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Case Report

Stress fracture after implant removal from the tibia reconstructed by the induced membrane technique: A case report

Eic Ju Lim [a], William T. Kent [b], Seungyeob Sakong [c], Whee Sung Son [c], Jae-Woo Cho [c], Jong-Keon Oh [c,*]

[a] Department of Orthopaedic Surgery, Chungbuk National University Hospital, Chungbuk National University College of Medicine, Cheongju, Republic of Korea
[b] Department of Orthopaedic Surgery, University of California, San Diego, San Diego, CA, United States
[c] Department of Orthopedic Surgery, Korea University Guro Hospital, Seoul, Republic of Korea

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ABSTRACT

Background: The induced membrane technique promotes vascularization and corticalization of the grafted bone and has become one of the mainstays in treatment of segmental bone defects. However, there are clinical concerns regarding the quality of bony consolidation using the induced membrane technique including a thin cortex formation and cortical notching after consolidation. We present the case of a tibial stress fracture in the bone reconstructed by the induced membrane technique after implant removal.

Case: A 49-year-old male presented post-traumatic osteomyelitis of the right tibia and was treated with staged segmental bone resection leading to an 11 cm defect which was reconstructed using the induced membrane technique. The patient requested implant removal at 33 months after bony consolidation. Four months after implant removal, he developed acute, atraumatic leg pain due to a tibial stress fracture caused by small notching in the reconstructed tibial segment. His stress fracture treated with intramedullary nailing and later healed uneventfully.

Conclusion: Caution is warranted prior to implant removal from bone reconstructed by the induced membrane technique as cortical notching may result in stress fractures.

Introduction

A critical-sized bone defect is a defect that will not heal spontaneously without further surgical intervention, such as an autologous bone grafting [1]. There are several well described techniques to address critical-sized segmental bone defects including distraction osteogenesis, vascularized bone graft, and the induced membrane technique [2,3]. The induced membrane technique promotes vascularization and corticalization of the grafted bone and is a two-staged procedure. The first stage consists of cement insertion at the defect to create an induced membrane by foreign body reaction, with second stage of autogenous bone grafting at the defect site after membrane formation [4]. This technique is has become one of the mainstays in treatment of segmental bone defects and favorable outcomes have been reported.

However, there are clinical concerns regarding the quality of bony consolidation using the induced membrane technique including

* Corresponding author at: Department of Orthopedic Surgery, Korea University Guro Hospital, 148 Gurodong-ro, Guro-gu, Seoul 08308, Republic of Korea.
E-mail address: jkoh@korea.ac.kr (J.-K. Oh).

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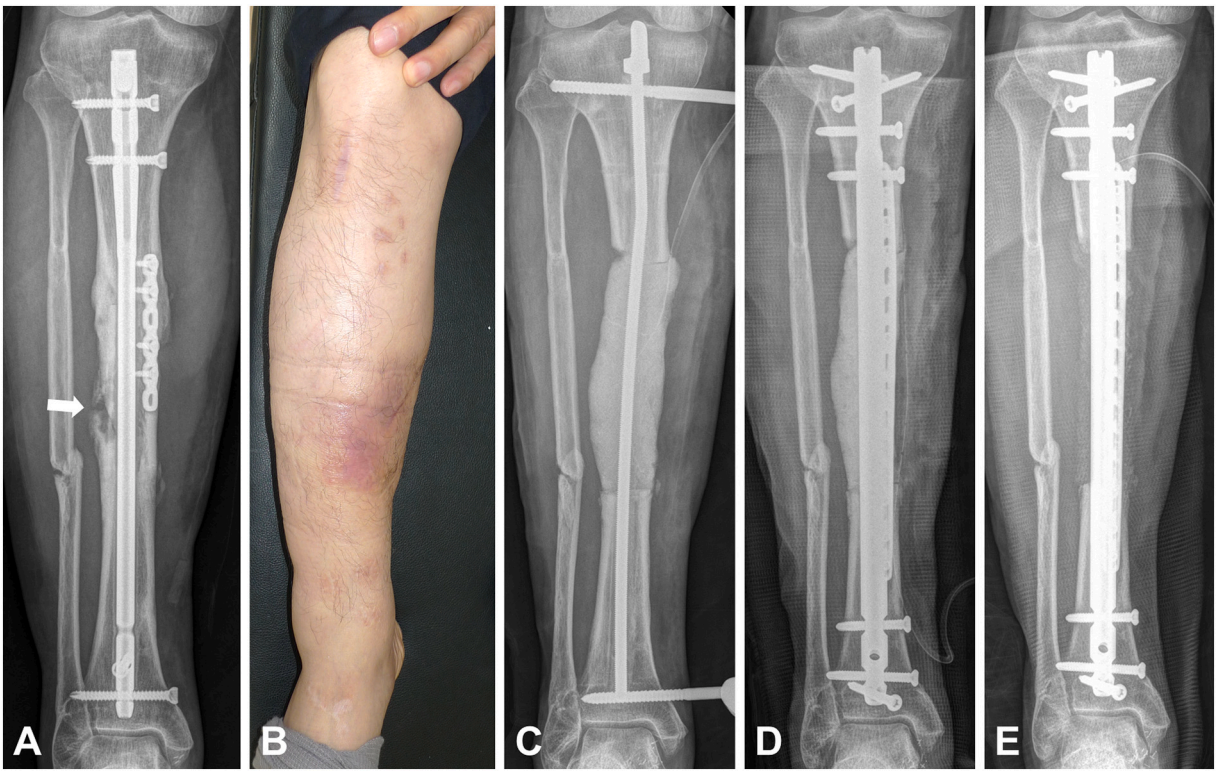

Fig. 1. Treatment process for post-traumatic osteomyelitis (A) Irregular bone resorption at the anterolateral cortex of tibia (white circle); (B) focal redness on the anteromedial side of the right lower leg; (C) segmental resection for post-traumatic osteomyelitis; (D) definitive fixation with cement spacer; (E) autologous bone graft for induced membrane technique.

a thin cortex formation and cortical notching after consolidation. There are many cases of patients with incomplete healing of four cortices (either two or three of four cortices healed on radiographs and CT scan) after bony reconstruction using the induced membrane technique but are symptom free, pain free, and have returned to normal function. Although there is incomplete cortical healing after bony reconstruction, with the implants in place, we have termed this an "implant-dependent union." We present the case of a tibial stress fracture in the bone reconstructed by the induced membrane technique after implant removal.

The patient was informed that their medical data would be submitted for publication, and they consented to the same.

Case report

A 46-year-old male fractured his right tibia while repairing an elevator and underwent open reduction with internal fixation at an outside hospital over three years prior to presentation to our institution. Three years after the initial surgery, he developed pain and erythema in the right leg, for which he was treated with surgical debridement and intravenous antibiotics at the same institution. After persistent infection, he was referred to our institution for treatment of his post-traumatic osteomyelitis of the tibial diaphysis.

On his initial presentation to our institution, physical examination revealed focal warm and erythema (Fig. 1). Plain radiographs of the tibia demonstrated bony resorption at the anterolateral tibial cortex. Labs were significant for an elevated C-reactive protein (CRP) (17.9 mg/L, normal <5.0 mg/L). The patient underwent staged segmental resection of the infected tibia with resection of 11 cm, and the tibia was stabilized with an antibiotic-coated threaded rod as has been previously described [5]. After serial debridements and confirmation of negative intraoperative cultures, a cement spacer was placed and the defect was stabilized with an intramedullary nail and plate construct. After healing of the wounds, normalization of inflammatory markers (sedimentation rate, CRP, white blood cell count), and eradication of the infection, the patient underwent the second stage of the induced membrane technique 8 weeks after first stage. A nice biologic membrane had formed and 68 g of autologous bone was harvested from the left iliac crest (18 g) and left proximal tibia (50 g) and placed at the defect site. Two years after bone grafting plain radiographs confirmed what appeared to be bony union (Fig. 2). CT scan of the tibia revealed a 40 mm long incomplete longitudinal defect under the plate with a varying width of the defect (1–6 mm). We decided to remove the plate and dynamize the nail by removing the interlocking screws in an attempt to stimulate bony healing.

Eighteen months after the dynamization, the width of the longitudinal defect had decreased as seen on the CT scan. A repeat CT scan prior to intramedullary nail removal demonstrated completely healed anterior, posterior, and lateral cortices with cortical continuity, while the medial cortex (the cortex under the plate previously) demonstrated a 3 mm (in width) defect at the center of the

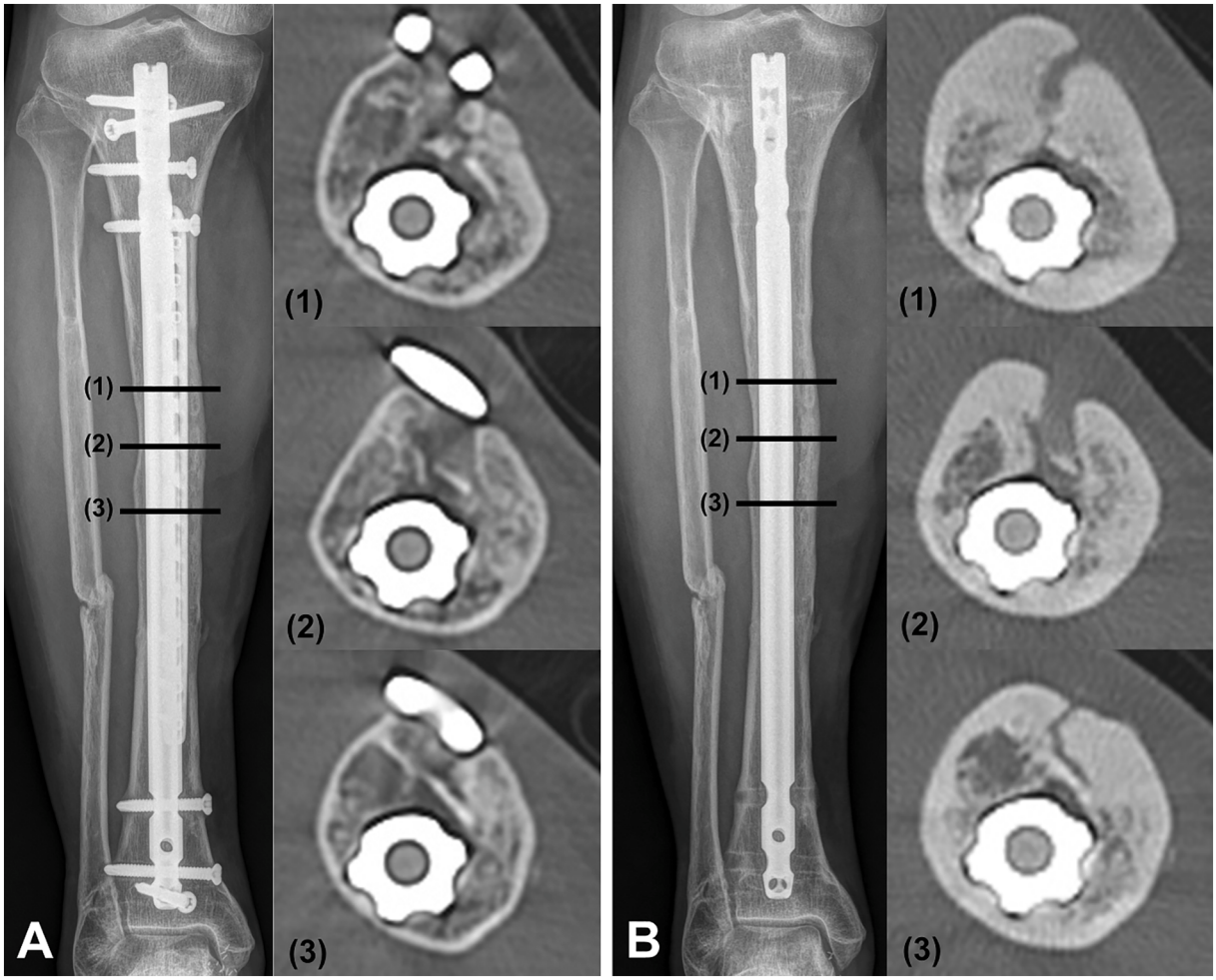

Fig. 2. Corticalization after the induced membrane technique. (A) The range of defect widths two years after the bone graft; (B) narrowed defect at 18 months after the dynamization.

bony consolidation site (a cortical notch) (Fig. 3). Based on patient preference the intramedullary nail was removed after complete union of 3/4 cortices.

Four months after the nail removal, the patient presented in follow up complaining of pain in the right leg without any traumatic event. No signs of infection, such as elevation of inflammatory markers or drainage sinus, were observed. Imaging demonstrated a fracture at the center of the previously noted 'notch' site of the reconstructed bone. This was stabilized with an intramedullary nail without opening the fracture site to preserve the fracture biology (Fig. 4). Postoperatively, the patient was made weight-bearing as tolerated. Three years after nailing, the fracture healed and the notch site completely consolidated. The patient is pain free, has returned to normal activity without restrictions.

Discussion

To our knowledge, this is the first case report describing a tibial stress fracture after implant removal from the bone reconstructed using the induced membrane technique. Our report highlights the importance of planning when considering implant removal after bony reconstruction using the induced membrane technique, especially in presence of cortical notching.

Although stress fractures and bone quality after the induced membrane technique has not been studied widely, in our experience the bony consolidation demonstrates overall lesser cortical thickness than is normally seen. In our study, the induced membrane technique was successful before implant removal because 3/4 cortices demonstrated continuous corticalization and junctional union (Fig. 2). Although notching at the medial cortex was identified on the CT scan pre-implant removal, there was deemed to be sufficient healing to undergo removal of the nail.

Risk factors for stress fractures include mechanical factors (bone density, alignment, and body habitus) and physiological factors (such as bone turnover rate, flexibility, and muscular strength) [6]. In our case, presumably, mechanical factors lead to the stress fracture. The tibial angulation at the fracture site, although minimal, concentrated the bending stresses resulting in the stress fracture.

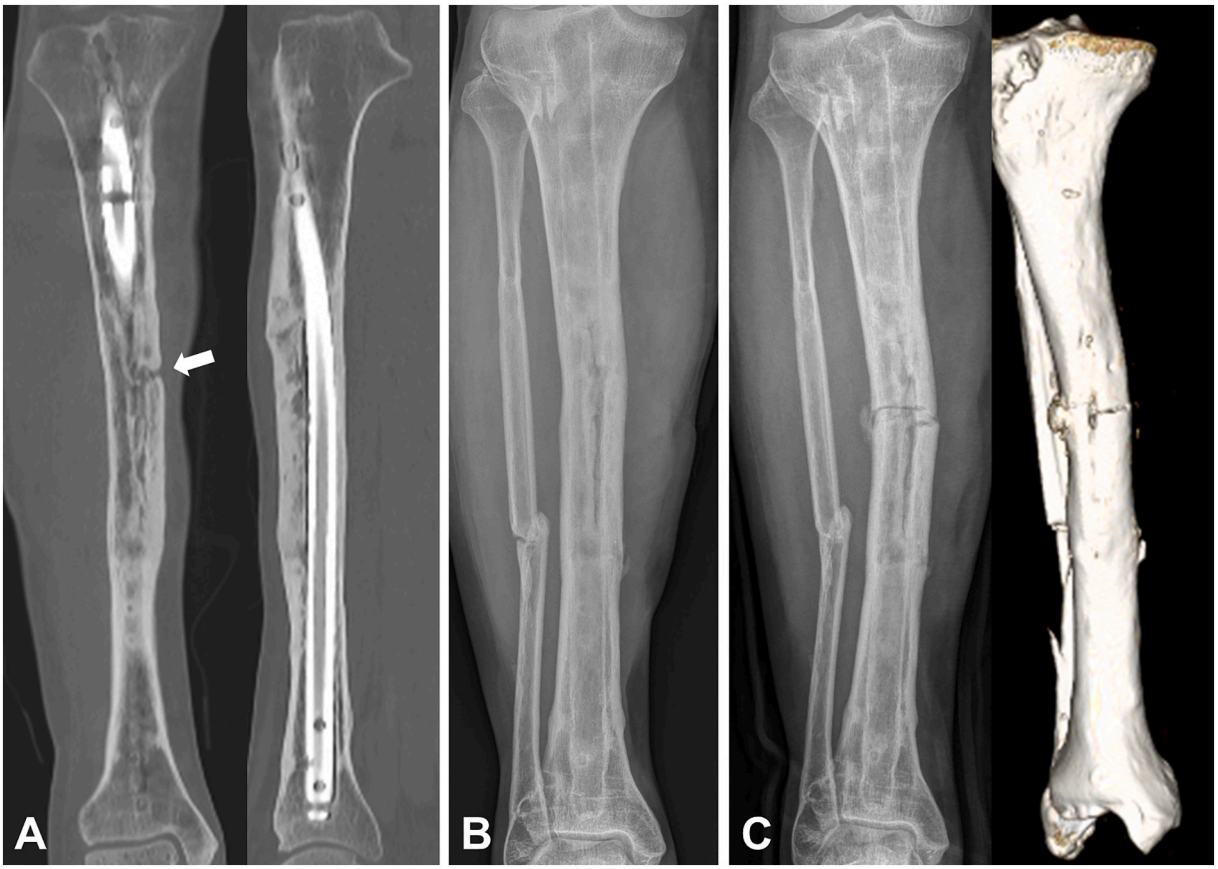

Fig. 3. The sequence of events leading to the stress fracture. (A) Bone union at the anterior, posterior, and lateral cortices, but notching visible on the medial cortex (white arrow); (B) postoperative radiograph after implant removal; (C) stress fracture at the previous notching site and callus formation.

Second, the cortical thickness was uneven and thin in some areas even after dynamization. Lastly, the notching acted as a strong stress-riser based on the fracture location. While there are reports of a stress fractures at a previous screw hole sites, no reports exists for stress fractures at a cortical notch after bone grafting [7,8]. Prior to implant removal, the patient had been asymptomatic with no pain and thus had what we term an "implant dependent union" – where 3 of 4 cortices had healed and the 4th cortex had just enough healing to have no clinical symptoms but was dependent on the nail for stabilization.

The reason for notching in bony formation when using the induced membrane has not been studied, but we propose several hypotheses for this phenomenon. First, damage to or lack of formation of the induced membrane during bone grafting can create defect areas during consolidation. In our experience, insufficient or uneven bony consolidation can occur at the site of opening the induced membrane during the second stage bone grafting. Second, uneven bone grafting placement in the membrane may cause resorption of the grafted bone. As a previous study has demonstrated, defects filled with a combination of autograft and demineralized bone matrix (DBM) have a higher incidence of bony resorption than those filled with purely autograft alone [9]. Thus, notching could theoretically occur at defect sites filled with DBM and autograft. Third, there could be residual low-grade infection. In this case, inflammatory markers and gross wound must be closely observed. Moreover, tissue culture and biopsy could be helpful. In this study, inflammatory markers were not elevated, and the wound was stable 3 years after bone graft. Thus, we did not consider low-grade infection as the cause of notching, and we did not open the fracture site during intramedullary nailing. However, because low-grade infection may be concealed even when the inflammatory markers are negative [10], residual infection should be considered.

In conclusion, as this case demonstrates, bony consolidation after the induced membrane technique should be scrutinized for cortical notching and overall cortical quality and thickness prior to implant removal.

Declaration of competing interest

None.

Fig. 4. Treatment for the stress fracture. (A) Postoperative radiograph of surgical treatment of stress fracture; (B) healed fracture at three years from fixation; (C) consolidation of the notching into a cortex.

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None.

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