CASE REPORT

Case Report: Large bone defect reconstruction in lower extremities with ipsilateral transposition fibular graft with combined inlay and onlay technique using plate and screw fixation (fibula pro tibia technique) [version 1; peer review: 1 approved]

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Abstract

Introduction: Management of large bone defect is a challenging problem. Hahns, in 1884, introduced the first use of fibula pro tibia to bridge a large defect of the tibia due to chronic osteomyelitis. In this case, we did a transposition of the ipsilateral fibular with inlay and onlay technique using a locking plate and screw into the defect of the tibia.

Case presentation: A 20-year-old male came to our emergency department at RSUD Dr. Saiful Anwar, Malang, Indonesia with an open fracture grade III B of his left lower leg. We found a large defect of the tibia approximately 7.5 cm after regular wound care for ten months. Then, we performed ipsilateral transposition fibular graft with combined inlay and onlay technique using a locking plate and screw fixation. No infections occurred and there was progressive callus formation with extending ossification along the periosteal tissue in the four-month postoperative evaluation. There was no leg length discrepancy, and the union sign showed that the patient could achieve full range of movement (ROM) and walk with crutches without pain with a Lower Extremity Functional Scale (LEFS) score of 62.

Discussion: Contralateral fibula graft carries a high risk of endangering the unaffected limb. The ipsilateral fibula can be utilized to replace the missing segment with minimal morbidity. The purpose of combining ipsilateral fibular transport with the inlay and onlay technique is to minimalize the gap defect between fracture fragments,

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Approval Status ✓

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version 1 27 Jan 2022	✓ view

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therefore enhancing the union rate of the bone.
Conclusion: The fibula pro tibia technique can be used as an alternative treatment option for large gap bone defects in lower extremities with minimal complication.

Keywords
large gap bone defect, transposition fibular graft reconstruction, inlay and onlay technique, fibula pro tibia, case report

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Introduction

Large segmental bone defects of the tibia are challenging for both surgeon and patient.[1,2] Segmental bone defects are most commonly caused by fractures from high energy trauma, osteomyelitis, benign or malignant bone tumor surgery, septic nonunion, and congenital abnormality.[2–4]

A free vascularized fibula graft is commonly used because it is mechanically strong, retains the intrinsic blood supply, osteogenic, and can be used for large bone defects in various places.[4,5] However, there are certain drawbacks of free vascularized fibula grafts, such as donor side morbidity (unaffected limb), peroneal nerve injury, and the surgery necessitates a microsurgery technique, thus requiring a long operating time.[2,3] In 1884, Hanh described an alternative technique using the ipsilateral vascularized fibula as a graft for a 12 cm segmental tibia defect due to chronic osteomyelitis in an eight-year-old male. Instead of cutting the fibula and performing a reanastomosis at a distance, Hanh simply transposed the fibula with his pedicle into the tibial defect.[3,4,6]

Ipsilateral vascularized fibula transfer (IVFT) allows the surgeon to transfer the fibula to the tibia as a complete graft without disrupting soft tissue attachment, blood supply and without needing microsurgical techniques, resulting in bone healing at both ends of the defect.[1,3,4]

In this case, we transposed the ipsilateral fibular with inlay and onlay technique using a locking plate and screw into the tibia gap defect in a one-stage procedure followed with serial radiographic X-ray evaluations and functional outcome evaluation using the Lower Extremity Functional Scale (LEFS) scoring system.[7] This report has followed the CARE and Surgical CAse REport (SCARE) checklist and guidelines.[8] In addition, written informed consent was obtained from our patient for publication of their data and clinical images.

Case report

A 20-year-old male came to our emergency department at RSUD Dr. Saiful Anwar Malang Indonesia with an open fracture grade III B of his left lower leg (Figure 1). The cause of the injury was a high-speed motorcycle collision. The patient did not consume any routine medication and did not have any other illness. We performed debridement, serial irrigation and applied an external fixation device on the affected leg (Figure 2). After regular wound care for ten months, the soft tissue condition improved, but we found a nonunion of the tibia with a large defect of approximately 7.5 cm (Figures 3 and 4). We planned to perform external fixation removal with a reconstruction of the bone defect using an ipsilateral transposition fibular graft with a combined inlay and onlay technique using a locking plate and screw fixation (fibula pro tibia technique).

Before the operation, we did a thorough preoperative evaluation that included measuring the extent of the bone defect and assessing the quality of the adjacent soft tissue and joints. A thorough excision of all avascular bone back to bleeding tissue was performed through an anterolateral approach. The peroneal nerve and its branches were identified and protected. The fibula is dissected from its surrounding soft tissue, keeping muscles and periosteum to protect the periosteal vascularization. The dissected fibula was moved to the posterior interosseus membrane of the tibial defect with the preserved vascularization without tension on the soft tissues. Then, the graft was fixed proximally and distally with a locking plate to improve stability. Meticulous care was taken during the transpose to avoid kinking or stretching of the vascularization. In addition, we performed an onlay technique using an ipsilateral avascular fibular graft fixated with screws to provide more mechanical strength and minimize the gap defect between fracture fragments, therefore enhancing the union rate of the bone (Figures 5 and 6). To ensure ankle stability, at least 10 cm of the distal fibula must be preserved. After receiving intravenous antibiotics for one week, the patient was allowed to go home. His left leg was braced and weight-bearing was prohibited until the vascularized bone graft healed and, periodically, the patient was followed up clinically and radiographically (Figure 7). No infections occurred in the four-month postoperative evaluation, and progressive callus formation with extending ossification along the periosteal tissue was seen in serial radiographic X-ray evaluations. Clinically, the LEFS score was 62 (good), there was no leg length discrepancy, and the union sign showed as the patient could achieve full range of movement (ROM) and walk with crutches without pain.

Discussion

Large segmental tibial defects have been treated successfully using a variety of procedures, including autogenous corticocancellous bone grafting, tibiofibular synostosis, ipsilateral vascularized fibula transfer (IVFT), allograft tibial reconstruction, free vascularized fibula transfer, and bone transport accompanied with Ilizarov technique.[1–3] Proximal transtibial amputation is one of the options of treatment, but amputation should be avoided if the foot and ankle vascularization is normal.[1] In addition, for most patients, shortening of limbs or amputation is an unacceptable condition.[3,9]

Figure 1. Initial clinical picture of the left lower leg.

Figure 2. Initial clinical picture of the left lower leg after debridement and application of external fixation.

Bone transfer or corticocancellous bone grafting can be used to treat shorter defects of up to 5 cm. In contrast, larger tibial defects usually need a more complicated repair procedure, such as bone transfer or a free vascularized fibula transfer.[3,9] The optimal treatment would provide appropriate vascularization as well as the availability of the essential

Figure 3. Clinical picture of the left lower leg after regular wound care for 10 months.

osteoinductive, osteoconductive, and osteoprogenitor components. It should also allow for early mobilization while reducing the possibility of leg length discrepancy or axial deformity.[3]

A variety of vascularized grafts are available for treatment. Vascularized bone grafts from the fibula or iliac crest have been applied for large lesions with satisfactory functional results. However, the iliac crest can only be used to treat defects 10–15 cm long, and the anatomical aspects of the iliac bone pose a congruency issue when replacing tubular bone such as the tibia and pose a high rate of donor morbidity, primarily pain and incisional hernias.[2,3]

The fibula is a suitable graft material because of its long, straight cortical bone that can bridge most defects, good structural strength, osteogenic potential, does not cause distant donor site morbidity and, unlike allografts, it has no immunogenicity, thus making the fibula a popular donor site for long bone defects.[1,5,10] The fibula also bears just 6–15% of the weight transmitted via the leg, and it is considered expendable.[4] The size of the fibular graft and its straight configuration allows it to fit into the femur or tibia medullary canal, allowing restoration of significant defects up to 26 cm in length.[3,5]

Fibula grafts can be harvested from the ipsilateral or contralateral limb. However, contralateral vascularized or non-vascularized fibula transfer carries a high risk of endangering the unaffected limb. The risk of donor-site morbidity and microvascular thrombosis should always be taken into account. Deep infection, peroneal nerve damage, long operation time, and contralateral unaffected limb ankle instability are all detrimental complications.[2] Infection, rejection, fracture, and nonunion have also been reported with these procedures.[1,9]

The fibula possesses dual vascularity, with endosteal and periosteal vessels, and this is preserved in fibula pro tibia and provide a firm mechanical and biological framework for union.[1,5] Experiments on Macaca monkeys showed that a vascularized pedicle graft of the ipsilateral fibula's shaft could be placed across a tibia defect and remained alive even when separated from the surrounding tissue.[1,4]

The main benefit of a perfused transplant is that the biological potential of living bone is preserved. In vascularized grafts, the osteocytes and other osteoprogenitor cells are maintained.[11] Therefore, the grafts take less time to consolidate, have

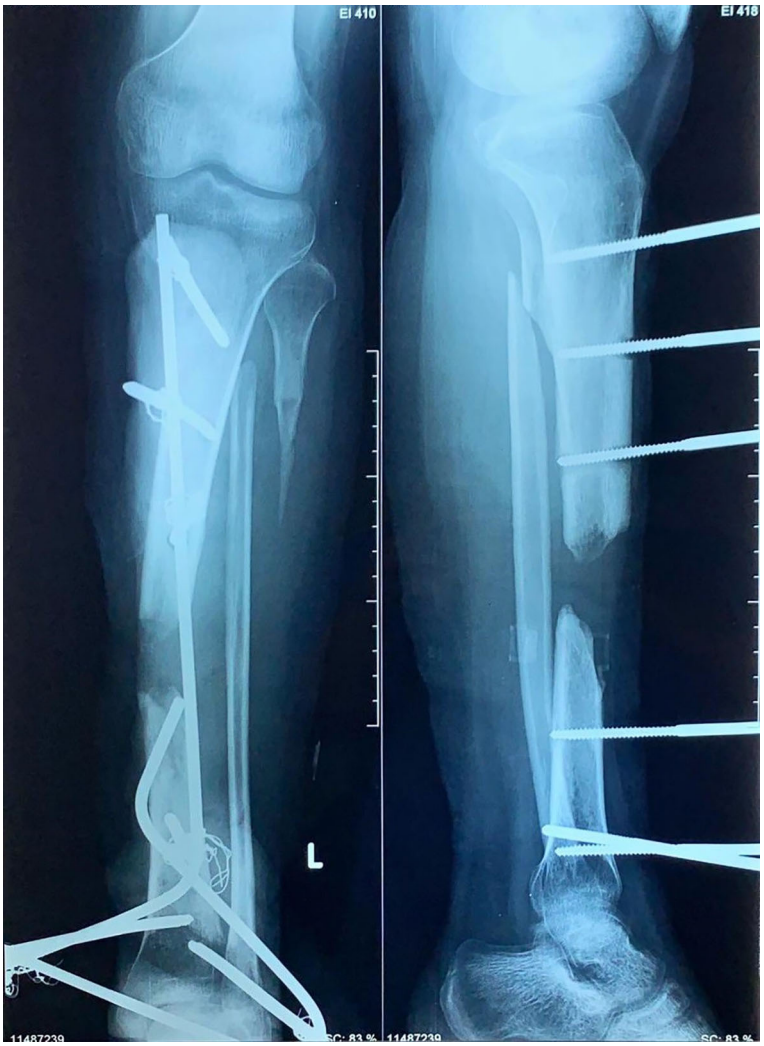

Figure 4. X-ray AP/lateral picture of the left lower leg after regular wound care for 10 months.

more remodeling potential, are more resistant to infection, and have better long-term mechanical characteristics. In addition, unlike an allograft, it has no immunogenicity.[1,4,5,10] The vascularized bone graft maintains its mass and architecture better than an avascular fibular graft, is biomechanically stronger and has better healing potential and hypertrophy. Furthermore, in scarred and avascular recipient locations, the vascularized bone transplant provides a significant source of vascularity.[5]

More benefits of a perfused transplant are that primary or secondary bone healing is used to integrate viable grafts rather than creeping substitution because the vascularized bone graft skips the creeping substitution process. Creeping substitution process characterized by graft necrosis, resorption, and new bone growth in avascular transplants.[5,10,11]

In a study by Föhn *et al*., the ipsilateral fibula was used as a bone graft and positioned into the proximal and distal medullary canal of the fractured site with its peroneal and periosteal vascularization.[9] The technique used in this case was the same, but we performed an additional onlay technique using an ipsilateral avascular fibular graft to provide more mechanical strength to the injury site. Moreover, the purpose of combining ipsilateral fibular transport with inlay and onlay technique is to minimize the gap defect between fracture fragments, therefore enhancing the union rate of the bone. Meanwhile, the downside of this technique is the need for a large incision to do the operation.

We use a locking plate to do the internal fixation because a locking plate is a type of internal fixator that combines the benefits of external fixation techniques with biological plating technique into one unit. Therefore, the lesion is stabilized,

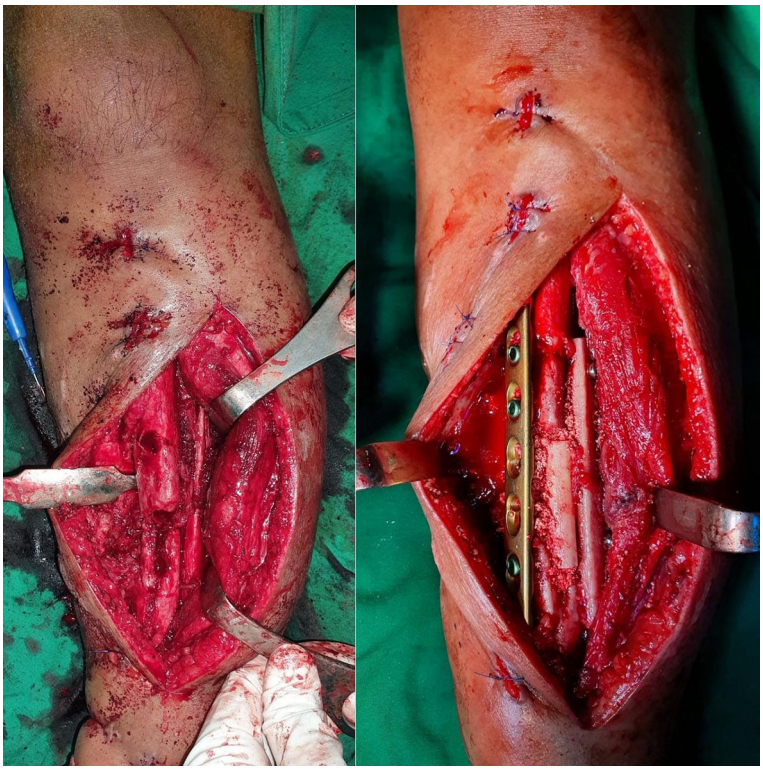

Figure 5. Intraoperative picture of the left lower leg. We performed ipsilateral transposition fibular graft with combined inlay and onlay technique using locking plate and screw fixation (fibula pro tibia technique).

reducing interfragmentary motion and inflammation and providing a better environment for graft incorporation and bone union.[5]

Mechanical stress or stress loading on bone is widely acknowledged as an essential aspect in maintaining a proper balance between bone formation and resorption. Adaptive response in which bone formation outpaces resorption can occur when mechanical stress on long bones is increased. However, if the external mechanical loading is greater than the bone's strength, a stress fracture will occur.[10] We planned gradual weight bearing with serial radiography follow-up to avoid stress fractures until the bone graft had hypertrophied sufficiently before total weight-bearing.

Föhn *et al*. accomplished a single-step fibula pro tibia procedure with no contralateral limb morbidity because they used ipsilateral fibula and less operation time because the graft vascularization was intact, thus micro anastomosis was not required.[9]

In this patient, an infection on the surgery site was not seen. This outcome was also found in the study of Koulouvaris *et al*.[3] He reported that the average infection rate was 2.1 percent in ipsilateral vascularized fibula transfer papers, albeit this varied depending on the number of osteomyelitis patients treated. In an average of 8.5 percent of cases, the fibula graft fractured, but a sound union was achieved within six months, and patient mobilization and the outcomes were described as good in the majority of cases.[3]

The fibula originally takes only one-sixth of the leg's static load. However, the fibula will grow if it is subjected to higher loading forces.[1] In the fibula pro tibia, the fibula undergoes hypertrophy and becomes an integral part of the static supporting architecture of the leg when it is subjected to more than usual weight-bearing loads.[2] Föhn *et al*., also described that the periosteum of the remaining fibula stumps also played a significant role in neo-ossification in fibula remodeling into a tibia-shaped dimension.[9] Gayito *et al*., in their study, reported that the bone remodeling process was observed with the gradual growth of the transferred fibula in the fibula pro tibia postoperatively. In their study, compared to the unaffected fibula, the diameter of the transferred fibula increased substantially by at least twice its initial size in eight years of observation.[2]

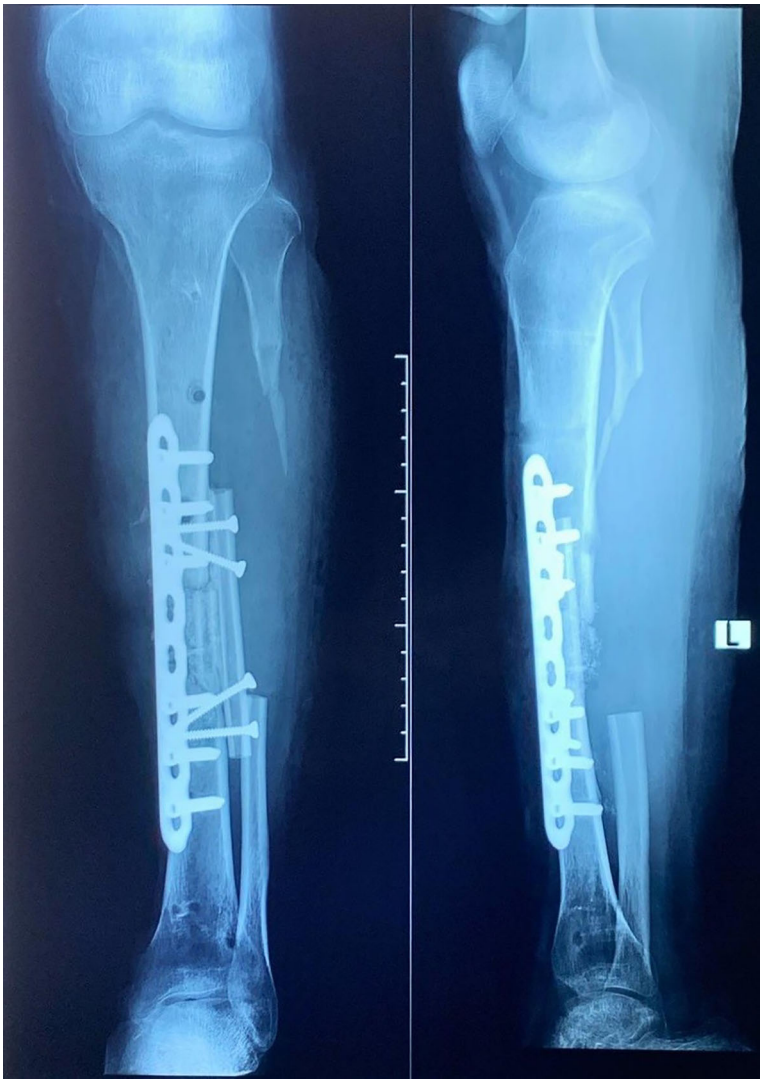

Figure 6. Postoperative X-ray AP/lateral picture of the left lower leg.

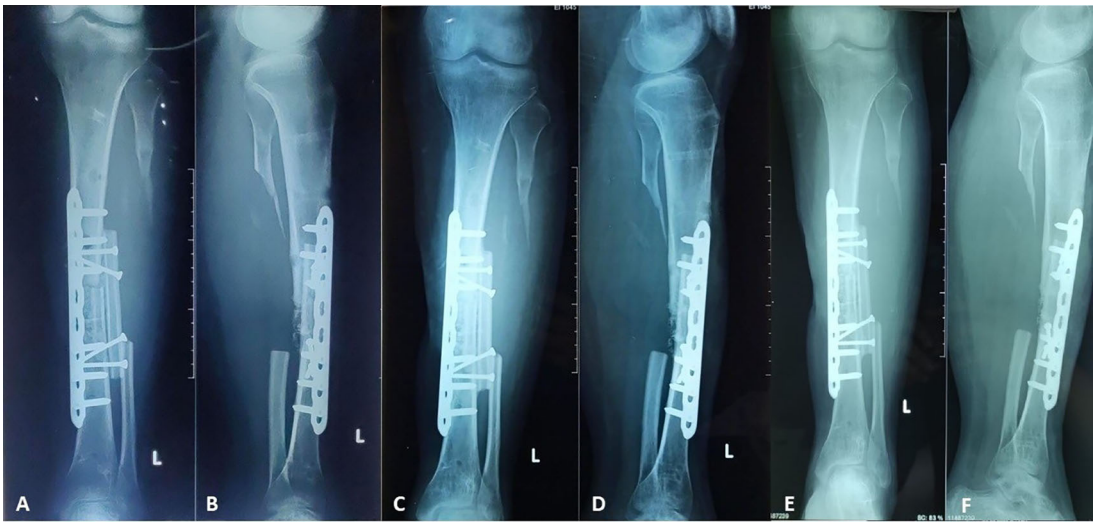

Figure 7. X-ray AP/lateral picture of the left lower leg evaluation. (A, B) One month. (C, D) Three months. (E, F) Four months.

The weaknesses of the fibula pro tibia technique are that this technique cannot be done for tibia defects that are very proximal or distal. The fibular graft can only be moved a certain distance without disrupting its vascularization and the disrupted vascularization can make the graft avascular.[1,4] Moreover, when implanted on an avascular and scarred bed, these avascular transplants are doomed to fail because if the union of the allograft is not achieved, a vascularization is impossible, and healing will never occur.[4] It is also important to ensure the preservation of 8–10 cm or the distal fibular length to maintain ankle stability and cause no substantial ankle morbidity.[12]

The 'fibula pro tibia' technique is an inexpensive, simple, and efficient method compared to allografts. The advantages of 'fibula pro tibia' include the transfer of a living autograft with remodeling capability, infection resistance, and better long-term mechanical qualities.[2]

Conclusion

Ipsilateral transposition fibular graft reconstruction with a combined inlay and onlay technique using plate and screw fixation (fibula pro tibia technique) can be used as an alternative treatment option for large gap bone defects in lower extremities with minimal complication.

Data availability

All data underlying the results are available as part of the article and no additional source data are required.

Consent

Written informed consent for publication of their clinical details and clinical images was obtained from the patient.

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This is an interesting article that would be suitable for indexing. The article provides a good treatment alternative for a wider hospital setting, not only in a fully equipped hospital, but also in a smaller hospital. It offered another perspective on open fracture with large bone gap cases. One of the accepted techniques for this kind of case is bone transport which is technically demanding and risk the patient's comfortability. This article proved that a simple external fixation and subsequent conversion is still efficacious.

The author should better describe the patient's peri-operative characteristics, including neurovascular status, smoking habit, diabetes, and so on, since these aspects may interfere with the results. Also, regarding the external fixator device, the author should mention why the custom made (using acrylic fixator) was applied, rather than more simple connecting rods and clamps.

Is the background of the case's history and progression described in sufficient detail?
Yes

Are enough details provided of any physical examination and diagnostic tests, treatment given and outcomes?
Partly

Is sufficient discussion included of the importance of the findings and their relevance to future understanding of disease processes, diagnosis or treatment?
Yes

Is the case presented with sufficient detail to be useful for other practitioners?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: orthopaedics and traumatology

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.