Continuous Segment Transport in the Treatment of Shaft Defects: Experimental and Clinical investigations

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Abstract: Discontinuous procedures for segment transport as a method of callus distraction have become routine even though each distraction increment disturbs the formation and maturation of the regenerate. Our goal was to observe whether a continuous distraction procedure would be superior to conventional discontinuous procedures in terms of the time required for distraction and the quality of the regenerate. After developing a continuous distraction apparatus, experimental investigations were carried out on sheep. Additionally, clinical investigations were performed on 4 patients with a modified apparatus.

INTRODUCTION

Segment transport as a method of callus distraction has become standard clinical practice in the treatment of post-traumatic defects. The basic conditions for this procedure are well-known and constantly being optimized. Discontinuous procedures (i.e., 1 mm transport distance, divided by 4 steps per day) have become routine although each distraction increment tears the sensitive, regenerated bony tissue and disturbs regenerate formation and maturation [1]. The question was, whether or not this situation could be improved by using a continuous transport system or by increasing the number of distraction steps (i.e., 10,000 times per day) during the distraction period.

FRACTURE FIXATION

To test the handling, a practical clinically applicable continuous distraction apparatus was developed and experimental investigations were carried out on sheep. We created a fracture gap of 50 mm by removing a bone cylinder. The length of the transported segment was 20 mm.

In a first series of 12 sheep, we used a combination of internal (reamed tibial nail) and external (pinless fixator) stabilizers which carried the distraction device. After completing the transport, the external fixator and the distraction device was removed. The intramedullary nail provided stable mechanical conditions and allowed healing and maturation of newly formed callus in the distraction gap.

We gave up on this model for the following reasons: infection and loosening of the proximal metaphyseal pinless clamps, disconnection of the pinless clamp from the mobile segment under high transport forces, and deep infection due to intramedullary and periosteal vascular damage. We therefore abandoned intramedullary fixation and the pinless fixator. The new model consisted of a rigid frame fixator which carried the distraction device. The transport segment was fixed on a semi circular ring system with threaded K-wires or with Schanz' screws.

DISTRACTION DEVICE

The goal was to establish a peak distraction force of 500 N. We decided to push the segment rather to pull it using a spring and to control the transport speed by a braking-motor with the advantage of minimizing the size and the energy consumption of the driving system. Another advantage was that we could easily change the spring-load and thus optimize the apparatus for a particular transport force. The DC-motor was equipped with a reduction-gear with an overall reduction of approx. 1.6E6 : 1 providing continuous transportation. The speed was controlled by an electronic speed control system and the apparatus was powered with rechargeable batteries. The gear was coupled onto a mechanical feed drive component which controlled the linear displacement of the transported bone segment.

Further investigations showed that transport may not be fully continuous. Dividing the distraction distance of 1 mm/day into steps of approx. 8,000 to 10,000 proved sufficient to maintain the advantages of continuous distraction.

RESULTS

First experimental investigations were carried out on sheep tibiæ with a continuous transport system. The investigations provided basic data on early callus formation and maturation under continuous distraction. Continuous distraction is possible at faster speeds of up to 2 mm/day, while still maintaining a high quality of regenerate formation.

Clinical investigations were done on 4 patients (2 femora; 2 tibiæ). Distractions of 1.5 mm/day with 10,000 steps were performed. The transport on both femora and on 1 tibia was successful with clinically good bone formation. In one of the tibia patients mechanical transport problems led to early maturation of the callus in the distraction gap, thus preventing further transport. Under conventional discontinuous transport conditions healing could be achieved. According to that patient, continuous transport was less painful than the conventional transport.

DISCUSSION

The sheep model was helpful to test the basic handling and function of the distraction device. The testing of the clinical, human application of the apparatus however could not be substituted by the animal model. The procedure is
very demanding for the patient as well as for the surgeon. It is still rather intensive and subject to complications requiring constant attention and intervention.

CONCLUSION

The procedure is an optimization of segment transport. Fast transport speeds were achieved by means of continuous tensile stresses whereby good regenerate formation was achieved.

REFERENCES