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Results of Masquelet technique in the treatment of non-union of humeral fractures

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Abstract
Introduction: Nonunion is found with an incidence of up to 15%, depending on the location of the fracture and is a complicated problem with significant long-term morbidity, both for anatomical and functional results. In case of a manifest nonunion the surgeon faces a challenging problem. Fracture nonunion sometimes occurs after treatment, and some patients are still difficult to heal after many times of treatment. In order to more effectively treat nonunion and heal patients with recalcitrant nonunion, a technique known as Masquelet technique is an alternative for these cases.
Aim and objective: The aim of this retrospective was to show the clinical and radiological outcomes achieved with the use of this reconstruction technique in the treatment of non-union of humeral fractures in order to characterize the defects treated and describe different aspects of this surgical approach.
Materials and Methods: This retrospective study enrolled consecutive patients with non-union of humeral fractures who were treated using Masquelet technique between January 2020 and December 2020 in Govt. Bone and Joint Hospital, Barzulla Srinagar. A total of 18 patients were enrolled in this study with mean age of 47.24 (range 18-67) years. There were 11 female and 7 male patients.
Results: In the last follow-up, all patients had clinical and radiographical signs of bone consolidation. None of them was lost to follow-up. Successful healing was detected in all patients after a median time period of six months (1 to 23). Median follow-up time was 12 months (11 to 29). Patients with successful bone healing were significantly younger (mean 43.7 years) than patients with persisting nonunion (mean 59.4 years).
Conclusion: The Masquelet technique, or the induced membrane technique, offers a feasible and simple alternative for a highly challenging condition such as non-union after repetitive procedures.

Keywords
Humeral bone defect, non-union, masquelet technique

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I. Introduction

Although conservative treatment and surgical techniques have been greatly improved, the incidence of nonunion is still close to 5% − 10% [1]. Nonunion after fractures most often appears in the leg and is less common in humeral fractures. Despite major advances in operative techniques and the design of implants for osteosynthesis, in humeral fractures, the rate of nonunion of the humeral shaft is still reported to range from 3% to 5% of all operatively treated fractures[2, 3].Whilst there may be some consensus on the nature of operative treatment in general, the choice of the fixation device (plate vsnail) is still debated [4].

There are several local and systemic factors known to disrupt the complex process of bone healing, leading to nonunion, which may include insufficient stabilisation, extensive soft-tissue trauma with compromised

vascularisation, high age, comorbidities (diabetes, rheumatoid arthritis, osteoporosis), medication (steroids, NSAIDs) and smoking[5-9]. Often there is a multifactorial origin to nonunion.

Bone nonunion that meets the diagnosis is difficult to self-healing and usually requires therapeutic intervention. In recent years, the many treatment methods of bone nonunion has been reported, such as plate or intramedullary nail with bone graft, external fixation, biological stimulation, pulsed ultrasound, vascularized fibula transplantation[10-14].The prognosis of patients who received these treatments were satisfactory. The majority of non-unions can be effectively managed with these techniques.

The Masquelet technique was first used on the late 1980s, but it wasn't reported until the year 2000. It is a relatively simple technique that allows to reconstructdiaphyseal and metaphyseal SBD of multiple causes and sizes, without the need for microsurgery skills or high-complexity hospital infrastructures[15-17]. It is based on the placement of a polymethylmethacrylate (PMMA) cement spacer, which causes a foreign body reaction

and subsequent formation of an induced biological membrane. In a second surgical stage, the spacer is removed, and the cavity (covered by the biological membrane) is filled with a bone graft, preferably an autologous graft. The biological membrane prevents graft resorption and formation of fibrous tissue at the bone-cement interface and secretes growth factors that promote bone consolidation[18-21].

II. Materials And Methods

Study population

This retrospective study enrolled consecutive patients with non-union of humeral fractures who were treated using Masquelet technique between January 2020 and December 2020 in Govt. Bone and Joint Hospital, Barzulla Srinagar.

Inclusion criteria:

- Patients > 18 years
- Failure of at least one surgical treatment of a confirmed non-union
- Patients that satisfied diagnostic standards of atrophic nonunion: i.e. an unhealed fracture within 9 months and X rays in 3 consecutive months not showing signs of fracture growth as well as no callus formation at the fracture ends or bone resorption accompanied by a visible bone defect and patients that had complete follow-up data.

Exclusion criteria:

- Pathological fractures due to primary or secondary lesions
- Patients with a history of diabetes mellitus, metabolic disorders, immune diseases or cardiovascular diseases
- Patients with long-term use of immunosuppressive agents or non-steroid anti-inflammatory drugs
- Patients that suffered from hypertrophic nonunion or infected nonunion.

Patient characteristics:

A total of 18 patients were enrolled in this study with mean age of 47.24 (range 18-67) years. There were 11 female and 7 male patients. Among 18 patients 13 (72.22%) had one prior operation for treatment of the fracture, 3 (16.67%) had two prior revision procedures and 2 (11.11%) had three prior revisions (Table I). The mean time period from trauma to nonunion surgery was 12.7 (range 2 to 27) months. There was a history of current or previous smoking in 8 (44.44 %) patients while 10 (55.56 %) patients were non-smokers.

Table 1: Demography of patients

Parameters		**No. of patients**	**Percentage**
Sex	Male	7	38.89
	Female	11	61.11
Age group	18-40 Years	3	16.67
	41-60 Years	8	44.44
	>60 Years	7	38.89
Laterality	Right	10	55.56
	Left	8	44.44
	Both	0	0
Prior procedures	One	13	72.22
	Two	3	16.67
	Three	2	11.11

Procedure:

In the first stage of the technique, the area of bone loss was carefully debrided and irrigated, with removal of any gross debris and nonviable pieces of bone or soft tissue with a wide resection of all ischemic and necrotic tissue to a well perfused margin. Once acceptable reduction of the fracture is achieved (ensuring anatomic length, alignment, and rotation), fixation was undertaken. Seven cases were fixed by plate and screw constructs, three were fixed by interlocking nail devices, six were fixed by Ilizarov frames and two cases were fixed by intramedullary flexible nails. Once fixation has been achieved, the defect was measured and filled with a polymethyl-methacrylate (PMMA) cement spacer. It was mixed with vanco-mycin in a ratio of 8g to each 40g of the spacer. The spacer was then inserted as a block during later stages of polymerization to allow proper sizing and shaping of the spacer. It is important to fill the whole defect with the spacer, from bone end to bone end. The wound was then closed carfully in a layered fashion with a watertight facial closure. In the presence of soft tissue defect, repair or reconstruction was per-formed.

The second stage of bone grafting was performed 4-8 weeks of the first surgery. The fracture was approached through the previous incision and careful dissection down to the defect. The biomembrane encapsulating the cement spacer was carefully incised and removed. The biomembrane capsule was irrigated to remove any residual debris. With the defect being open , bone graft was placed to fill the entire defect. Once the

defect was completely filled, the biomembrane was closed with absorbable suture followed by wound closure in a layered fashion.

Post-operative follow-up and evaluation:

The surgical wound was monitored after one week. In the third week, the stitches were removed. Follow-ups were then carried out at weeks 4, 8 and 12, and monthly thereafter until bone consolidation. Follow-ups confirmed progressively increased ability to stand on both feet. We recorded complications need for surgical corrections and the time elapsed until the patient regained the ability to stand on both feet without assistance. For the radiological evaluation, AP and lateral X-rays of the affected segment were taken and used for determining time to bone consolidation, interpreting it as the presence of radiographical consolidation of at least three cortical bones.

III. Results

In the last follow-up, all patients had clinical and radiographical signs of bone consolidation. None of them was lost to follow-up. There was no statistically significant dependency between the use of an intramedullary nail or a plate and the occurrence of an atrophic, or hypertrophic nonunion. In the case of an infection as reason for nonunion, patients required significantly more operative interventions compared to other patients in order to control the infection.

Successful healing was detected in all patients after a median time period of six months (1 to 23). Median follow-up time was 12 months (11 to 29). Patients with successful bone healing were significantly younger (mean 43.7 years) than patients with persisting nonunion (mean 59.4 years).

The length of the treated bone defect was, on average, 4.5 cm (range 3-9), which accounted for 17.5% (range 7.5-30) of the total bone length. In 50% of cases, defects were larger than 4 cm. Regarding radiological evaluation, there were no cases of massive graft resorption, fractures of the graft marrow, or major complications related to the implant.

Bone consolidation was confirmed at an average of 7 months (range 4-11). The ability to stand on both feet was regained at 4 months. At the end of the follow-up, none of the patients walked with assistance. No differences were observed in the time to consolidation between patients who suffered open fractures and those with closed fractures, nor with respect to the affected bone or the type of autograft used to fill the SBD. These factors did not affect patients when regaining the ability to stand on both feet without assistance. 2 (11.11%) of patients had a recurrent infection 12 months after consolidation. The patient was treated by removal of the IMR, reaming, debridement, antibiotic IMR, and intravenous antibiotic therapy, after which remission of osteomyelitis was achieved.

Analyzing the fracture site 9 (50%) were shaft-fractures, 7 (38.89 %) distal humeral fractures and 2 (11.11%) periprosthetic humeral fractures were found.

IV. Discussion

By following the Masquelet technique in the treatment of non-union of humeral fractures, we have seen 100% bone healing rate. The limitation of the study was the inclusion of a less number of patients and applying a standardised treatment concept for all patients. Treatment of nonunions, especially in patients with large and complex defects and disturbed biology, remains a major challenge in orthopaedic and trauma surgery. Each fracture presented with a specific risk profile and biomechanical situation, requiring individualised treatment within the therapeutic concept, making comparisons difficult. Although the overall risk of nonunion dramatically increases in the presence of several risk factors, it is possible to avoid the influence of adverse mechanical factors on bone healing. Commencing with a simple avoidable mechanical problem that leads to initial failure, a high number of frustrated operative treatments and complications such as infections may lead to a difficult local environment with disturbed biology.

Karger, Masquelet and Begue proposed the use of an autologous iliac crest graft as the reference standard due to its osteoconductive, osteoinductive and osteogenic properties [22-24] and recommended using chips no larger than 1-2 mm. They claimed that both iliac crests are enough to harvest a graft to fill defects of up to 15-20 cm [23-25]. However, if this is not enough, a bone substitute or a morcellised allograft from a bone bank can be used, not to exceed a 1:3 ratio [22, 24]. Nevertheless, this ratio is determined in a purely empirical way, since there are no studies to support it. There is even literature claiming that good results have been achieved with a 1:1 ratio [23]. In our case, using a heterogeneous sample as to the type of graft used, we reached total consolidation in all patients, since the strength of this procedure is not strictly dependant on the iliac crest morcellisedautograft.

The BRI, according to Gouronet al., shows that the technique allows for a successful reconstruction of bone defects of a third of the length. In cases with greater-sized defects, they use, empirically, a cortical bone allograft.

In this way, they aimed to increase the stability and volume of the graft marrow [26]. Masquelet, however, states that his technique can be used in bone defects of up to 25 cm without the need for structural grafts [22, 27]. In our series, structural bone grafting was used in two patients with a SBD >30% of the length of the affected bone.

Another aspect that is still debated on the literature is the time period between the two surgical stages. A period of 6-8 weeks was described empirically as optimal, based on histopathological findings in animals [22, 24, 28]. Aho and colleagues showed that vascularization of the membrane reaches its peak at the fourth week and decreases to less than 60% at the third month [29]. Specimens collected at the fourth week also showed the highest expression of vascular endothelial growth factor, interleukin-6 and type I collagen, while those collected at the second month showed less than 40% of these values [29]. Pelissier and colleagues studied the technique in rabbits and found a peak of bone morphogenetic protein 2 at the fourth week after spacer implantation, followed by a gradual decline [30]. By the sixth month after surgery, no inflammatory reaction was observed, thus losing the theoretical biological benefits of the induced membrane [31, 32].

With respect to the analysis focused on the length of the bone defect, we observed, like the SoFCOT, that it does not seem to affect the time to consolidation [22, 23, 29] nor the nonunion rate [23], or the time needed to regain the ability to fully stand on the limb23. The Masquelet technique has been used successfully in bone defects >20 cm. We observed this same trend, since the progression of our greater-sized SBDs was comparable to that of smaller defects.

V. Conclusion

The Masquelet technique, or the induced membrane technique, offers a feasible and simple alternative for a highly challenging condition such as non-union after repetitive procedures. This technique is increasingly used due to the proven properties of the membrane, which allow for a favourable environment for neovascularization, bone induction and consolidation in a previously hostile bone environment. Clinical and radiological results are quite satisfactory for a highly complex condition treated with a relatively simple and feasible procedure.

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