DOI 10.18019/1028-4427-2016-4-71-75

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

M.A. Stepanov, N.I. Antonov, D.Iu. Borzunov

FSBI Russian Ilizarov Scientific Center for Restorative Traumatology and Orthopaedics of the RF Ministry of Health, Kurgan

Introduction The decrease in the external osteosynthesis index during limb lengthening is a relevant problem to solve by the current orthopaedics, especially in regard to children. Intramedullary rods in pediatric orthopaedics are contraindicated due to open growth plates. The use of intramedullary wires reduces the period with the fixator on the patient's limb but the index of osteosynthesis remains rather high. **Purpose** To analyze the results of the combined use of the Ilizarov fixator and an internal plate of an original design for experimental tibial lengthening. **Material and Methods** Leg lengthening was performed in 6 experimental dogs using the Ilizarov fixator and plating. The procedure of segmental lengthening by 14-16 % from the initial length was performed in the manual mode with the rate of 1 mm per day produced with 4 steps. **Results** The planned amount of lengthening was achieved in all the animals. The use of plating enabled to remove the fixator on the day of distraction completion. The index of external osteosynthesis was 12.7±0.7 day/cm. The regenerated bone was of normoplastic type. It acquired a homogenous structure after 30 days of fixation in the majority of cases. As for the complications, the resorption round one of the screws that fixed the plate was observed along with soft tissue inflammation but it did not affect the experiment results. **Conclusion** The combined use of plating and the Ilizarov fixator decreased the external osteosynthesis index and prevented the complications related to regenerated bone fracture or deformity after the fixator removal.
Keywords Combined leg lengthening, internal plate, the Ilizarov fixator, dog, experiment

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 osteosynhesis 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

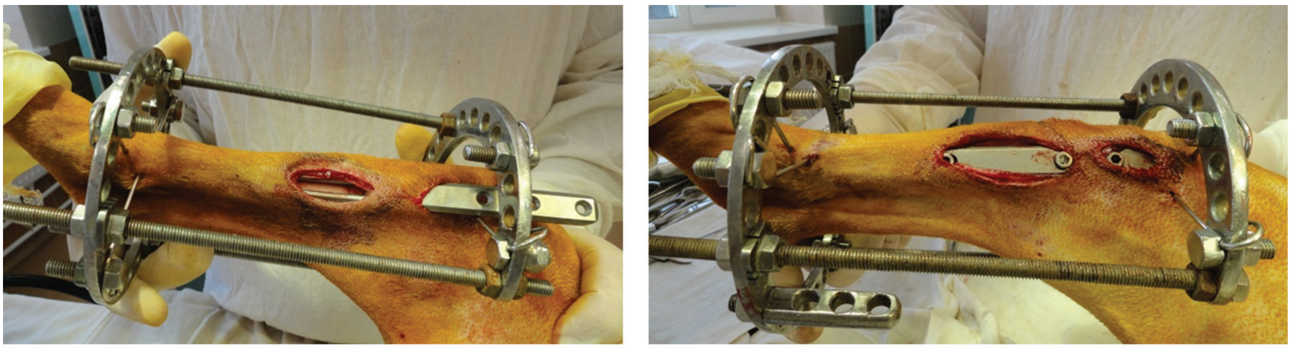
The study used 6 experimental mongrel dogs at the age from one to five years that underwent lengthening of the tibia by 14-16 % using the Ilizarov fixator and the internal plate of authors' design. The plate is intended to hold bone fragments in the correct position during distraction and after removal 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

🕮 Stepanov M.A., Antonov N.I., Borzunov D.Iu. Experimental rationale of combined distraction osteosynthesis using an internal plate and the Ilizarov fixator. *Genij Ortopedii*, 2016, No 4, pp. 71-75 (In Russ). DOI 10.18019/1028-4427-2016-4-71-75

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.



a b

Fig. 1 Stages of the surgery: Application of the plate (**a**), Fixation of the plate to bone (**b**)

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.

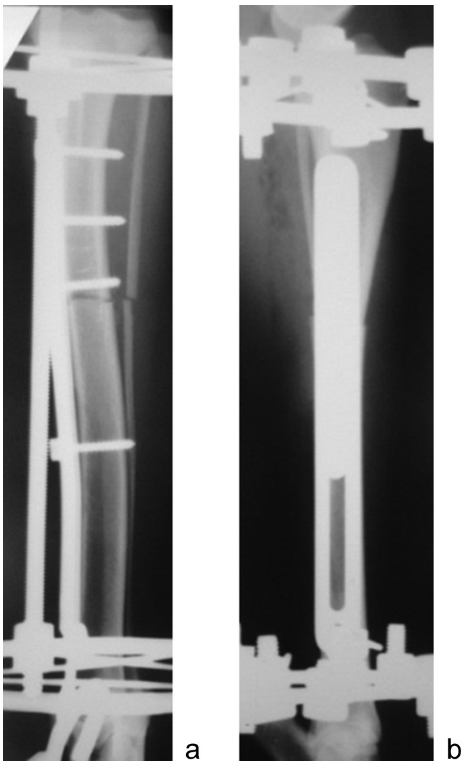


Fig. 2 The Ilizarov fixator and the plate applied. X-rays of the canine leg bones after surgery: anteroposterior (AP) view (**a**), lateral view (**b**)

Fig. 3 Dog at a stage of the experiment

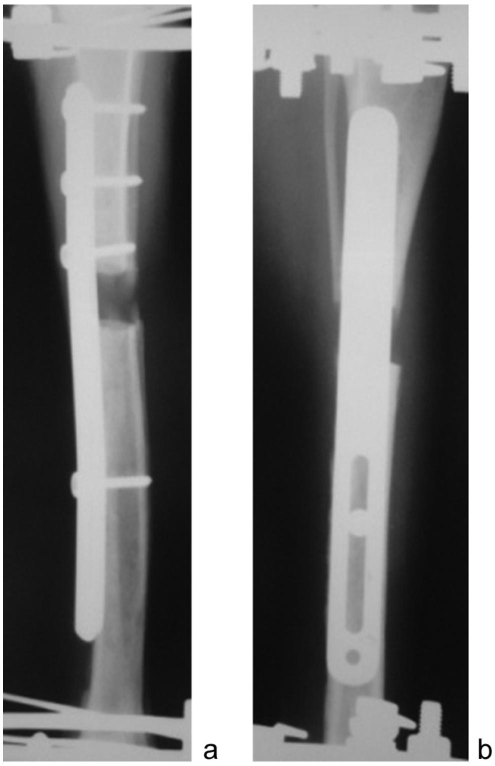


Fig. 4 X-rays of the leg bones on day 14 of distraction: AP view (**a**), lateral view (**b**)

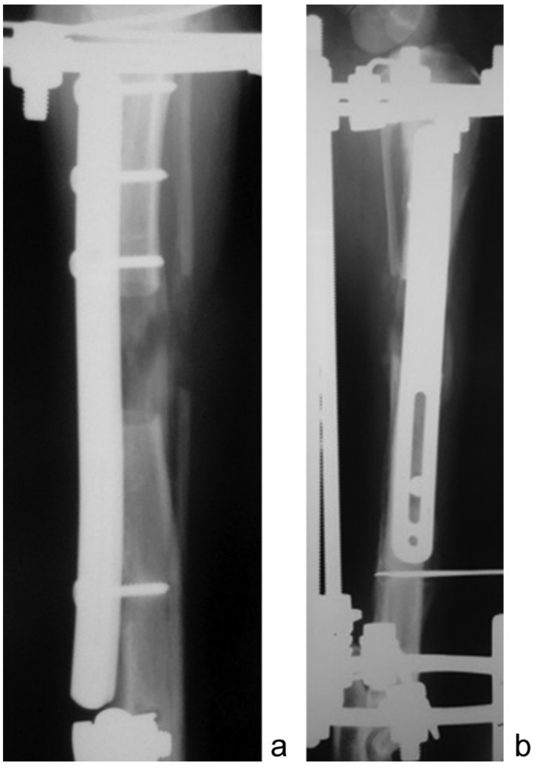


Fig. 5 X-rays of leg bones on the day of lengthening completion: AP view (**a**). Lateral view (**b**)

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**).

Fig. 6 X-rays of leg bones on day 30 of fixation: AP view (**a**). Lateral view (**b**)

Fig. 7 Anatomic preparation of the leg: The leg medial surface in the area of plate implantation (**a**). Cartilaginous tissue growing into the plate slot (**b**)

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

1. Gubin A.V., Borzunov D.Y., Malkova T.A. The Ilizarov paradigm: thirty years with the Ilizarov method, current concerns and future research. *Int. Orthop.* 2013. Vol. 37, N 8. pp. 1533-1539. doi: 10.1007/s00264-013-1935-0
2. Popkov D.A., Yerofeyev S.A., Chirkova A.M. Udlinenie goleni s ispol'zovaniem intramedulliarnogo napriazhennogo armirovaniia (eksperimental'noe issledovanie) [Leg lengthening using intramedullary stressed reinforcement (experimental study)]. *Genij Ortop*. 2005. N 4. pp. 81-89
3. Stepanov M.A., Kononovich N.A., Gorbach E.N. Reparativnaia regeneratsiia kostnoi tkani pri udlinenii konechnosti metodikoi kombinirovannogo distraktsionnogo osteosinteza [Bone tissue reparative regeneration for limb lengthening by the technique of combined distraction osteosynthesis]. *Genij Ortop*. 2010. N 3. pp. 89-94
4. Sokolovskii O.A., Serdiuchenko S.N., Brodko G.A., Ur'ev G.A. Uravnivanie dliny nizhnikh konechnostei – istoricheskie rakursy i sovremennye tendentsii [Equalization of the lower limb length – historical perspectives and current trends]. *Med. Novosti.* 2011. N 7. pp. 11-19
5. Popkov A.V., Aranovich A.M., Novikov K.I., Mingazov E.R., Popkov D.A. Udlinenie goleni u detei kombinirovannoi metodikoi s primeneniem vysokodrobnoi kruglosutochnoi distraktsii [Leg lengthening in children by the combined technique using high-divisional round-the-clock distraction]. *Genij Ortop.* 2016. N 2. pp. 51-56
6. Harbacheuski R., Fragomen A.T., Rozbruch S.R. Does lengthening and then plating (LAP) shorten duration of external fixation? *Clin. Orthop. Relat. Res*. 2012. Vol. 470, N 6. pp. 1771-1781. doi: 10.1007/s11999-011-2178-2
7. Iobst C.A., Dahl M.T. Limb lengthening with submuscular plate stabilization: a case series and description of the technique. *J. Pediatr. Orthop*. 2007. Vol. 27, N 5. pp. 504-509
8. Oh C.W., Song H.R., Kim J.W., Choi J.W., Min W.K., Park B.C. Limb lengthening with a submuscular locking plate. *J. Bone Joint Surg. Br*. 2009. Vol. 91, N 10. pp. 1394-1399. doi: 10.1302/0301-620X.91B10.22325
9. Rozbruch S.R., Kleinman D., Fragomen A.T., Ilizarov S. Limb lengthening and then insertion of an intramedullary nail: a case-matched comparison. *Clin. Orthop. Relat. Res.* 2008. Vol. 466, N 12. pp. 2923-2932.doi: 10.1007/s11999-008-0509-8

10. Endo H., Asaumi K., Mitani S., Noda T., Minagawa H., Tetsunaga T., Ozaki T. The minimally invasive plate osteosynthesis (MIPO) technique with a locking compression plate for femoral lengthening. *Acta Med. Okayama*. 2008. Vol. 62, N 5. pp. 333-339
11. Uysal M., Akpinar S., Cesur N., Hersekli M.A., Tandoğan R.N. Plating after lengthening (PAL): technical notes and preliminary clinical experiences. *Arch. Orthop. Trauma Surg.* 2007. Vol. 127, N 10. pp. 889-893
12. Oh C.W., Shetty G.M., Song H.R., Kyung H.S., Oh J.K., Min W.K., Lee B.W., Park B.C. Submuscular plating after distraction osteogenesis in children. *J. Pediatr. Orthop. B*. 2008. Vol. 17, N 5. pp. 265-269. doi: 10.1097/BPB.0b013e32830688d8
13. Wu C.C., Chen W.J. Tibial lengthening: technique for speedy lengthening by external fixation and secondary internal fixation. *J. Trauma.* 2003. Vol. 54, N 6. pp. 1159-1165
14. Paley D., Herzenberg J.E., Paremain G., Bhave A. Femoral lengthening over an intramedullary nail. A matched-case comparison with Ilizarov femoral lengthening. *J. Bone Joint Surg. Am.* 1997. Vol. 79, N 10. pp. 1464-1480

Received: 21.09.201

Information about the authors:

1. Mikhail A. Stepanov, Ph.D. in veterinary sciences, Russian Ilizarov Scientific Centre for Restorative Traumatology and Orthopaedics, Kurgan, laboratory of pyogenic osteology and limb defect management, leading researcher, veterinarian
2. Nikolai I. Antonov, Ph.D. in biology, Russian Ilizarov Scientific Centre for Restorative Traumatology and Orthopaedics, Kurgan, Laboratory for Reconstructive Joint Replacement and Arthroscopy; e-mail: aniv-niko@mail.ru
3. Dmitrii Iu. Borzunov, M.D., Ph.D., Russian Ilizarov Scientific Centre for Restorative Traumatology and Orthopaedics, Kurgan, deputy director on scientific activities; e-mail: borzunov@bk.ru