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Surgical treatment of aseptic nonunion in long bones: review of 193 cases

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Abstract The surgical treatment of aseptic nonunion often represents a more challenging situation for the orthopaedic surgeon than treatment of the primary fracture. In fact, it may be necessary not only to "rivitalize" the nonunion area, but also to exchange the bone fixation devices and to place some refill material in the bone gap. Several surgical techniques and different kinds of bone gap refills have been reported in the literature for the treatment of long bone nonunion. We present the results of 193 cases of long bone nonunion that have been treated in a period of 11 years (1992–2003) by a mostly open approach to the nonunion site with or without autologous bone graft interposition. The site (27 humerus, 44 forearm, 48 femur, 74 tibia) and the type of nonunion (179 atrophic, 19 hypertrophic) was considered in the surgical planning as were the mechanic and biological problems. New osteosynthesis was performed in 139 cases: with plate and screws in 82 cases, with intramedullary nails in 31 cases, with external fixators in 15 cases and with other devices in 11 cases (e.g. interfragmentary screws, k-wires). Cancellous or corticocancellous bone graft, always autologous from the iliac crest or from the anterior tibial tuberosity, was used in 183 cases (94.8%). Healing of the nonunion was successful in 179 cases (92.7%) in a mean time of 5.8 months. 14 patients (7.2%), all atrophic nonunion, healed with further surgery in a mean time of 19.2 months. Best results were obtained by the use of the intramedullary nail (31 cases): 99% healed in 5.2 months for the lower limb and 100% healed in 7.4 months for the upper limb. Good results have been achieved by plate (82 cases): 89.5% healed in 4.5 months for the lower limb and 94.1% in 6 months for the upper one. The worst results were observed with external fixation (15 cases). However, this device was used in the most complex situations, when severe soft tissue sufference was present. In this group, the mean healing time was 7.1 months (69.2% of cases) in the lower limb and 8 months (50%) in the upper one. Bone graft alone (54 cases) led to healing in 34 of 35 cases (97%) in the lower limb in 6 months and in 17 of 19 cases (89.4%) in 6.4 months in the upper limb.

Key words Nonunion • Bone graft • Osteosynthesis • Fracture

Introduction

Not always do fractures heal, independently of the choice of treatment (conservative or surgical). Nonunion can follow insufficient mechanical stabilization of a fracture or failure of the biological processes which control the biosynthesis of the repair tissue [1]. Insufficient mechanical stabilization may be due to defective periosteal or endosteal vascularization, or to soft tissue interposition between the fractured bone ends (periosteum, muscle, fascia). Mechanical and biological factors often influence each other and not always is it possible to establish the first cause of a fracture nonunion. Certainly an insufficient surgical stabilization favours fibrous tissue formation between the moving bone fragments, instead of primary woven bone bridging the fracture or osteons progressing through the forced and compressed bone ends (so-called primary healing, but corresponding to physiological remodelling). Defects of the biological factors controlling the bone healing process are less known, but certainly do exist, because it is not unusual to observe nonunion in otherwise perfectly fixed fractures.

Long bone nonunion is classified as hypertrophic or atrophic in relation to the radiographic aspect [2]. The hypertrophic type is characterized by large bone apposition, however it is positioned in a way that does not restore the skeletal lever continuity. The atrophic type is characterized by a low or absent production of bone matrix.

The treatment of nonunion is finalized to correct both causes: provide mechanical stability to the fracture and favour biological appositional activity of osteogenic cells. In case of nonunion with a previous satisfactory osteosynthesis, it can be enough to add a biological supplement of vital osteogenic cells (bone graft) or factors stimulating differentiation of cells of the osteoblastic line [3]. The bone graft interposition acts as a gap filler, which also has osteoinductive and osteoconductive properties [4]. In the case of a mechanical problem, the stability at the nonunion site has to be corrected and this can be achieved by new osteosynthesis or by the change of the bone fixation devices [5–13].

Mechanical analysis of the nonunion treatment should take in consideration the differences between the upper and lower limbs. Indeed, the upper limb is less mechanically stressed than the lower because of weight-bearing during standing and walking. Nonetheless, even the upper limb levers have to support functional stresses, in particular concerning rotation [14].

In hypertrophic nonunions without bone loss, often the new osteosynthesis or the substitution of the mobilized bone fixation does not require bone graft.

The nonunion site can be revised in an open or closed fashion. In the case of intramedullary nailing, the reaming of the medullary canal is by itself a powerful factor capable of activating the healing process [5, 7, 15, 16]. However, in most cases open surgery is used to remove the dense fibrous tissue interposed between the nonunited bone ends, to change the bone fixation devices and to insert the bone graft when required.

In this report, we review our experience with aseptic nonunion in long bones over an 11-year period.

Materials and methods

We retrospectively reviewed the clinical and radiographic results of 193 cases of long bone nonunion in 186 patients (140 males, 46 females) of median age 51 years (range, 17–81 years). The patients had been treated with different surgical techniques in a period of 11 years (1992–2003) in the Orthopaedics Department of Brescia University.

Nonunion diagnosis was based on the clinical evidence of pain and instability at the fracture site and on the absence of healing signs on radiographs. Healing of the nonunion was diagnosed on basis of a clinical recovery (residual function without pain or instability) and radiographic detection of fusion of the nonunion line. Nonunion treatment was considered successful when it led to fracture healing with a single surgical act; when further surgery was required, the results were considered unsuccessful.

We assessed: the site of nonunion; the type of nonunion (hypertrophic or atrophic); the surgical technique used (osteosynthesis, osteosynthesis with bone graft, or bone graft); and the time for nonunion healing.

Results

The mean time between primary fracture treatment and surgical correction of the nonunion was 7.8 months (range 3–36 months). Overall, 184 cases of nonunion (95.3%) had been treated with standard open surgical techniques [17, 18]: surgical approach as small as possible, removal of fibrous tissue and necrotic bone tissue from the nonunion site, new osteosynthesis or substitution with different fixation devices.

New osteosynthesis had been performed in 139 cases (72.0%): with plate and screws in 82 cases, with intramedullary nails in 31 cases, with external fixators in 15 cases, and with other devices in 11 cases (e.g. interfragmentary screws, k-wires). Cancellous or corticocancellous autologous bone graft from the iliac crest or from the anterior tibial tuberosity had been used in 183 cases (94.8%). In 5 cases (once in a forearm, twice in a humerus and twice in a tibia), a vascularized fibular graft had been used because of a bone loss larger than 5 cm.

Only 10 cases were treated without bone graft: of these 9 had closed surgery with percutaneous k-wire (1 case) with

reamed intramedullary nail on the tibia (5 cases), or external fixator on the femur (1 case); all resulted in healing. One external fixation of tibia and one of humerus did not heal.

Healing of the nonunion was successful in 179 cases (92.7%) in a mean time of 5.8 months (Table 1). The remaining 14 cases (7.2%), all atrophic nonunion (Table 2), healed with further surgery in a mean time of 19.2 months. In 139 cases, a new osteosynthesis or change of bone fixation devices had been performed. Best results were obtained by use of an intramedullary nail (31 cases): 99% healed in 5.2 months for the lower limb and 100% healed in 7.4 months for the upper limb. Good results have been

Table 1 Characteristics of 193 cases of nonunion

Site	Nonunion type	Bone graft only, *n*	Osteosynthesis and bone graft, *n*	Osteosynthesis only, *n*	Healing rate, *n* (%)	Mean healing time, months
Humerus (*n*=27)	22 atrophic 5 hypertrophic	5	21	1	23 (85)	5.5
Forearm (*n*=44)	41 atrophic 3 hypertrophic	14	29	1	42 (95)	5.7
Femur (*n*=48)	43 atrophic 5 hypertrophic	6	40	2	45 (94)	5.9
Tibia (*n*=74)	68 atrophic 6 hypertrophic	29	38	7	69 (93)	6.0
Total (*n*=193)	174 atrophic 19 hypertrophic	54	129	10	179 (93)	5.8

Table 2 Cases of unsuccessful treatments for nonunion, by site of nonunion

Nonunion site	Unsuccessful treatment
Humerus	1 osteosynthesis 2 vascularized fibular graft 1 osteosynthesis + bone graft
Forearm	1 osteosynthesis + bone graft on ulna 1 bone graft on radius
Femur	2 osteosynthesis + bone graft 1 bone graft
Tibia	3 osteosynthesis + bone graft 2 osteosynthesis
Total	14 (7.2%)

Table 3 Healing times and rates for different nonunion treatments

Nonunion treatment	Cases, *n*	Healing time, months	Healing rate, *n* (%)
Upper limb			
Plaster cast + bone graft	4	4.6	4 (100)
Plate	34	6.0	32 (94.1)
Intramedullary nail	10	7.4	10 (100)
External fixator	2	8.0	1 (50)
Bone graft	15	6.4	13 (86.6)
Other type of osteosynthesis	6	3.5	5 (83.3)
Lower limb			
Plaster cast + bone graft	24	6.3	23 (95.8)
Plate	48	4.5	43 (89.5)
Intramedullary nail	21	5.2	21 (100)
External fixator	13	7.1	9 (69.2)
Bone graft	11	6.0	11 (100)
Other type of osteosynthesis	5	4.0	5 (100)

achieved with a plate (82 cases): 89.5% healed in 4.5 months for the lower limb and 94.1% healed in 6 months for the upper one. The worst results were observed with external fixation (15 cases). However, this device was used in the most complex situations, when severe soft tissue sufference was present. In this group, the mean healing time was 7.1 months (69.2% of cases) in the lower limb and 8 months (50%) in the upper one. Bone graft alone (54 cases) led to healing in 34 of 35 cases (97%) in the lower limb in 6 months and in 17 of 19 cases (89.4%) in 6.4 months in the upper limb.

Successful healing (percent) and mean time for healing in relation to the surgical technique used are reported in Table 3.

Discussion

There are several surgical techniques to treat aseptic nonunion of the long bones. Usually a distinction is made between the upper and lower limbs in planning the treatment of this fracture complication which is observed in 0%–25% of cases. In fact, the upper limb has different anatomical and biomechanical characteristics than the lower limb, such as no weight-bearing, curves in the medullary channel and greater rotational stress forces. For these reasons, some authors [18, 20] prefer to use compression plates to treat nonunion in the upper limb (humerus, forearm) rather than intramedullary nails. In the lower limb (femur and tibia), the best reported results have been obtained with the use of reamed intramedullary nails or with plate and screws [5, 7, 19, 20–22,].

In this paper, we analyzed 193 cases of aseptic nonunion of the long bones (71 in the upper limb, 122 in the lower limb), mostly treated in an open fashion to "rivitalize" the nonunion site and to place an autologous bone graft with osteoinductive properties (bone graft used in 177 cases, 91.7%). The importance of autologous bone graft was confirmed by the results obtained in those cases treated without a new osteosynthesis: in the upper limb 89.4% of the cases healed in a mean time of 6.4 months (19 cases) and in lower limb 97.2% healed in a mean time of 6 months (37 cases). The percentage of failure of bone graft without new osteosynthesis (9 of 177 cases, 5%) was lower than that after the use of a new osteosynthesis alone without bone graft (3 of 16 cases, 18.7%).

We considered separately the vascularized fibular graft as it has been used only for major bone loss, and it led to healing in 3 of 5 cases (2 failures in the humerus).

We used plate and screws for new osteosynthesis in 34 of 71 cases in the upper limb (48%) and in 46 of 122 cases in the lower limb (38%). We used an intramedullary nail in 22 of 122 cases in the lower limb (17%) and in 10 of 71 cases in the upper limb (14%). In the 10 cases of nonunion of the upper limb, where we used an intramedullary nail, we had always placed an autologous bone graft. Healing was obtained in all cases in a mean time of 7.4 months without further surgical operations.

Overall, nonunion healing was reached in 179 of 193 cases (92.7%) in a mean time of 5.8 months. In the remaining 14 cases, healing was obtained in a mean time of 19.2 months after further surgical treatment. This report confirms the importance of an open technique and of autologous medullary or corticomedullary bone graft to treat aseptic nonunion of long bones. The percentage of nonunion healing was 92.7%. This suggests that the use of other devices such as bone substitutes, growth factors or vascularized bone graft should be considered only in case of major bone loss.

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