Injury, Int. J. Care Injured 46S4 (2015) S39–S50

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Treatment of atrophic tibia non-unions according to 'diamond concept': Results of one- and two-step treatment

Arash Moghaddam[a]*, Severin Zietzschmann[a], Thomas Bruckner[b], Gerhard Schmidmaier[a]

[a] *HTRG - Heidelberg Trauma Research Group, Trauma and Reconstructive Surgery. Center for Orthopedics, Trauma Surgery and Spinal Cord Injury. Heidelberg University Hospital, Schlierbacher Landstraße 200a, D-69118 Heidelberg, Germany*

[b] *Institute of Medical Biometry and Informatics, University of Heidelberg, Im Neuenheimer Feld 305, D-69120 Heidelberg, Germany*

KEYWORDS

'diamond concept'
RIA
Reamer-Irrigator-Aspirator
BMP-7
non-union
Masquelet
ETN PROtect™

ABSTRACT

Background: The successful treatment of atrophic tibia non-unions and tibia non-unions with large bone defects or infections is a major challenge in orthopedic and trauma surgery. This article evaluates the use of the 'diamond concept' using a one-step or two-step procedure according to 'Masquelet technique' in the treatment of atrophic tibia non-unions.

Methods: Between February 2010 and March 2014, 102 patients with atrophic non-unions were treated according to the 'diamond concept' in our center. Ninety-nine were available for follow-up. Forty-nine received a one-step treatment (Group 1, G1) and 50 patients received a two-step treatment according to the 'Masquelet technique' (Group 2, G2). Clinical and radiological parameters were measured preoperatively as well as 4, 6, and 12 weeks and 6 and 12 months postoperatively. In order to evaluate the subjective health of patients, we used the SF-12 questionnaire. Data analysis was performed one year after treatment.

Results: The rate of consolidation in G1 was 84% and 80% in G2. The time to heal in G2 was 8.6 ± 2.9 months, which is significantly longer than in G1 being 6.9 ± 3.1 months. In comparison patients in G1/G2 had an average of 3.2/6.7 previous major surgeries. In G1, 4 of 8 patients who did not heal successfully showed positive intraoperative cultures. In G2, 26 patients (52%) initially presented with positive cultures. The results of the SF-12 questionnaire improved in both groups during the postoperative follow-up, but showed no significant differences between groups. In 29 patients a gentamycin-coated nail was used for reosteosynthesis. These patients showed by trend a lower rate of complications at a higher rate of consolidation.

Conclusions: Our study showed that the 'diamond concept' is a suitable method for safely and effectively treating non-unions with large defects or infections. The use of an antibiotic-coated nail provides a therapeutic benefit. For large bone defects of infected non-unions the two-step procedure after Masquelet is an efficient way to eradicate the infection and treat the bone defect successfully.

Introduction

The successful treatment of tibia non-unions is an enormous challenge in orthopedic and trauma surgery, especially in treating atrophic non-unions and non-unions with large osseous defects or infections. These patients often suffer from loss of function of the affected extremity, increased pain, and a substantial decrease in the quality of life. Because of repeated, unsuccessful operations, hospital stays are longer, which has social and economic consequences [1,2].

The 'diamond concept' combines numerous elements in the treatment of non-unions [3,4]. Here the optimization of stability, e.g. by reosteosynthesis, the improvement of vascularization, the use of osteoconductive material such as cancellous bone grafts, and the addition of growth factors such as bone morphogenetic protein 7 (BMP-7) are included [5-7].

Particularly challenging is the successful treatment of defect and infected non-unions of the tibia. Currently the method of choice is callus distraction with the Ilizarov technique, comprised of bone resection and transport [8]. Treatment with an Ilizarov fixator is lengthy, often burdensome and associated with various complications and disadvantages for patients [9].

Given these circumstances the two-step 'Masquelet procedure' as a supplement to the 'diamond concept' represents a valid alternative [10]. In comparison to the one-step method, the first step of the two-step approach involves non-union debridement and surgical wound sanitation followed by the placement of a cement spacer layered with antibiotics. The goal of this procedure is effective infection eradication, as well as the induction of the Masquelet membrane. In the second step the cement spacer

* Corresponding author at: Consultant Orthopaedic & Trauma Surgeon. Center for Orthopedics, Trauma Surgery and Spinal Cord Injury. Heidelberg University Hospital, Schlierbacher Landstraße 200a. Tel.: +06221/ 56 35394.

E-mail address: arash.moghaddam@med.uni-heidelberg.de (Arash Moghaddam).

is removed and the defect is filled according to the principles of the 'diamond concept'. The goal of this study was to compare clinical, functional and radiological outcomes of the one-step method with the two-step method, both according to the 'diamond concept' and draw possible conclusions for future therapy strategies from these results.

Patients and methods

Between February 2010 and March 2014, 424 patients with non-unions were treated in our center. During this period of time we registered 114 patients prospectively in the context of a standardized medical trial, who were treated surgically for a tibia non-union. 52 patients received one-step treatment (Group 1, G1) and 50 patients received two-step treatment according to the 'Masquelet technique' (Group 2, G2). In both groups, bone reconstruction was performed following the 'diamond concept' principles [3,4]. In the other 12 patients, medullary reaming with intramedullary osteosynthesis was performed.

Data analysis

Clinical and radiological parameters were measured preoperatively as well as 4, 6, and 12 weeks and 6 and 12 months postoperatively. Therefore the permanent medical care of our patients was ensured. The goal of these strict follow-ups was to diagnose possible complications as early as possible and to intervene when needed. That way, the success of consolidation could be monitored closely.

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

All data were analyzed one year after surgery.

Indication for treatment

The indication for treatment was made irrespective of the course of recovery according to strict criteria of the 'diamond concept': Patients who had defect gaps of less than 1 cm or who were clinically without infection were treated with the one-step approach (G1). Patients who had a defect gap bigger than 1 cm or clinical signs of infection (warmth, swelling and redness) were treated with the two-step approach after Masquelet (G2). Patients with intraoperative findings that suggested an infection required a change in methods from a one-step to a two-step procedure. Exclusion criteria were possible pregnancy, less than 18 years of age, current treatment for malignant tumors as well as immune suppression or autoimmune diseases.

Risk profile

In order to assess the risk of a non-union after trauma, we used a scoring system developed by Moghaddam et al. [1] (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. According to scores, patients were grouped as low (0-9 points), middle (10-20 points) or high-risk patients (>20 points).

Calori et al. published the Non-union Scoring System (NUSS) that includes 15 factors that predicate the chance of healing of a non-union and the need for a specialized therapy [11] (Table 2). A score of 0-25 indicates a classic non-union that heals well with standard treatment. A non-union with a score of 26-50 demands a more specialized treatment. A score of 51-75 requires an even more individualized therapeutic concept. With a score over 75, one should primarily consider amputation [11]. We calculated both scores preoperatively.

Surgical treatment

Pre-surgical care

Besides general surgical preparation every patient received an x-ray of the lower leg with the adjacent joints in two levels. In case of the use of the RIA technique an x-ray of the ipsi- or contralateral femur was taken. A CT-scan and a dynamic contrast enhanced MRI of the lower leg were optional imaging possibilities to control the status of vascularization [12].

'Masquelet technique' (G2)

Step 1 (Fig. 3)

In a first step, previously implanted osteosynthesis material was completely removed, the proximal and distal ends of the non-union gaps were debrided down to healthy bone and cement with antibiotics was implanted in the defect gap to induce a Masquelet membrane and start an effective osteitis therapy. Finally, a reosteosynthesis was performed to ensure optimal stability.

Step 1 could be repeated several times until there were no further clinical or microbiological signs of infection.

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

Localisation			
Humerus	Prox. 4 point	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	Middle risk	
Type 3	>20 Points	High risk	

[a] Affected bone; [b] Affected limb; Prox, proximal; Diaph, diaphysal.