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Technical Note

Ankle arthrodesis using a modified Masquelet induced membrane technique for open ankle fracture with a substantial osteochondral defect: A case report of novel surgical technique

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ABSTRACT

Reconstruction of a bone defect using the Masquelet induced membrane technique has been well described. However, there are few reports of arthrodesis using this technique. In this case report, we describe a modified Masquelet technique for ankle arthrodesis with nailing. The patient was a 32-year-old man who sustained an open fracture of the right ankle with a substantial osteochondral defect as a result of a fall. Immediately after the injury, a staged procedure using the Masquelet technique was planned. The bone defect was filled with bone cement in the acute stage, but replacement of the cement was needed 6 months after the injury because of a prolonged inflammatory reaction. Ten months after the injury, the bone cement was removed, and ankle arthrodesis was performed using an IM nail with a combination of autologous and artificial bone. As a modification of the Masquelet technique, the anterior surface of the transplant site was covered with a large but thin layer of cortical bone instead of suturing the incised membrane. At 1 year postoperatively, firm bony union was achieved and the implant was removed. At follow-up 3 years after his injury, the patient is able to walk, undertake physical work, and has no clinical signs of infection. Our experience suggests that a modified induced membrane technique may be useful when treating an open limb fracture with an extensive osteochondral defect where preservation of the joint is difficult and arthrodesis is considered.

Introduction

In recent years, several reports have described bone defect reconstruction surgery using the Masquelet induced membrane technique [1–4]. This technique is a staged surgical procedure that does not require advanced surgical skills, such as microsurgery, and is widely used to repair large bony defects after trauma, resection of bone tumours, and debridement of osteomyelitis. In the first stage, the bony defect is filled with a cement spacer to prevent soft tissue involvement and induce the membrane over the spacer. In the second stage, about 2–3 months later, the induced membrane is incised, the spacer is excised, autologous cancellous bone is grafted, and the incised membrane is re-sutured over the transplant site.

Although the induced membrane technique could also be used for large osteochondral defects, there are few reports of arthrodesis surgery using this method [5–7]. This case report describes a modified Masquelet technique for ankle arthrodesis with nailing and demonstrates use of this strategy in the treatment of a severe open limb fracture with a substantial osteochondral defect.

Case report

A 32-year-old man presented to our emergency department after a fall while cleaning windows. He had an open wound on the lateral side of the right heel, and a large free bone fragment that had fallen onto the ground was brought in with him (Fig. 1). XR showed an unstable ankle fracture with no distal tibiofibular joint. Debridement and spanning external fixation were performed immediately after the injury. Although the free bone fragment was a large piece of osteochondral tissue containing the distal tibiofibular joint, it was discarded because of severe contamination. In view of the open fracture of the right ankle and the extensive osteochondral defect, we planned staged treatment that included ankle arthrodesis using the Masquelet technique.

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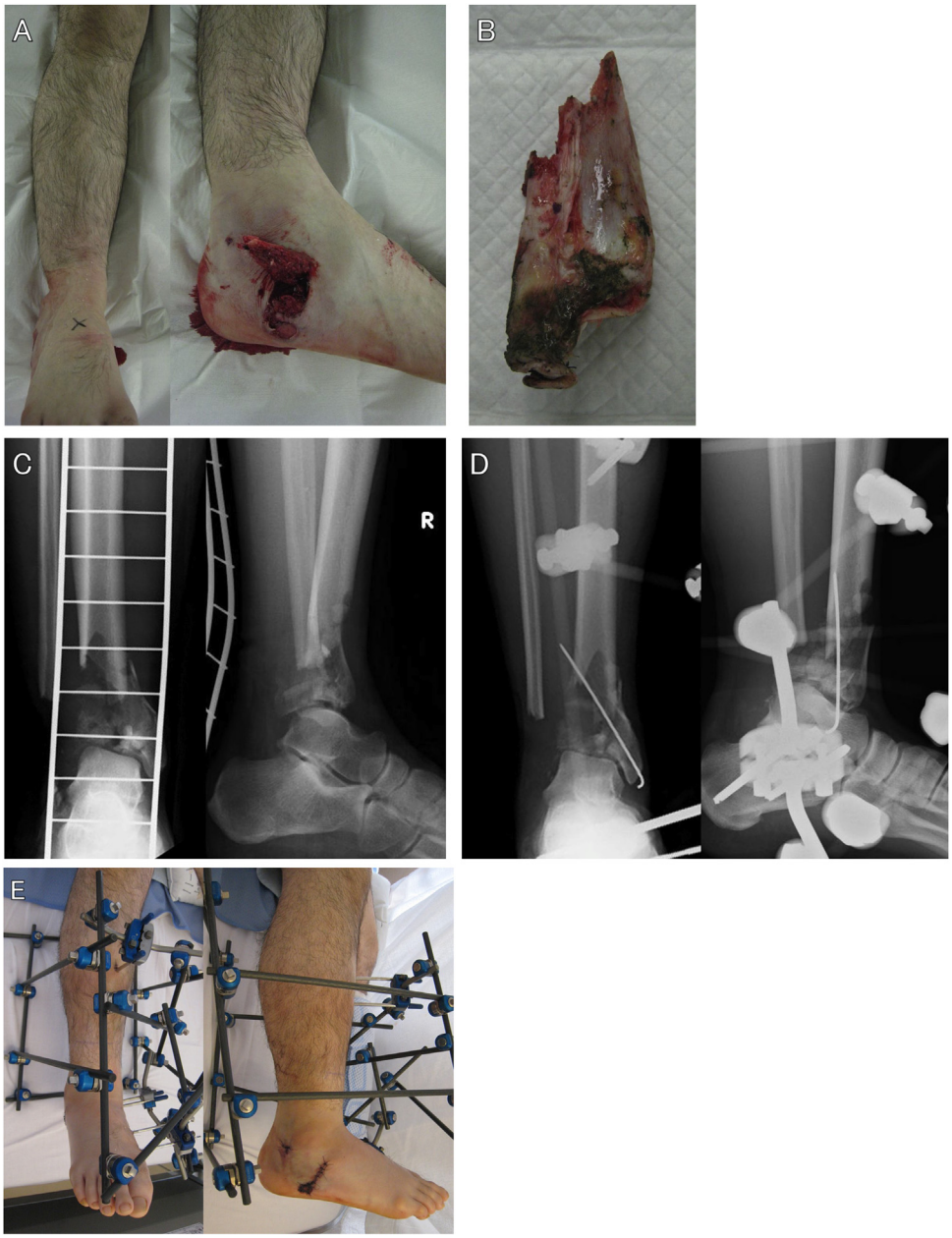

Fig. 1. Images of a 32-year-old man who suffered an open fracture of the right ankle as a result of a fall. (A) An open wound on the lateral side of the right heel identified at the time of presentation. (B) A huge free bone fragment containing the distal tibiofibular joint that had fallen onto the ground at the injury site and was severely contaminated by dirt. (C) Initial XR showed an extremely unstable right ankle with no distal tibiofibular joint. (D, E) Debridement and spanning external fixation was performed as primary care. The medial malleolus was temporarily fixed by a Kirschner wire.

At 2 weeks after the injury, temporary fixation wires were applied and the defect was filled with polymethylmethacrylate (PMMA) antibiotic cement as the first stage of the induced membrane technique (Fig. 2). A combination of 40 g of PMMA and 120 mg of gentamicin sulfate was used as the antibiotic bone spacer and divided into multiple segmented blocks with the aim of facilitating extraction of the spacer in the second stage. Negative pressure wound therapy was applied for the skin defect of the heel after debridement, and full-thickness skin grafting for the heel defect was performed 6 weeks after the injury (Fig. 3). Four months after the injury, signs of infection was seen at the insertion site of the external fixation pin, so the external fixator was removed and replaced by a U-shaped plaster splint. When the patient's inflammatory markers had not returned to normal by 6 months after the injury, all the Kirschner wires were removed and the defect was refilled with non-antibiotic-impregnated segmented PMMA spacers after radical debridement (Fig. 4).

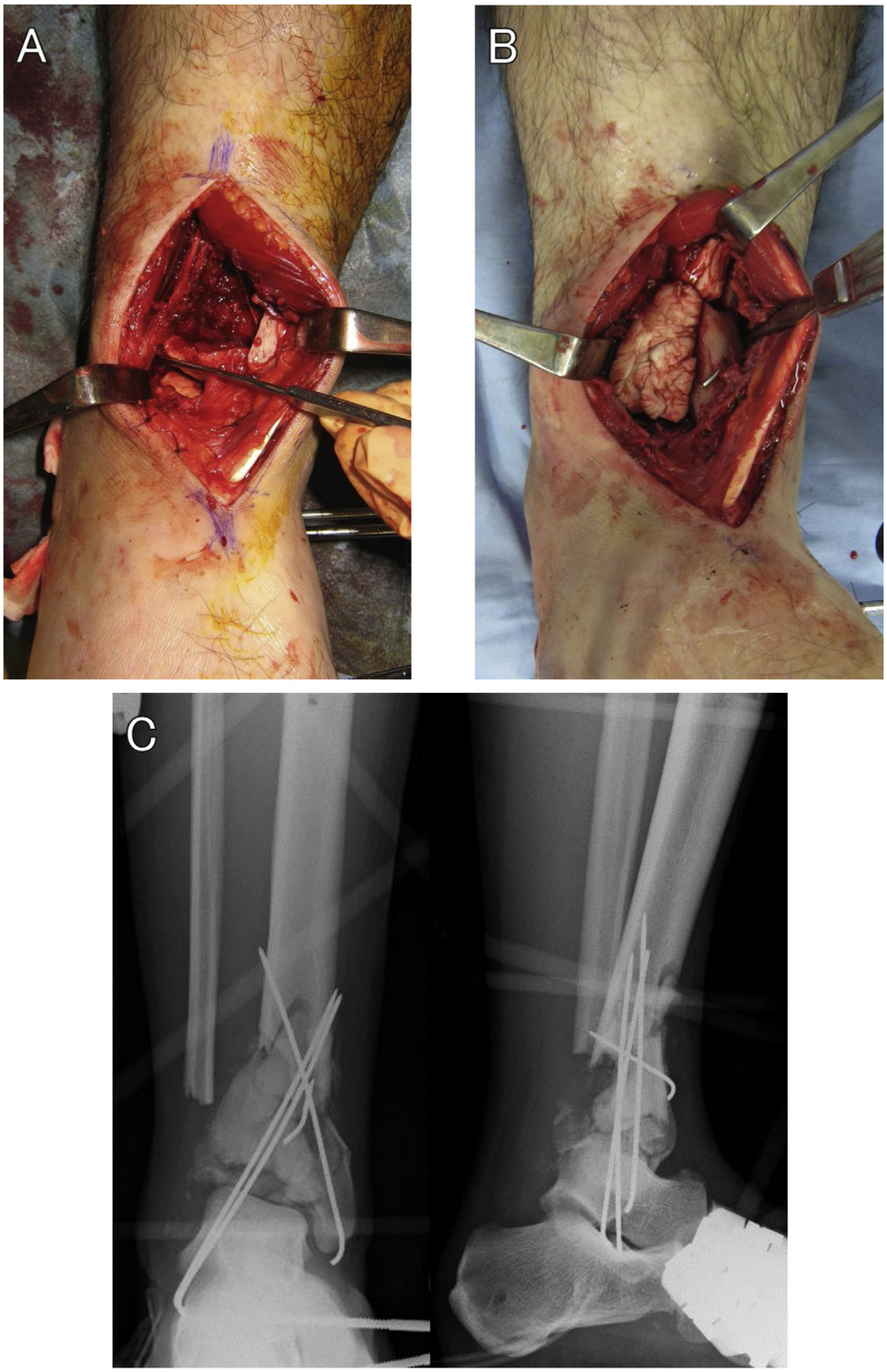

Fig. 2. The first stage of the induced membrane technique at 2 weeks after injury. (A) The substantial osteochondral defect of the right ankle was exposed by an anterolateral approach. (B) The defect was filled with antibiotic bone cement spacer. (C) Postoperative XR. Additional Kirschner wires were inserted.

At 10 months after the injury, the inflammatory markers had returned to normal. As a final stage, the bone cement was removed and ankle arthrodesis was performed using a Phoenix Ankle Arthrodesis Nail (Zimmer Biomet, Warsaw, IN, USA; Figs. 5 and 6). The bony defect was filled with a combination of autologous cancellous bone from the iliac crest and beta-tricalcium phosphate (β-TCP; OSferion, Olympus Terumo Biomaterials Co., Ltd., Tokyo, Japan). After insertion of an IM nail for definitive internal fixation

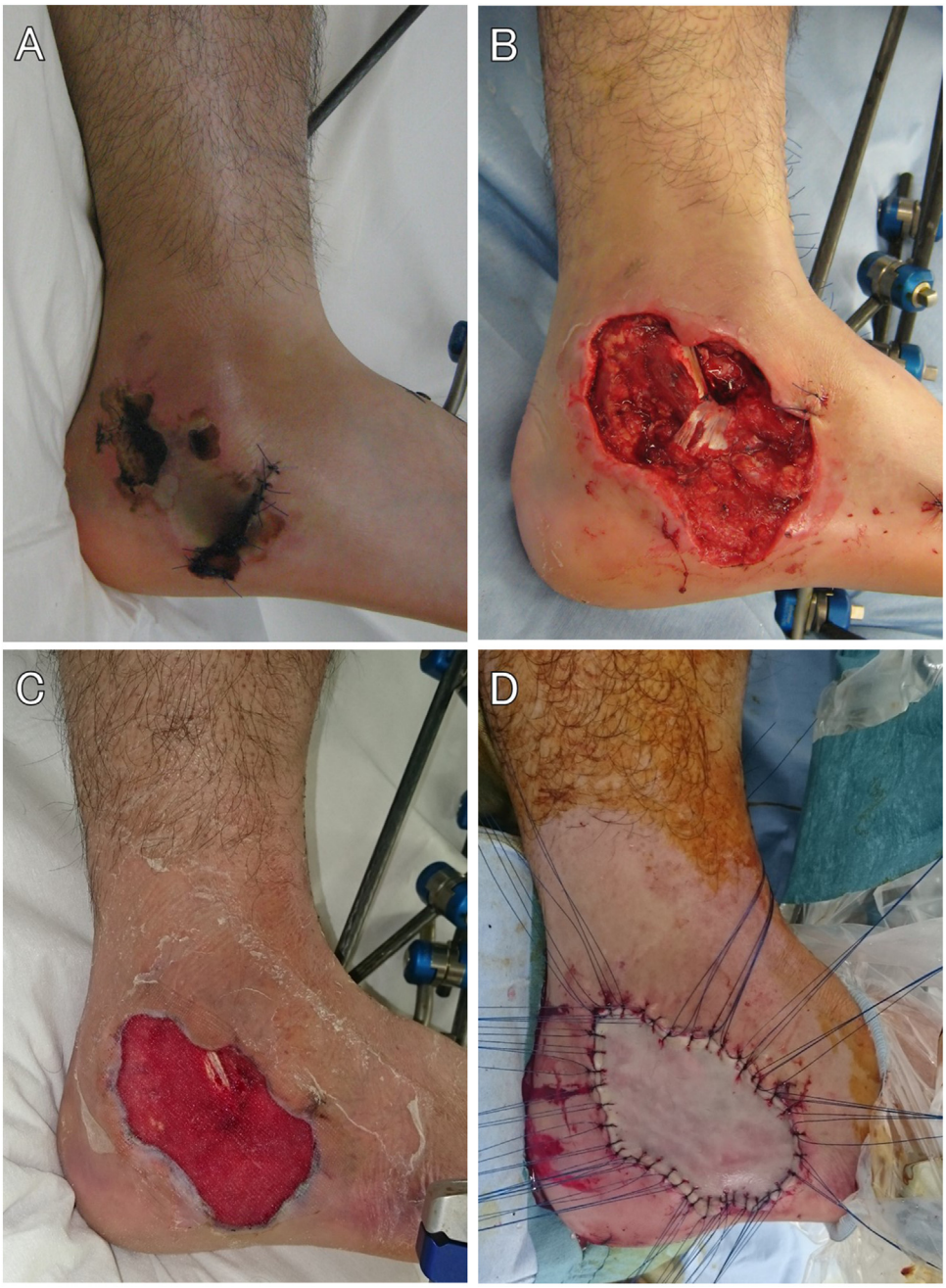

Fig. 3. Treatment of the open wound on the heel. (A) Skin necrosis had occurred after initial treatment. (B) Radical debridement was performed at the same time as the first stage described in Fig. 2(C, D) Good granulation was obtained by negative pressure wound therapy, and skin grafting was performed 6 weeks after the injury.

and resection of the proximal articular surface of the talus, half of the bone defect estimated intraoperatively was harvested from one side of the iliac crest as autologous cancellous bone, mixed with the same volume of β-TCP, and grafted to the defect. We also harvested a thin layer of cortical bone from the inner plate of the ilium. The lateral surface of the bone grafting site was supported by a layer of elongated trimmed cortical bone just under the induced membrane, and the adjacent anterior surface was covered with a wide layer of cortical bone instead of suturing the incised membrane. Postoperative treatment consisted of non-weight bearing for 2 months and full weight bearing at 5 months.

At 1 year after the definitive arthrodesis surgery, firm bony union was achieved and the implant was removed (Fig. 7). At final follow-up 3 years after his injury, the patient has no clinical signs of infection, is able to walk, and has returned to performing heavy physical labour (Fig. 8).

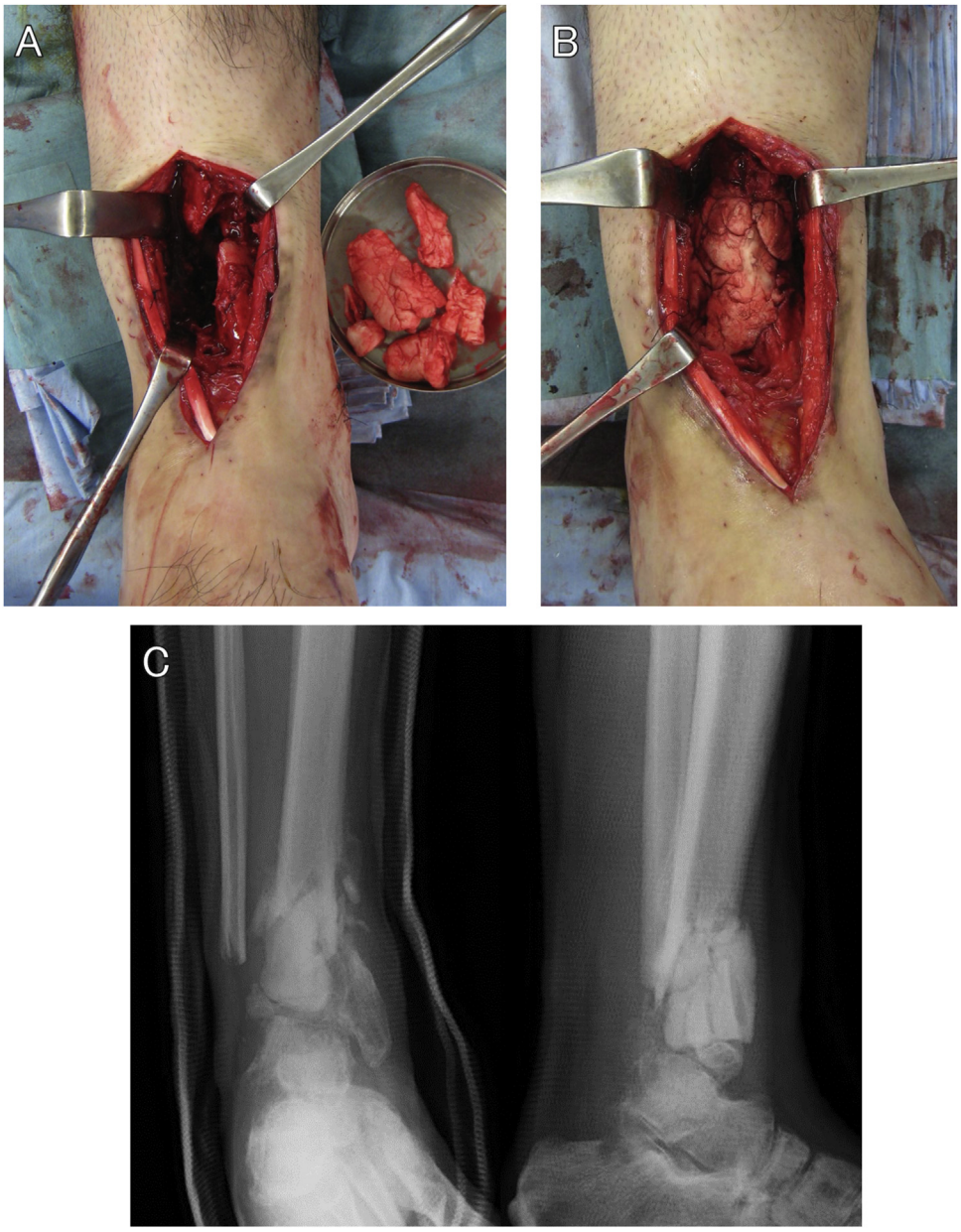

Fig. 4. Further debridement and replacement of the bone cement at 6 months after injury. (A) The previous antibiotic spacers were removed piecemeal. (B) Non-antibiotic segmented spacers were refilled after the additional debridement. (C) Postoperative XR. A larger quantity of cement was used to fill the defect than in the previous surgery.

Discussion

Arthrodesis surgery using the Masquelet induced membrane technique is not common, and there had been only a few case reports on use of this procedure for arthrodesis of the small joints of the hand or foot [5–7]. In the present patient, an outstanding result was achieved using a staged ankle arthrodesis with the induced membrane technique to treat a fresh open ankle fracture with a substantial osteochondral defect, in whom preservation of joint function was considered impossible. To the authors' knowledge, this is an exceptionally valuable case report of successful arthrodesis in which the Masquelet technique was applied as initial treatment of an open injury involving a major joint in a lower limb.

One disadvantage of the Masquelet technique may be the inadequate amount of autologous bone available. Although a reamer-irrigator-aspirator could be a good method for supplementing a massive bony defect [2,3,8,9], some complications have been reported when this strategy was used [10,11]. Sasaki et al. reported good outcomes of segmental bone loss reconstruction using the Masquelet technique with a combination of approximately equal proportions of autologous cancellous bone and β-TCP [12]. Furthermore, Olesen et al. described a potentially better outcome of the induced membrane technique with nailing than that with plating in terms of not only the amount of bone needed for the graft but also the duration of treatment [13]. In the present case, use of an IM nail in place of plates and an artificial bone mixture meant that the amount of autologous bone required could

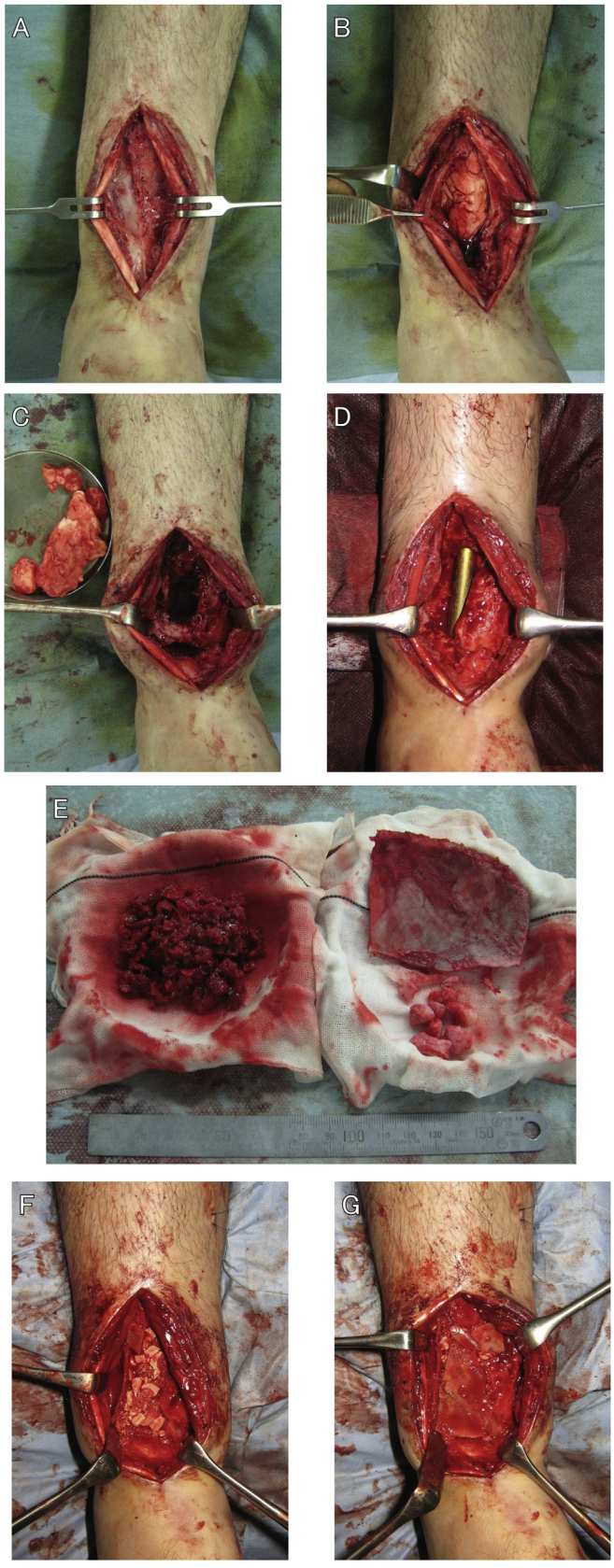

Fig. 5. Intraoperative macroscopic pictures showing the nailing and bone grafting surgery as the final stage of the staged treatment. (A) A secure membrane was induced over the spacer. (B, C) The membrane was incised, and the segmented bone cement spacers were excised. (D) The size of the bony defect was estimated intraoperatively after inserting a nail and resecting the articular surface of the talus. (E) Cancellous and cortical bone was harvested from the iliac crest and the inner iliac plate. (F) Autologous cancellous bone and the same volume of artificial beta-tricalcium phosphate was mixed and grafted to the bony defect around the nail. The lateral aspect of the bone grafting site was supported by elongated trimmed cortical bone just under the induced membrane. (G) Another layer of cortical bone was trimmed and placed on the anterior aspect of the transplant site instead of suturing the incised membrane.

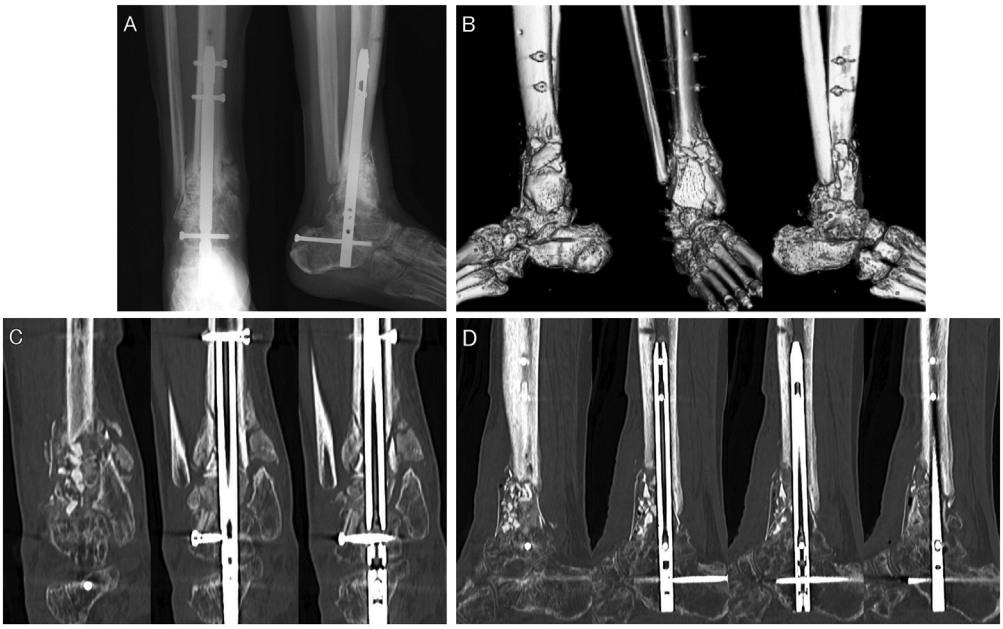

Fig. 6. XR (A) and CT images (B–D) obtained immediately after the definitive arthrodesis surgery demonstrated in Fig. 5.

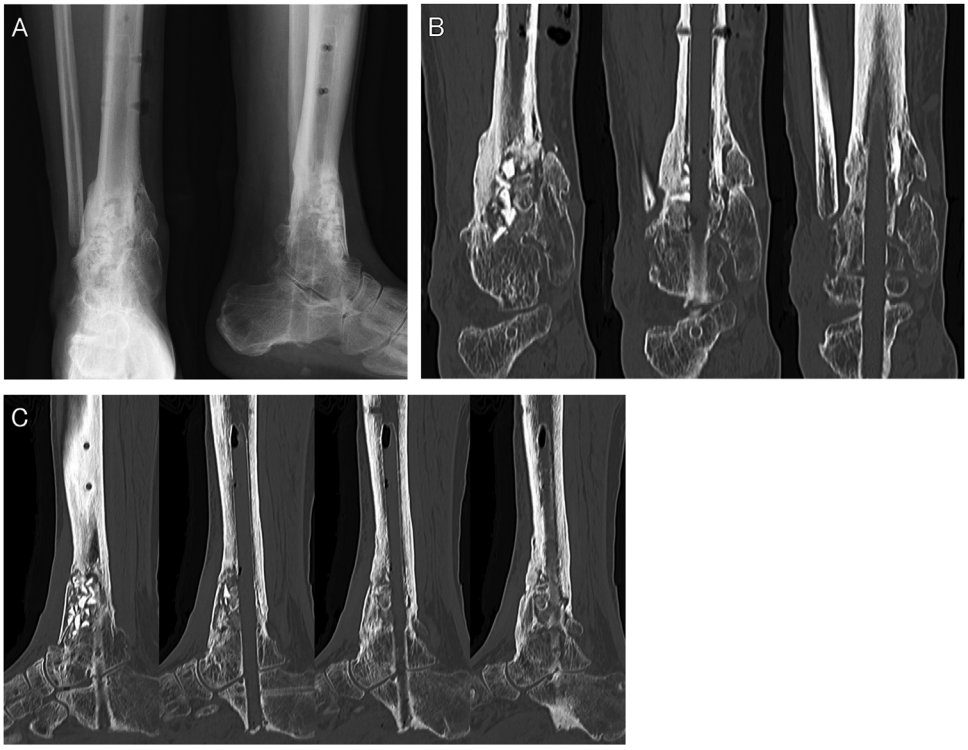

Fig. 7. Firm bony union was achieved and the nail was removed at 1 year after the arthrodesis surgery. XR (A) and CT images (B, C) just after removal of the implant.

be minimized, resulting in a shorter period of limited weight bearing after the final stage of the surgical intervention.

In the first stage of the induced membrane technique described here, we prepared and used a PMMA antibiotic cement spacer in a manner similar to that used in cases with more long-standing infection [2]. However, we used non-antibiotic cement when the spacer needed to be replaced to avoid the possibility of bacterial carriage being masked by the antibiotic spacer. A comparative study is required to determine whether antibiotic agents should be mixed with the cement spacer from the beginning of the first stage of this surgical procedure regardless of whether the trauma is recent or not.

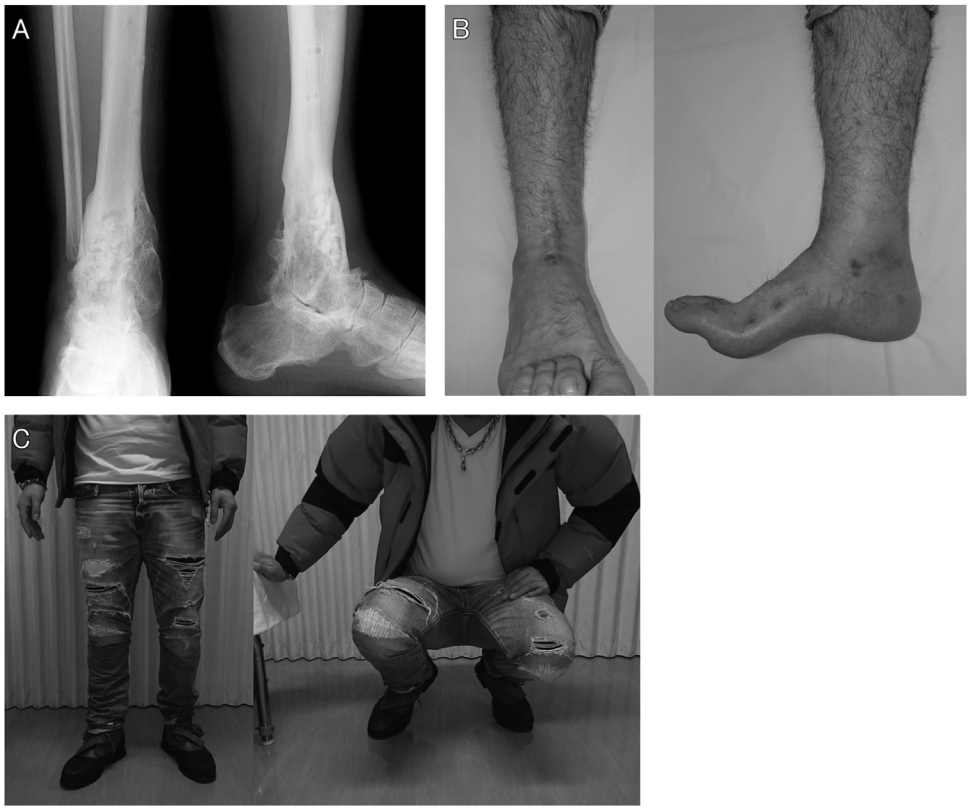

Fig. 8. Final follow-up at 3 years after the injury. (A, B) Complete fusion of the talocrural joint is achieved. Autokinetic movement of the toes is good and there is no hammer toe. (C) The patient was able to crouch down using one hand for support.

Conclusions

The authors achieved a good outcome using staged ankle arthrodesis with a modified Masquelet induced membrane technique to treat a patient with a severe open ankle fracture and a substantial osteochondral defect, in whom preservation of joint function was considered impossible. Use of an IM nail and artificial bone enabled us to reduce the required amount of autologous bone.

Ethical approval

All procedures performed involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

The patient who is the subject of this case report provided informed consent for his case to be published.

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Declaration of Competing Interest

The department to which the first author belongs received funding for operating costs from Saku Central Hospital of the Nagano Prefectural Federation of Agricultural Cooperatives for Health and Welfare, Suwa Central Hospital, Doujin Hospital, Medtronic Sofamor Danek Co., Ltd., Stryker Japan Co. Ltd., and HOYA Technosurgical Co., Ltd. The other authors declare that they have no conflicts of interest.

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