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Original Research Paper

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TO STUDY THE COMPARISON BETWEEN LONG TERM RESULTS OF DIFFERENT METHOD OF MANAGING POST-TRAUMATIC LONG BONE DEFECTS

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ABSTRACT

BACKGROUND: The severe long bone defects usually follow high-energy trauma and are often associated with a significant soft-tissue injury. The goal of management of these open long bone defects is to provide stable fixation with maintenance of limb length and soft-tissue coverage. Thus, we aimed to compare the different methods in the treatment of patients with post-traumatic long bone defects, based on the long-term functional and self-evaluation results.

METHODS: We retrospectively reviewed data on patients with post-traumatic long bone defects of the lower extremities from August 2018 to December 2020. The patients are divided into three groups according to the surgical method used to treat the defects (group 1, free vascularized fibular transfer; group 2, distraction osteogenesis; group 3, the induced membrane technique). Data including the complication rates, entire treatment period, long-term visual analog scale scores, and Sickness Impact Profile (SIP) scores during follow-up were recorded.

RESULTS: A total of 300 patients were included, with 105, 125, and 70 patients in groups 1, 2, and 3, respectively. The major complication rates were 22.6%, 25.8%, and 26.6% for the groups ($P > 0.05$), respectively. The mean treatment durations for bony defects, from surgery to non-protected weightbearing, were 65.1, 46.5, and 56.6 weeks for each group, respectively. At 2 years postoperatively, the average SIP scores for each group were 10.5, 11.7, and 11.5, respectively ($P > 0.05$).

CONCLUSION: Patients who sustained long bone defects can be advised that either one of these three methods which typically results in long-term outcomes equivalent to others. Level of evidence: retrospective study.

KEYWORDS :

INTRODUCTION

Reconstruction of post-traumatic long bone defects is a formidable problem. As the techniques for microsurgery and distraction osteogenesis have evolved, the techniques for reconstructing long bone defects have also evolved. Tissue transfer has been proven to be effective not only for ensuring an adequate soft tissue envelope through pedicled or free-tissue transfer but also for reconstructing bony defects with free vascularized bone grafts. Even in the presence of complex defects in soft tissue and bone, microsurgical techniques can be used to create vascularized composite osteocutaneous flaps in a single procedure. [1,2] The Ilizarov technique has also been widely used for treating bone defects, bone nonunion, and nonunions that are associated with poor soft-tissue coverage [3–5].The technique of induced membrane was first described in 2000 by Masquelet et al., and many further reports have confirmed its clinical validity [6,7].

Table 1: Bone defects classification

Surgical options (in order of preference)		*Bone defect type* *I <2 cm*	*II 2–6 cm*	*III 6–12 cm*	*IV >12 cm*	*Host category*
Soft tissue defect type	α	Primary bone grafting with internal fixation	Masquelet with primary internal fixation or non-vascularised graft in upper limb or child	Acute and gradual shortening and lengthening with Ilizarov fixator-trifocal or Masquelet with primary internal fixation or fibula graft in a child or upper limb defects	Acute and gradual shortening and lengthening with Ilizarov fixator or vascularised fibula graft or Masquelet with primary internal fixation	A
		Shortening	Acute and gradual shortening and lengthening with Ilizarov fixator-Bifocal	Acute and gradual shortening and lengthening with Ilizarov fixator-Trifocal	Acute and gradual shortening and lengthening with Ilizarov fixator	B
	β	Acute shortening/flap for wound management or Masquelet-induced membrane technique	Masquelet-induced membrane technique or Open bone transport	Bone transport through the induced membrane or Masquelet-induced membrane technique	Osteo-myo-cutaneous vascularised fibula graft in upper limbs or Bone transport through the induced membrane	A
		Acute shortening for wound healing/flap and fixation preferably with Ilizarov construct	Open bone transport or bone transport through the induced membrane	Open bone transport or bone transport through the induced membrane	Consider amputation in type B and C host	B
	γ	Convert a γ to β/α wound, bony stabilisation with ex-fix	Convert a γ to β/α wound, bony stabilisation with ex-fix	Convert a γ to β/α wound, bony stabilisation with ex-fix	Convert a γ to α wound, bony stabilisation with ex-fix Consider amputation	A
		Make every effort to convert a B to A host and a γ to β or α wound	Make every effort to convert a B to A host and a γ to β or α wound	Consider amputation, especially in C host	Consider amputation in type B and C host	B

Table 2: Local and systemic risk factors

	Systemic risk factors	*Local risk factors*
1	Age >80 years	Active infection
2	Low vitamin D levels	Multiple previous incisions with extensive scarring
3	Thyroid and parathyroid disorders	Compound grade III fractures with soft tissue loss
4	Hypogonadism	Osteoporosis with T score <−2.5
5	Diabetes	Prior local irradiation
6	Smoking	Vascular insufficiency
7	Long-term (>3 months) NSAIDs use	
8	Malnutrition	
9	Immunosuppressive medication	
10	Alcoholism	
11	Malignancy	
12	Renal failure requiring dialysis	
13	Systemic inflammatory disease	
14	Systemic immune compromise	
15	Hepatic insufficiency	

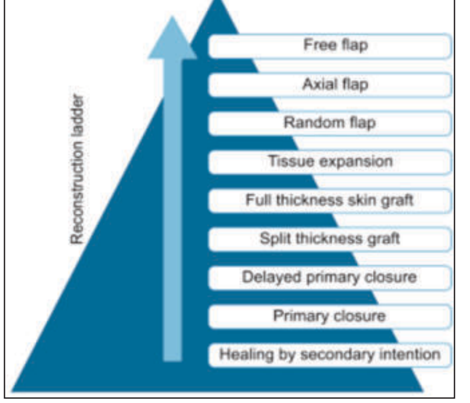

Figure 1: Soft tissue reconstruction ladder

METHODS

We retrospectively reviewed data on 300 patients who sustained post-traumatic long bone defects of the lower extremities between August 2018 to December 2020 at PCMS & RC, Bhopal, Madhya Pradesh. There were 175 men and 125 women, with a mean age of 45.2 years. The injuries were mostly caused by traffic accidents.

All of the patients were divided into three groups based on their therapeutic regimens. Patients in group 1 (FVFG group) were treated with free vascularized fibular graft, those in group 2 (DO group) were treated with distraction osteogenesis, and those in group 3 (IM group) were treated with the induced membrane technique.

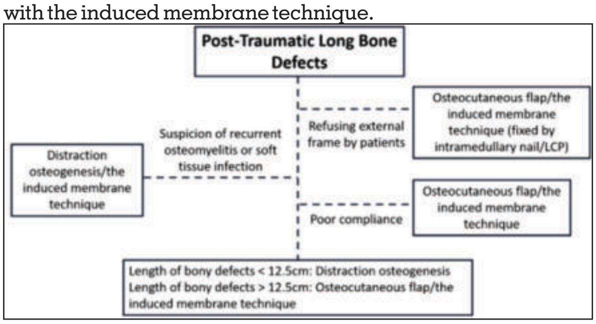

Figure 2: A precis algorithm of choose which option based on some factors

Data collection

All patients' preoperative data were collected through a review of their charts. The preoperative information included smoking history, diabetes history, movement function, and sensation of the affected limb Major complications were defined as the existence of one of the following: late amputation, nonunion of the transplanted bone, refracture without a second injury, hardware failure, massive infections, recurrent osteomyelitis, donor-site morbidity, and residual deformities that required additional surgery. The durations of treatment from surgery to weight bearing and the final walking status were recorded with respect to functional outcomes.

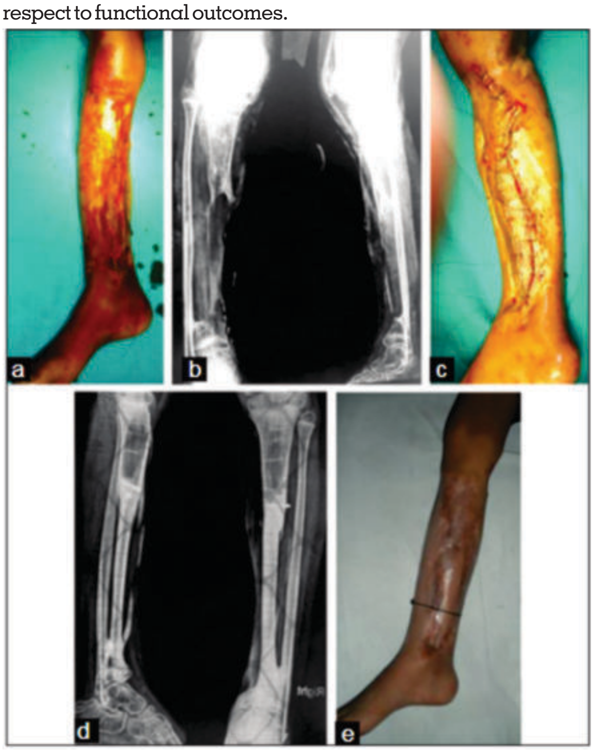

Figure: A 14-year-old boy with a compound fracture right leg. (a) Pre-operative photo, (b) Pre-operative X-ray, (c) Immediate post-operative, (d) 6 months post-operative, (e) 6 months post-operative X-ray showing hypertrophy of fibula

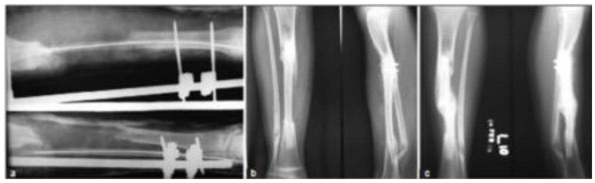

Figure : (a) Pre-operative X-ray of 22-year-old boy with defect left tibia, (b) 6 months post-operative X-ray showing satisfactory healing with hypertrophy, (c) 10 months post-operative X-ray showing healed stress fracture in transferred free fibula

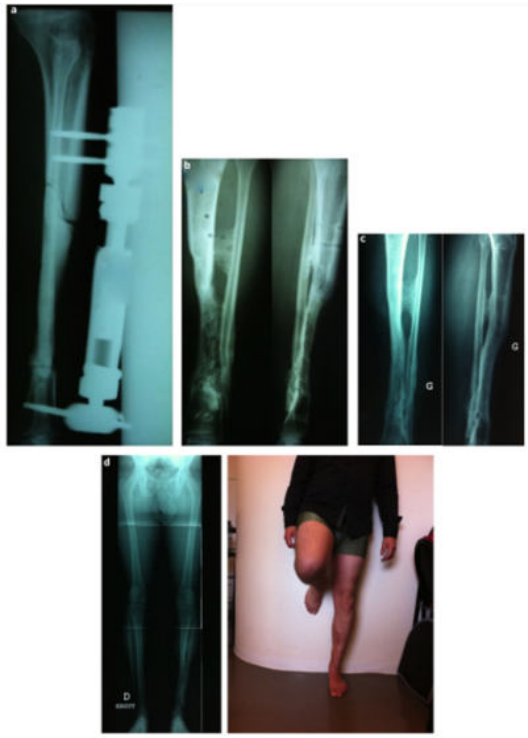

Figure: Infected open tibial fracture, treated by emergency nailing. Wound care left a 15 cm defect. **a:** induced membrane technique step 1, associating external fixation, cement spacer and soft-tissue reconstruction by soleus muscle flap. **b:** radiologic bone healing 1 year after grafting. **c:** radiologic aspect at 19 years' follow-up: peripheral densification and central resorption in the reconstructed segment. **d:** good functional outcome: the patient plays squash

Figure: Infected open humeral fracture with multiple procedures. **a:** radiologic aspect prior to induced membrane technique; 6 cm defect after wound care. **b:** radiologic aspect at 10 years' follow-up;

slight peripheral densification and persistent central bone density.

Figure. Infected open tibial fracture. Iterative wound care left 25 cm defect. **a:** cement filling and soft-tissue repair by latissimus dorsi flap. Single-plane external fixation clearly insufficient, with gradual leftward drift of the apparatus leading to consolidation in varus, whereas primary alignment had been satisfactory. Partial correction osteotomy by resection of a lateral corner of the distal metaphysis was performed after consolidation. **b:** at 15 years' follow-up, good peripheral corticalization of the reconstruction, but insufficient axial correction. The patient was asymptomatic. 4 cm limb-length discrepancy, managed by insole and heel.

RESULTS

The demographic and injury characteristics of the 300 patients in this study are shown in Table 1. There were 105, 125, and 70 patients in groups 1, 2, and 3, respectively. The major etiology was road traffic accident. There were 29, 37, and 39 patients who sustained infected nonunion and/or osteomyelitis in each group. The most frequently cultured organisms were Staphylococcus aureus and Pseudomonas aeruginosa. Mean lengths of bone defects were 11.0 ± 8.7 cm, 10.5 ± 8.4 cm, and 11.5 ± 9.1 cm for each group (P > 0.05). In total, 12,17, and 4 patients required soft-tissue repair in groups 1, 2, and 3, respectively.

Table 1 Demographics Characteristics

	Group 1 Free vascularized fibular transfer N=105	Group 2 Distraction osteogenesis N = 125	Group 3 The induced membrane technique N =70
Male Sex	68%(N=71)	74.2% (N=92)	67.1% (N=47)
Age (yrs)	36.5 ± 5.9α	35.7 ± 5.6α	35.2±5.0α
Mean follow-up (mos)	27	29	24
lengths of bone defects (cm)	11.0 ± 8.7α	10.5 ± 8.4α	11.5 ± 9.1
Number of patients who sustained infected nonunion and/ or osteomyelitis	27.4% (N=29)	28.0% (N=35)	49.4% (N=34)
Number of patients who received Soft tissue coverage	11.3% (N=12)	12.9% (N = 16)	5% (N = 4)

Radiographicresults

The radiologic healing/consolidation times were 18.2 ± 7.5, 44.7 ± 19.5, and 38.1 ± 21.2 weeks for groups 1, 2, and 3, respectively. (Table 2) Complications

Major complications in the FVFG group comprised hardware failure and/or refracture (7 cases), nonunion (5 cases), joint ankylosis or fusion (6 cases), > 3 cm LLD (3 cases), and residual deformity requiring secondary procedures (3 cases).

Complications in the DO group comprised pin-site infection (8 cases), premature or poor quality of consolidation (6 cases), deep infection (1 case), joint ankylosis or fusion (8 cases), > 3 cm LLD (3 cases), clubfoot or dropping foot (6 cases), and residual deformity requiring secondary procedures (2 cases). Complication in the IM group comprised hardware failure (3 cases), joint ankylosis or fusion (6 cases), > 3 cm LLD (5 cases), clubfoot or dropping foot (3 cases), and residual deformity requiring secondary procedures (4 cases). The overall complication rates were 22.6%, 25.8%, and 26.6% for each group (P > 0.05), respectively. (Table 2)

Table 2 Complications and long-term outcomes of each group.

	Group 1 Free vascularized fibular transfer n = 105	Group 2 Distraction osteogenesis n = 125	Group 3 The induced membrane technique n = 70
Complication rates	24 22.6%α	32 25.8%α	19 26.6%
Detailed incidence of specific complication	Hardware failure and/or refracture (7 cases), nonunion (5 cases), joint ankylosis or fusion (6 cases), > 3 cm LLD (3 cases), and residual deformity requiring secondary procedures (3 cases	Pin-site infection (8 cases), early or failed consolidation (6 cases), deep infection (1 case), joint ankylosis or fusion (8 cases), > 3 cm LLD (3 cases), clubfoot or dropping foot (6 cases), and residual deformity requiring secondary procedures (2 cases)	Hardware failure (3 cases), joint ankylosis or fusion (6 cases), > 3 cm LLD (5 cases), clubfoot or dropping foot (3 cases), and residual deformity requiring secondary procedures (4 cases)
Radiologic healing/ consolidation times (weeks)	18.2 ± 7.5b	44.7 ± 19.5	38.1 ± 21.2
Time from surgery to total non protected weight bearing (weeks)	65.1 ± 22.4α	46.5 ± 19.2α	56.6 ± 18.9
Percentage of patients with unrestricted walking distance	82.1%α (87 patients)	81.8%α (102 patients)	81.0%α (57 patients)
Percentage of patients with monopedal weight bearing	6.6%α (7 patients)	8.3%α (11 patients)	6.3%α (5 patients)
VAS at 1 year follow-up	3.57 ± 2.56α	3.71 ± 2.87α	3.83 ± 2.67
VAS at 2 year follow-up	2.67 ± 2.33α	2.78 ± 2.14α	2.67 ±1.98
SIP at 1 year follow-up	11.5 ± 8.3α	12.3 ± 9.3*	12.5 ± 8.7
SIP at 2 year follow-up	10.5 ± 7.8α	11.7 ± 8.5α	11.5 ± 8.2α

DISCUSSION

Our results overall showed that the three methods had similar complication rates and functional results in the treatment of posttraumatic long bone defects. According to the radiographic and clinical results, although the mean radiologic healing/consolidation time of the FVFG group was lesser than that of the DO and IM groups, it took extra time for compensatory hypertrophy to develop before full weight-bearing in patients treated with the free vascularized fibular graft, and this extra time ranged from 6 to 18 months, with a mean of 11 months (the sufficient compensatory hypertrophy was defined as a 50% increase in the original caliber of the transferred fibular).

The major complications in the FVFG group comprised hardware failure and refracture, due to early weight-bearing before sufficient healing and compensatory hypertrophy. Ankle function results were relatively poor in patients treated with distraction osteogenesis and induced membrane, which is in fact due to failure to prevent ankle stiffness due to prolonged immobilization. Pin-site infection mostly occurred in patients who were not conscious of self-pin-site-care. We also noticed that poor consolidation in the DO and IM groups was highly associated with the soft-tissue condition because most patients who sustained poor consolidation also sustained delayed wound healing or partial flap necrosis. Clubfoot or dropping foot was common in patients treated with retrograde bone distraction. The rate of secondary lower limb osteotomy for a residual deformity reveals the difficulty of maintaining good alignment with a single plane fixator. This is in fact mainly a matter of lack of vigilance in maintaining the lower limb axis. In severe defects (> 20 cm), a circular or hybrid external fixator is preferable to a single-plane model, and intramedullary nailing is not effective in this case due to the degree of stress exerted entirely on the locking screws.[25] In the DO group, docking-site revision and autogenous bone grafting became inevitable when the bone gap was over 12 cm. Thus, we regarded the method of distraction osteogenesis as the two-stage procedure when the length of bony defects was larger than 12 cm. The overall complication rates showed no significant statistical difference among the three methods.

Contrary to our speculation, at two years, both percentage of patients with an unrestricted walking distance and percentage of patients with mono pedal weight bearing showed no significant statistical difference among the three groups. Based on the patient's long-term life quality, chronic pain and walking statue, there was no significant indication for the selection of certain reconstructive methods.

The study has several limitations. It may be supposed that patients who responded to our invitation for assessment were those with the best results in terms of function and resumption of activities, inducing a bias. Besides that, the choice of approach was mainly determined by the surgeon's preference, and the generalizability of our results beyond level I trauma centers is uncertain. The outcomes may have been influenced by the expertise of physicians and other care givers. Moreover, this study was not a randomized controlled trial, and it is possible that superior results could be achieved if the surgeon has advanced skills and experience in performing these three methods. Further studies concerning the cost-utility analysis and long-term quality of life are needed for more comprehensive decision making for long bone defects.

CONCLUSION

Overall complication rates were analogous among the three methods of treatment, and special attention should be paid to alignment, external fixator stability, and care of all foot and ankle joints. Several factors may contribute to the healing or consolidation in bony reconstruction. Early radical debridement with extensive wound care and suitable coverage is a prerequisite for continuing with reconstruction. The entire duration of treatment and times of operation may be considered among the major affecting factors for the selection of the bony reconstruction method. A circular external fixator and intramedullary nail provide better stability than a monolateral external fixator and locking plates, which may benefit early partial weight bearing, thus stimulating consolidation. For patients who treated with induced membrane, an approach worth exploring is to cross over from external to internal fixation in step 2

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