Case Report
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The "Bell-Tent Technique" for Management of Periarticular, Cavitary Bone Defects of the Tibia: A Case Report

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Learning Point of the Article:

Soft-tissue reconstruction should be planned in conjunction with bone reconstruction and preferably done in the same sitting to reduce the chances of wound dehiscence and shorten the duration of treatment.

Abstract

Introduction: Cavitary bone defects require complex, multidisciplinary reconstructive modalities, ranging from bone regeneration using distraction osteogenesis to the induced membrane technique and its modifications. The aim of this study was to put forth an innovative way of managing large, peri-articular cavitary defects, using a modified Masquelet technique along with the addition of a surgical polypropylene mesh.

Case Report: A 34-year-old male, with a large, peri-articular cavitary bone defect of the proximal tibia, underwent joint preservation surgery using the combination of a non-vascularized fibula along with cancellous autografting, secured using a polypropylene mesh. The design of this construct resembled a camping tent, which is why it was given that name. A knee-spanning Ilizarov frame provided the requisite stability until clinico-radiological union.

Results: Clinico-radiological union was achieved at 9 months following the frame application. At final follow-up of 37 months, he demonstrated a clinically stable knee with 0–70° of flexion (5° extensor lag persisted), which enabled him to use stairs and public transport, and radiographs showed a consolidated proximal tibia in good alignment. The patients' adjacent joints were salvaged, and the bone defect healed without any major complications. His skin defect required a supplementary medial gastrocnemius flap.

Conclusion: The bell-tent technique may represent a useful joint-preserving reconstructive option for selected patients with large peri-articular cavitary defects of the tibia. In this case, it facilitated biological reconstruction, maintenance of limb alignment, and preservation of adjacent joint function. Further studies are required to establish its reproducibility and long-term outcomes.

Keywords: Cavitary defects, chronic osteomyelitis, dead space management, joint-sparing, non-vascularized fibula; relative stability.

Introduction

Chronic osteomyelitis is a vexing condition that was traditionally treated using lengthy antibiotic regimes and repeated surgical debridement [1]. It represents a major economic burden for every healthcare system and substantially affects the quality of life of affected patients and their families [1]. Defect management following eradication of infection is the foremost challenge, for which a multitude of options, ranging from vascularized or non-vascularized bone grafting to bone transport, are available, each having its own benefits and demerits. The aim of this study was to put forth an innovative new way of managing large peri-articular cavitary defects, using a modified Masquelet technique, combining the structural durability of a non-vascularized fibula with the superior

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Figure 1: (a) Initial anteroposterior (AP) and lateral (Lat) radiographs of the patient, showing a maluniting proximal tibia fracture with implants in situ; (b) Clinical pictures of the patient at initial presentation; (c) AP and Lat radiographs of the patient at presentation to our centre, showing a varus malunion of the proximal tibia with a large cement spacer in situ. Anterior cortical deficiency can be appreciated by extravasation of cement in the anterior part of the tibial plateau; (d) 18-flourodeoxyglucose positron emission tomography images showing tracer concentration in the proximal tibia, joint space, and parts of the medullary cavity.

osteoinductive properties of cancellous bone graft, along with the addition of a surgical polypropylene mesh. We have termed this innovative method the "bell-tent technique."

Case Report

A 34-year-old male soldier, a non-smoker, suffered a compound fracture of the proximal tibia during a road accident, for which he underwent wound debridement and internal fixation of the fracture using a nail-plate construct (Fig. 1a). He subsequently developed surgical site infection, for which multiple debridements along with a cement spacer insertion were performed. A few months later, he presented to our center with pain and an inability to bear weight on the affected limb. Clinical examination revealed a stiff knee with only a jog of movement, a discharging sinus, and a varus deformity of the proximal tibia, along some abnormal mobility at the fracture site (Fig. 1b). Radiographs showed a non-union fracture of the proximal tibia with a cement spacer in situ (Fig. 1c). An 18-flourodeoxyglucose positron emission tomography (FDG-PET) scan was performed to delineate the anatomical extent of infection within the bone, which revealed tracer concentration in the proximal tibial metaphyseal region (Fig. 1d).

Figure 2: (a) Adherent skin with sinus tract; (b) large cavitary defect of proximal tibia uncovered after satisfactory debridement, with intact articular surface; (c) void filled with antibiotic-laden cement spacer; (d) immediate post-operative radiograph showing stemmed cement spacer with temporary external fixation in situ.

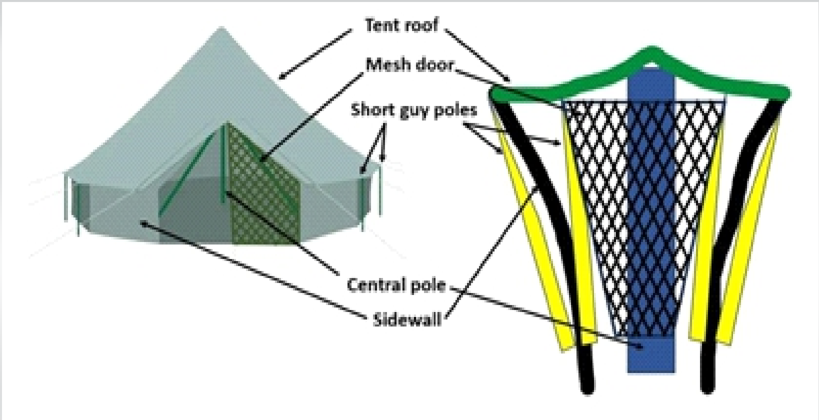

Figure 3: Illustration of the "bell-tent technique;" arrows denote corresponding parts of the "tent," namely the central pole, short-guy poles, roof, sidewalls, and mesh door.

Quantitative C-reactive protein (Q-CRP) values were recorded for serial monitoring. The patient was given an "antibiotic-free holiday" of 2 weeks before contemplating any surgical intervention.

Using the previous midline scar and a medial parapatellar arthrotomy (Fig. 2a), the knee joint was exposed after clearing all intra- and extra-articular adhesions. The cement spacer was removed carefully without damaging the existing bone stock. After obtaining five specimens for culture from the medullary canal, posterior cortex, subchondral bone, surrounding soft tissue, and joint fluid, an extensive debridement was performed until satisfactory clearance of all inviable bone and soft tissues was obtained. The posterior cortex of the proximal tibia was intact, and on making multiple cortical drill holes, fresh punctate bleeding was observed. The entire anterior cortex, comprising approximately 35–40% of the circumference, was absent, exposing a large, 6 × 8 cm cavitary defect in the proximal tibia, extending up to the posterior cortex (Fig. 2b). The articular surface was intact, with around 5 mm of subchondral bone centrally. The meta-diaphyseal junction was in a state of fibrous union.

Next, the medullary canal was reamed with flexible reamers and irrigated using pulsatile jet lavage. An antibiotic-impregnated cement spacer mounted on an Ilizarov rod (as a stem) was prepared, to which 4 g of Vancomycin and 4 g of Meropenem were added. The spacer was carefully inserted into the defect, followed by application of a temporary external fixator (Fig. 2c and d). Postoperatively, 4/5 cultures were positive for Klebsiella pneumoniae, sensitive to Meropenem and Tigecycline; the patient was started on 2 weeks of injectable culture-specific antibiotics, followed by oral antibiotics for 6 weeks. At the end of 2 months, the wound condition improved, and serial Q-CRP monitoring showed a declining trend, which prompted us to plan a definitive reconstructive procedure.

Surgical technique

Through the previous surgical approach, the knee joint was exposed, the cement spacer removed, and a thorough

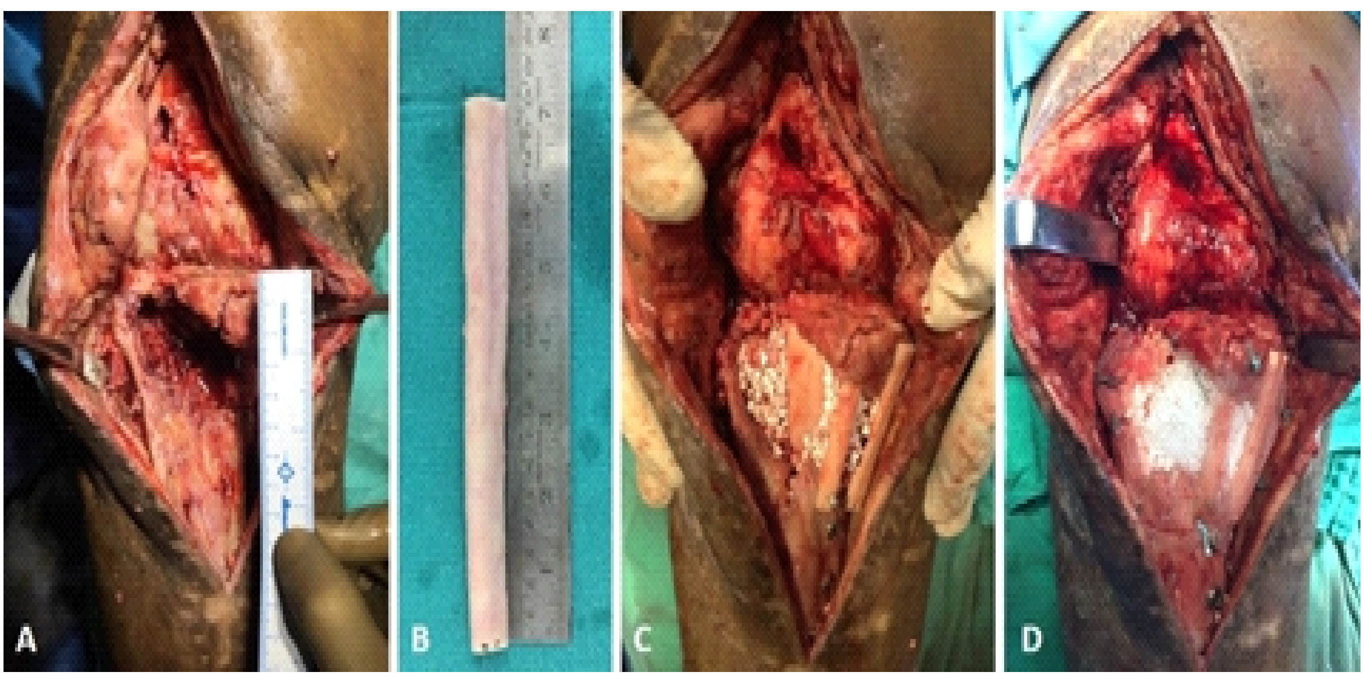

Figure 4: (a) Second stage of surgical procedure following debridement, a cavitary defect measuring 6 × 8 cm was present; (b) Ipsilateral fibular graft measuring 18 cm in length; (c) Bone grafting of cavity using the bell-tent method, with a central fibular pole and three short-guy fibular struts, void filled up with a mix of cancellous and synthetic bone graft in the ratio 3:1; (d) Polypropylene mesh applied to secure the graft and substitute the deficient anterior wall.

Figure 5: Long leg films and clinical pictures, showing a restoration of normal limb alignment.

debridement with pulsatile lavage was performed. As before, intra-operative samples were sent from different anatomical sites, which later came out negative for any growth. For reconstruction of the cavitary defect, the patient's ipsilateral fibula, along with iliac crest bone graft, was harvested and combined in a unique way, which we have termed the "bell-tent technique," akin to the design of a camping tent (Fig. 3). Details of this technique are as follows:

1. To provide a robust central pivot, the length of the fibula required was estimated to be at least twice the maximum length of the defect. Hence for a 6 cm-long cavity (Fig. 4a), a graft measuring 18 cm was harvested, sparing the upper and lower fourths of the fibula (Fig. 4b). The graft was cut into two portions, one of 12 cm, which became the "central pole;" the other 6 cm segment was cut into three longitudinal struts of cortical bone, much like "short-guy poles" of a bell-tent that support the roof circumferentially (Fig. 3 and 4c). The posterior tibial cortex was in a state of fibrous union, which facilitated prying open of the anterior cortical defect to impact the fibular strut in the canal. The canal itself was widened beforehand using appropriately sized K-nails and flexible reamers, up to the required depth, which enabled unhindered passage of the fibula. The strut was inserted antegrade and was then tapped in a retrograde fashion using a bone holding forceps, until its subchondral position was confirmed by direct vision and by fluoroscopy. Once secured, the strut was held in position by two cortical screws, while K-wire bits were used to affix the short-guy poles.

2. Next, a mixture of morselized iliac crest bone graft and synthetic bone graft (Allogran R, Biocomposites, USA) in the ratio of 3:1, was prepared and packed into the void between the central pole, side walls, and roof (Fig. 4c). The anterior cortical defect was closed using a surgical polypropylene mesh (Ethicon, J&J, USA), analogous to a "mesh door," to contain the graft within the cavity (Fig. 3 and 4d).

3. Following wound closure, a pre-constructed, knee-spanning

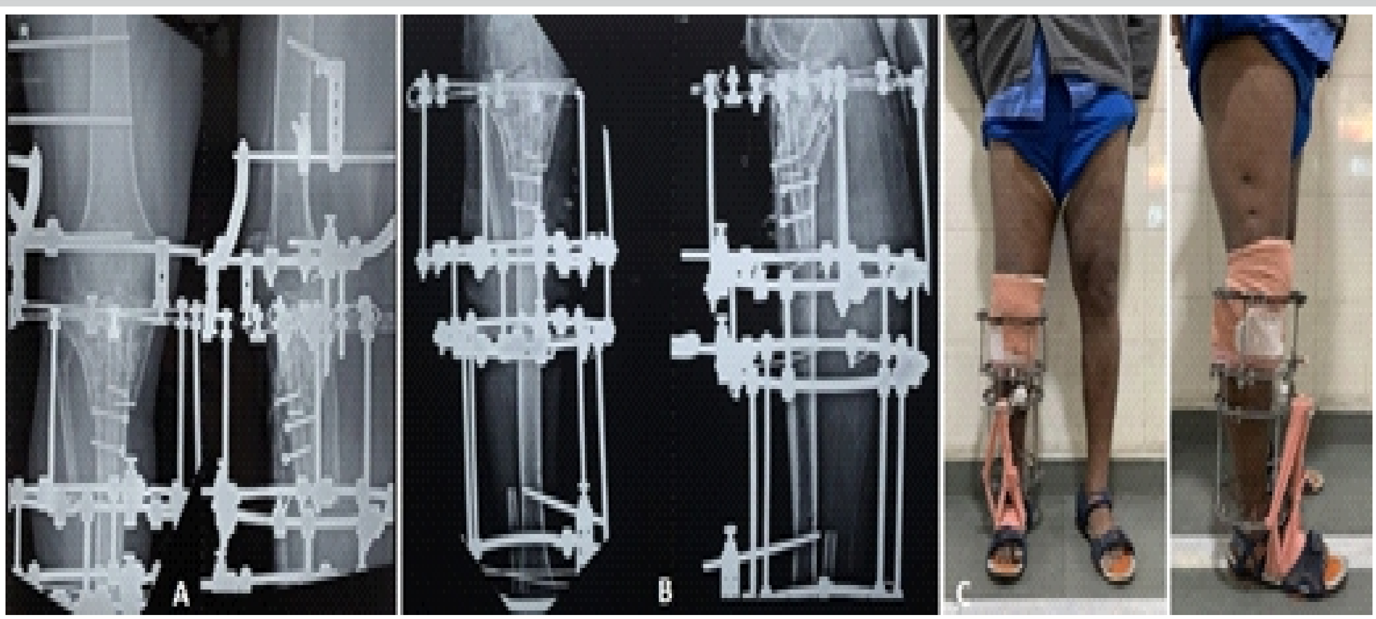

Figure 6: (a) Anteroposterior and lateral radiographs of the knee joint demonstrating the radiolucent carbon-fiber ring over the joint and position of subchondral "raft" wires; (b) radiographs following removal of the knee-spanning portion of the frame; (c) clinical images following removal of the knee-spanning portion of the frame.

Figure 7: Skin breakdown over anteromedial tibia, exposing underlying bone; medial gastrocnemius flap done after excising redundant skin and mesh to provide adequate soft-tissue cover.

Ilizarov frame was applied, using multiple subchondral "raft wires," to support the articular surface, affixed to a radiolucent carbon-fiber ring, that enabled clear visualization of the joint and status of graft integration (Fig. 5). The varus malunion was corrected acutely at this stage; post-operative long leg films showed good limb alignment (Fig. 5). Weight bearing was permitted as per tolerance, using a walking aid. In about 4 months, the graft looked sufficiently consolidated to remove the upper (knee-spanning) part of the frame and commence range of motion (ROM) exercises (Fig. 6a, b, c). Active quadriceps strengthening exercises and full weight bearing were permitted with the help of two crutches. The knee ROM achieved was 0–30° with a 10° extensor lag.

4. Clinico-radiological union was seen at 9 months post-operative, and the frame was removed. By this time, the fragile skin over the anteromedial aspect of the proximal tibia had dehisced, exposing the underlying bone, for which a medial gastrocnemius flap, along with patellofemoral adhesiolysis, was performed (Fig. 7). The previously inserted mesh was found to be adherent to the overlying redundant skin and had to be excised in totality, warranting the need for flap cover. Within the erstwhile cavity, the graft was completely incorporated, hence the screws and wire-bits were removed, leaving behind no metallic implants. Continuous passive motion as well as strengthening exercises were commenced.

Follow-up and Results

At final follow-up of 37 months, he demonstrated a clinically stable knee with ROM of 0–70° (5° extensor lag persisted), which enabled him to use stairs and public transport, and radiographs showed a consolidated proximal tibia in good alignment (Fig. 8). Table 1 shows a comparative analysis of his radiological deformity parameters before and following the intervention. No major complications apart from superficial pintract infections were encountered.

Discussion

Chronic osteomyelitis is a progressive, low-grade inflammation of bone caused by pathogens, resulting in destruction and sequestrum formation [2]. The symptoms include chronic pain, swelling, persistent sinus or drainage, impaired wound healing, and their duration may vary considerably, with intermittent waxing and waning, giving the false impression of a remission. Imaging modalities include plain radiography, magnetic resonance imaging, and FDG-PET, which has the highest sensitivity and specificity in detecting inflammatory activity in remote locations such as the medullary cavity [3]. The most widely used classification system of chronic osteomyelitis in adults is the Cierny-Mader classification [4]. We have limited our discussion to the management of Type 3 (localized) osteomyelitis, with full-thickness cortical involvement, requiring complex dead-space management.

Figure 8: (a) Three-year follow-up radiographs (anteroposterior and lateral) of the patient, showing graft consolidation; (b) clinical pictures of the limb, showing a satisfactory appearance and alignment.

Table 1: Comparison of pre- and post-operative radiographic parameters

Parameter	Pre-operative	Post-operative
MPTA	81°	86°
PPTA	87°	84°
MAD	Not done	9 mm
LLD	28 mm	10 mm

MPTA: Medial proximal tibial angle, PPTA: Posterior proximal tibial angle, MAD: Mechanical axis deviation, LLD: Limb length discrepancy

Adequate surgical debridement remains the cornerstone of treatment, and soft-tissue reconstruction is an obligatory part of the procedure. In the tibia, the anteromedial cortex has the least muscle cover and blood supply, while the posterior cortex has a more vascular muscle bed and a better blood supply; hence, it was not disturbed. Antibiotic delivery and duration remain a topic of contention; however, there is enough evidence to support polymethylmethacrylate (PMMA) as an efficient vehicle for local antibiotic delivery in high concentrations [5]. A number of alternatives with antimicrobial and osteoconductive properties, such as calcium sulfate-hydroxyapatite composite (Cerament G/V, Bonesupport, Lund, Sweden), calcium sulfate (Stimulan, Biocomposities, USA), and Bioactive glass S53P4 (BonAlive, Turku, Finland), have been used with reasonable success for infection control as well as defect management [6,7]. Bone regeneration using the time-tested Ilizarov method has shown wonderful results, but it is interminable, and active cooperation of the patient is essential [8]. Isolated uni-cortical defects have been successfully treated with hemi-corticotomy, leaving the posterior cortex intact, and gradual segmental transport using the Ilizarov technique [9]. The proponents of this method of semi-focal bone transport have reported shorter external fixator indices and fewer complications as compared to traditional Ilizarov bone transport [10].

The induced membrane technique of Masquelet has been widely used for defect management with encouraging results [11]. Cancellous bone grafting can be combined with a non-vascularized fibular autograft, as in our described technique, to provide structural support and reduce the quantity of cancellous graft required [12]. We believe this results in earlier weight bearing and prevents a late collapse. Vascularized bone grafts, by virtue of their inherent vascularity, unite more rapidly with the host bone and are more resistant to infection; however, their application in the management of long bone defects remains limited, due to inaccessibility to microsurgery at many centers [13]. Our described technique uses a polypropylene mesh to substitute the deficient anterior wall and contain a large volume of bone graft within the cavity. Kalantar et al. described a modified Masquelet technique using polypropylene mesh and PMMA together for the treatment of large traumatic bone defects, without any major complications [14]. It is prudent to state that polypropylene invokes severe tissue reactions and carries a substantial risk of catching an infection; hence, it should be used with caution.

Conclusion

Chronic cavitary bone defects involving the periarticular region of long bones can be successfully salvaged with the described "bell-tent technique," in combination with stable external fixation. The method offers the unique advantage of early weight bearing and joint mobilization, while minimizing the drawbacks associated with prolonged duration of external fixation. Further studies are required to establish its reproducibility and long-term outcomes.

Clinical Message

Soft-tissue reconstruction should be planned in conjunction with bone reconstruction and preferably done in the same sitting, to reduce the chances of wound dehiscence and shorten the duration of treatment.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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