Experimental rationale of combined distraction osteosynthesis using an internal plate and the Ilizarov fixator

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INTRODUCTION

Current requirements to the quality of rendering medical care and patient’s comfort during treatment dictate their priorities. Patient’s quality of life and the reduction of his/her inpatient stay are one of the most important issues. The provision of comfortable conditions for patients throughout the stage of bone fixation with the apparatus on is one of the research areas that have clinical relevance. In order to improve the Ilizarov method, the combined or consecutive use of different osteosynthesis variants and techniques of fragment fixation were introduced [1]. First reports on the successful combined use of an intramedullary rod and an external fixator were made in the 1990s. This combination allowed surgeons to significantly reduce the index of external fixation thus improving the patients’ quality of life during treatment and accelerate the rehabilitation process [9, 14]. The technology was based on an experimental study [3]. However, the intramedullary blood supply is impaired by rod introduction into the bone canal and the risk of osteomyelitis becomes higher. There are publications on bone fragment fixation with a more sparing combination – intramedullary wires and an external fixator [2, 5].

In the recent years, studies that combined the use of plating with external fixation for limb bone lengthening have been also reported. This combination, as in the case of an intramedullary rod, is aimed at reducing the period of patient’s stay with the fixator on and at decreasing the rate of complications [6, 10, 13]. The use of this technique was preferred in children with open growth plates as far as an intramedullary rod implantation into the medullary canal through growth plates is inappropriate [7, 8, 12]. The authors used regular plates for bone segment fixation that were implanted after completion of the lengthening procedure and resulted in the reduction of the external fixation period [10, 11]. In view of the literature data, it is evident that the combined use of plating and external fixation appears to be a promising solution. However, profound preclinical studies and the development of a special plate for combined osteosynthesis are necessary due to the lack of original plates for limb lengthening, scarcity of the information to take into account, and small series of clinical cases treated.

The purpose of the study was to develop a model of a combined osteosynthesis for limb lengthening using the Ilizarov fixator and the internal plate of an original design aimed at a future clinical introduction.

MATERIALS AND METHODS

The study used 6 experimental mongrel dogs at the age from one to five years that underwent lengthening of the tibia by 14-16 % using the Ilizarov fixator and the internal plate of authors’ design. The plate is intended to hold bone fragments in the correct position during distraction and after removal of the fixator when the distraction lengthening is over. The material for manufacturing of the plates and the plate dimensions were selected empirically. Care of animals, surgeries and euthanasia...
were performed in accordance with the rules of protection of experimental animals (Order No 755 of the USSR Ministry of Health from 12.08.1977). The experiment was approved by the Ethics Committee of FSBI RISC for RTO.

The plate was made of a titanium alloy to reduce its weight and provide strength characteristics. Its width corresponded to the diameter of the canine tibia. The plate was curved wavelike, and the curvature repeated the anatomic curvature of the tibia that made it possible to achieve an adequate contact of the plate with the tibia. The secured contact of the plate with the fragments improved fixation rigidity, reduced the risk of osteosynthesis instability and, as a consequence, the risk of delayed consolidation and nonunion.

Transosseous osteosynthesis of the canine right lower leg bones was performed under general anesthesia in the operation room using the Ilizarov fixator of two supports. Transosseous wires were inserted at the level of the proximal and distal tibial metaphyses. Osteotomy was performed at the boundary of the middle and upper thirds of the tibia. The plate of the original design was introduced through a small additional cut of soft tissues from the medial segment surface at the level of the proximal metaphysis and placed on the tibial shaft after preliminary separation of the soft tissues from the bone.

The plate extended from the upper third of the tibia to its lower third and did not have any contact with the Ilizarov fixator wires. The plate was secured to the proximal tibial fragment with three screws and to the distal tibial fragment with a screw inserted only through the top part of the slot. The screw in the slot was not drawn to the plate tightly so it enabled sliding in the slot during distraction (Fig. 1). The bone regenerated under the smooth plate part. Thus, the deformities at the level of the regenerated bone after the fixator removal were prevented. When the lengthening procedure was over, the plate was locked through small cuts-punctures in the operation room being finally fixed to the distal bone fragment. For this purpose, the screw in the plate slot was fully tightened and two more screws were added, one was screwed through the top part of the slot and the other one through an additional hole in the plate lower part. The Ilizarov fixator was removed on the same day. The animals were withdrawn from the experiment by a sodium thiopental overdose 30 days after fixation with the plate. Clinical, radiological, anatomical, and statistical methods were used in the study. Statistical studies were performed using Microsoft Excel 2016. The mean values and their average error were determined for descriptive statistics.

RESULTS

In the X-rays after surgery, the tibial axis was correct, there were no translations (transverse displacements) observed (Fig. 2). The postoperative period was uneventful. Soft tissue edema that measured from 1 to 1.5 cm without well-defined borders was observed in the canine leg for 5–7 days. The edema subsided by the start of distraction.

Distraction started on day 7 after surgery with the rate of 1 mm per day made with 4 steps and continued for 21–28 days depending on the leg length. The animals used the operated limb actively throughout the experiment period (Fig. 3). The first signs of regeneration were observed in the X-rays on day 14 of distraction. The regenerated bone was of typical structure in the form of longitudinal bands extending from the proximal and the distal fragments (Fig. 4). Bone axis was correct, no displacement of fragments was observed.

Bone axis by the end of distraction (21–28 days) was correct in the X-rays in all the cases. Regenerated bones parts were of a longitudinal striated structure, their extent was 12 ± 1.2 mm. The connective-tissue interlayer of 5 ± 1.5 mm was located in the middle part of the regenerated bone (Fig. 5). The stability of the plate was beyond doubt. At this stage of the experiment, the plate was locked with screws at the level of the distal fragment through the slot and the lower hole in the operation room, and then the fixator was dismounted. The mean amount of lengthening was 26 ± 1.3 mm. The index of external osteosynthesis made 12.7 ± 0.7 day/cm.
After 30 days of bone fixation with the plate, the regenerated bone acquired a uniform structure in most of the cases. In several cases, areas of higher density were revealed in the middle part – the marks of the connective tissue interlayer. The regenerated bone was of normoplastic type, the periosteal reaction was poorly marked (Fig. 6).

Upon euthanasia on day 30 after fixation with the plate, the following manifestations were observed when anatomical preparations were studied. The slot in the plate was filled in with connective and cartilaginous tissues and the entire surface of the plate was covered with an envelope of dense connective tissue. The bone under the plate was covered with a changed muscular tissue. There were no necrotized tissues or areas (Fig. 7).
Bone tissue resorption around one of the screws and associated local inflammation of tissues that was arrested with antibiotics were the complications encountered. They did not affect the experiment results.

There were no cases of metal breakage or deformity of the regenerated bone during the experiment.

Thus, the developed by us plate in combination with the Ilizarov fixator showed high efficiency and minor complications during experimental lengthening of lower leg bones.

REFERENCES


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