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Infected tibia defect fractures treated with the Masquelet technique

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Abstract

The treatment after open and infected fractures with extensive soft tissue damage and bone deficit remains a challenging clinical problem. The technique described by Masquelet, using a temporary cement spacer to induce a membrane combined with reconstructive soft tissue coverage, is a possible solution. This study describes the work-up, operative procedure, complications, and the outcome of a homogenous group of patients with an open and infected tibia fracture and segmental bone loss treated with the Masquelet technique (MT).

This retrospective study evaluates patients having sustained an open tibia fracture treated with the MT between 2008 and 2013 with a follow up of at least 1 year. The defect was either primary, caused by a high-grade open fracture or secondary due to a non-union after an open fracture. Prerequisite conditions prior to the procedure of the Masquelet were a defect zone with eradicated infection, an intact soft tissue cover and stability provided by an external fixation.

Volume of the defect, time until the implantation of the spacer, time of the spacer in situ and the time to clinical and radiological union were evaluated. Patient records were screened for reoperations and complications. The functional clinical outcome was measured.

Eight patients were treated with a follow up over 1 year. The spacer was implanted after a median of 11 (2–70) weeks after the accident. The predefined conditions for the Masquelet phase were reached after a median of 12 (7–34) operations.

Seven patients required reconstructive soft tissue coverage. The volume of the defect had a median of 111 (53.9–621.6) cm^3, the spacer was in situ for a median of 12 (7–26) weeks. Radiological healing was achieved in 7 cases after a median time of 52 (26–93) weeks.

Full weight bearing was achieved after a median time of 16 (11–24) weeks. Four patients needed a reoperation. The lower limb functional index was a median of 60% (32–92%).

Seven out of 8 patients treated in this group of severe open and infected tibia fractures did both clinically and radiologically heal. Due to the massive destruction of the soft tissue, patients needed several reoperations with soft tissue debridements and reconstruction before the spacer and the bone graft could be implanted.

Abbreviations: LLFI = lower limb functional index, MT = Masquelet technique, VAC = vacuum assisted closure.

Keywords: bone defect, bone reconstruction, cement spacer, induced membrane technique, infection, Masquelet, open fracture, soft tissue destruction

1. Introduction

Injuries of the tibia with segmental bone loss, extensive destruction of the soft tissue, and a concomitant infection remain a clinical challenge. There are several treatment options for these patients.[1] Non-vascularized autografts require a well-perfused recipient site for successful graft integration, and there is an inherent potential for resorption with longer grafts making them less suitable for large defects of segmental bone loss. Vascularized bone grafts have an improved rate of survival in a poorly vascularized bed; but, graft site morbidity is a drawback and it requires micro vascular operative skills. The use of structural allografts will eliminate donor site morbidity, but can be complicated by infection, incomplete remodelling, fracture, and disease transmission. Segment transport should be mentioned too.

Autologous bone grafting within induced granulation tissue membranes, otherwise known as the Masquelet technique described in 1986,[2] is a relatively simple method of treating segmental bone defects in the upper and lower extremities. Thorough debridements are needed to remove all dead and infected tissue and an antibiotic cement spacer is temporarily implanted in this well prepared environment. Soft tissue coverage of the defect is another prerequisite to induce a biomembrane. Repeated superficial debridements may take place during the time of the implanted spacer in situ. The induced membrane is made of a type 1 collagen-heavy matrix with fibroblastic cells and contains high concentrations of growth and osteogenic factors.[3,4] The best timing of the spacer explantation remains under debate as well as the use of additional growth factors.[4,5] During cement spacer removal the membrane is opened for insertion of bone graft and the membrane is then closed. The membrane is supposed to protect against autograft bone resorption by

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supplying it with growth factors and vascularization and preventing soft-tissue interposition. It serves as a barrier to outward diffusion of growth and osteoinductive factors throughout bone healing. The definitive fixation can be obtained either with a nail or plate.

To date, there remains little clinical evidence from homogenous groups of patients for the treatment outcome of infected, open tibia fractures with segmental bone loss and additional soft tissue destruction. The current evidence comes from the series presented by Masquelet and from inhomogeneous small case series as well as case reports or cases without infection.[6–21]

This paper is unique as it shows the work up and surgical technique in a homogenous group of patients with open and infected tibia fractures using the MT. The clinical and radiological results of this group of patients treated in 1 center are presented. Moreover, the patient functional outcome is described using the lower limb functional index, a scale to measure the subjective patient-reported outcome of the function of the lower extremity.[22]

2. Patients and methods

2.1. Setting

We retrospectively analyzed the data of 8 consecutive patients treated by the induced membrane technique for open and infected tibia fractures with bony defects in a level 1 trauma center in Switzerland. The bone defects and infection were either primary (as result of an open fracture) or secondary (non-union after an open fracture). Patients operated between 2008 and 2013, with a follow up of at least 1 year, were included. All patients agreed that their data and questionnaires were used for scientific purpose. No approval from the ethical committee was needed. Patient characteristics were scored (Table 1). All but 1 of the patients had suffered from a high-energy trauma.

2.2. Pre-Masquelet phase

In polytrauma patients, damage control surgery was performed first. The soft tissues and the fractures were debrided, temporarily stabilized, and covered by vacuum assisted closure (VAC) therapy or immediate soft tissue reconstructive surgery. At least 5 probes for microbiological cultures were taken and preoperative standardized antibiotics with a second generation cefazolin were started. In grade II and III open fractures according to Gustilo and Anderson,[23] gentamycin was added. The antibiotic regime was changed according to the specific microbiological analysis.

The required conditions prior to the start of the treatment according to Masquelet were for the group with a primary infection as well as for the group with a secondary infection: a zone of vital bone, free of infection and a complete soft tissue coverage.

A multidisciplinary team including an orthopedic trauma surgeon, a reconstructive surgeon, and a microbiologist treated all patients.

Table 1

Patient characteristics.

Sex	Male	6
	Female	2
Age	Median of 57 y (34–77)	
High energy	Yes	7
	No	1
Gustillo and Anderson	1	3
	2	1
	3	4
AO classification	41 C2	1
	42 C3	3
	43 A3	1
	43 C2	2
	43 C3	1
Injury type	Car crash	2
	Pedestrian	1
	Motorbike accident	3
	Fall from height	1
	Minor trauma	1

AO = Arbeitsgemeinschaft für Osteosynthesen.

2.3. Masquelet phase

In the Masquelet procedure, bone ends were debrided until bleeding. The fracture was temporarily stabilized with an external fixator. The cement spacer was implanted with an overlap to the bone ends to provide a more extensive induction of the membrane.

After several weeks, the resultant thin fibrous membrane was incised and the cement spacer removed. The contained void was filled with cancellous autograft. Autograft was obtained from the iliac crest or from the femoral canal (using the reamer irrigator aspirator)[24,25] depending on the volume of the defect. Allobone was added if it was not the first cancellous bone plastic or if the volume of the defect was more than approximately triple the amount of harvested autograft. Growth factors were added only if the cancellous bone graft was following another one that had not healed. Finally, the membrane was closed.

Either a locking plate or an intramedullary nail provided definitive stability.

2.4. Postoperative management

The extremity was protected from load bearing by a limitation weight bearing 15 kg or a total restriction in case of critical soft tissues. On the first postoperative day routine radiographs were performed. Standardized postoperative radiographs and routine clinical controls were performed after 6 weeks, 3, 6, and 12 months. Full weight bearing was restricted until radiographic signs of union. The clinical outcome was monitored with a lower limb functional index.[22] This was obtained after the last outpatient consultation.

2.5. Data analyzed

The volume of the bone loss was measured by calculating the defects in the antero-posterior and the lateral x-rays using the formulas of the volume of cones and cylinders described by Stafford and Norris.[24] Medical files were analyzed for the type of fixation, time between the initial trauma and the insertion of the spacer, as well as the time that the spacer was in situ. The application of allobone to the graft as well as growth factors was recorded (Table 2). The total number of operations from the accident until the last procedure was calculated. Time to radiological fracture healing was measured. According to Angelini et al[26] radiographic union was defined as bridging bone on a minimum of 3 cortices in antero-posterior and lateral radiographic views. Time to full weight bearing was evaluated from the patient charts. Furthermore, the number of reoperations and complications after the Masquelet procedure was evaluated. The clinical outcome was measured with the lower limb functional index according to Gabel et al.[22]

Table 2

Patient treatment characteristics.

	Volume of the defect (cm^3)	Initial ex fix	Primary infection	Time to spacer (wk)	Time of spacer (wk)	Definitive fixation	Growth factors
1	336.3	Y	Y	6.43	12	Tibia nail	N
2	88.7	N	N	44.57	8	Prox. tibia LISS plating	Y
3	621.6	Y	N	5.43	14	Prox. tibia LISS plating	Y
4	206.2	N	N	48	11	Hindfoot arthrodesis nail	N
5	53.9	Y	Y	1.85	16	Tibia nail	N
6	134.1	Y	N	5.57	26	Tibia nail	N
7	59.6	Y	N	70	7	Distal tibia LCP	Y
8	75.2	Y	N	15.28	12	Tibia nail	N
Median	111.4	Y=6 N=2	Y=2 N=6	10.85	12	Nail=4 Plate=3 Arthrodesis=1	Y=3 N=5

LISS=less invasive stabilization system, LCP=locking compression plate.

3. Results

3.1. Patient characteristics

During the study period, 10 patients were treated with the Masquelet technique for open tibia fractures. Two patients had a follow up of less than 1 year and were excluded. Eight consecutive patients (6 men and 2 women) with a median age of 57 years (range 34–77 years) were analyzed. According to the Gustillo-Anderson classification[23] there were 3 patients with a grade 1, 1 grade 2, and 4 with a grade 3 open fracture. Two patients with an open bone defect were primarily infected. The remaining 6 became infected in a later phase. The cause of the injury was a traffic accident in 6, a fall from height in 1, and a low energy trauma in the last patient. The volume of the bone defect was in a median of 111 cm^3 (range 53.9–621.6 cm^3) (Table 1).

3.2. Pre-Masquelet phase

On median, 12 (7–34) interventions were necessary to achieve well vascularized defect with a solid soft tissue coverage before the MT could be started. The team of reconstructive surgeons treated the soft tissue defects with a gracilis flap in 3 and a latissimus dorsi flap in 2 patients. A gastrocnemius flap and an anterolateral thigh flap were used in 2 other patients. One patient did not need reconstructive surgery for soft tissue closure.

All but 1 patient had a staphylococcus infection. The antibiotic regime was changed according to the bacterial resistance pattern.

3.3. Masquelet phase

The Masquelet procedure could be initiated after a median of 11 weeks (2–70 weeks). The cement spacer was implanted for a median period of 12 weeks (7–26 weeks). Growth factors were added in 3 patients (Table 2).

In 4 patients the treatment plan was adapted due to different reasons.

- One patient had an acute coronary syndrome during the Masquelet phase which led to a prolonged period of the spacer in situ.
- In 1 patient the soft tissue coverage was complicated by multiple reoperations.

In 2 patients the spacer was exchanged before definitive cancellous bone graft in order to get bacterial biopsy confirmation that infection was eradicated.

Full weight bearing was achieved after a median time of 16 weeks (range 11–24 weeks). Radiological union could be seen in 7 of the patients after a median time of 52 (26–93) weeks. One patient had a partial radiological union, but was pain free during daily life and did not wish further treatment (Table 3).

The median lower limb functional index was 60 (range 32–92)%.

3.4. Complications after Masquelet phase

Four patients had a straightforward healing after the start of the Masquelet phase. A clinical case is provided in Fig. 1.

Four patients had complications after the initiation of the Masquelet phase.

One patient had a symptomatic pseudarthrosis. The tibia nail was dynamized after which the pain decreased but there remained an asymptomatic non-union after 12 months. Due to the lack of complaints in daily life a further expectative therapy strategy was chosen.

Table 3

Radiological outcome.

	Radiological union	Time to radiological union	Operations until Masquelet	Time to full weight bearing
1	Partially	—	7	20 wks
2	Yes	52 wks	10	13 wks
3	Yes	45 wks	14	13 wks
4	Yes	26 wks	12	11 wks
5	Yes	56 wks	12	11 wks
6	Yes	93 wks	34	19 wks
7	Yes	63 wks	15	24 wks
8	Yes	51 wks	9	21 wks
Median	—	52	12	16

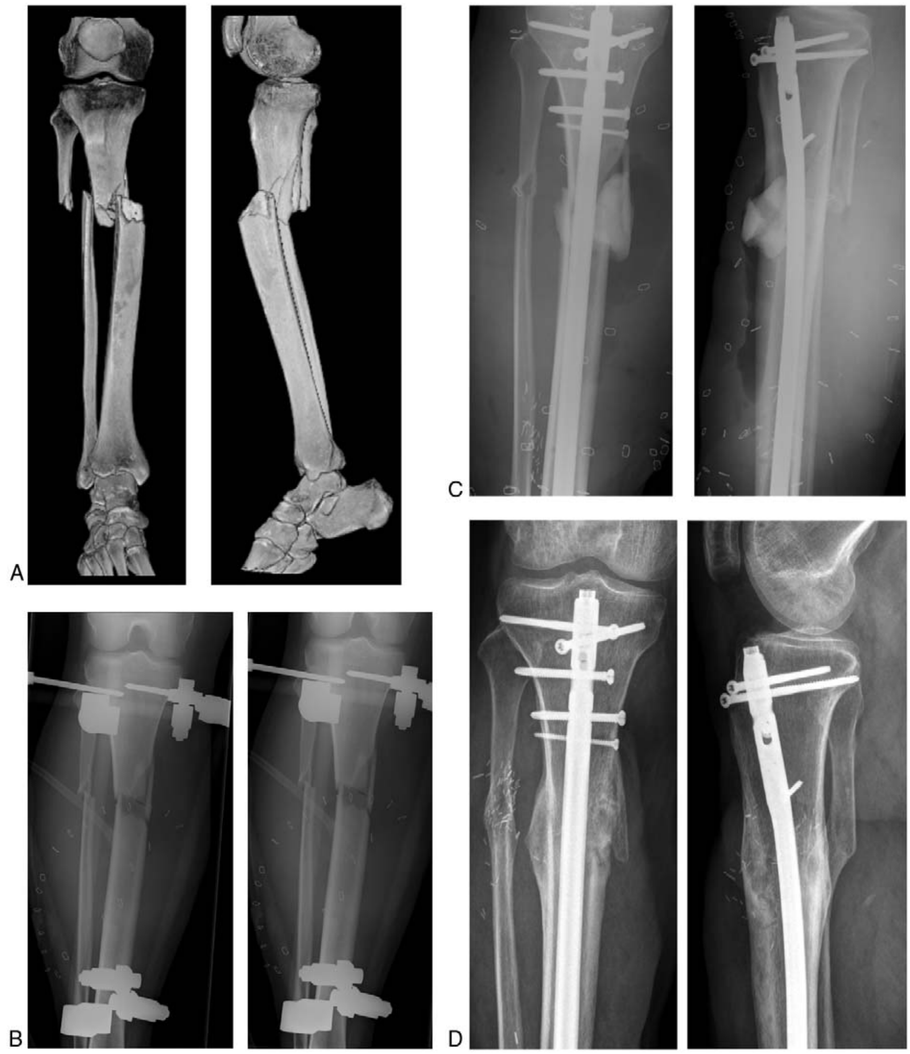

Figure 1. A. Male, 53 years; tibia fracture after a bike accident (AO 42 C3, Gustillo-Anderson 3b). B. Temporary treatment with an external fixation. C. Stage I of the Masquelet phase after 12 days. The spacer was exchanged after 16 weeks for a spongiosa plastic. Meanwhile 12 operations were needed to obtain adequate soft tissue coverage with a latissimus dorsi flap. D. Radiological healing after 56 weeks, full weight bearing 11 weeks after the spongiosa plastic.

One patient's tibia nail migrated distally and nearly perforated into the ankle joint. The patient was reoperated and a locking plate gave additional stability. Further clinical and radiological healing was uneventful. Figure 2 summarizes the courses of this patient.

In 2 patients the implant (1 nail and 1 plate) was removed. In 1 of these patients the removal was complicated with a claw toe for which a tenolysis of the Musculus. flexor hallucis longus was performed. This patient also received a scar correction (Table 4).

4. Discussion

Treatment of large bone defects due to extensive soft tissue injuries combined with an infection remains a challenge in orthopedic trauma surgery. We describe 8 consecutive patients with open and infected tibia fracture treated according to the 2-stage bone reconstruction technique described by Masquelet. Despite the fact that standard treatment protocols often have to be adapted to patient related factors, all but 1 showed radiological healing. The functional index of the lower limb was 59%.

The procedure of Masquelet is technically simple and has the advantage that the soft tissues and the infection can subside during the time of the spacer in situ. This is important, especially in those polytrauma patients with massive damage of the soft tissue. This can be seen in the large number of reoperations needed (median of 12) until the Masquelet phase could be started.

There remains little evidence in literature regarding the results of the technique according to Masquelet in large homologues groups except those described by Masquelet.[9–11] Nor are there randomized controlled trials available.

Despite this study being unique in describing a relative large and homogenous group of patients, the sample size remains small and there are inherent limitations due to the retrospective design.

We acknowledge the drawback of the small sample size and the consequence that it is difficult to draw definitive conclusions. However, despite these limitations there are some unique strengths of this well-defined patient cohort. It is the first and only paper in the English literature reporting solely on cases with

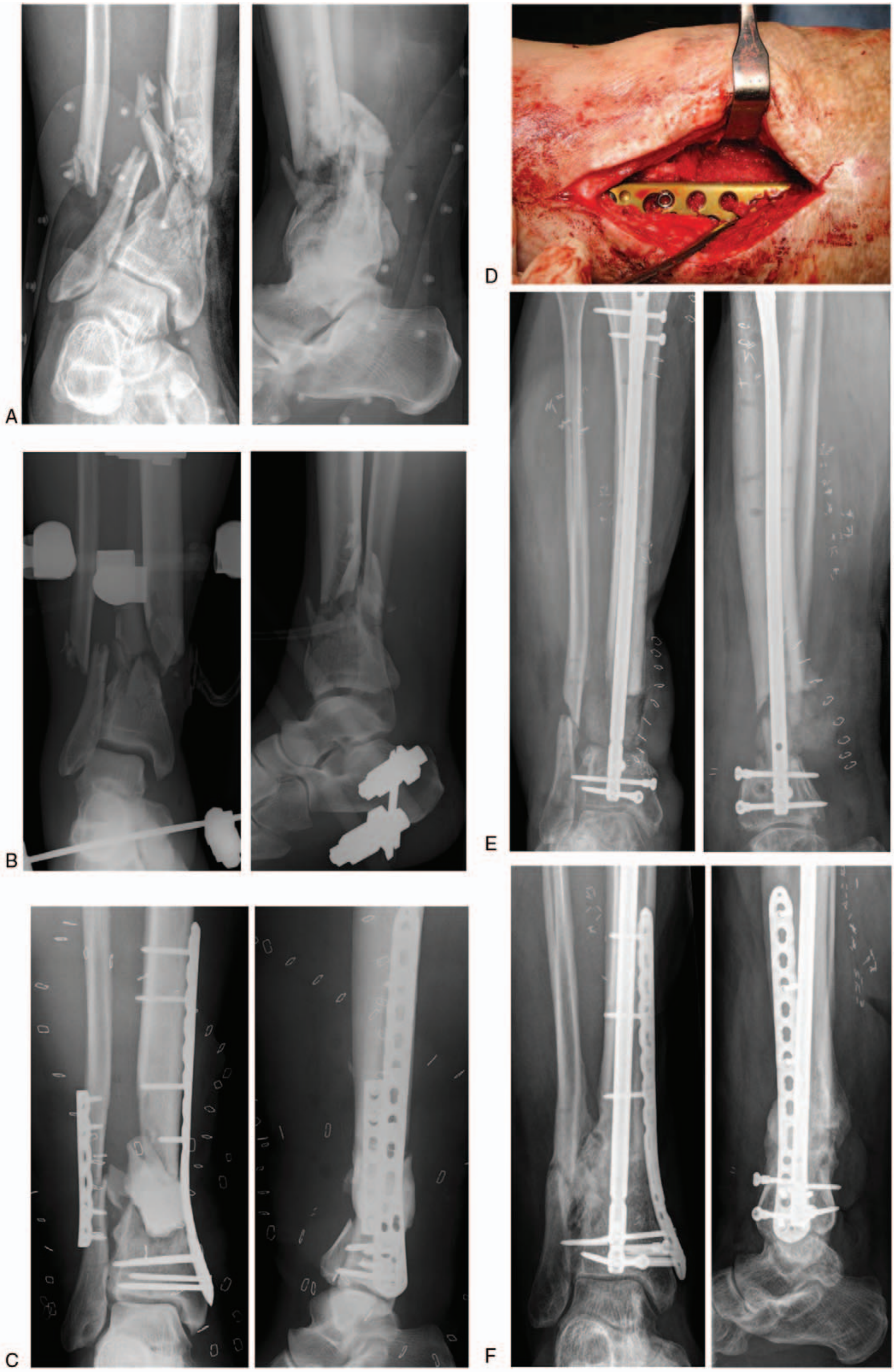

Figure 2. A. Male, 53 years, distal intra-articular tibia fracture (AO 43-C2) after a crush accident, Gustillo Anderson 3. B. Initial treatment with an external fixation. C. Fixation with a distal tibia plate and a first Palacos spacer 5 weeks after trauma. Musculo-catenous flap coverage, initially with a gracilis flap, after infection and necrosis a latissimus dorsi flap. D. Spongiosa plastic after removal of the Palacos Spacer 31 weeks after the accident. E. Spongiosa plastic in situ. F. Radiological union 93 weeks after the initial trauma. Additional stability has been given by a plate after distal migration of the nail.

Table 4

Complications and further treatment needed after Masquelet.

	Complication	Treatment
1	Pseudarthrosis → spongiosa plastic and dynamization nail	One superficial debridement One dynamisation of the nail
2	Migration of the nail towards the ankle joint	Four superficial debridements One plate osteosynthesis
3	Claw toe Disturbing osteosynthesis material	One scar correction One tenolysis of the flexor hallucis longus muscle One implant removal
4	Disturbing osteosynthesis material	One implant removal

a traumatic tibia bone defect and a proven infection, treated by the Masquelet technique. Additionally, the volume measurements that we performed in combination with a radiological, functional, and clinical outcome are unique.

A systematic review in 2016[15] shows that the current evidence consists of limited studies with a high variety in data reporting. This review underlines the underpowered current data concerning the clinical outcome of the Masquelet technique.

The review shows that only in the papers from Olesen et al[6] and Wang et al[16] all patients had an additional infect. In the work of El Alfy, there are 13 patients with an infected tibia, but no volume is being measured nor the functional outcome is reported. The same applies to Wang et al[16] in which all tibia defects had an infect but also no clinical outcome is being provided. A recent study from Gupta et al[8] describes a prospective case series of the Masquelet technique in 9 tibia defects. Eight of these were infected. However, due to a non-remitting infection 2 patients were excluded. The clinical outcome is being described using the range of motion but no functional outcome score has been used.

A summary of the relevant English literature concerning the outcome of the MT in tibia defects is shown in Table 5. This table gives an overview of the available literature and the main results that are provided. This study would add an additional homogenous set of 8 patients with a traumatic tibia bone defect and an infect treated with the MT.

A complete standardized treatment is impossible for these, often severely injured patients. Seven out of 8 had other, partly life-threatening injuries that had to be treated first or simultaneously. Therefore, despite a local standardized protocol, the treatment had to be adapted in accordance with the individual needs of the patient. Despite the homogeneity of the group considering only tibia fractures, we have included shaft and intra articular fractures. Most case series that have been published are treating shaft fractures of the long bones. The difficulties are best shown at 1 of the patients that had to be revised after the definitive Masquelet operation of a distal tibia fracture AO 43 C2 as the tibia nail had migrated distally and was close to perforating the ankle joint. An additional plate osteosynthesis was added and the patient was free of pain and could work for 100% with full weight bearing. The patient finally had an uneventful healing with radiological consolidation and a functional score of 78% (LLFI).

The optimal duration of the cement spacer in situ is still debated.[4] The function of the membrane and the importance of preserving it have been shown by Aho et al.[3] Current literature advocates 1 month as an optimal timing for the explantation of the spacer and implantation of the cancellous bone graft. The patients we treated had a median time of spacer in situ of 12 weeks. Especially those patients with a massive destruction of the soft tissues were not ready for the second step after 1 month. Several re-debridements had to be done with exchange of the spacer but maintaining the membrane in 4 cases due to cardiac problems in 1 patient and soft tissue problems in another. The other 2 exchanges of the spacer were done to obtain probes to prove an infect free situation. They both healed uneventfully. These 2 patients may suggest that a careful handling of the membrane does not necessarily disturb healing. Despite the spacer being in situ for an average of 3 months, radiological healing was achieved in all but one of the patients.

In our group, there were no differences between the patients in which we used growth factors compared with those without

Table 5

Papers reporting the Masquelet technique in tibial defects.

	Patients total	Number of tibias (%)	Number of infections (%)	Number of tibial defect and infection (%)	Volume	Clinical outcome score
Taylor et al[17]	69	35/69 (51%)	7/69 (10%)	N/A	N/A	N/A
Apard et al[18]	12	12/12 (100%)	7/12 (58%)	7/12 (58%)	N/A	N/A
Azi et al[19]	33	19/33 (58%)	23/33 (69%)	N/A	N/A	MSTS functional score
Donegan et al[20]	11	6/11 (55%)	3/11 (27%)	2/12 (17%)	N/A	N/A
El-Alfy and Ali[7]	17	13/17 (77%)	17/17 (100%)	13/13 (100%)	N/A	No score, measurement of ROM
Gupta et al[8]	9	9/9 (100%)	8/9 (89%)	8/9 (89%)	N/A	No score, average range of motion
Karger et al[9]	84	61/84 (73%)	41/84 (49%)	N/A	N/A	N/A
Olesen et al[6]	8	6/8 (75%)	3/8 (38%)	2/6 (33%)	N/A	N/A
Stafford and Norris[24]	25	19/25 (76%)	12/25 (48%)	5/19 (26%)	Yes	N/A
Wang et al[16]	32	20/32 (63%)	32/32 (100%)	20/20 (100%)	Yes	N/A
Giannoudis et al[21]	43	11/43 (26%)	21/43 (49%)	7/11 (64%)	N/A	N/A

MSTS = musculosceletal tumor society, N/A = not available, ROM = range of motion.

growth factor. The number of patients however, is too small to draw definite conclusions. Masquelet and Begue[27] described difficulties with bone union in combination with the use of growth factors. Whether this is due to the dosage of the growth factors or other reasons is still an issue of debate. Definitive fixation was achieved with a nail in 4 cases and with a plate in 3 cases. In 1 case, an ankle arthrodesis was performed using a Hindfoot Arthrodesis nail (Synthes). We did not see differences in healing and complications between the different implants.

5. Conclusion

The induced membrane technique according to Masquelet offers an established solution for complex injuries of the tibia with segmental bone and soft tissue destruction. This study describes a multidisciplinary approach that provides reliable results in these complex problems. A standardized protocol with adaption due to the complexity of the patients provides good results with radiological healing in 7 out of 8 patients. All patients had a clinical healing with full weight bearing and the patient outcome score was satisfactory. The patient and treating team, however, should be prepared for multiple (re)operations and complications. Despite the above, an intensive and prolonged standardized treatment will often lead to satisfactory clinical and radiological results in infected tibial defects.

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