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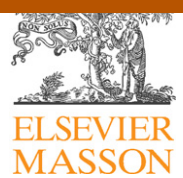

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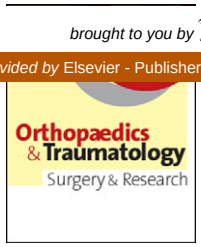

CLINICAL REPORT

Tibial segmental bone defect reconstruction by Ilizarov type bone transport in an induced membrane

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KEYWORDS
Open fracture;
Bone defect;
Fasciocutaneous flap;
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Summary The management of combined loss of skin coverage and bone substance in the lower third of the leg is problematic. A recommended sequential strategy associates removal of infected tissue and coverage followed by treatment of the bone defect. We report a technique without microsurgery, using Masquelet's induced membrane technique to manage the bone loss, associated to bone transport and coverage by a fasciocutaneous flap with distal pedicle. In a patient presenting with a 10 cm defect with bone exposure, this 2-step procedure allowed consolidation at 7 months without functional sequelae; the fixator was kept in place for 9 months. Neither microsurgery nor cancellous bone graft was required. Using a spacer to induce a membrane facilitated bone transport and distal consolidation.

Introduction

Loss of cutaneous and boney substance in the lower third of the leg secondary to infected open fracture raises complex treatment issues as the bone is poorly vascularized, surrounded only by tendons and fasciocutaneous tissue. Free muscle flap coverage is required in extensive or circumferential lower limb bone loss [1]. Free fasciocutaneous flaps (FCF) have proved as effective as free muscle flaps in lower limb reconstruction [2,3], even in case of sepsis [4]. Free flaps are becoming less frequently indicated [5,6], in favour of pediculated flaps, which are easier to obtain and induce fewer and less severe complications. Sural neurocutaneous flaps show great flexibility of use [7]. Perforator flaps are a novel approach [6,8]. Bone defects may be managed by fibula [9—11] or free vascularized iliac crest [12], using Masquelet's induced membrane technique [13—15] or bone transport [16—28].

The present case report is of bone defect managed by part of Masquelet's procedure, associating pediculated FCF cover to bone transport. This 2-stage technique may offer a new perspective in the management of such lesions. It has the interest firstly of involving no microsurgery for bone loss and soft-tissue reconstruction. Secondly, it conserves bone

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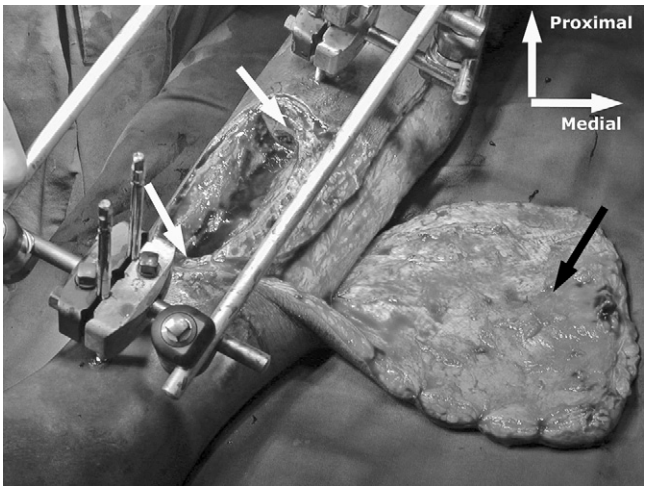

Figure 1 Distal fasciocutaneous flap (black arrow) and monoblock resection of infected bone (white arrow).

capital, requiring no cancellous bone graft, by preparing the transport site by means of a temporary spacer to facilitate transport and distal consolidation.

Observation

Mr D., 27 years old, was referred to the Pointe-à-Pitre hospital in Guadeloupe on February 29, 2004, from a neighbouring English-speaking Caribbean island, following an open fracture of the right lower limb sustained 1 month before, when his motorcycle was overturned by a car. The fracture was grade III A on Gustilo's classification [29]. Clinical check-up found a bifocal fracture stabilized by Hoffmann I external fixator transfixation pins, with anteromedial soft tissue loss exposing the lower third of the tibia for more than 6 cm around the distal fracture line. There was no sensorimotor or vascular impairment. X-ray check-up showed bifocal tibial fracture with an oblique proximal line at the union of the proximal and mid thirds, and a transverse distal line at the union of the mid and distal thirds. There was an associated fibular fracture at the union of the mid and distal thirds. Biological analysis found CRP at 151 mg/L, leucocytes at 11,400/L (normal: 4000—10,000) and 8.3 g/dl anemia (normal: 13—17). The patient was operated on 7 days after admission, for debridement, removal of the original fixator and fixation of a monoplanar Hoffmann II fixator on the medial side of the limb. One week later, debridement was repeated, the patient having initially refused radical exeresis of the infected bone. Two months after admission, a 10 cm bone fragment was dissected by oscillating saw at the distal tibial site, up to the presumed healthy area. A gentamycin-impregnated cement spacer was introduced, with coverage by distally pediculated FCF (Figs. 1 and 2). Bacteriological analysis of soft tissue and bone samples found *Aeromonas hydrophyla* and *Pseudomonas aeruginosa* infection. Antibiotherapy was initiated: amikacin 15 mg/kg/dqy perfusion for 10 days and pefloxacin 400 mg per os for 45 days. Cutaneous status was satisfactory, and the infection appeared to be controlled. Four months after admission, the spacer was removed, an Orthofix™ lengthening fixator (three pins in the proximal, two in the distal and two in the mid epiphysis) replaced the Hoffmann II, and proximal metaphyseal corticotomy was performed for the bone transport. The flap harvesting site was covered by a dermo-epidermal graft. Intermediate fragment transport was initiated on Day 10, at a rate of 1 mm per day (divided in four increments of 0.25 mm). Two weeks later, the patient was discharged home to achieve bone transport. Partial weight-bearing with two crutches was allowed. The patient was followed up monthly by control X-ray. Consolidation was achieved 7 months after initiation of the transport procedure, and the fixator was removed at 9 months, with crutches prescribed for a further month.

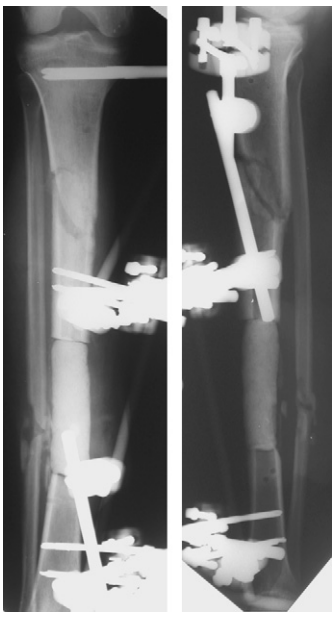

Figure 2 Cement spacer in place on antero-posterior and lateral X-ray.

At 3½ years' FU (late January, 2008), the patient was walking normally, without limp, and without orthopedic heel; monopodal stance was stable (Fig. 3), running was possible, ROM was 0/130° in the knee and 20/30° in the ankle. Consolidation showed 4° valgus and 15 mm shortening of the tibia (Fig. 4).

Discussion

In this patient treated in second intention, the cleansing of the initial open fracture site was uncertain, and we chose to dissect the infected bone, which had lost its periosteal connections, as recommended by most authors [13,19,23]. *Pseudomonas aerugionosa* and *Aeromonas hydrophyla*, found in biological analysis, are especially virulent, the latter sometimes causing necrotizing fasciitis requiring amputation [30].

We did not use the whole of Masquelet's et al. procedure [13], as the 10 cm defect seemed too great, although certain authors set no limit [13,14,15], and preferred a bone transport technique [14]. With such extensive loss of substance, the patient's bone capital available for autograft seems to us to be severely depleted, raising the threat of amputation if consolidation required further grafting or in case of

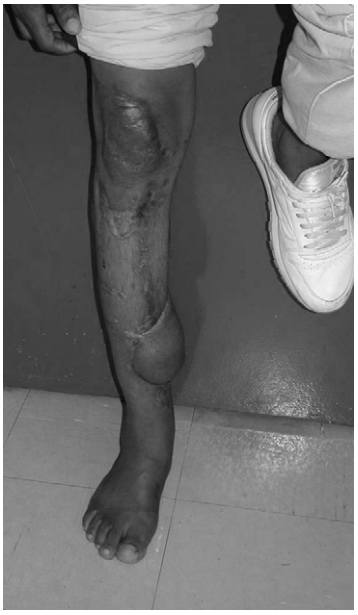

Figure 3 Stable monopodal stance; esthetic blemish of the flap, which could be degreased.

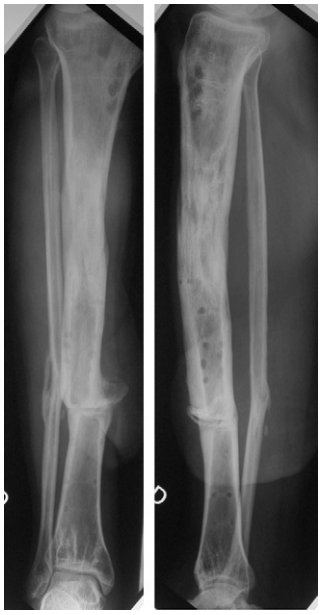

Figure 4 Anteroposterior view with consolidation of the tibia in 4° valgus, and lateral view with centered consolidation.

the slightest graft lysis on recurrence of sepsis. Our cement spacer contained gentamycin, whereas Roussignol et al. [15] advise using cement without antibiotics.

The bone defect might have been managed by free vascularized fibula, which is solid cortical bone but fragile under sepsis condition [9]. Legré et al. [12], on the other hand, consider vascularized bone to be sturdier under sepsis than conventional grafts and particularly recommended in traumatology, although, like Tropet et al. [10] they admit the risk of fatigue fracture until graft tibialization, which for some authors necessitates maintaining the dynamic external fixator in place for 1 year until significant hypertrophy is secured [10]. Legré et al. [12] warn against the risk of failure with microsurgery: its reliability is hard to assess, depending as it does on the patient's general status, the type of flap and the operator's experience. According to Masquelet [31], the only recommended free vascularized bone is the fibula (especially for severe defects up to 20 cm), the iliac crest and rib having been abandoned. For El-Gammal et al. [11], defect length is the prime factor affecting the final result: where it is less than 12 cm, they recommend the Ilizarov technique, and free microvascularized fibula otherwise.

The distally pediculated FCF provides a wide surface area, ease of harvesting and great reliability, with perforating pedicles, two from the posterior tibial artery and two from the fibular artery [32]. The drawback is the resulting esthetic blemish, as the flap is thick and may require degreasing [32]. It can now be usefully replaced by perforating flaps of more recent design, based on perforating rami, notably from the posterior tibial artery, which can be dissected adiposo-fascially [6,33].

Bone transport may entail specific complications: failure of contact consolidation at end of transport, tegument invagination during transport, insufficient regenerate maturity, decentering, and fixator pin infection. The fixator needs to be maintained while the regenerated bone matures and distal consolidation is ongoing, to avoid iterative fracture—although this does not preclude resumption of function, as weight-bearing is encouraged. According to Paley et al. [16], 1 cm of regenerated bone takes 1 month to consolidate and distal consolidation is obtained at 6 months' stable contact between the distal and transported fragments. Saleh and Rees [23] consider grafting to be mandatory where the contact area is small. Table 1 presents the need for grafting according to the various authors. Rozbruch et al. [34] performed debridement, usually with associated bone graft, where the defect was not greater than 1 cm. Paley et al. [16] reported interposed soft tissue hindering transport in two cases of severe (16 and 17 cm) bone defect. In the present case, transport enabled the defect to be filled and distal consolidation to be achieved without additional graft. The spacer no doubt facilitated transport, creating a free space when it was removed. Pelissier et al. [35] reported, in rats, that the prime role of the spacer is mechanical, preventing the site being invaded by fibrous tissue; its second role is biological, creating a pseudo-synovial membrane, acting on angiogenesis by producing vascular endothelial growth factor (VEGF), on osteoblast/osteoclast interaction regulation of bone metabolism by producing transforming growth factor (TGF) β1, and on osteo-induction by bone morphogenetic protein (BMP) secretion. These factors probably promoted consolidation and regenerate maturation. Dividing the spacer into several parts, to be progressively ablated during transport, as suggested by Rigal and Tripon [26], is an interesting idea but requiring successive interventions, with consequent risk of infection. Preparing the bone transport site with an induced membrane probably also shortens the time of consolidation and of maintaining the external fixator to respectively 7 and 9 months—less than in most series reported in the literature (Table 1). When the spacer is ablated, the X-ray shows bone tissue formation (Fig. 5), indicating osteo-induction by the induced membrane.

Table 1 Consolidation time and external fixation time according to mean bone defect dimension and possible need for grafting in the bone segment transport technique.

Authors	Date	Cases	Mean bone defect (cm)	Consolidation time (months)	External fixation time (months)	Need for bone graft at end of transport (cases)
Paley et al. [16]	1989	25	6.2	13.6	Not shown	No
Dagher and Roukoz [17]	1991	9	6.5	7.7	7.55	No
Green et al. [18]	1992	17	5.14	Not shown	9.6	6
Cattaneo et al. [19]	1992	28	4	Not shown	9	No
Cierny and Zorn [20]	1994	21	6.5	Not shown	17	10
Marsh et al. [21]	1994	10	4.1	Not shown	8.7	3
Dendrinos et al. [22]	1995	28	6	Not shown	10	3
Song et al [24]	1998	27	8.3	7.1	8	25
Paley and Maar [25]	2000	19	10.7	Not shown	16	10
Rozbruch et al. [27]	2006	25	6	Not shown	10.8	12
Trigui et al. [28]	2008	9	4.1	9	10	6
Current study	2010	1	10	7	9	No

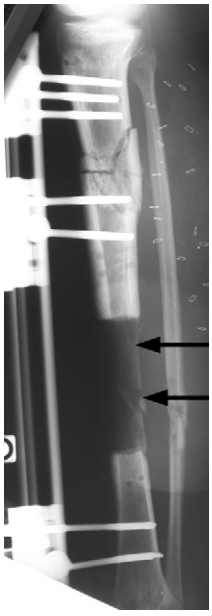

Figure 5 Removal of the spacer reveals surrounding bone formation.

Conclusion

Radical treatment of infection, associating exeresis of infected bone and adapted antibiotherapy, is the reference attitude towards chronic bone infection. Distally pediculated FCF coverage without microsurgery is of interest where the dorsal skin of the limb is healthy. Preparing the transport site with a cement spacer and inducing a membrane probably promotes bone segment transport by limiting fibrous interposition, and distal consolidation by growth factor production. The technique conserves cancellous bone capital, and is feasible in countries in which means are limited, especially with respect to microsurgery. Further case studies could confirm whether consolidation and fixator times are indeed shorter and whether bone graft is indeed not required.

Conflict of interest

None.

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