

Original Article

Treatment of atrophic femoral non-unions according to the diamond concept: Results of one- and two-step surgical procedure



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ABSTRACT

Background: The treatment of non-unions in long bones poses a great challenge, particularly in cases of infection or large osseous defects. This article evaluates the use of the diamond concept in the treatment of femoral non-unions in a one-step or two-step procedure according to the Masquelet technique.

Patients and methods: Between February 2010 and March 2014, 88 patients with atrophic femoral non-unions were included in our study. The treatment was performed in one step (Group G1) on 41 patients and in two-step Masquelet technique (Group G2) on 47 patients, according to the diamond concept. In 72 cases it was decided to apply the growth factor BMP-7. The mean age of patients was 49.9 ± 15.3 . The data were analysed after following up all patients for at least 12 months after surgery.

Results: 74% of patients achieved consolidation in an average of 9.3 months. Positive bacterial cultures were found in 16 cases (18%). The consolidation rate in G2 was dependent on the non-union localisation and the osteosynthesis method applied. 83% of patients treated by intramedullary reaming achieved consolidation, while this was the case for only 60% of patients with osteosynthesis plates. Smokers in G2 had a larger average osseous defect and a lower consolidation rate. The quality of life as assessed with the SF-12 questionnaire had improved in both groups, with no significant differences between G1 and G2 one year after surgery.

Conclusions: One-step therapy is a suitable method of treatment for aseptic femoral non-unions with small osseous defects, using BMP-7 and RIA in the case of primarily failed atrophic non-union treatment. The Masquelet technique is an efficient means of eradicating infections in non-unions. In combination with intramedullary nailing, this technique is the method of choice for the treatment of femoral shaft non-unions with large defects.

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1. Introduction

The femur is the strongest bone in the human body, and its ability to bear stress is key to a patient's mobility. Subsequent occurrence of delayed union or non-union, with an incidence of 9.3% in recent research, is a serious diagnosis for the affected patients with far-reaching consequences for their everyday lives.¹ Prolonged periods of pain and physical disability, long hospital stays and resultant long-term unemployment all entail financial

disadvantages and a substantial decrease in the quality of life.^{2,3} Femoral non-union, in comparison to tibial non-union, has been shown to result in a particularly high rate of unemployment and early retirement. Mental conditions such as depression may also occur as a consequence of the posttraumatic psychological distress.^{4,5} The treatment of non-union is complex and expensive, placing a burden on the public health system. The costs resulting from the patient's inability to work are relevant to the public economy.^{3,6}

Non-unions involving large osseous defects or infections are particularly problematic.⁷ They may result in repeated unsuccessful treatment, persistent infection, limb-length inequalities and deformity, culminating in the loss of the extremity or, in the course of a septic response, even the loss of life.^{8,9}

A successful therapeutic concept for the effective treatment of impaired fracture healing is the “diamond concept”.^{10,11} This is

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based on five equally important factors: osteogenicity (mesenchymal stem cells), osteoconduction (scaffolds), osteoinduction (growth factors), mechanical stability and vascularity. The diamond concept can be combined with the two-step Masquelet procedure, as we demonstrated for the first time in a clinical study on tibial non-unions.^{12–15}

The goal of this study is to analyse the outcome of femoral non-unions treated according to the diamond concept and to evaluate our one-step and two-step femoral non-union treatment procedures.

2. Patients and methods

Between February 2010 and March 2014, 424 patients with non-unions were treated in our centre. During this period of time we registered 91 patients with atrophic non-unions of the femur with localisation distal to the lesser trochanter who were treated at our clinic according to the diamond concept. Two patients subsequently had to be excluded from our study due to lack of follow-up. One patient opted not to participate.

88 patients met the criteria and were finally included in the study.

41 patients received one-step treatment (Group 1, G1) and 47 patients received two-step treatment according to the Masquelet technique (Group 2, G2). In both groups, bone reconstruction was performed according to the diamond concept principles^{10,11,16} (Fig. 1).

The study did not cover patients with trochanteric non-union or above, since other types of treatment are used in these cases. Further exclusion criteria included an existing pregnancy, legal minority, a malignant tumour undergoing acute treatment, ongoing immune suppression and autoimmune diseases.

2.1. Data collection and analysis

Clinical and radiological parameters were measured preoperatively as well as 4, 6, and 12 weeks and 6 and 12 months postoperatively. The goal of these strict follow-ups was to monitor the success of consolidation, ensure the ongoing medical care of our patients, diagnose possible complications as early as possible and intervene when needed.

In order to measure the subjective health of patients, we used the SF-12 questionnaire both preoperatively and at every follow-up. The patients' subjective contentment with the treatment (0 = very dissatisfied to 10 = very satisfied) was measured with our own questionnaire.

An experienced trauma surgeon analysed all radiological and clinical data 1 year after surgery. The following factors were taken into account:

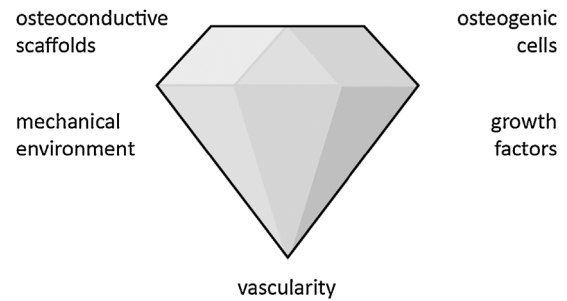


Fig. 1. The 'diamond concept'.

- Consolidation present in at least 3 of 4 planes.
- Secondary implant loosening.
- Any deviation of the secondary axis.

In addition, the results of the SF-12 questionnaire were evaluated with the help of the scoring sheets provided. To give an accurate overview of the course of healing, we evaluated all questionnaires from before surgery as well as from all follow-up visits after surgery.

2.2. Risk profile

In order to assess the individual risk of a non-union after trauma, we used a scoring system developed by Moghaddam et al.¹⁷ (Table 1). This system includes specific, differently weighted parameters such as the localisation of the fracture, soft tissue damage, smoking status and co-morbidities, which increase the risk of developing a non-union. Patients were grouped as low-risk (score of 0–9), medium-risk (score of 10–20) or high-risk (score >20).

To classify the non-union prior to surgery, we applied the Non-Union Scoring System (NUSS) developed by Calori et al.¹⁸ (Table 2). This system rates the severity of a non-union with a score from 0 to 100, taking 15 factors into account. A score of 0–25 indicates a classic non-union that is likely to heal well with standard treatment. A score of 26–50 calls for a more specialised treatment. Scores of 51–75 indicate a more complex non-union that is unlikely to heal without a highly specialised therapeutic concept. For a score of 76 or more, amputation should primarily be considered, as healing is highly unlikely.

2.3. Indication for treatment

The indication for treatment was determined in accordance with the diamond concept, observing strict criteria.¹⁴ Patients who had osseous defects of less than 2 cm or who were clinically free of

Table 1
Score to estimate the individual risk of patients for delayed union of long bone fractures.¹⁷

Localisation						
Humerus	Prox.	4 points	Diaph.	6 points	Distal	2 points
Forearm	Prox.	4 points	Diaph.	6 points	Distal	2 points
Femur	Prox.	4 points	Diaph.	6 points	Distal	8 points
Tibia	Prox.	6 points	Diaph.	8 points	Distal	4 points
Soft tissue	1° open	4 points	2° open	6 points	3° open	10 points
	Fasciotomy	4 points ^a	Previous fracture	8 points ^a	Neurological disorder	6 points ^b
Smoking	Smoker	15 points	Previous smoker	5 points	Non-smoker	0 points
Comorbidity/medication	NSAID	4 points	Bisphosphonate	6 points	Diabetes	4 points
Type 1			<10 points			Low risk
Type 2			10–20 points			Medium risk
Type 3			>20 points			High risk

^a Affected bone.

^b Affected limb.

Prox, proximal; Diaph, diaphyseal.

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