Combined effect of Ilizarov technique, low-intensity pulsed ultrasound, and teriparatide for limb reconstruction of Gustilo–Anderson type IIIc open tibial fracture with a large bone defect in elderly patients with severe osteoporosis: A case report

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Research Article

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Abstract

Background

Gustilo–Anderson type IIIc tibial open fracture with large bone defects in severely osteoporotic elderly patients is a rare injury that may be a challenging clinical scenario.

Case presentation

This study presents the case of a 68-year-old man who sustained a Gustilo–Anderson type IIIc open tibial fracture with a large bone defect. The patient had severe osteoporosis and the bone was contaminated; therefore, we determined that the bone could not be returned to the tibia. The patient underwent acute limb shortening and gradual lengthening with an Ilizarov external fixator combined with low-intensity pulsed ultrasound and teriparatide administration for limb reconstruction, which allowed immediate full weight-bearing capacity. The fixator was removed at 12 months postoperatively, and by this time, the fracture had completely healed. At the most recent 5-year follow-up after the injury, the patient reported fully weight-bearing capacity without walking aids and had full knee and ankle range of motion.

Conclusions

To the best of our knowledge, this is the first study to report the use of combined Ilizarov technique, low-intensity pulsed ultrasound, and teriparatide for limb reconstruction of Gustilo–Anderson type IIIc open tibial fractures with large bone defects in elderly patients with severe osteoporosis.

Background

The incidence of open tibial fractures in the elderly is increasing due to the growing elderly population. Open tibial fractures with large bone defects are an increasing problem, and their treatment is challenging. Gustilo–Anderson type IIIc open tibial fractures with large bone defects are less common in elderly patients with severe osteoporosis than in young patients. However, the literature on the outcomes of open tibial fractures with large bone defects in elderly patients treated with modern techniques is limited.

Case Presentation

A 68-year-old man was injured while electrically reeling a wire rope on a fishing boat. Shortly after, the patient was transported to our hospital's emergency room. On clinical examination, two large soft-tissue defects were observed in the medial left ankle (Figure 1). The patient's left foot was pale, and we did not palpate any arteries in his lower legs. Next, pulses from his peroneal, tibialis anterior, and tibialis posterior arteries as well as the capillary refill, color, and temperature were compared between the injured and uninjured feet. Then, the paramedics brought in a 75-mm tibia that had fallen out of the body on the fishing boat. The bone was contaminated; therefore, we determined that the bone could not be returned to the tibia (Figure 2a, b and c). The peroneal, tibialis anterior, and tibialis posterior arteries were injured on 3D CT angiography (Figure 3a and b). Six hours after the injury, we debrided the soft tissues of the injury in the operating room. After debridement, the size of the soft-tissue defect was 40 mm × 80 mm. We decided that acute limb shortening and gradual lengthening would be a reasonable method for rapid revascularization. Accordingly, we shortened the fibula with a 75-mm osteotomy to match the length of the tibia. We resected and prepared a spike in the distal tibial fragment (Figure 4a). We crimped the fracture sufficiently and fixed it with an Ilizarov external fixator for temporary ankle joint-bridging fixation (Figure 4b and c). We reconstructed the anterior and posterior tibial arteries and veins with end-to-end anastomosis.

Revascularization was completed six hours after injury, after which, the circulation in the injured foot improved. Now, the size of the soft-tissue defect was 20 mm × 80 mm. We used negative pressure wound therapy to address the soft-tissue defect (Figure 4d). After the patient gained consciousness following anesthesia, the ankle joint circulation was good and automatic movement of the ankle joint and toes was possible (Figure 4e). Although the patient had mild renal dysfunction, he did not undergo hemofiltration and recovered without any permanent organ damage.

Two days after the injury, we cleaned the open fracture again, performed additional debridement, and reapplied negative pressure wound therapy. Fourteen days after the injury, an osteotomy was performed at the proximal tibia with an Ilizarov external fixator for gradual limb lengthening (Figure 5a). Three weeks after the injury (one week after the osteotomy), we initiated gradual lengthening of the proximal tibia. We noted that the bone strength was weak at the time of wire insertion; therefore, we measured bone density and identified primary osteoporosis. A baseline dual-energy X-ray absorptiometry scan showed that his femoral neck bone mineral density was 0.441 g/cm^2 and T-Score of -3.3 standard deviation. He was started on a once-weekly injection of 56.5 µg teriparatide. Furthermore, after osteotomy, treatment with a low-intensity pulsed ultrasound stimulation (LIPUS) device (SAFHS 2000, Exogen, Inc., Piscataway, NJ) was started for 20 min/day for the fracture and osteotomy sites. This device had a frequency of 1.5 MHz, a signal burst width of 200 µs, a signal repetition frequency of 1 kHz, and an intensity of 30 mW/cm^2. The patient was allowed to walk with full weight-bearing capacity immediately after the surgery (Figure 5b). He also began knee and ankle range of motion exercises. We performed bone lengthening at a rate of 0.75 (0.25 × 3) mm/day. Radiography performed one year later revealed good callus formation (Figure 5c). The fixator was removed after one year. The patient returned to his original job as a fisherman two months after the fixator removal. At the 5-year follow-up after injury, radiographs showed good callus formation and bone union (Figure 6a, b, c and d). The patient was independently mobile, with a knee range of motion of 0°–140°, ankle dorsiflexion at 5°, and *plantar flexion at 50°* (Figure 7a, b and c). During the 12 months with the fixator inserted, there were a few superficial pin-tract infections, which were treated with empirical oral antibiotics and daily pin-tract dressings.

Discussion And Conclusions

Treatment of high-energy open tibial fractures is challenging. Gustilo–Anderson type IIIc open tibial fractures were mainly treated with amputation in the past [1]. The complication rates are high for Gustilo–Anderson type IIIc open tibial fractures, which are associated with more severe soft-tissue loss and/or arterial injury requiring repair [2]; these complications include secondary amputation, nonunion, infection, and malunion [3-5]. The acceptance rate of amputation is poor in eastern-culture patients, especially in Japanese elderly patients [6]. Adaptation to a prosthesis is relatively easier in young amputees than in elderly amputees [7]. In our patient, there was a bone defect; soft-tissue defect; and peroneal, tibialis anterior, and tibialis posterior artery tears. The advantage of acute shortening is that it is easier to reconstruct the arteries and veins with end-to-end anastomosis. Furthermore, soft-tissue defects were smaller in genaral; therefore, function reconstruct was possible in our elderly patient, despite his presentation. In Gustilo–Anderson type IIIb open tibial fractures treated with acute shortening,gradual lengthening is usually subjected to a second-stage procedure performed after union of the fracture [8]. The main disadvantage of this approach is prolonged treatment duration. In Gustilo–Anderson type IIIc open tibial fractures, lengthening is delayed to prevent traction on vascular anastomoses as they heal, which may potentially risk the revascularization procedure. In our study, we performed early lengthening without causing any harm to vascular repair, as lengthening was performed at the proximal tibia most distant from the vascular injury. Management of open injuries of the limbs are challenging, as there are still many gray areas in decision-making regarding salvage, timing, and reconstruction type. As a result, there is still an unacceptable rate of secondary amputations, which leads to tremendous waste of resources and psychological devastation of the patient and their family [9]. In addition, limb salvage is more cost-effective than amputation and prosthesis use [10, 11]. Our patient achieved a satisfactory functional status and avoided psychological trauma due to amputation; he was able to return to his original position as a fisherman.

It is difficult to reconstruct large bone defects in elderly patients with severe osteoporosis due to decreased bone formation. LIPUS has been used to treat leg lengthening [12, 13]. Intermittent administration of human parathyroid hormone (PTH) has an anabolic effect on the bone in humans and is expected to be a potent agent for fracture healing [14]. Several recent studies have revealed that intermittent treatment with PTH stimulates osteogenesis in experimental fracture healing of cortical bones and that the effects of PTH on cortical bone repair are site-specific. Aspenberg *et al.*, in a prospective, randomized, double-blind study of conservative fracture treatment for 102 postmenopausal women with distal radial fractures, showed that the time to healing was shorter in patients who received 20 mg teriparatide than in the placebo group patients [15]. Warden *et al.* reported that teriparatide and LIPUS have contrasting additive rather than synergistic effects during fracture healing [16]. Teriparatide primarily increased the callus bone mineral content without influencing its size, whereas LIPUS increased callus size without influencing the callus bone mineral content in rat models [16]. We have reported combined effect of teriparatide and low-intensity pulsed ultrasound for nonunion patients [17]. Furthermore, we have reported intractable fractures such as pathological fractures in patients with Alagille syndrome or nonunion after ankle fracture for Charcot arthropathy that was treated with LIPUS and an Ilizarov external fixator [18, 19]. Early ambulation and immediate weight-bearing capacity may improve limb circulation and enhance the healing process, based on the fact that the speed of fracture healing is usually proportional to the amount of available circulation to and between fragments [20, 21].

One of the most important advantages of using Ilizarov external fixators is the excellent recorded knee and ankle range of motion within a short time after surgery. Active and passive movements of both the joints were allowed and encouraged during the entire course of treatment immediately after application of the frame. The main disadvantages of Ilizarov external fixators are that they are technically demanding and there is absolute necessity of adequate care of the frame. From our point of view, the fact that the patient could achieve immediate weight-bearing capacity and could be discharged and return to work is adequate justification for this procedure.

Declarations

Ethics approval and consent to participate

The patient received prior information before providing her written, informed consent in accordance with the Declaration of Helsinki. The article was approved by the ethics committee of Akita University Hospital (registration number 1970).

Consent for Publication

Written, informed consent was obtained from the patient for publication of this article and any accompanying images. A copy of the written consent is available for review by the Editor of this journal.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

All authors declare that they have no competing interests.

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Authors' contributions

KN performed the surgery. MN helped with surgery and helped to draft the manuscript. MM and YS helped draft the manuscript. All authors read and approved the final manuscript.

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Not applicable

Abbreviations

LIPUS: Low-intensity pulsed ultrasound stimulation

PTH: parathyroid hormone

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Figures

Figure 1

Two large soft-tissue defects in the medial left ankle

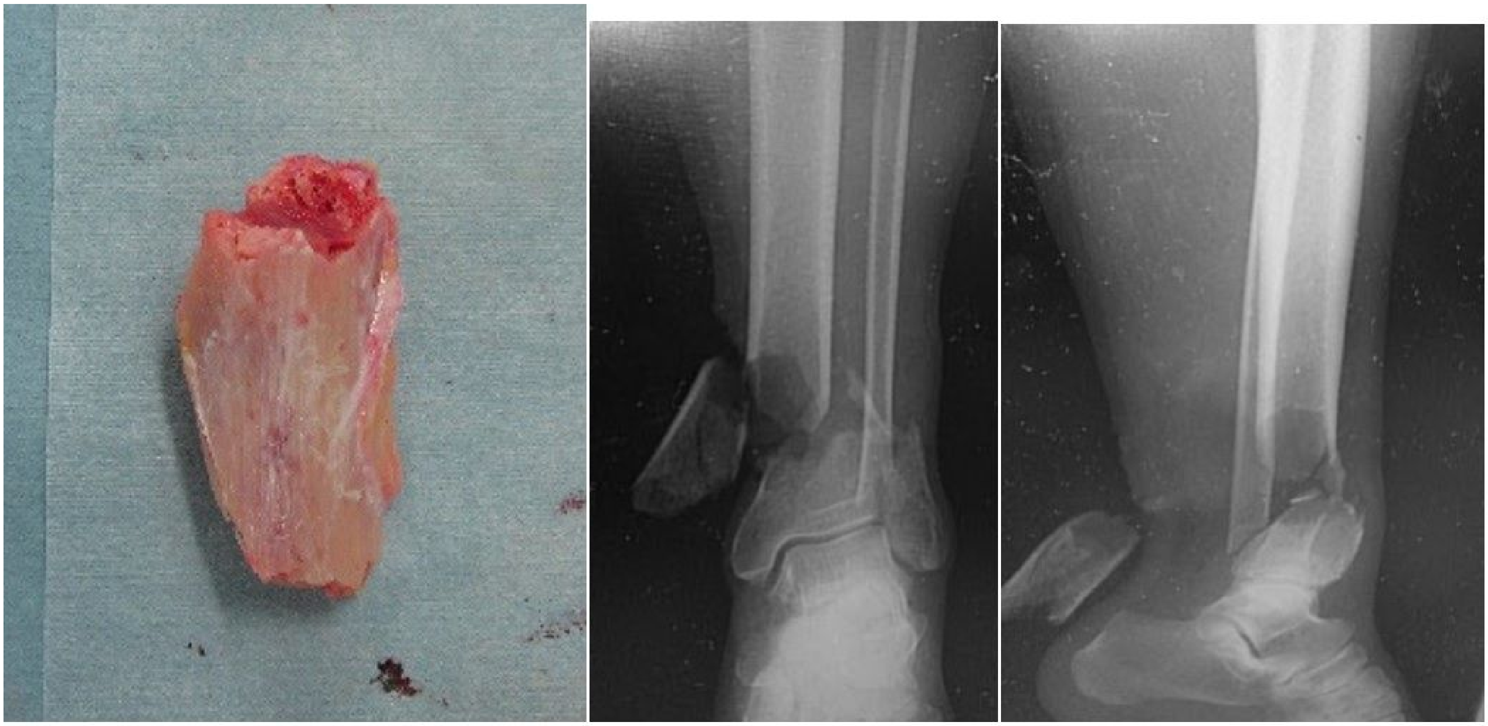

Figure 2

(a) The contaminated large bone that fell out of the body; (b and c) X-ray images taken in the emergency room

Figure 3

(a) 3D computed tomography angiography image with the bone; (b) 3D computed tomography angiography image without the bone 3D, three-dimensional

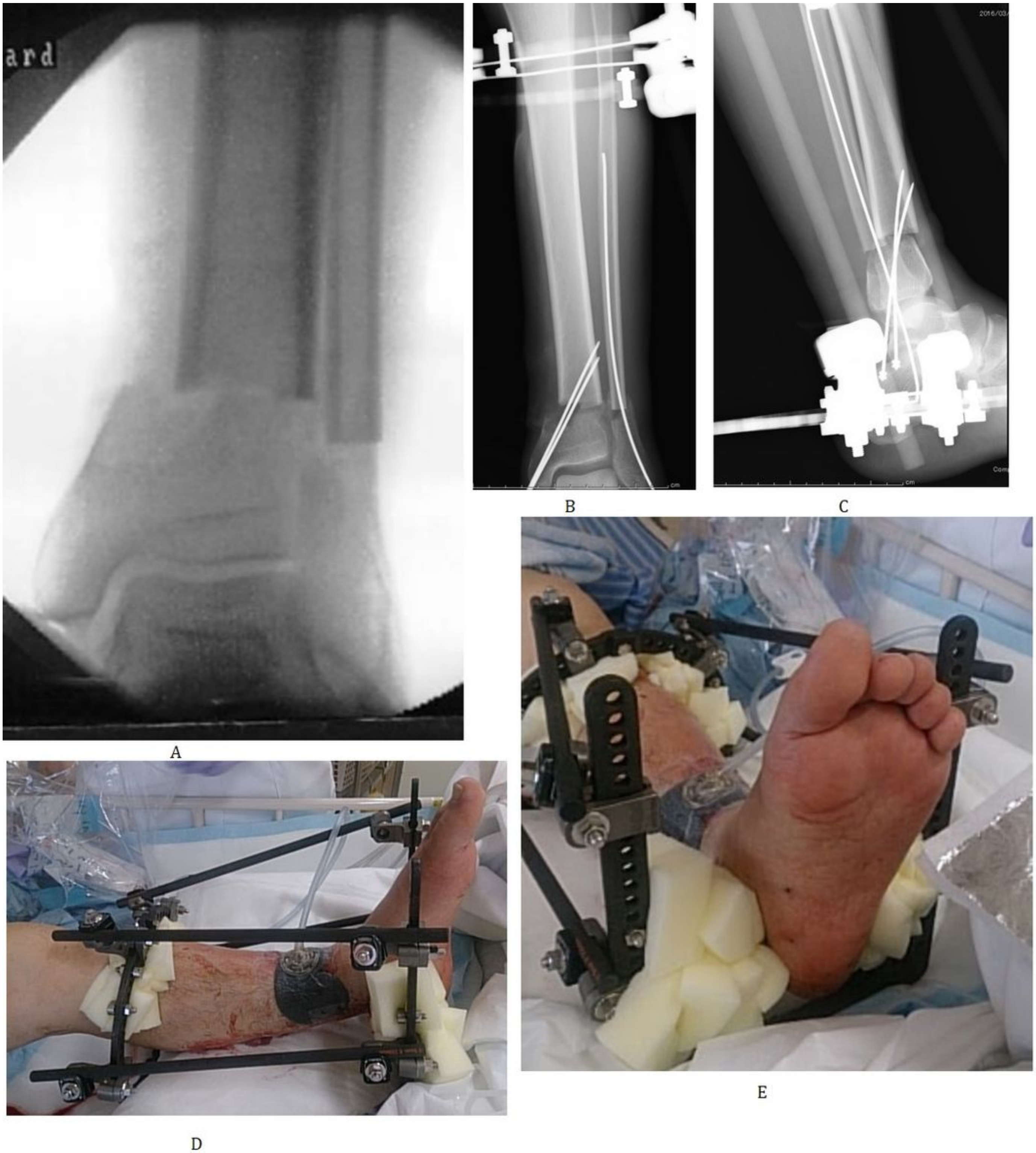

Figure 4

(a) Shortened fibula with a 75-mm osteotomy to match the length of the tibia; (b and c) the fibula was fixed with an Ilizarov external fixator for temporary ankle joint-bridging fixation; (d and e) clinical photograph of the fibula was fixed with an Ilizarov external fixator for temporary ankle joint-bridging fixation

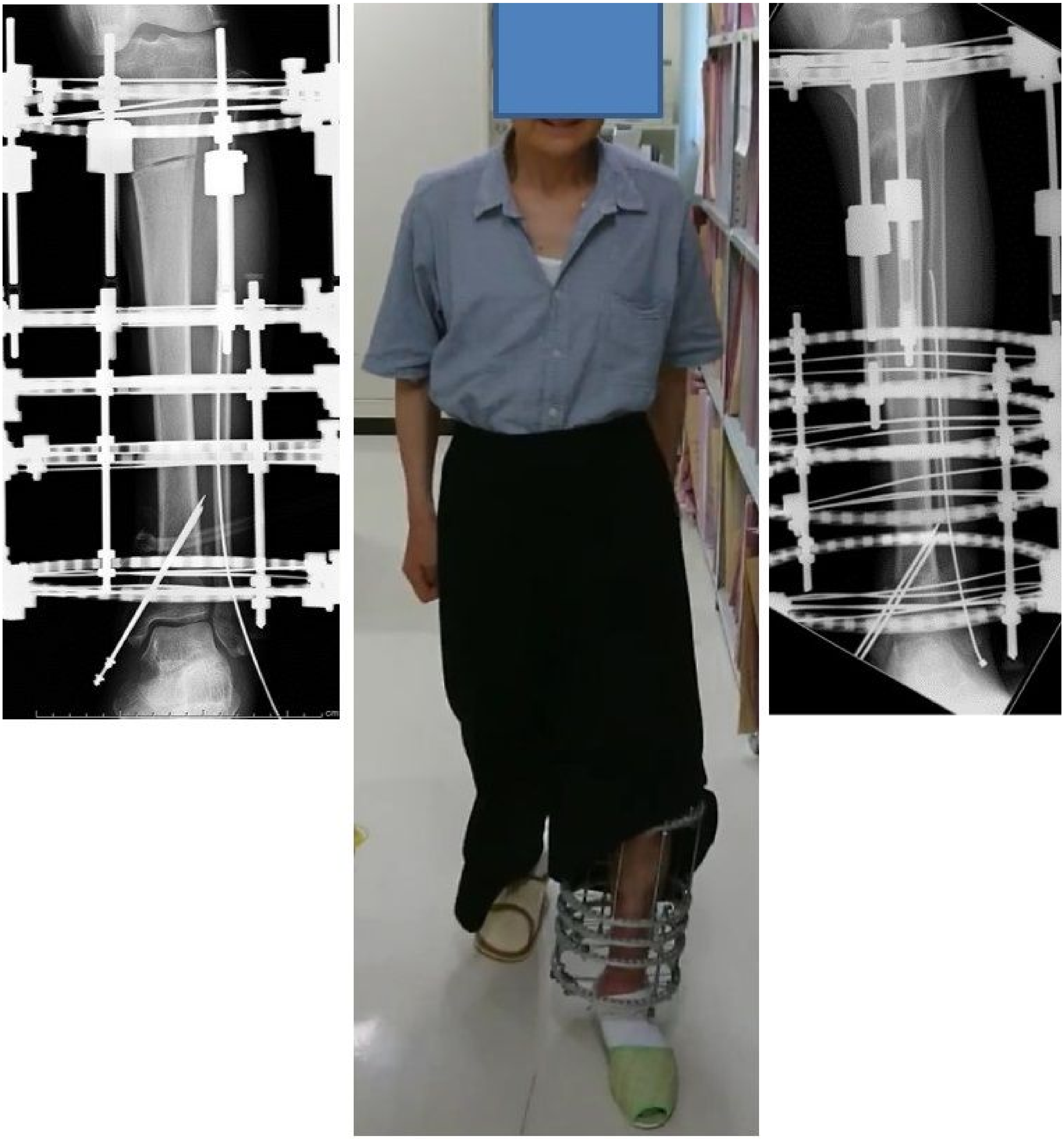

Figure 5

(a) Osteotomy at the proximal tibia with an Ilizarov external fixator for gradual lengthening; (b) bone lengthening at a rate of 0.75 (0.25 × 3) mm/day; (c) walking with full weight-bearing capacity immediately after surgery

Figure 6

(a, b, c and d) X-ray images taken at postoperative 5-year follow-up

Figure 7

(a, b, and c) Clinical photograph at postoperative 5-year follow-up

Supplementary Files

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