ORIGINAL ARTICLE

CORRECTIVE PROCEDURE IN DIAPHYSEAL BONE GAPS: BONE TRANSPORT FIXATED WITH PLATE

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SUMMARY

The objective of this study is to describe a new bone transport system not requiring the use of transfixating wires. The system, which is constituted by a plate, a movable conveyor and a hauling device, was set up on the right tibia of 17 sheep intending to fill a 1-cm bone gap. Bone transport started 7 days after surgery on a rate of 0.8 mm/day, divided into 0.2 mm at each 6 hours. X-ray images of anteroposterior and lateral planes were taken immediately after surgery and on a weekly basis until transport was finished. In all 12 animals completing the study, the bone gap was filled with regenerated formation and target focus consolidation. The study shows that the system presented here effectively performs bone transport, eliminating the use of transfixating wires or pins.

***Keywords:** Osteogenesis, Distraction ; Bone regeneration; Bone plates.*

***Citation:** Picado CHF, Garcia FL. Corretive procedure in diaphyseal bone gaps: bone transport fixated with plate. Acta Ortop Bras. [serial on the Internet]. 2007; 15(1):47-49 . Available from URL: http://www.scielo.br/aob.*

INTRODUCTION

Large diaphyseal defects usually result from high energy trauma to extremities or from dèbridements in cases of chronic osteomyelitis, and they represent a significant challenge for orthopaedic doctors [1,2]. The principle of osteogenesis by traction described by Ilizarov[3,4] is an excellent biological method for filling bone gaps on long bones, but it frequently presents complications caused by metal wires transfixing and cutting through soft parts' envelope, such as joint stiffness, pain, infection at wires' path, scars, vascular and nervous injuries, compartment syndrome, and sympathic-reflex dystrophy [5-7], at rates ranging from 1 to 200%[6].

This motivated the development of new mechanical systems that could be able to perform bone transport without using transfixing wires [8-11] while compliant with previously established biomechanical principles of stability and fragments' separation rate and rhythm.

The objective of this study is to present a new system able to perform bone transport without using transfixing wires or pins.

MATERIALS AND METHODS

The principle of this system consists of fixating key bone fragments with a plate acting as a stabilizer to these fragments. Attached to that plate and able to slide having it as a guide, a mobile car is mounted, which is fixated by means of two screws to the intermediate fragment to be transported. The mobile car is pulled by a 1-mm steel wire bonded to it by one end to the other to a traction device. The traction device has: a support by which it is fixated to the plate and, consequently, to the bone, a hollow tube fixated to the support by one of its extremities and that will seat internally to soft parts, ending at an infinite crown-thread system at the opposite end, externally to soft parts, which is manually activated by means of a graduated handle. The wire-free end of the mobile car protrudes through the hollow tube, attaching to the infinite crown-threaded system that will pull and move the mobile car together with the bone fragment attached to it, thus performing bone transport.

The plate has round holes on its ends and a single oval compression hole, more centrally positioned, next to target fragment enabling compression between bone fragments at target point when the transported fragment reaches the target fragment (Figure 1).

The study described hereon was approved by the Committee on Ethics in Animal Experiments of our Institution and the application of this new bone transport system was experimentally tested on 17 adult sheep, with average weight of 35 kg. The animals were submitted to 12-hour fasting previously to surgery. They were anesthetized with Nembutal^R at 30mg/kg dosage. Following trichotomy of the right lower limb's medial surface, antisepsis was performed using iodine solution and sterile drapes placement.

The surgical technique consisted of causing a 1 cm-long bone defect at the diaphyseal portion of the tibia, followed by osteotomy in one of the remaining bone ends, creating a third fragment about 2.5 cm long, which is the fragment to be transported. Proximal and distal fragments were fixated by the plate while the intermediate fragment to be transported was fixated to the mobile car whose wire was attached to the traction device. The attachment of the plate and the mobile car to the bone was made with 3.5 mm cortical screws. All osteotomies were performed with a Gigli saw. On the first four operated animals, the bone defect was produced while keeping periosteal coating's integrity and, on the other 13 animals, the defect was produced by removing the bone cylinder together with the periosteum (Figure 2).

Following wound closing (Figure 3), tenotomy of the common calcaneus muscle of the operated limb was performed, intending to preclude the animal from applying load to the limb during the first postoperative weeks.

All operated animals were kept in individual cages for 24 hours before they could be returned to the animal lab, where they were kept in collective stalls comprising 3 animals each at most at the same time, under veterinary surveillance, replacing dressings in an alternate days basis until surgical wounds healed. As a prophylactic measure, 2 doses of a combination of procaine penicillin and benzatine penicillin at 40.000 UI/kg dosage were administered via intramuscular on the first week after surgery.

Transport started 7 days after surgery by turning the graduated handle of the traction device at approximately ¼ cycle at each 6 hours, corresponding to 0.8 mm daily movement of the transported fragment.

X-ray images at anteroposterior and lateral planes were taken immediately after surgery, and on a weekly basis until the end of

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Study conducted at the Department of Biomechanics, Medicine and Locomotive Apparatus Rehabilitation, University of São Paulo, Medical College, Ribeirão Preto..

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Received in: 08/18/06; approved in: 11/29/06

transport, that is, until the moment in which the transported fragment reached the target fragment. Once transport was finished, the animals were submitted again to surgery for fixating transported fragment against target, as well as for removing the traction device and the mobile car.

RESULTS

From the 17 operated animals, only 12 completed the experiment. Two animals were sacrificed due to infection at surgical site, which did not respond to antibiotic therapy; one animal underwent a tibial fracture just below the plate while it was being transported to X-ray tests, and it also had to be sacrificed, and; two animals died during the first surgery as a result of anesthesia complications.

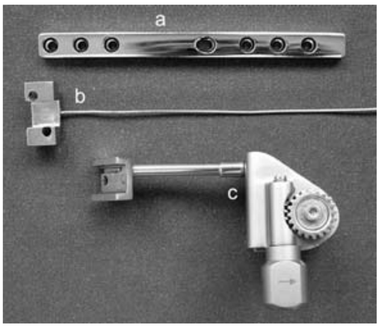

***Figure 1 –** Transport system elements: (a) plate, (b) mobile car, (c) traction device.*

***Figure 2 –** The produced bone gap and the attached transport system, with plate fixating key fragments, traction device fixated to target fragment and mobile car attached to the fragment to be transported (osteotomy site is indicated by the arrow).*

***Figure 3 –** System introduced on a sheep's tibia.*

In the other 12 animals, bone transport was successfully achieved, that is, the transported fragment reached the target fragment, a fact occurring typically 2 weeks after transport, as seen on the weekly X-ray documentation. Regenerated matter formation and target core union occurred in all those animals (Figure 4).

The animals were allowed to apply load on the operated limb approximately 6-8 weeks after the first surgery, limping only when running.

DISCUSSION

Osteogenesis by traction has long been used successfully for fixing diaphyseal defects in long bones [12-17] and it presents advantages compared to vascularized bone graft, a method that is also used in these cases, but it is technically more difficult and invasive, additionally to introduce a significant morbidity at donor site, and because it is not structurally strong enough when used on the femur [8,10]. Nevertheless, the classical bone transport using a round external fixator is associated to a number of complications associated to transfixing metal wires, including pain, infection at wires' path, joint stiffness, scars, injuries to nerves and vessels, compartment syndrome, and sympathic-reflex dystrophy [5,6,7].

In literature, we found some authors who pursued the reduction of these complications incidence by means of alternative mechanical systems.

Brunner et al.[9] in 1990, published their experience using a single-plane external fixation system combined to an intramedullary nail, successfully performing bone transport in sheep tibiae.

Alonso and Regazonni[8] , also in 1990, reported their results on bone transport using only an AO tubular external fixator.

Apivatthakakul and Arpornchayanon[18] , in 2002, published a case report of two patients in whom bone defect was addressed with bone transport combining a plate and a Wagner's stretcher.

Baumgart et al.[19] described, in 2004, an automatic and powered bone transport system with a single central handle combined to an external fixator, and they report its clinical use in a patient.

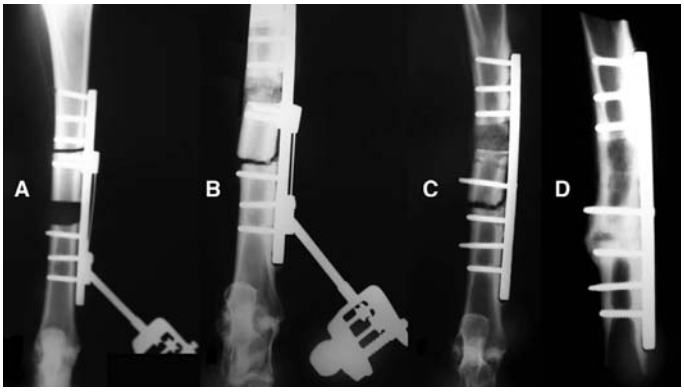

***Figure 4 –** X-ray images at anteroposterior plane showing the system introduced on a sheep's tibia:*
(A) early postoperative period
(B) the transported fragment reaches the target site
(C) the mobile car and the traction device have been removed and the transported fragment was fixated to the plate
(D) target site union and regenerated matter remodeling 12 weeks after transported fragment fixation.

The use of these above described alternative mechanical systems mitigated some complications associated to transfixing wires, but they could not totally eliminate them, as these systems still require external fixators. There is obviously a shortage of studies describing bone transport systems not using external fixators.

Hyodo et al.[11] described, in 1996, a system with no external fixating element, which combined an intramedullary nail to a flexible handle, and successfully performed bone transport in 12 dog femurs.

Herford[10] published, in 2004, his results using a plate-guided transport system, also without wires or pins, in 4 patients with mandibular bone defects.

The main idea of the system described hereon is to perform bone transport without using any external fixation element, that is, with no metal wires or pins passing through soft tissues, using a plate or a mobile car and a traction device. This system had some modified and improved prototypes by means of mechanical assays in our laboratory until we reached to a final version regarded as feasible to be introduced in sheep [20].

The plate was built with a length of 12 cm for allowing fixation of proximal and distal fragments avoiding metaphyseal region of sheep's tibiae and avoiding the need of plate molding. The 1-cm defect produced corresponds to a segment of approximately 5% of bone's total length.

Osteotomies performed for creating an intermediate fragment to be transported are made on diaphyseal cortical bone, a fact that led us to use a slower transport rate (0.8 mm/day) than the one recommended by Ilizarov(4).

The results achieved with this system proved that it is able to successfully perform bone transport. That fact encouraged us to adjust it to our patients by resizing its basic elements (plate, mobile car, and traction device) and keeping its functioning principles. The requirement of an additional surgery for fixating the transported fragment at transport's completion is a drawback of the method. Furthermore, it does not allow for a simultaneous adjustment of discrepancies on limbs' length, once the system was developed uniquely intending bone transport. However, transport is made without the complications associated to wires or pins that are usually employed in traditional external fixation systems.

CONCLUSION

The experiment shows that the system described hereon effectively performs bone transport.

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