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ORIGINAL STUDY

A modified technique of internal bone transport

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A modification of the technique of internal bone transport is presented. It decreases bone and soft tissue complications during bone transport, increases patient's comfort, the volume of the fixator is smaller and painful scarring is limited.

Nine patients with a mean age of 23.9 years were treated with this technique. The aetiology was tumour, trauma or sequelae of infection. The mean bone loss was 7.2 cm in length. Transportation was achieved with a special pulley system. The mean follow-up time was 18.3 months. The external fixation time ranged from 5 to 13.2 months, the mean distraction index was 12.1 days/cm. The mean length of bone transport done was 6.3 cm. An excellent bone result was obtained in 4 cases, a good result in 4 cases and a fair result in one case. An excellent functional result was obtained in 2 lower extremity cases, a good result in 3 cases. Preoperative DASH scores of the upper extremity cases improved from a mean of 80.1 to a mean of 15.85. Complications were seen in 4 cases.

Keywords : bone defect ; bone transport ; technique ; modification.

INTRODUCTION

High-energy trauma, tumours and chronic osteomyelitis are frequent causes of bone defects of the extremities. Despite all primary treatment efforts, composite tissue defects may persist and need to be treated by further reconstructive methods (*5,8,17*).

In this study, we present an original modification of the technique of internal bone transport used for the treatment of large bone defects with the Ilizarov method. In this technique, only the osteotomised fragment is transported by an internal pulley system constructed from cannulated screws and cerclage wire and the osteotomised fragment is transported axially without jeopardising the surrounding soft tissues. Thus painful pin tract infections and scarring are avoided. The contact ratio of the bones at the docking site is very high, the fixator mass is reduced while the comfort of the patient is increased.

MATERIAL

Bone defects were treated in 6 male and 3 female patients using our modification of internal bone transport. The mean age was 23.9 years (range : 15 to 41) and the mean duration of pathology from the initial trauma to the time of surgery was 18.3 months (range : 9 to 25). The bone defect was in the lower extremity in 5 patients (3 tibias, 1 femoral condyle, and 1 fibula including the

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lateral malleolus) and in the upper extremity in 4 patients (radius in 2 and ulna in 2). The mean size of the defect was 6 cm (range : 4 to 9), and the mean bone loss (defect + shortening) was 7.2 cm (range : 4 to 11). Patients underwent an average of 4.6 operations (range : 1 to 14), prior to this treatment.

The aetiology of bone loss was trauma in 5 cases (2 tibias, 2 ulnas and 1 radius). Bone defects of the tibia were in patients with open fractures following a fall or a road traffic accident. The bone defect of the radius was caused by an open fracture of the radius following a sports accident. Bone defects of the ulna were caused by a fall from a height and by an agricultural accident. The mean defect in these 5 trauma cases was 5.6 cm (range : 5 to 6), the mean bone loss was 7 cm (range : 5 to 9), the mean delay from the initial trauma to the final operation was 51.6 months (range : 25 to 90), and the average number of previous surgical interventions was 6.2 (range : 2 to 14).

In one case partial epiphysial arrest of the lateral condyle of the femur, lateral shortening and deformity of the knee were present as a result of haematogenous osteomyelitis of the distal femur in childhood. The bone loss causing the defect in the lateral condyle was 4 cm when compared to the medial condyle.

In 3 cases the aetiology was tumoral : a chondrosarcoma of the proximal tibia, a haemangioendothelioma of the distal fibula, and an aneurysmal bone cyst localised in the distal diaphysis-metaphysis junction of the radius. In these three cases, the duration prior to surgery was mean 10.7 months, the mean size of the defect was 8 cm (range : 7 to 9) and the average number of prior surgeries was 3 (range : 2 to 5).

The results were evaluated as bone results and functional results. The criteria to evaluate bone results were bone union, presence of infection, deformity and limb length discrepancy. The parameters for evaluation of the functional results of the lower extremities were pain, independent performance of daily activities, abnormality of gait, and walking distance. The "disabilities of the arm, shoulder and hand" score (DASH) was used for evaluation of the functional results of patients operated on their upper extremities.

Surgical technique

Transportation of the bone fragment is done by a 'transport pulley system' placed into the bone defect (fig 1a,b) while the extremity is stabilised with a circular external fixator. Transport is achieved by two motor

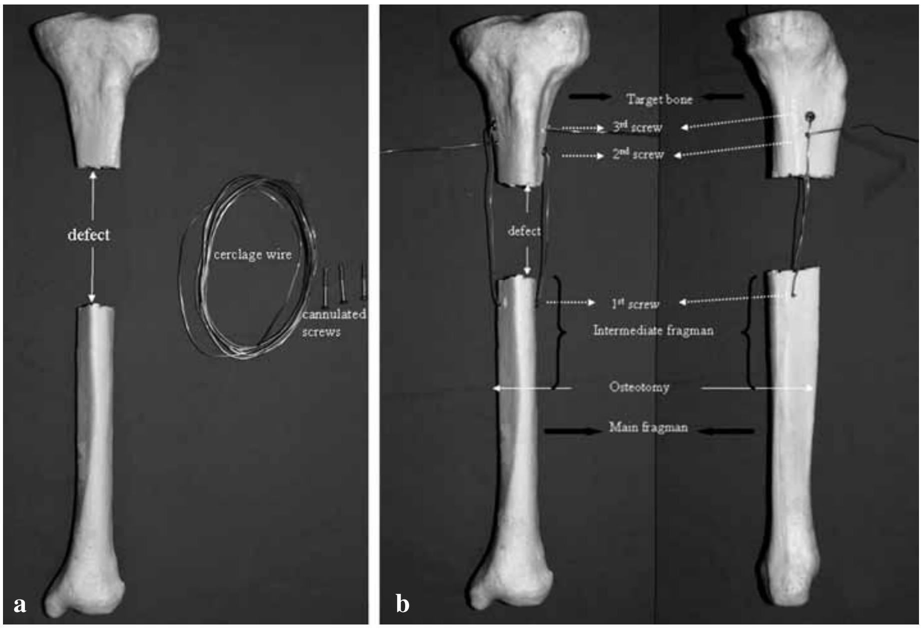

Fig. 1. — The bone-only transport pulley system composed of 3 cannulated screws through which the cerlage wire passes : a) Bone defect of the tibia and the cannulated screws with cerclage wire, b) A view of the application of the transport pulley system on the bone defect. The $1^{st.}$ screw is on the proximal third of the (future) intermediate fragment and the 2^{nd} and 3^{rd} screws are placed opposite each other on the target bone.

Fig. 2. — The motor unit seen from above and from the side. The rod held by the offset of the fixator hoop pulls the cerclage wire. As the nuts on the rod turn 360°, the cerclage wire and the fragment of bone attached to it move 1 mm.

units localised in the medial and lateral of the extremity, fixed to the frame and pulling cerclage wires (fig 2). All infected and avascular tissues were removed first, to ensure a clean and viable defect bed.

The modified technique of internal bone transport is performed in 3 steps. The first step is debridement and surgical removal of all necrotic, infected or foreign tissues to obtain a viable bed. For this purpose, MRI scanning is very useful to evaluate the extent of bone necrosis and soft tissue infection. The second step is the formation of a 'transport pulley system'. The first screw is placed close to the edge of the main fragment. It should be at least 1 cm from the edge and in the first third of the future intermediate fragment. The second screw is placed at about 1 cm distance to the edge of the target bone and the third one is placed at 1 cm further to the second one. All three screws are placed in a medial-lateral direction and in the midline of the bone. The first and the second screw heads may be placed either medially or laterally, but the third one is preferably inserted opposite to the second. Once the screws are in place, a cerclage wire is passed through the screws in the direction from the head to the tip, first from the first screw and then each end of the wire is passed through one of the other screws. The ends of the cerclage wire are then passed out of the skin in the same direction of the second and the third screws. The second step ends with closure of the wound. The third step involves the application of a circular external fixator, the osteotomy of the main fragment in order to obtain an intermediate fragment (fig 3a,b,c) and the connection of the cerclage wires that were previously taken out of the skin, onto the motor units. The fixator frame may merely be composed of proximal and distal rings connected by simple bars and providing only stabilisation to the extremity, or it may be more complex including hinges and multiple motor units due to other pathologies of extremity such as shortening and deformities.

Once the transport is completed, the intermediate fragment is fixed to the fixator frame with transosseous K wires or two half pins, the motor units are removed and the docking site is bone grafted (fig 4a,b).

RESULTS

Bone union was achieved in all cases. The mean duration of follow-up was 18.3 months (range : 9 to 25). The mean length of bone transport done was 6.3 cm (range : 4.5 to 8.5), the mean lengthening to correct shortening was 1.8 cm (range : 0 to 4), the mean distraction index was 12.1 days/cm (range : 8 to 14) and the external fixation time ranged from 5 to 13.2 months (average : 8.1). Evaluation of functional results of the lower extremity cases revealed excellent results in 2 cases and good results in 3, whereas DASH scores of the upper extremity cases improved from a mean preoperative score of 80.1 (range : 91 to 69) to a mean score of 15.85 (range : 4 to 36) on final evaluation.

The bone results evaluation of the lower extremity cases revealed excellent results in 2 cases and good results in 3 cases. The mean duration of the fixator stay was 10.4 months (range : 7.1 to 13.1) and the mean length of bone transport was 6 cm (range : 4 to 8). The mean lengthening was 1.7 cm (range : 0 to 3).

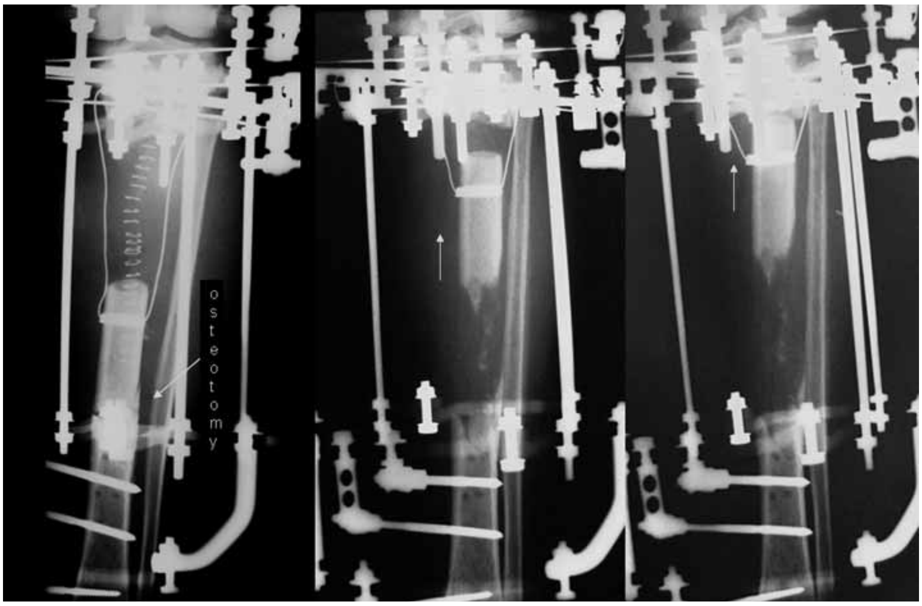

Fig. 3. — Progressive docking of an intermediate fragment

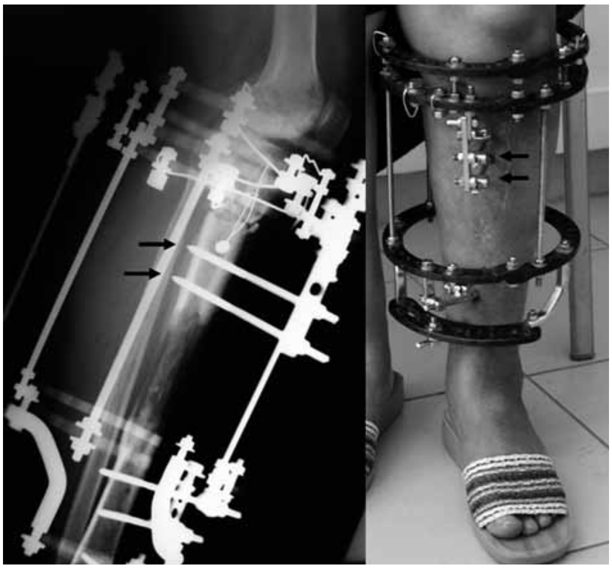

Fig. 4. — When transport is completed, the intermediate fragment is fixed with 2 half-pins. At the same time, early cancellous bone grafting is performed.

The bone results evaluation of the upper extremity cases revealed excellent results in 1 radius and 1 ulna, a good result in 1 ulna and a fair result in 1 radius case. The mean bone transport was 6 cm (range : 5 to 9) and mean lengthening was 1.25 cm (range : 0 to 3). The mean duration of the fixator stay was 5.2 months (range : 4.3 to 7.1).

In 3 cases with active infection, the infection was resolved before the fixators were removed, and the other 3 cases with resolved infection had no relapse. The two patients who had resection for neoplasm did not have recurrences.

We experienced 3 major and 1 minor complication, 4 patients had grade 1 or grade 2 pin site problems. One patient with a bone defect of the ulna developed an anxiety reaction towards the fixator treatment. In 2 patients with a defect of the radius, the 1st screw cut out off the intermediate fragment before the defect was closed. One patient with bone defect and shortening of the tibia had a transient paralysis of the fibular nerve. Pin sites problems were managed by oral antibiotics and wound care. No wire or pin was removed for this problem.

DISCUSSION

Bone defects resulting from trauma, infection or tumour may be treated successfully by various methods (*9,11,16*). According to many authors, distraction osteogenesis is the best choice of treatment for complicated defects especially when bone deformities, soft tissue coverage problems, infection or shortening of the extremity accompany the defect (*10,12,15*). We treated 7 such cases of complicated bone defects and 2 cases of large bone defects caused by resection of malignancies by a new modification of internal bone transport.

Internal or external bone transport techniques have their own advantages and disadvantages. In the external technique, bone is transported in an axial direction and progressive compression in the docking site is possible. However the longitudinally placed neurovascular structures may be strained by the transverse transosseous wires. Painful scars on the skin, fibrosis of the muscle tissues and secondary complications on the joints limit the use of this method to defects up to 4 cm (*6,15*). In the new modification of internal bone transport technique, the bone is axially transported also by an internally placed transport pulley system. The cerclage wires pulling the osteotomised fragment lie within the defect parallel to the neurovascular structures and are not dependent on the surrounding soft tissues. This helps to avoid complications on the neurovascular tissues and skin.

Because of fewer and milder complications affecting soft tissues, patients tolerate the internal technique better than the external technique. The classical technique is performed using oblique K wires and the intermediate fragment is pulled by a force equal to the sum of the longitudinal vector components of the oblique wires. Together with the transverse components, the force on the bone where the wires penetrate is higher and thus the risk of wire cut-out is higher, especially on osteoporotic bones. The obliquity of the pulling wires continuously changes as the transport progresses thus the motor unit has to be revised to accommodate the direction of pull. When the transport is completed, the fixator needs to be revised and the intermediate fragment needs to be fixed (*1,4,7*). In our modification, bone transport is done axially. The pulling wires do not change direction throughout the transport process thus revision of the motor units is not needed. The cannulated screws transmit the force of the pulling wires to a wider contact area of bone thus decreasing the risk of cut-out. Cut-out of the screws was seen in 2 of our cases where there was a defect of the radius with shortening. Because the mean duration of the pathology before our treatment in these patients was 3 years (range : 2 to 4) and several previous surgeries had damaged the bones, eventually severe osteoporosis and the fragility of the radius were the causes of this complication.

Stabilisation of the extremity is achieved by a circular external fixator. The main objective in choosing the circular external fixator is its modularity in stabilising deformed extremities affected by disuse osteoporosis or insufficient bone stock (*2,3,15*). The size and complexity of the fixator are determined not by the size of the defect but rather by additional problems of the involved extremity such as deformity or shortening. In the upper extremity, the more complicated structure of muscles and neurovascular elements make the treatment more prone to complications. The neurovascular structures may be damaged during the application of transverse transosseous wires or pins, or may be entrapped by them during bone transport or lengthening or deformity correction (*13,14*). With the “bone transport pulley system” that is placed internally the risk of neurovascular complication is minimal, because the transport pulley system is placed under direct vision and its placement and direction of movement is parallel to the neurovascular structures.

The proposed internal bone transport technique is the treatment of choice for a bone defect complicated with infection, deformity, osteoporosis, limited bone stock or soft tissue coverage problems, or for large bone defects.

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