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Case report

Joint-preserving reconstruction of a traumatic distal tibial defect using the Capanna technique: a case report

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ABSTRACT

Introduction and importance: Massive segmental bone defects constitute a complex therapeutic challenge. The most widely-accepted techniques to address such defects, i.e., distraction osteogenesis and vascularized bone grafts, are associated with significant limitations. The Capanna technique, which combined a structural allograft with a vascularized fibular graft, has emerged as an effective alternative for cancer patients. However, few reports exist on its use outside this context. The case presented here extends the indications of the Capanna technique to the traumatic scenario, where it can also allow preservation of the joint.

Presentation of case: 63-year-old male with an open IIIC fracture of the right distal tibia also involving the ankle joint that was sustained in a high-energy motor vehicle accident. Following a damage-control surgery and a rectosigmoid tumor resection, the 12 cm bone defect was addressed by means of the Capanna technique. A structural tibia allograft was used in combination with a contralateral vascularized fibular graft, both of which were fixed with an anterolateral plate. Bone transport and arthrodesis were ruled out. The patient's clinical course was favorable, with healing of the graft and an acceptable outcome in terms of function and joint range of motion.

Clinical discussion: This case highlights the versatility of the Capanna technique, showing that it can effectively be used outside the oncologic scenario, to address post-traumatic defects with joint involvement.

Conclusion: Use of the Capanna technique without recourse to arthrodesis appears to be a valid alternative in the treatment of intra-articular post-traumatic bone defects.

1. Introduction

Segmental bone defects constitute a significant therapeutic challenge for the orthopedic surgeon. The wide variety of techniques used for managing them together with the absence of a treatment that can be regarded as the gold standard make the challenge even more formidable [1,2]. The two most commonly used techniques for managing defects larger than 5 cm are distraction osteogenesis with an external fixator and vascularized bone grafts, although both are associated with limitations such as protracted treatment times in the case of the former and poor mechanical stability in the case of the latter [2].

The technique developed by Capanna [3], which combines a vascularized graft with a structural allograft, has been shown to be effective in the context of complex reconstructions, particularly in the case of cancer patients undergoing chemotherapy. The vascularized graft induces revascularization and osteogenesis while the structural allograft provides mechanical stability. Over time, the allograft progressively resorbs while the vascularized graft hypertrophies and gradually assumes the mechanical and biological functions of the reconstructed segment [4].

This is a case where the Capanna technique rather than an arthrodesis was successfully applied to address a traumatic segmental bone defect in the distal tibia also involving the ankle joint. To the best of the authors' knowledge, this is the only report in the literature with these characteristics. This case report has been reported in line with the SCARE checklist [5].

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2. Presentation of case

The patient was a 63-year-old male who, after sustaining a high-energy motor vehicle accident, was admitted to the emergency department. The patient presented with an open grade IIIC metaphyseal-diaphyseal fracture of the right distal tibia that also involved the ankle joint (Table 1).

On the day of admission, a damage-control surgery was performed where an artery bypass was conducted to revascularize the foot together with an aggressive debridement. The resulting 12 cm bone defect was obliterated with vancomycin and gentamycin-loaded cement (Vancogenx, Tecres, Sommacampagna, Italy) and stabilized with an external fixator (Hoffmann III, Stryker Corp, Portage, USA). The soft tissues were treated with vacuum-assisted closure (VAC) therapy (Fig. 1).

Two days later, a new debridement of the necrotic bone was carried out until viable bone was encountered (paprika sign); the cement spacer was also replaced (Fig. 2). In addition, the soft tissue defect was covered with a free latissimus dorsi flap by a plastic surgeon.

Table 1
Case timeline.

Date	Event
Day 0	Patient sustains his fracture
Day 0	Initial WBCT[a] scan showing a rectosigmoid tumor
Day 0	Damage-control surgery (debridement + external fixator)
Day 2	Second debridement and cement spacer replacement
Day 2	Coverage of soft tissue defect with free latissimus dorsi flap
Day 79	Resection of rectosigmoid neoplasm
Day 134	Removal of external fixator, pin site debridement and placement of a plaster cast.
Day 146	Tibial reconstruction with Capanna technique.
Day 146	Positive samples for *S. aureus*: antibiotic treatment for 8 weeks
Day 232	Normal blood work
Day 237	Progressive weight-bearing authorized
Day 511	Full weight-bearing. Discomfort following long walks. No functional limitations.

[a] Whole-body computed tomography.

The CT-scan performed on admission revealed a non-occlusive rectosigmoid neoplasm. As no metastasis was present, it was decided to resect the neoplasm, which made in necessary to postpone the second reconstructive stage until the patient was clinically stable.

Finally, final reconstruction through the Capanna technique was performed four months after the accident. Twelve days before, a prior surgical step was carried out consisting of removal of the external fixator, debridement of the pin sites, and immobilization of the limb with a plaster cast. During the Capanna procedure, the cement spacer was removed and a debridement of the tibia was carried out until viable bone was encountered. The resulting bone defect was filled with a tibial shaft allograft obtained from a tissue bank (State Blood & Tisue Bank, Spain). A "trench" was cut into the allograft to accommodate a vascularized fibular graft from the contralateral side (Fig. 3). This graft, which was placed in direct apposition to both tibial fragments, was anastomosed termino-terminally to the anterior tibial artery and its accompanying veins. To allow postoperative monitoring of viability, the graft included an island skin flap. Fixation was completed with an anterolateral distal tibial plate (ALPS, Zimmer Biomet, Warsaw, USA) (Fig. 4).

The immediate postoperative course was encouraging, with proper vascularization of the fibular graft, good tolerance to rehabilitation and satisfactory radiographic results. The samples obtained intraoperatively were positive for *Staphylococcus aureus*, but the infection was effectively treated with an 8-week-long course of levofloxacin (750 mg/12 h) and rifampicin (600 mg/24 h). Proprioceptive weight-bearing was introduced gradually from the third month post-op. At one year, the patient was able to walk with full weight-bearing, without any significant functional limitations, except for some occasional discomfort when walking long distances. Fig. 5 shows satisfactory graft integration and no signs of hardware failure; however, a syndesmosis injury is visible and should be monitored. If the patient develops symptoms of instability or discomfort in the future, treatment with a trans-syndesmotic screw should be considered. The flap healed satisfactorily and ankle range of motion was 5° dorsal flexion and 20° palmar flexion. Long-term follow-up was not possible due to patient relocation.

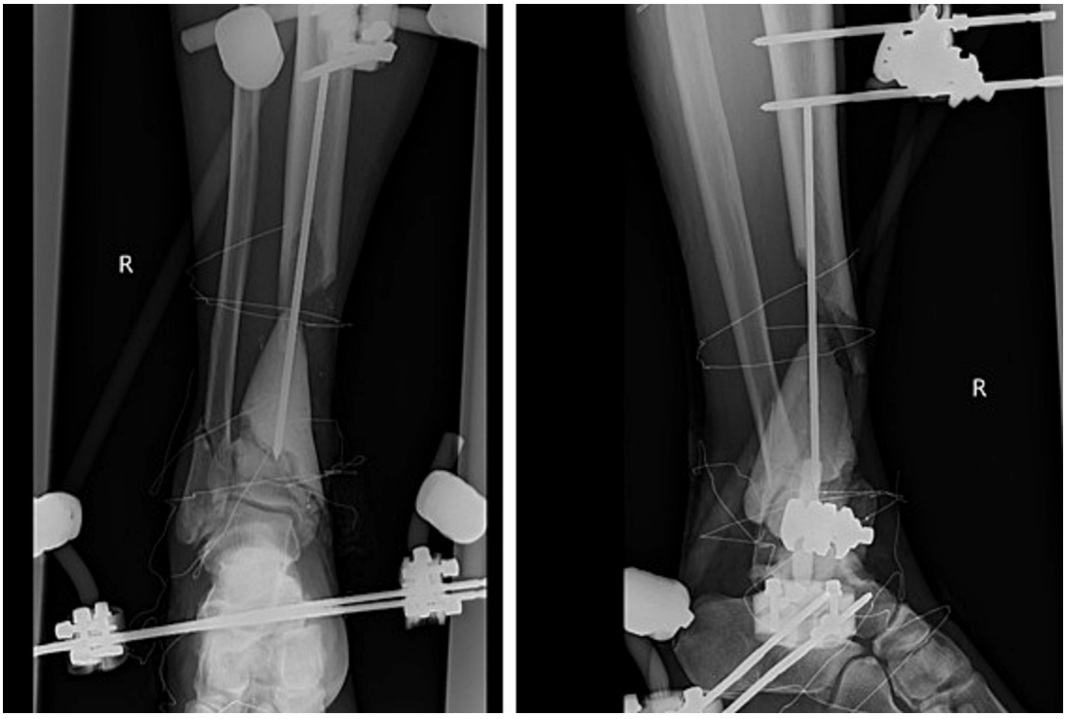

Fig. 1. Radiographs performed following the damage-control procedure showing a bone defect resulting from the initial debridement as well as the external fixator (Hoffmann III, Stryker Corp, Portage, USA) used to stabilize the ankle.

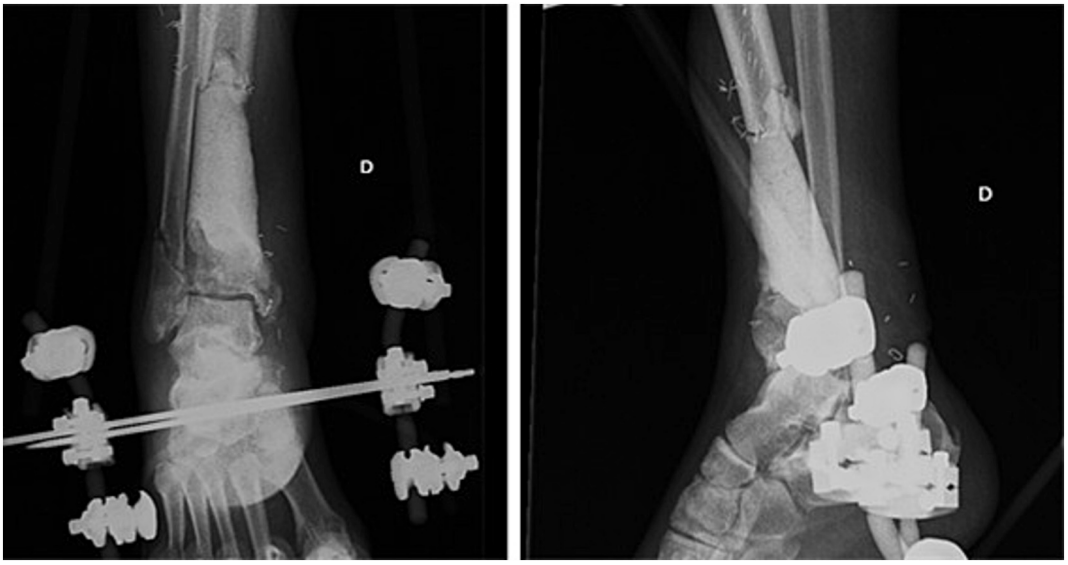

Fig. 2. Radiographs performed two days after the patient was admitted to hospital showing the new cement spacer in place.

Fig. 3. (a) Tibial segment obtained from a tissue bank (State Blood & Tissue Bank, Spain) from which the structural allograft was obtained (left); (b) vascularized fibular graft from the contralateral leg including an island skin flap (right).

3. Discussion

The case presented here constitutes, to the best of the authors' knowledge, the first report in the medical literature on the use of the Capanna technique to reconstruct a segmental bone defect in the distal tibia also involving the ankle joint, without recourse to arthrodesis. It is also one of the few cases where the technique, originally developed to mechanically reinforce vascularized fibular grafts in patients where chemotherapy led to a higher risk of fracture and nonunion, was used outside the context of oncology [3,4,6–8].

The authors evaluated several techniques as options for reconstructing the affected limb, including bone transport. Although this procedure is currently considered the gold standard [2], it is associated with several important limitations, including the need for prolonged use of external fixators, the high risk of pin tract infection and fractures of the regenerate, and the unpredictability of union rates at the docking site [1,4]. The 12 cm defect described in the present report would require an excessively prolonged external fixation time, which was unfeasible in this case given the patient's reluctance to wear a fixator due to the discomfort generated by the distal pins.

The Masquelet technique [9], which consists of inducing a pseudosynovial membrane through the local tissue reaction to a cement spacer, followed by the placement of bone allograft into the resulting cavity, was also considered. However, this option was ultimately

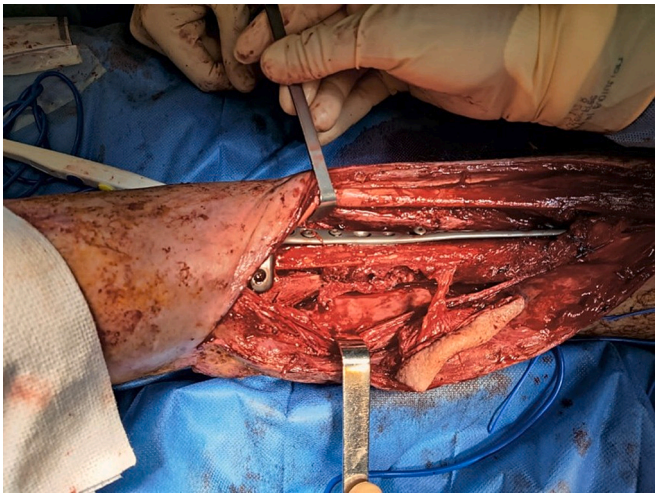

Fig. 4. Image showing the vascularized fibular graft lodged in the structural allograft's intramedullary canal. Fixation was obtained with an anterolateral plate (ALPS, Zimmer Biomet, Warsaw, USA).

discarded due to the massive size of the defect—which raises concerns about the quality of the regenerated bone [10]—and the significant periarticular involvement present in this case.

Another option reviewed was the use of structural bone allografts, associated with such advantages as initial mechanical stability, bone stock preservation and the possibility to actively move the adjacent joints [11]. Nonetheless, their use in isolation has been shown to result in high rates of infection, fracture and nonunion, which in many cases make it necessary to subject patients to additional surgeries [4,12].

Finally, the use of a vascularized fibular graft was considered given the intrinsic blood supply of these grafts, which endows them with an excellent osteogenic potential and high rates of union to the host bone [8]. However, the limited mechanical strength of these grafts, particularly in weight-bearing areas such as the tibia, means that their use should be restricted to pediatric patients or to the upper limb [2,8].

In the face of these limitations, a decision was finally made to carry out a biological reconstruction using the Capanna technique [3], which combines a structural allograft with a vascularized fibular graft, harnessing the mechanical advantages of the former and the biological properties of the latter. Over the first few years after the procedure, the allograft provides structural support while the partially weight-bearing fibular graft undergoes progressive hypertrophy. As the allograph resorbs, the fibula gradually takes on its structural function [4], a synergy that allows for faster bone healing, fewer complications, and earlier mobilization of the affected limb [7,13]. This makes the Capanna technique an appropriate alternative, not only for cancer-associated but also for septic bone defects [14,15].

Application of the Capanna technique to a bone defect also involving a joint poses an additional challenge as the reconstruction must ideally preserve the function of the joint. Although arthrodesis is a valid reconstructive option that is frequently resorted to in the context of segmental defects involving the ankle [15,16], the procedure unfailingly leads to an irreversible loss of mobility in the joint. Several authors [16,17] have also pointed out that joint fusion increases the risk of secondary osteoarthritis in the adjacent joints due to a phenomenon called *compensatory mechanical overload*, in addition to being associated with high rates of nonunion and considerable mortality. In the case of our patient, it was decided not to perform an arthrodesis so as to preserve the joint and avoid the long-term functional consequences resulting from the procedure. This was possible because the authors succeeded in preserving the talar and the distal tibial joint surfaces. Anatomical reduction and stabilization of the joint were obtained at the same time as the bone allograft united to the vascularized fibular graft. Although the graft did not reach as far as the joint, the skeletal

Fig. 5. Anteroposterior and lateral radiographs performed at one year from the Capanna operation. The image shows good integration of the allograft and hypertrophy of the fibular graft. Long-term follow-up was not possible due to patient relocation.

stabilization achieved resulted in an indirect resolution of the existing ligament instability which, together with the preservation of the joint's congruency, helped obtain an acceptable functional range of motion (5° dorsal flexion, 20° plantar flexion).

As far as the specificities of the case are concerned, following Capanna's recommendations [3], an intramedullary configuration was selected for the vascularized fibular graft in the allograft's medullary canal to ensure the stability of the union. Fixation was achieved using an anterolateral distal tibial plate. An intramedullary configuration allowed for a more intimate contact between the grafts and the host bone, in addition to providing a more mechanically robust structure [7,18]. Alternatively, Capanna also described an onlay configuration, reserved mainly for femur reconstructions [18]. As regards the origin of the vascularized fibular graft, although Ozaky et al. [6] proposed the use of the ipsilateral fibula, in this case it was decided to abide by the original Capanna technique and harvest the graft from the contralateral side [3].

This case highlights the versatility of the Capanna technique, showing that it can effectively be used outside the oncologic scenario, and opens the door to it being used to address complex post-traumatic defects, even in the presence of joint involvement. Nevertheless, a long-term follow-up is required to monitor the extent of graft integration, the ankle's functional evolution, and the durability of the results obtained.

4. Conclusions

Employing the Capanna technique while avoiding arthrodesis appears to be a valid alternative in the treatment of intra-articular post-traumatic bone defects.

CRediT authorship contribution statement

Kilian Fraga Lavía: Conceptualization, methodology, validation, formal analysis, investigation, writing—original draft preparation, writing—review and editing, visualization, supervision. **Sergi Barrantes Verdoy:** Conceptualization, methodology, writing—review and editing. **Eric Ruzafa Martínez:** Conceptualization, methodology, writing—review and editing. **Oriol Bermejo Segú:** Conceptualization, methodology, writing—review and editing. All authors have read and approved the final manuscript.

Informed consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Ethical approval

This case report was exempt from ethical approval. According to the guidelines of the corresponding institution, single-patient case reports without experimental intervention are exempt from ethical committee approval. Therefore, no reference number is applicable. Written informed consent for publication was obtained from the patient.

Guarantor

Kilian Fraga Lavía.

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Declaration of competing interest

None.

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