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ORIGINAL STUDY

Bifocal and trifocal bone transport for failed limb reconstruction after tumour resection

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The aim of the present study is to assess the results of bifocal and trifocal bone transport for elimination of bone defects due to failed limb reconstruction after tumour resection. Thirteen patients, nine with giant-cell tumour and four with osteosarcoma, with bone defects resulting from wide tumour resection were managed by bone transport with an Ilizarov frame. The ages ranged from 12 to 46 years. Bone transport was used as a second line of management after failure of other modalities for reconstruction. According to the Enneking system for the functional evaluation after surgical treatment of musculoskeletal tumours, the percentage rating of function was 47% in one case, 70% in 2 cases and more than 85% in 10 cases. Most of the complications were treated successfully during the course of treatment. Bone transport with two or three osteotomies is a reliable method for eliminating bone defects as a limb salvage procedure after failure of other modalities for reconstruction.

Keywords : bone defects ; bone tumours ; Ilizarov method ; limb reconstruction.

INTRODUCTION

Several options are available for limb reconstruction after tumour resection, with varying degrees of success and failure. Prosthetic reconstruction can provide immediate stability and allows for early mobilisation after surgery, but it carries the risks of loosening and late failure. Biological reconstruction has the advantages of providing a stable and durable limb, but it has the disadvantages of prolonged treatment and rehabilitation time (*11,13*). In case of failure of any of these modalities due to infection, loosening or local recurrence, the scope of reconstruction becomes very narrow and amputation may be the eventual outcome. The aim of the present study is to assess the results of bifocal and trifocal bone transport in management of bone defects resulting from wide tumour resection after failure of other modalities for reconstructions.

PATIENTS AND METHODS

Between 1998 and 2007, thirteen patients with failed limb reconstruction after tumour resection were treated by distraction osteogenesis in our institution. Five were males and eight were females. The ages ranged from 12 to 46 years with an average of 24.5 years. The pathology was giant-cell tumour in 9 cases and osteosarcoma in 4 cases. The lesions were located in the proximal tibia in

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Fig. 1a. — *This 16*-year-old male patient with an osteosarcoma of the proximal tibia. was initially managed by wide resection and prosthetic replacement but it became infected. The prosthesis was removed and the defect was filled with bone cement impregnated with antibiotic to control infection.

Fig. 1b. — After radical debridement the defect measured 28 cm

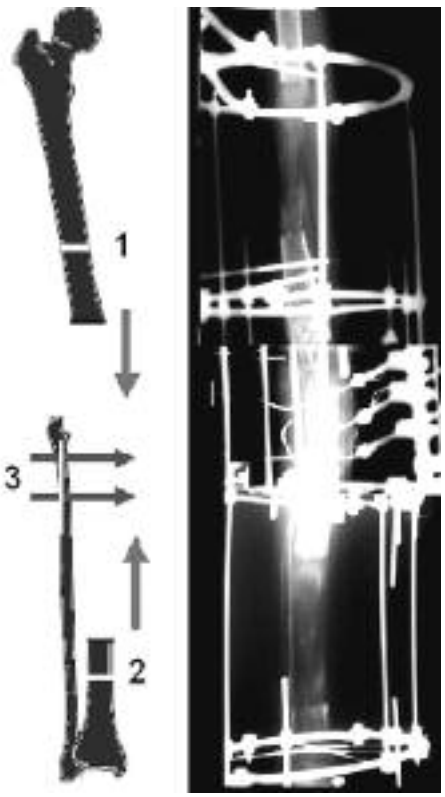

Fig. 1c. — He was managed by trifocal bone transport, femoral (1), tibial (2) and fibular (3). The radiograph at the time of docking shows good femoral and tibial regenerate.

8 cases and the lower femur in 5 cases. Distraction osteogenesis was used as a second line of management after failure of other modalities for reconstruction. The failure of primary management was mainly due to infection (fig 1) or local recurrence (fig 2). Most of the cases underwent several operative procedures before distraction osteogenesis. These procedures included curettage and bone graft (3 cases), curettage and bone cement (6 cases) wide resection and prosthetic replacement (2 cases), management of infection (7 cases), and extracorporeal irradiation (2 cases). The time elapsed between diagnosis and distraction ranged from one year to three years with an average of 1.9 years. The soft tissues were deficient in two cases. Infection was present in 7 cases. All the patients with osteosarcoma had finished their chemotherapy before the beginning of distraction.

An Ilizarov external fixator was used to treat bone defects in 12 cases and to treat shortening and nonunion in one case. All the patients were informed about the procedure in details including the treatment duration and possible complications and they agreed to it. The knee joint was resected in all the cases as it was contaminated either by the tumour or by infection. After radical debridement (removal of the tumorous tissue, unhealthy tissues and infected implants) the length of the defects ranged from 10 to 28 cm with an average of 16.5 cm.

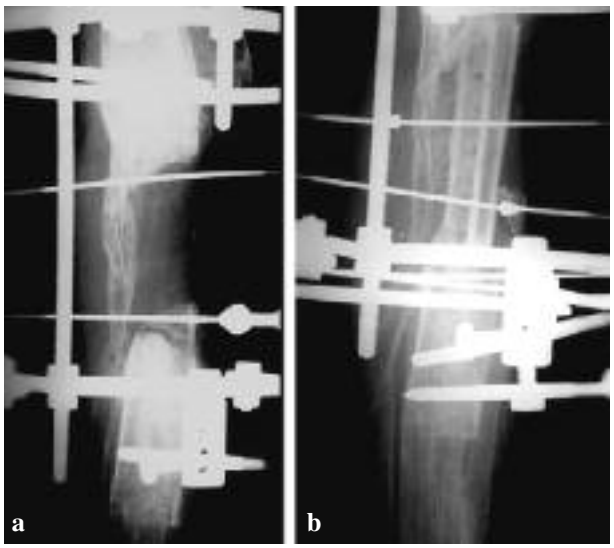

Fig. 1d. — The fibular regenerate was collapsed (a), so it was augmented with a free fibular graft from the contralateral side (b).

Fig. 1f. — The patient with good alignment and a stable limb

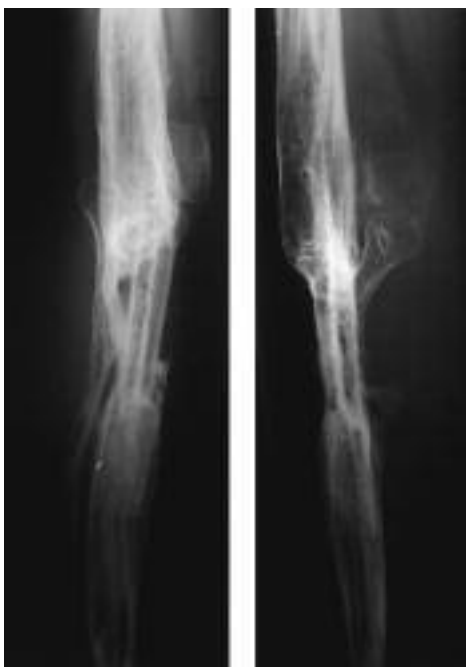

Fig. 1e. — After removal of the frame with good healing of the fibular graft and full consolidation of the regenerated bone.

Double corticotomies and bifocal bone transport were done in 11 cases, three corticotomies and trifocal bone transport were done in two cases (fig 1c). Distraction was started after a latent period of one week at a rate of one mm/day and this was further adjusted according to the quality of the regenerated bone as seen in the serial radiographs during follow-up. Partial weight bearing was allowed from the early post-operative days ; once docking was reached, full weight bearing was encouraged to stimulate healing of the docking site and maturation of the regenerated bone. Freshening of the bone ends and autogenous bone graft was routinely done at the docking site to enhance healing and to reduce the time of external fixation. Free fibular graft was used in cases treated with trifocal osteotomies to augment the weak fibular regenerate (fig 1d).

RESULTS

The follow-up period ranged from 2.9 to 6.5 years with an average of 4.5 years. The duration of treatment ranged from 12 months to 19 months with a mean of 14.5 months. The healing index (time in frame in months per each cm of distraction) ranged from 1 to 1.9 months with a mean of 1.2 months. The tumours were eradicated in all the cases without local recurrence or distant metastasis except in one case. The defects were eliminated in

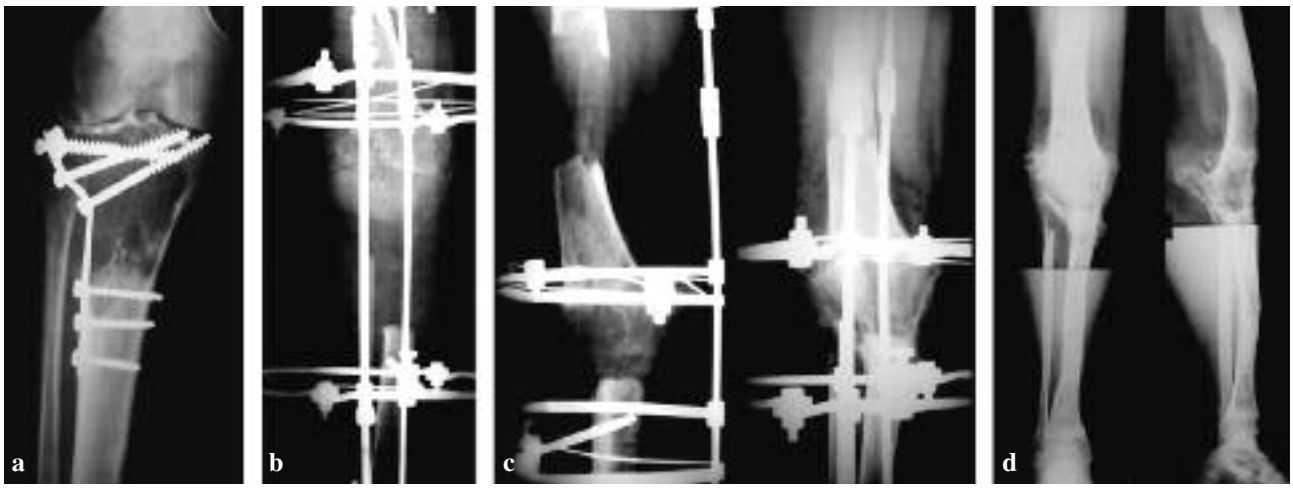

Fig. 2. *— **a.*** Thirty-two year-old female patient with GCT of the proximal tibia. She was managed by curettage and bone grafting but the lesion recurred; ***b.*** Wide resection and bifocal bone transport was carried out with an Ilizarov external fixator ; ***c.*** At the time of docking, when freshening of the bone ends and bone graft were done ; ***d.*** After removal of the frame with sound knee fusion and full consolidation of the regenerated bone.

all the cases. Infection was eradicated in all the infected cases without the need for prolonged antibiotics and without reactivation throughout the period of follow-up. The time to full weight bearing ranged from 3 to 7 months post-operatively with an average of 4.5 months. In the two cases with soft tissue defects the wounds were left open to drain while bone transport was carried-out. As the distraction process was going on, the soft tissues crept gradually until they completely healed without the need for major plastic surgery. The complications included pin tract infection in 9 cases, delayed consolidation of the regenerated bone in 4 cases, soft tissue invagination at the docking site in 5 cases, local recurrence in one case, refracture in 2 cases and limb length discrepancy of about 4 cm in one case. By the end of treatment, 12 patients had their knees fused and one had above knee amputation. All the patients were able to perform their daily activities without problems. Most of the patients were satisfied with their results. The percentage rating of function was 47% in one case, 70% in 2 cases and more than 85% in 10 cases according to the Enneking system for the functional evaluation after surgical treatment of musculoskeletal tumours (*3*).

DISCUSSION

Surgical treatment of locally aggressive and malignant bone tumours ranges from intralesional excision and packing with bone cement or bone graft to wide resection plus reconstruction with modular prostheses, allografts or vascularised bone grafts. These methods are not without complications, and failure may occur due to local recurrence, loosening, infection or re-fracture (*1,14*). Reconstruction of the bone defects after failure of these modalities represents a true challenge. The defects are usually large and the soft tissues may be deficient. Infection may further complicate the condition and make reconstruction extremely difficult. Limited options are available for the management of such difficult problems. Ham *et al* (*6*) reviewed the oncologic results and survival of the end prostheses in 32 patients with primary bone sarcoma of the distal femur and found that end prosthesis-related complications occurred in 41% of the cases. Revision of the end prostheses was required in five cases (16%) and amputation of the involved limb was performed in four patients (13%) because of local recurrence in two of them and infection in the other two patients (*6*).

Distraction osteogenesis has been used extensively in the management of post traumatic bone defects ; it has been used with promising results as a primary line of management in reconstruction of bone defects after tumour resection (*2,4,10,16*).

In this study we used bone transport in the management of bone defects and/or shortening resulting from tumour resection in 13 cases in which the primary lines of reconstruction had failed. The knee joint was involved in all the cases, so extraarticular resection and bone transport aiming for knee fusion was done in most of the cases. The defects created by tumour resection are usually large and the expected time of external fixation is long, so the construct must be stable enough to outstand this duration. We routinely did freshening of the bone ends and bone graft at the docking sites because in large segment transport the forward end of the transported segment becomes covered with a layer of fibrous tissue and non-viable bone. Frequent compression and distraction at these sites will be time consuming and may fail to achieve union. So freshening of the bone ends and autogenous bone graft was done at these sites to stimulate bone healing. This is in agreement with Green *et al* (*5*) who recommend bone grafting of the future docking site to shorten the treatment time.

Infection was eradicated in all the infected cases without the need for prolonged antibiotics and without reactivation throughout the period of follow-up. This is compatible with the observation of Ilizarov that the infection is burnt in the fire of regeneration. He attributed this to the massive increase in blood supply of the limb during distraction (*9*). One of the advantages of the distraction process is its ability to bridge soft tissue defects without the need for major plastic surgery. During distraction osteogenesis not only the bone but also the soft tissues are lengthened and this helps in spontaneous closure of the soft tissues defects (*15*). In our study the soft tissues were deficient in 2 cases and they healed completely during the distraction process without the need for plastic surgery. Although most of our cases ended up with knee arthrodesis, they were satisfied with their results as they were able to do their living activities without pain or instability. This is in agreement with Harris *et al* (*7*) who compared the functional outcome after different modalities for the treatment of bone tumours and found that patients with an arthrodesis of the knee perform the most demanding physical and recreational activities, although they have difficulty with sitting.

Some authors believe that the biological stimulus of the distraction osteogenesis may induce local recurrence or distant metastasis. Harris *et al* (*8*) performed distraction in a case of fibrous dysplasia and this was complicated by a malignant fibrous hystocytoma. In our study we had one case of local recurrence, in a 12-year-old boy with an osteosarcoma of the proximal tibia. Initially he was managed by wide resection, extracorporeal irradiation and reimplantation of the irradiated segment, but he developed infection and sequestration of the irradiated segment. Many surgeries were done to control infection, without improvement. Two years after the index surgery, radical debridement was done and an Ilizarov external fixator was applied to treat the resultant defect. The patient developed local recurrence 3 months after the start of distraction. He was managed by above knee amputation and he is disease free at the time of writing, four years after amputation. We do not know the exact cause of this recurrence, whether it was the natural history of the disease or from the biological stimulus of the distraction process.

The most common complication in our study was pin tract infection. It occurred in 9 cases. Three of them required exchange of the infected wires, and 6 cases improved with local measures and a short period of systemic antibiotics. The two cases that were complicated by refracture were treated by reapplication of the frame and bone graft. The five cases that were complicated by soft tissue invagination at the docking site were treated by surgical elevation of the skin and soft tissue from the docking sites and local bone grafting. The patient who ended up with shortening of 4 cm refused to undergo further distraction and accepted the shoe lift. One of the four cases that were complicated by delayed consolidation of the regenerated bone was treated by autogenous bone graft and three were treated by alternating compression and distraction. The major disadvantage of the distraction process is the long external fixation time. The time of treatment in our

study ranged from 12 months to 19 months with a mean of 14.5 months. However, this is comparable to the treatment time in other methods of biological reconstruction. Laffosse *et al* (*12*) reported on 12 patients with bone defects created by tumour resection in the lower limbs, treated by a vascularised fibular graft. The mean time to full weight bearing in their series was 13.9 months (range : 8 to 41) (*12*). With distraction osteogenesis patients can reach full weight bearing with the frame early in the course of treatment (average : 4.5 months postoperative in our study). The time of treatment with distraction osteogenesis can be reduced by doing multiple level corticotomies and the use of bone graft at the docking site to stimulate bone healing.

CONCLUSION

Bone transport is a valid option for the management of bone defects created by wide tumour resection. Bifocal or trifocal osteotomies help in achieving rapid filling of large defects. Trifocal osteotomies appear as a good method to eliminate large defects in the lower limb more than 20 cm. It can simultaneously address the major problems of failed limb reconstruction which include bone defects, infection and soft tissues defects. The effect of the biological stimulus of the distraction process on local recurrence or distant metastasis remains to be proved.

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