Case Series

DOI: 10.7860/JCDR/2025/75664.20669

Orthopaedics Section

Challenges and Outcome of Infected Non Union of Bones using Masquelet Technique: A Case Series

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ABSTRACT

Infected non union of bones poses a significant challenge for orthopaedic surgeons due to the complexity of the problem, which includes bone necrosis, segmental bone loss, sinus tract formation, fracture instability, and scar adhesion of soft tissues. Bone infections remain a prevalent complication following fracture fixation. Effective management involves a multi-step approach, including debridement, soft tissue reconstruction, and bone stabilisation. The induced membrane technique, a two-stage process, has been successfully used to treat bone defects in both the upper and lower extremities. Here, four cases of infected non union treated using the Masquelet technique at various locations are presented. This technique involves a two-stage approach, where an induced membrane forms around a cement spacer, leading to the successful resolution of infection and bone union. Challenges encountered in these cases included recalcitrant infection, complex deformities, sclerotic bone ends, large bone gaps, shortening, and joint stiffness. Co-morbid factors such as smoking, diabetes, and hypovitaminosis D also influenced treatment choices and duration. All four cases treated with the Masquelet technique showed successful resolution of osteomyelitis, osseous union, and improvement in functional outcomes. Follow-up assessments revealed an average Visual Analogue Scale (VAS) improvement from 30 to 7.5, complete eradication of infection, and an average Lawton-Brody instrumental activities of daily living scale improvement from 13/23 to 21/23, with complete union of bone achieved in all four cases. Hence, it was concluded that the Masquelet technique is an effective approach for treating infected non union of bones, leading to the successful resolution of infection and bone union. Patience and perseverance are essential for achieving optimal outcomes.

Keywords: Eradication, Fracture, Induced membrane, Segmental bone loss

INTRODUCTION

Non union is a severe complication that can occur after a fracture and can result in significant patient suffering. Despite advancements in surgical procedures, the management of anatomical and functional outcomes remains complex [1]. Non union is associated with technical shortcomings (such as a plate that is too short or too weak) or injury severity (including bone loss, poor soft-tissue coverage, infection, or contamination) [2]. The presence of infection further complicates the management of non union in various ways. The existence of bone necrosis and sequestrae, segmental bone loss, sinus tract formation, fracture instability, soft-tissue damage, and scar adhesion contribute to the complexity of managing the condition [3].

Before addressing any diseased non union, it is necessary to remove and excise contaminated tissues through debridement. Additionally, it is crucial to first restore the vascular soft-tissue envelope [4].

The Masquelet technique, developed by French surgeon Alain-Charles Masquelet, is a staged procedure that combines temporary skeletal stabilisation with the implantation of an antibiotic spacer. This spacer is left in place for a period of 6 to 8 weeks, during which a "pseudomembrane" forms around it. The inclusion of antibiotics, in theory, enhances the likelihood of completely eliminating the infection. In the second phase of the treatment, the pseudomembrane is opened, the antibiotic spacer is removed, and the bone graft is inserted [4-7].

The induced membrane serves as a protective barrier that promotes the revascularisation and corticalisation of the bone graft while also limiting the resorption of the cancellous bone [8]. Authors hereby, present four cases treated with the Masquelet technique for infected non unions, where the defects post-debridement ranged from 1.5 cm to 4 cm, and discuss the challenges faced regarding the resolution of the condition, osseous union, and functional outcomes.

CASE SERIES

Case 1

A 40-year-old right-handed female fell from a chair, sustaining injuries to her right forearm, which were diagnosed as radius and ulna fractures [Table/Fig-1a]. These were initially managed surgically by internal fixation using compression plating of both the ulna and radius six months ago [Table/Fig-1b]. After the surgery, she developed compartment syndrome and underwent a fasciotomy [Table/Fig-1c]. One month later, she underwent flap coverage, followed by complaints of multiple discharging sinuses from the same site after two months. Six months later, the patient visited the Outpatient Department (OPD). The patient reported no known co-morbidities. The culture sensitivity of the discharging sinus was performed and reported as *Escherichia coli* inoculation. The X-ray of the right forearm showed implant failure with no signs of union [Table/Fig-1d,e].

The patient underwent a wound debridement procedure, implant exit, and external fixator application with sequestrectomy, followed by the insertion of an antibiotic cement spacer and antibiotic beads for both bones in the right forearm. A 4 cm bony defect was identified [Table/Fig-1f-j]. This case was complicated by Volkmann's contracture, which is a complication resulting from inadequate blood supply (poor vascularity). The patient received systemic antibiotic coverage with Cefoperazone Sulbactam (1.5 grams IV BD) and Amikacin (750 mg IV once daily). Additionally, a combination of Gentamicin (180 mg) and Tobramycin (80 mg) was mixed into the bone cement to provide local antimicrobial prophylaxis.

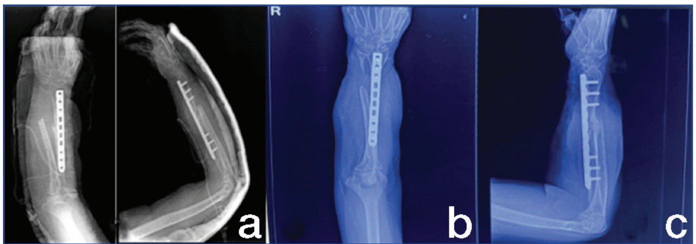
After four weeks, the external fixator was removed, and Erythrocyte Sedimentation Rate (ESR) and C-Reactive Protein (CRP) levels were monitored weekly [Table/Fig-1k-m]. Eight weeks later, when the wounds had healed, and the ESR and CRP levels had normalised, the patient was taken for the stage 2 procedure [Table/Fig-2].

[Table/Fig-1]: a) Post trauma X-ray; b) Initial surgery X-ray; c) Post fasciotomy image; d,e) Presenting X-ray; f-i) wound debridement procedure, implant exit, and external fixator application with sequestrectomy, followed by the insertion of an antibiotic cement spacer and antibiotic beads for both bones in the right forearm; j) Postoperative X-ray; k) At 4 weeks postoperative stage 1; l,m) At 8 weeks postoperative stage 1.

Case	Laboratory findings		
	Date	ESR (mm/h)	CRP (mg/dL)
Case 1	Baseline	16	Positive (10.2)
	Week 1	74	Negative (<5)
	Week 2	48	Positive (29.10)
	Week 3	84	Positive (6.43)
	Week 4	60	Negative (<5)
	Week 5	64	Negative (<5)
	Week 8	44	Positive (6.06)
	Week 9	-	Negative (<5)
Case 2	Baseline	14	Negative (<5)
	Week 1	30	Negative (<5)
	Week 2	-	Positive (74.41)
Case 3	Baseline	82	Positive (6.24)
	Week 1	70	Positive (14.87)
	Week 2	40	Positive (9.99)
	Week 4	70	Positive (11.37)
	Week 6	150	Positive (68.72)
	Week 7	60	Positive (11.24)
Case 4	Baseline	38	Negative (<5)
	Week 1	24	Negative (<5)
	Week 2	66	Positive (22.17)
	Week 3	40	Negative (<5)
	Week 6	20	Negative (<5)

[Table/Fig-2]: Laboratory findings of all cases.

Eight weeks later, the patient underwent removal of the antibiotic spacer and beads, followed by Open Reduction Internal Fixation (ORIF) with a 10-holed Locking Compression Plate (LCP) for the radius. The procedure included an iliac crest bone graft on the right side and resection of the distal ulna on the right side [Table/Fig-3a-c]. Later, at the 10-month follow-up, the patient showed no clinical evidence of infection, as illustrated in clinical photographs [Table/Fig-4a-j].



[Table/Fig-3]: n-p) Postoperative X-ray.

Case 2

An 11-year-old boy presented with a history of a thorn prick injury to his great toe, which subsequently led to an infection. Prior to this incident, the patient had been apparently normal; however, one and a half years ago, he sustained a thorn prick in the great toe and developed swelling in and around it [Table/Fig-5a]. Despite multiple unsuccessful debridement surgeries, he subsequently presented with a deformity of the great toe and a persistent infection. The patient reported no known co-morbidities. Culture sensitivity revealed *Staphylococcus aureus*, and an X-ray of the right foot showed a bony defect [Table/Fig-5b], measuring 1.5×0.5 cm, present at the middle phalanx of the great toe. This case presented several challenges, including a shortened toe, a varus deformity, and shortening of the first ray, which complicated the treatment approach.

The patient underwent wound debridement and had an antibiotic cement spacer placed [Table/Fig-5c,d] in the right great toe, where a 1.5 cm bone defect was present. Clindamycin was administered as a systemic antibiotic, while vancomycin (80 mg) and tobramycin (80 mg) were used in the cement mixture.

The wounds healed, and there was no longer any discharge, as evidenced in the clinical picture six weeks after the stage-1

[Table/Fig-4]: (a-j) Postoperative clinical photographs of 10 month follow-up.

procedure. Both ESR and CRP levels returned to normal [Table/Fig-2]. After six weeks, a fusion of the first Metatarsophalangeal (MTP) joint was performed on the right-side, utilising an iliac crest bone graft with plate fixation. No clinical evidence of infection was present at the nine-month follow-up, as demonstrated in the clinical photographs [Table/Fig-5e-m].

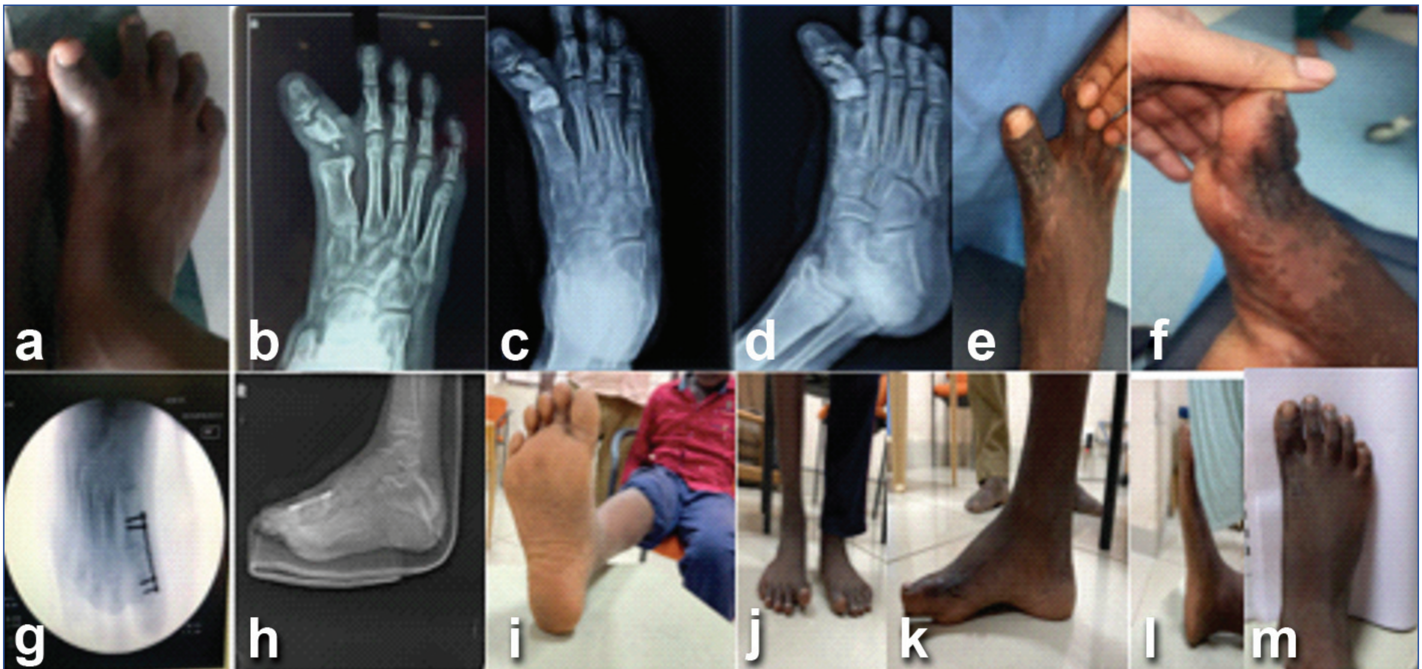
Case 3

A 57-year-old male patient presented to the outpatient department with complaints of pain, swelling, and discharge from his right forearm for the past 25 days. The symptoms had a gradual onset, and the patient also noticed bloody discharge over the ulnar aspect of his right forearm. Notably, he did not report any fever or recent trauma.

The patient's medical history revealed a significant injury following a slip and fall onto his right forearm seven years ago, resulting in fractures of both the radius and ulna bones of the right forearm, which were treated with ORIF and plating at a local hospital. Six years later, the patient underwent implant removal due to pain around the implant site, during which the ulna refractured and was stabilised with a K-wire. However, the patient developed pain and swelling over the right forearm two months later, leading to the removal of the Titanium Elastic Nail System (TENS) and the initiation of antibiotic therapy.

The patient has a known history of hypertension. He underwent debridement and resection of the diseased bone in the right ulna, followed by the application of an antibiotic cement spacer and beads to address a 3.5 cm bone defect [Table/Fig-6a-d]. The patient received vancomycin as a systemic antibiotic, and both vancomycin and tobramycin were incorporated into the cement mixture.

Seven weeks later, after ESR and CRP levels normalised [Table/Fig-2], the patient underwent removal of the antibiotic spacer and beads. This was followed by ORIF with dual plating and right iliac crest bone grafting for the right ulna. No clinical evidence of infection was present at the six-month follow-up, as evidenced by clinical photographs [Table/Fig-6e-m].



[Table/Fig-5]: a) Patient presenting with a deformity of the great toe; b) Presenting X-ray of right foot was showing bonny defect; c,d) X-ray after showing cement spacer; e,f) clinical picture six weeks after stage-1 procedure; g,h) Postoperative stage 2 X-ray; i-m) Clinical photographs showing patient at nine month with no clinical evidence of infection and complete weight bearing.

[Table/Fig-6]: a-d) Preoperative X-rays; e-h) Postoperative X-rays; i-m) Clinical photographs showing patient at 10 months with no clinical evidence of infection and showing full range of motion.

Case 4

A 48-year-old male was involved in a Road Traffic Accident (RTA) and sustained a fracture of the femur shaft three months ago. He underwent ORIF with plating but subsequently developed a Surgical Site Infection (SSI). The patient had a known case of Type 2 Diabetes Mellitus (T2DM) and had been on regular medication for the condition for the past five years. The culture sensitivity test revealed *Staphylococcus aureus* inoculation, while the X-ray of the left femur showed no cortical continuity with the implant in-situ [Table/Fig-7a-c].

The patient underwent wound debridement, followed by the placement of an external fixator and an antibiotic cement spacer to manage a 2 cm defect [Table/Fig-7d]. Cefoperazone sulbactam (1.5 grams i.v. BD) was used as a systemic antibiotic, and vancomycin (80 mg) and tobramycin (80 mg) were incorporated into the cement mixture. Serial monitoring of ESR and CRP was conducted, and the external fixator was removed six weeks later [Table/Fig-2]. Seven weeks later, when the ESR and CRP levels had normalised, the patient underwent the removal of the antibiotic spacer and nailing of the left femur [Table/Fig-7e-h]. During a follow-up appointment four months later, the patient was able to sit cross-legged, perform a straight leg raise, and there were no signs of clinical evidence of infection, as can be seen in the clinical photographs [Table/Fig-7i-m].

DISCUSSION

Non union of radius and ulna shafts can cause significant anatomical and functional impairment, particularly when complicated by infection [9]. Infected non union of forearm are relatively rare but pose a complex challenge due to bone necrosis, segmental bone loss, and soft-tissue damage [10]. Treatment typically involves a two-step approach. The initial phase includes hardware removal, culture analysis, and temporary stabilisation using external fixation or splinting. Extensive irrigation and debridement may be necessary, potentially resulting in a bone defect. In such cases, the Masquelet approach can be employed to address the gap and promote healing. The second phase involves definitive fixation after administering targeted antibiotics and normalising inflammatory markers [11].

In the present paper, a total of four cases are discussed, including two cases of fractures of both the radius and ulna, one case of a fracture of the great toe, and one case of a femur shaft fracture.

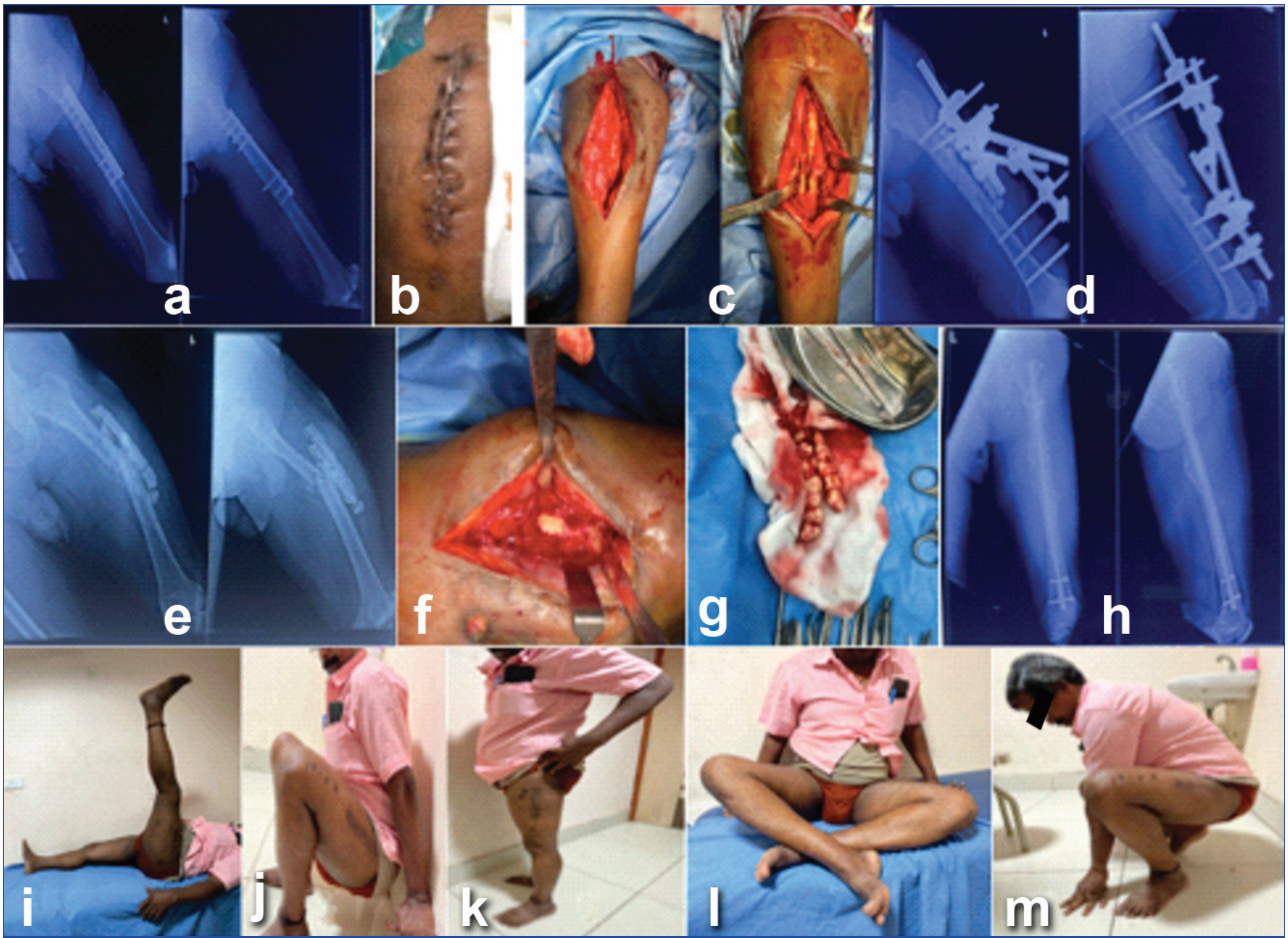
In this case series, two patients with infected non unions of the forearm were successfully treated using a two-stage procedure. Case 1 involved a patient with an infected non union of the radius and ulna, who underwent debridement, external fixation, and antibiotic therapy, followed by the removal of the spacer and fixation with a LCP and bone grafting, resulting in a successful outcome at 10 months. Case 3 involved a 57-year-old patient with an infected ulna non union, who underwent a two-stage procedure using the Masquelet approach, resulting in no evidence of infection at six months. The Masquelet approach has been effectively used to address forearm non unions with defects up to 5.4 cm [12] and has been combined with corrective osteotomy and 3D modeling to manage complex cases [13]. However, potential complications of the Masquelet technique include implant instability, infection, graft breakage, and bone absorption.

In India, walking barefoot is common, making feet susceptible to minor injuries that can sometimes lead to serious infections. Feet are often exposed to injuries such as cuts, bruises, and puncture wounds from thorns, but most are minor and self-treated. However, deep-seated infections involving bones can occur, especially in areas with limited medical access, leading to late presentation and potentially serious consequences. While rare, puncture wounds can cause infections, particularly in the metatarsal bones and calcaneus [14].

This report describes a rare case of a thorn prick injury to the great toe, resulting in a persistent infection and a bony defect. An 11-year-old boy suffered a thorn prick injury to his great toe, which led to a persistent infection and deformity despite multiple debridement surgeries. The case presented several challenges, including a shortened toe, a varus deformity, and shortening of the first ray, which complicated the treatment approach. The infection was caused by *Staphylococcus aureus*, and an X-ray revealed a bony defect.

In Stage 1 of treatment, the patient underwent wound debridement, and an antibiotic cement spacer was placed in the toe to address the 1.5 cm bone defect. Systemic and local antibiotics (clindamycin, vancomycin, and tobramycin) were administered, resulting in healed wounds, no discharge, and normalised ESR and CRP levels after six weeks. In Stage 2, a fusion of the first MTP joint was performed using an iliac crest bone graft with plate fixation. After nine months, there was no clinical evidence of infection, and the patient showed significant improvement.

The literature reports few cases of osteomyelitis resulting from thorn injuries [15]; however, it does not report any similar cases treated using the Masquelet induced membrane technique. Wounds that penetrate the plantar fascia are classified as deep injuries and have an increased susceptibility to infectious consequences. Children have a higher risk of developing osteomyelitis compared to adults because they possess a comparatively larger quantity of cartilaginous tissue, particularly growth plate cartilage. The risk of osteomyelitis or pyarthrosis is greatest in puncture wounds located



[Table/Fig-7]: a) Presenting X-ray of the left femur showed no cortical continuity with implant in-situ; b) Presenting clinical picture; c) Stage 1 procedure; d) X-ray after stage 1 showing cement spacer; e) X-ray six weeks after stage 1 procedure after removal of external fixator; f) Induced membrane seen during stage 2 procedure; g) stage 2 procedure showing removed antibiotic spacer; h) Postoperative X-ray; i-m) Clinical photographs showing patient at four month sitting cross-legged, with no clinical evidence of infection, performing a straight leg raise and complete weight bearing.

in the forefoot (zone 1), which spans from the metatarsal neck to the end of the toes. In comparison, the risk is lower for puncture wounds in the midfoot or hindfoot (zones 2 or 3) [15].

The results of the present cases have shown that the most common pathogen was *Staphylococcus aureus*, which was observed in three out of four cases, while the remaining case reported *E. coli* inoculation. In our series, all patients underwent second-stage surgery between 6 and 8 weeks. Prior to this, we ensured clinical and laboratory control of the infection, confirming that it was under control before proceeding with the next stage of treatment. All four infected non unions healed successfully, with no recurrence of infection, demonstrating the effectiveness of our treatment approach.

The fourth case in the present paper involved a 48-year-old diabetic male with a femur shaft fracture who developed a SSI after ORIF. The challenges of this case included managing a complex femur fracture complicated by SSI with *Staphylococcus aureus*, a 2 cm bone defect, and the patient's underlying T2DM. He underwent a two-stage procedure: Stage 1 involved debridement, placement of an external fixator, and an antibiotic spacer; Stage 2 involved spacer removal and femur nailing after seven weeks. At four months, no infection was evident, and mobility improved, including the ability to sit cross-legged and perform straight leg raises.

Similarly, Wong TM et al., described a series of nine patients treated with this technique of staged bone grafting following the placement of an antibiotic spacer to successfully manage osseous long bone defects [16]. At the time of initial spacer placement, the injured limbs were properly stabilised and aligned, resulting in successful osseous consolidation across all cases. In another similar study, Musa RA et al., evaluated the induced membrane technique in reconstructing open distal femur fractures with bone defects in 10 patients [17]. The technique achieved radiological union in all patients, with a mean union time of 8.5 months. It was found to be a reliable and economical approach.

Ma XY et al., studied the effectiveness of the induced membrane technique in treating infected forearm non union in 32 patients [18]. No recurrence of infection or loosening of internal fixation was observed, concluding that this approach is a successful treatment. Liu X et al., analysed 23 patients and found that 21 cases were successfully repaired without recurrence of infection, with 20 patients achieving excellent functional outcomes [19]. Pelissier P et al., discovered that induced membranes release growth factors, promoting bone regeneration [20]. The cement spacer triggers a foreign body response, leading to the development of a highly vascularised biomembrane that surrounds it. This biomembrane releases significant amounts of growth factors, such as Vascular Endothelial Growth Factor (VEGF), Transforming Growth Factor (TGF) Beta-1, and Bone Morphogenic Protein (BMP-2). These factors enhance the likelihood of graft consolidation and inhibit graft resorption [17].

CONCLUSION(S)

The Masquelet-induced membrane technique has proven effective in reconstructing complex fractures with bone defects in the forearm, femur, and great toe, even in cases complicated by infection. This technique, which involves delayed bone grafting within a biologically induced membrane created by an antibiotic-impregnated cement spacer, offers a viable solution for managing infected bone defects. It is a cost-effective, safe, and reliable approach that does not require specialised instrumentation, making it an attractive option for orthopaedic surgeons.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Sep 24, 2024
- Manual Googling: Jan 16, 2025
- iThenticate Software: Jan 20, 2025 (13%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Sep 21, 2024**
Date of Peer Review: **Nov 27, 2024**
Date of Acceptance: **Jan 22, 2025**
Date of Publishing: **Feb 01, 2025**