance Score (MEPS) were used to evaluate clinical outcomes at the final follow-up. Plain radiographs were reviewed for bone union and the presence of re-loosening or for the presence of peri-prosthetic fractures.

At the final follow-up, the ROMs of the elbow was 102.5° (range, 90–120°) from extension to flexion, 60.0° (range, 40–80°) in pronation, and 58.5° (range, 35–80°) in supination. The mean preoperative VAS and MEPS were 5.1 and 46.5, and theses scores were improved to 2.6 and 79.0, at the final follow-up ($P < .05$). Union of the grafted bone with the distal humerus was achieved at an average of 4.5 months (range, 3–6 months). Re-osteolysis recurred in 2 cases, and additional surgery for bone grafting was performed in 1 case.

Autogenous fibular strut bone grafting is an effective technique when revision TEA has large bone defects around the prosthesis resulting in a relatively stable prosthesis fixation and good union rate with a satisfactory clinical outcome after TEA revision.

Abbreviations: MEPS = mayo elbow performance score, ROM = range of motion, TEA = total elbow arthroplasty, VAS = Visual Analog Scale.

Keywords: autogenous fibular strut, bone defect, bone graft, revision, total elbow arthroplasty

1. Introduction

Total elbow arthroplasty (TEA) shows a relatively higher failure rate compared to replacement arthroplasty for other joints, with a mean failure rate varying from 33% to 94% at 10 years.[1–4] Although the elbow joint is not a weight-bearing joint, the incidence of aseptic loosening of the prosthesis may occur more frequently because the elbow moves not only in the sagittal plane, but also rotates with valgus and varus forces in a semi-constrained prosthesis.[3,5] The main cause of loosening is failure at the bone–cement interface, which results in a massive amount of bone loss at the distal humerus and proximal ulna.[5,6] The amount of bone loss influences the stability and lifespan of the prosthesis, thus creating the need for a revision TEA.[7,8]

Several techniques have been introduced to reconstruct bone defects of the distal humerus or proximal ulna, such as allograft–prosthesis composite, strut allograft, or tumor prosthesis.[2,7,9,10] Autogenous bone grafting for the reconstruction of bone loss during revision surgery can provide good bone healing potential, but is not widely used at present because of concerns about the possibility of donor site morbidity and the small amount of grafted bone mass that can be harvested. On the other hand, an allograft can provide a large bony mass for the defect, whereby it has the possibility of a delayed or non-union between the host and grafted bone, resorption of the allograft, or even the possibility of infection.[5,11]

The purpose of this study was to introduce an autogenous fibular strut and iliac corticocancellous bone graft to reconstruct a large bone defect in revision TEA and to report the clinical and radiologic outcomes.

2. Materials and methods

2.1. Patients and data processing

After approval of the Institutional Review Board (SC18RESI0004), a retrospective review of the medical records

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

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Table 1

Patients demographics.

Case	Sex/Age(y)	Reason for initial TEA	Prior implant	Reason for revision	Time from initial TEA to revision (y)
1	F/31	Elbow contracture	Coonrad-Morrey	Aseptic loosening	10
2	M/46	Traumatic arthritis	Kudo	TB infection	2
3	F/41	RA	Pritchard-Mark II	Aseptic loosening	8
4	F/57	RA	Coonrad-Morrey	Aseptic loosening	8
5	M/48	RA	Pritchard Mark II	*S. aureus* infection	27
6	M/67	Traumatic arthritis	Kudo	Aseptic loosening	5.5
7	F/63	Osteoarthritis	Kudo	Infection	12.5
8	F/62	RA	Kudo	Aseptic loosening	11
9	F/76	Osteoarthritis	Pritchard Mark II	Aseptic loosening	5.5
10	F/52	RA	Coonrad-Morrey	Aseptic loosening	25

RA = rheumatoid arthritis, S. aureus = staphylococcus aureus, TB = tuberculosis, TEA = total elbow arthroplasty.

of 10 cases of revision TEA between March 2007 and May 2016 was performed. The patients comprised 3 men and 7 women with a mean age of 54.3 years (range, 31–76 years). The mean follow-up period was 8.2 years (range, 3.5–11 years). Ten patients underwent revision TEA with autogenous fibular strut bone and iliac corticocancellous bone graft using a semi-constrained Coonrad-Morrey implant (Zimmer, Warsaw, IN, USA). The mean time from primary TEA to revision surgery was 11.45 years (range, 2–27 years). The revision TEA was performed in 3 patients who had periprosthetic infection and in 7 patients with aseptic loosening of the prosthesis. Three patients (case numbers 4, 8, and 10) had already undergone the first revision surgery without bone grafts; therefore, autogenous bone grafting was performed during the second revision surgery (Table 1).

2.2. Operative technique

The revision surgeries were performed at a single institute and by a single surgeon (S.W.S.). For cases of infected TEA, revision surgery was performed in 2 stages. In the first operation, the prosthesis and bone cement were removed, and the infected soft tissues and bone were thoroughly debrided. A bridging fixator was applied from the mid-humeral to the mid-ulnar shaft (Fig. 1). For the subsequent 6 weeks, we prescribed intravenous or oral antibiotics, as appropriate for the infected organism. Then we educated patients self-dressing technique so that they could prevent infection of the pin sites, and after 3 months, the external fixator was removed under local anesthesia. Patients wore an elbow brace (limited motion brace) before revision surgery. Laboratory results, including erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP), were monitored with radiologic improvement for 3 months. For patients infected with TEA by *Staphylococcus aureus,* revision surgery was performed for 6 months with normalized ESR and CRP levels, and consolidation of lytic bones on plain radiographs. In the case of tuberculosis infection, revision surgery was performed after 9 months because of the prolonged use of anti-tuberculosis medication. One patient with infected TEA who was unable to identify the pathogen due to previous treatment with antibiotics and surgical debridement at another hospital, we performed revision surgery 3 months after the first surgery. For the 7 cases affected by aseptic loosening, we performed a one-stage revision TEA.

During the revision surgery, the patient was placed in the supine position with a sandbag under the scapula, and a pneumatic tourniquet was applied around the upper arm. The affected arm was placed over the chest with the elbow flexed at 90°. A curvilinear long skin incision was made, including the previous scar, centered just lateral to the tip of the olecranon. The ulnar nerve was identified and transposed anteriorly in the subfascial method for patients who underwent initial TEA at other hospitals. Exploring the ulnar nerve was not necessary for

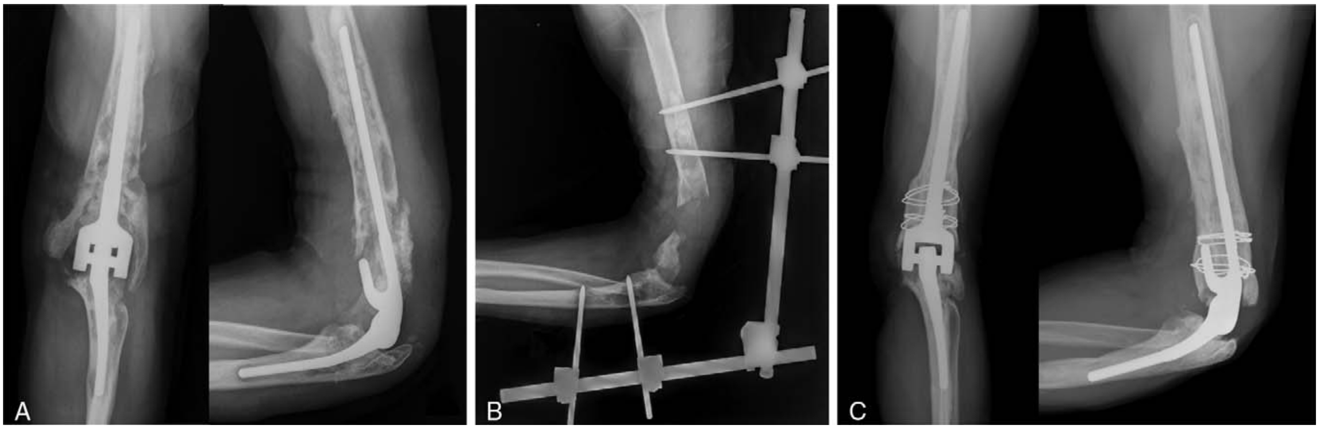

Figure 1. A case of infected prosthesis. (A) Initial AP and lateral plain radiographs of the left elbow show osteolysis around the humeral stem and bone–cement interface. (B) Application of an external fixator following implant removal. (C) Six years after revision surgery, the grafted bone showed union with the humerus forming tubular bone around the stem.

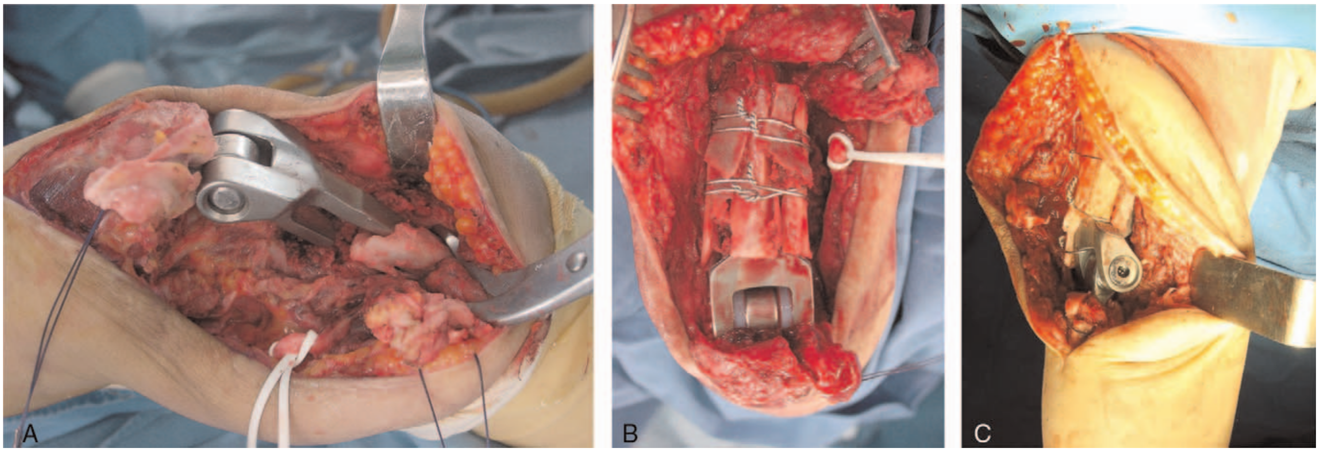

Figure 2. The surgical procedures. (A) Insertion of revision implants in the appropriate position after calculating bone loss. (B & C) Grafting of bisected fibular strut bones to medial and lateral aspect of the humeral stem fixed with cerclage wiring and additional autogenous iliac corticocancellous bones.

patients who had an initial TEA at our hospital because the ulnar nerve had previously been transposed anteriorly. The elbow joint was exposed using a triceps-reflecting approach, in which the triceps tendon was identified and incised using the chevron method. The triceps were then retracted distally to expose the distal humerus, proximal ulna, and radial head.[12]

Before inserting the revision implants, we harvested the fibular bone from the contralateral lower limb and corticocancellous bones from the contralateral iliac crest. The fibular bone was cut longitudinally into 2 long struts. The harvested iliac bone (cortical portion) was then shaped into several sticks, each 3-cm in length, and sufficient cancellous bone was also prepared. Revision surgery was performed using a long-stem Coonrad-Morrey implant. The revision implants were inserted using antibiotic-mixed bone cement (Fig. 2A), except for the distal portion of the humerus stem, because the cement may disturb the union of the grafted bone. The fibular struts were placed parallel to each other at the site of the cortical defect in the distal humerus as 2 columns. Additionally, the prepared iliac bones were grafted the into unfilled spaces between the fibular struts. The grafted bones were fixed using 3or 4 cerclage rings (Fig. 2B, C). Finally, the reflected triceps tendon was repaired.

2.3. Postoperative rehabilitation

Postoperatively, a long arm splint was applied for 6 weeks, and a short leg splint was applied for 2 weeks for the leg where the fibula was harvested. We recommend gentle passive range of motion (ROM) exercise after removal of the splint with a functional brace for the next 6 weeks. Three months postoperatively, patients were allowed to move their elbow in light daily, such as eating, reading, or changing clothes, and lifting things less than 2 lb for repetitive lifting and less than 10 lb for a single lift to prevent re-loosening.

2.4. Clinical assessment

Postoperatively, the patients visited the hospital at 2 weeks, 1 month, 2 months, every 2 months until 1 year, and then annually for follow-up evaluations with the same orthopedic doctor. ROM of the elbow joint was checked in the following planes: flexion, extension, pronation, and supination. For clinical assessment, the visual analog scale (VAS) and Mayo Elbow Performance Score (MEPS) were evaluated preoperatively and at the final follow-up. Neurological complications, elbow extension power (graded by the Medical Research Council scale), and intraoperative humeral fractures were also assessed for the presence of complications.

2.5. Radiologic assessment

To evaluate radiological outcomes, 2 orthopedic surgeons assessed the anteroposterior, lateral, medial, and lateral oblique radiographs of the elbow at the final follow-up. The time to union between the grafted bone and humerus, presence of prosthesis re-loosening, and periprosthetic fractures were assessed.

2.6. Statistical analysis

SPSS version 21.0, for Windows (SPSS Inc., Chicago, IL) was used for statistical analyses. The Wilcoxon signed rank-sum test was used to assess the differences between preoperative and postoperative changes in ROM, VAS, and MEPS scores. A P value less than .05 was considered at P statistically significant.

3. Results

3.1. Clinical outcomes

Preoperatively, the mean total ROM of the elbow was 63.0° (range, 20–100°), mean extension was 46.5° (range, 20–80°), mean flexion was 109.5° (range, 90–120°), mean pronation was 36.5° (range, 10–60°), and mean supination was 35.0° (range, 10–60°). At the last follow-up, the mean total ROM of the elbow was 102.5° (range, 90–120°), mean extension was 25.5° (range, 15–35°), mean flexion was 128.0° (range, 115–135°), mean pronation was 60.0° (range, 40–70°), and mean supination was 58.5° (range, 35–80°). The mean VAS scores decreased from 5.1 (range, 4–7) preoperatively to 2.6 (range, 1–4) at the final follow-up ($P < .05$). The mean MEPS score improved from 46.5 points (range, 40–60 points) preoperatively to 79.0 points (range, 60–90 points) at the final follow-up ($P < .05$) (Table 2).

Table 2

Clinical outcomes.

		Extension		Flexion		Pronation		Supination		VAS		MEPS	
Case	Sex/Age	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	F/31	80	25	110	125	30	70	30	60	4	3	40	80
2	M/46	60	35	120	130	20	40	20	40	5	3	45	90
3	F/41	30	25	120	135	40	50	40	50	5	1	60	85
4	F/57	20	25	125	130	60	40	50	35	5	3	45	80
5	M/48	30	25	90	125	45	80	50	80	5	2	40	80
6	M/67	25	30	90	120	45	50	30	50	6	3	45	75
7	F/63	20	15	120	135	45	80	50	80	6	2	45	80
8	F/62	80	25	100	130	20	80	20	80	4	3	45	75
9	F/76	80	25	100	115	10	40	10	50	7	4	40	60
10	F/52	40	25	120	135	50	70	50	60	4	2	60	85

MEPS = mayo elbow performance score, VAS = visual analog scale.

3.2. Radiological outcomes

The mean preoperative length of bone loss of the distal humerus was 6.11 cm (range, 1.5–9 cm). The mean length of harvested fibula was 12.4 cm (range, 5–21 cm). In average, evidence of bone union between the grafted and host bone was observed 4.5 months (range, 3–6 months) after the operation, and integration and remodeling of the grafted bone was completed at 11.2 months (range, 6–18 months) in average (Table 3). Fracture of the humeral shaft occurred in 2 patients while removing the humeral stem and bone cement and was treated using additional wiring (Fig. 3A and B). The fracture was united without additional surgical procedures and was united at the same time as the union of the grafted bone and the host bone (Fig. 3C). At the final follow-up, the bone–cement interface did not change in three patients, shallow radiolucent lines around the prosthesis were identified in 5 patients, and re-osteolysis occurred in 2 patients. One patient with progressive re-osteolysis underwent re-revision surgery for an allogenic bone graft with plate fixation (Fig. 4).

3.3. Complications

The triceps function was grade V in 2 patients, grade IV in 7 patients, and III in 1 patient according to the Medical Research Council scale. A patient who underwent revision TEA due to

Table 3

Radiologic outcomes.

Patient	Sex/Age	Preoperative bone loss (Humerus, cm)	Length of harvested fibula (cm)	Time to bone union (month)	Remodeling time (month)
1	F/31	8.6	18	5	12
2	M/46	9	21	6	18
3	F/41	8	15	4	13
4	F/57	4.5	8	3	6
5	M/48	1.5	5	4	8
6	M/67	4.5	10	5	14
7	F/63	6	12	5	7
8	F/62	8	15	5	12
9	F/76	7	12	4	12
10	F/52	4	8	4	10

Figure 3. A case with aseptic loosening. (A) Initial AP and lateral radiographs showing osteolysis of the distal humerus and proximal ulna. (B) Postoperative radiographs after TEA revision with an autogenous fibular strut bone and iliac bone graft. (C) At the 5-year follow-up, the implant was stable and the grafted bone had remodeled into tubular bone.

Figure 4. A case with re-loosening after revision TEA. (A) Preoperative AP and lateral views. (B) Six months after revision surgery, re-osteolysis at distal humerus was occurred. (C) Re-revision was performed by allogenic distal humerus and fixed with plate and screws.

elbow contracture after burn scar had repetitive low-grade infection and resultant soft tissue defect; the defect was covered by a latissimus dorsi free flap. Two patients had radial nerve palsy after the operation and recovered spontaneously within 6 months (Table 4).

4. Discussion

TEA has a relatively high failure rate, which can occur much sooner than other replacement arthroplasties such as the knee, hip, and shoulder joint.[1–5] As failed TEA is accompanied by a large amount of bone loss around the elbow joint, reconstruction of the defect is the most important and challenging factor to achieve successful outcomes in revision TEA. Furthermore, infection of the prosthesis gives rise to extensive bone resorption rather than aseptic loosening, so it is even more difficult to reconstruct the massive bone loss in revision surgery for infected TEA.[13–16]

For the reconstruction of large bone defects in revision TEA, several methods can be considered, such as tumor prosthesis, allograft–prosthesis composite, autogenous bone graft, arthrodesis of the elbow, and resection arthroplasty.[1,14,17–19] Revision TEA using allograft–prosthesis composite can provide a large bone mass without morbidity at the donor site and show relatively good clinical outcomes.[10,11,18] However, the composite graft technique has several potential problems, such as prolonged union time or nonunion between the allograft and the host bone, resorption of the grafted bone, or periprosthetic infection.[11] To prevent failures involving incorporation of the allograft, rigid fixation between the grafted bone and the host bone is important for successful results. Although the final results of allograft and autograft incorporation might be the same, autografts may have a shorter bone healing time than allografts.[20]

However, it is difficult to maintain the stability of the prosthesis using only the allograft, and several optional procedures can be considered to improve bone union between the graft and the humerus. Rhee et al [15] reported 16 cases of revision TEA treated by impaction grafting with satisfactory results due to rapid bone union and satisfactory filling effects. They also suggested a technique in which the grafted bone could be united with the humerus. As the other technique, Sanchez-Sotelo et al[21] reported the clinical outcomes of a peri-prosthetic fracture which was associated with TEA using an allogenic fibular strut with autogenous trabecular bone grafts. Although they used strut allograft augmentation, strut bone could improve bone stock, high union rates, and implant survival. In our study, the strut fibular bone can also function as a basic skeleton for the medial and lateral columns, and the autogenous iliac bone fills the defect between the 2 strut bones and increases the bone union rate. As described in the surgical techniques, we cut the fibular bone into 2 long struts and placed them parallel to each other to work as medial and lateral columns. Moreover, once the struts of the fibular bone and the iliac corticocancellous bones united and later remodeled into a tubular structure, this could wrap the distal portion of the humeral stem and provide adequate stability for the prosthesis.

If surgeons use allogenic distal humerus, they can restore the original form of the medial and lateral condyles from the flexor and extensor muscles.[7,17] In our study, although we could not reconstruct the original structure of the medial and lateral condyles in revision TEA, there were no cases of significant functional loss of the hand and wrist. Some studies have shown that removal of the medial and lateral condyles during revision surgery confers advantages with respect to the interaction of the humerus-ulna prosthesis, maintenance of soft tissue tension, and wound closure.[2,9,17] In primary TEA, non-anatomic force transmission through the semi-constrained prosthesis results in wear of the bushing or polyethylene and stress shielding at both humeral condyles leading to resorption over time.[5] Therefore, it does not seem necessary to use allogenic distal humerus to reconstruct the normal structure of both condyles.

As we used the long segment of the autogenous fibular bone, concerns about the donor site still remain. Donor-site morbidity of the fibula has been reported in 2% to 38% of cases, including early complications such as cellulitis, wound dehiscence, abscess or hematoma, long-term morbidities with joint stiffness, gait

Table 4

Complications.

Patient	Sex/Age(y)	Tricpes MRC scale	Complications
1	F/31	Grade IV	Recurrent low grade infection
2	M/46	Grade V	-
3	F/41	Grade IV	Humeral fracture during revision surgery-Radial nerve palsy
4	F/57	Grade IV	Humeral fracture during revision surgery Re-loosening
5	M/48	Grade IV	Re-loosening
6	M/67	Grade V	-
7	F/63	Grade IV	Radial nerve palsy
8	F/62	Grade III	Weakness of elbow extension
9	F/76	Grade IV	-
10	F/52	Grade V	-

MRC = medical research council.

abnormalities, lower leg discomfort, sensory deficits of the calf and toes, or muscular weakness.[22–24] However, studies have shown that most patients had no long-term functional loss of the lower extremities following free fibular graft harvesting.[22,24] Although this study involved only a small number of cases, none of our patients complained of lower extremity dysfunction in last follow-up as well. Harvesting bone as needed and using a precise procedure can prevent complications at the donor site.

Given that there was only 1 case of additional surgery for re-loosening after the revision TEA and the other 9 patients maintained the revision prosthesis with relatively good results, we believe that our patients had already experienced a disastrous result following careless use of their initial prostheses, they restricted the use of their elbow by themselves. In addition, these patients were instructed to use the elbow in light activities such as eating, dressing, and reading.

The main limitations of this study are the small number of patients and relatively short follow-up period; moreover, this is a retrospective case series without a comparison group. Because of these limitations, it is difficult to determine true complications and outcome rates. Furthermore, the surgical technique and application of external fixation in the 3 infected cases may have influenced our clinical results. Despite the limitations mentioned above, our study is worth introducing a helpful technique for revision TEA that requires reconstruction of bone defects.

5. Conclusion

TEA revision with autogenous fibular strut and iliac bone grafts improves the bone mass in the distal humerus defect and results in a greater rate of bone union and shorter bone healing time than allogenic bone grafting. Furthermore, this method enables TEA revision using a semi-constrained implant instead of salvage surgery, such as arthrodesis or resection arthroplasty of the elbow, with good clinical results.

Author contributions

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Methodology: Yoon Min Lee, Seok Whan Song.
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Validation: Yoon Min Lee.
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Writing – original draft: Yoon Min Lee.
Writing – review & editing: Yoon Min Lee, Seok Whan Song.

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