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Original article

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A new device for intramedullary femoral osteotomy

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Abstract

Introduction Osteotomy is an important part of orthopaedic interventions and can result in an injury to the periosteum reducing regenerative capabilities of the bone. **Material and methods** A device for processing the femur was developed to allow osteotomy be produced from the medullary canal. An experimental study was conducted on femoral models in two comparison groups (20 models in each). Osteotomy of the femoral shaft was performed at a distance of 15 cm from the apex of the greater trochanter. Duration of bone intersection and magnitude of partial and complete defects of the simulated periosteum were evaluated. **Results** The average duration of osteotomy was 482.8 ± 15.4 s in the main group and 181.3 ± 16.1 s in the control group. The average overall length of injury to the simulated periosteum to the entire depth was 1.4 ± 3.0 mm in the main group being significantly less in the control measuring 13.6 ± 3.8 mm (Mann-Whitney U-test = 7.0, p = 0.00). The average total length of partial injury to the periosteum (1.4±2.6 mm) was significantly less in the main group than in controls (21.8 ± 5.8 mm, Mann-Whitney U-test = 0.0, p = 0.00). **Discussion** The surgical device offered, as opposed to existing devices, allowed bone intersection to be performed with high accuracy. The presence of endoscopic control of the osteotomy depth ensured preservation of the periosteum. The device could be used for several bone cuts using a single surgical approach. **Conclusion** The use of the device slightly increased duration of the osteotomy and facilitated minimally invasive intervention retaining periosteum at the osteotomy site and provided better conditions for bone regeneration.

Keywords: osteotomy, endoscope, minimally invasive surgery, periosteum

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INTRODUCTION

Modern orthopaedics is associated with a range of complex high-tech surgical interventions on bones and joints with use of various osteotomies [1]. The result of treatment in the cases would depend on the way the bone integrity is broken. Various types of osteotomies and devices for the performance have been developed. A separate surgical approach is normally used to produce an osteotomy. A minimal trauma to the periosteum at the performance is essential for osteogenesis and for the surrounding soft tissues [2, 3, 4]. The use of standard surgical instruments including osteotomes, wire and oscillatory saws can be associated with an injury to periosteum and the soft tissues. There is also a risk of injury to blood vessels and nerves during this stage of the operation. The skin scar at the site of the osteotomy is a cosmesis defect. Protective devices can be used to minimize injury to the surrounding soft tissues [5]. Minimally invasive techniques have been offered for bone transection procedure using drills, miniature osteotomes [6, 7]. However, the use is accompanied by the intersection of the periosteum. Minimally invasive methods require intraoperative radiographic control and are associated with radiation exposure to the patient and medical staff. A combination of external and internal fixation can be used for bone defect replacement or limb lengthening [8]. The use of intramedullary constructs is associated with a traumatic effect on the medullary canal. Intramedullary osteotomy can be recommended with use of IM nail employing one surgical approach. The purpose of the study was to evaluate the capabilities with the device developed for processing the femur during intramedullary osteotomy.

MATERIAL AND METHODS

A device for processing the femur was developed to reduce traumatic manipulations in the medullary canal of the femur including osteotomy (patent of the Russian Federation No. 2717706 dated 08/15/2019). The working model was made of aluminum tubes and plates (Fig. 1).

Two devices of different lengths were manufactured to process the femoral canal at different depths. Internal fixators were attached at the end of each to allow the distal end of the device move perpendicular to the axis of the bone inside the medullary canal. Fixators were controlled by the surgeon by rotating the knurled nuts to make the studs, metal strings attached to them and located inside the device, move (Fig. 2).

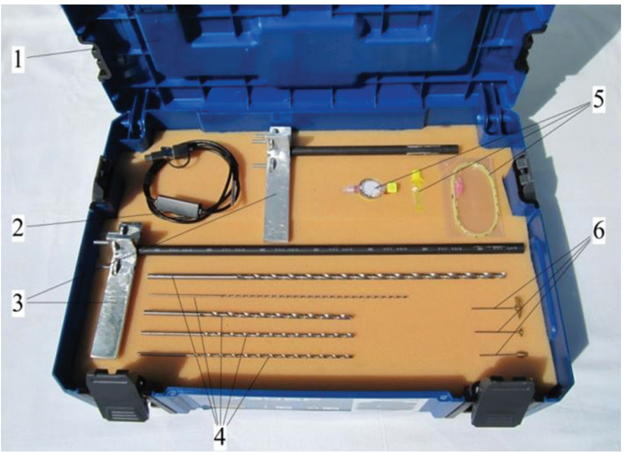

Fig. 1 Appearance of the device placed in a case: case (1), flexible endoscope (2), device for processing the femur (3), set of drills (4), components of the flushing system (5), set of cutters (6)

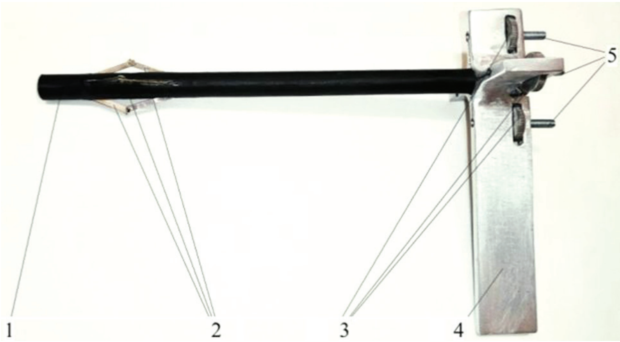

Fig. 2 Device design: distal end of the device (body) (1), internal fixators (2), knurled nuts (3), handle (4), studs (5)

There was a flexible endoscope, a lavage tube, and an instrument for medullary manipulations inside the device. For an osteotomy, a device with a cutter was placed into the medullary canal from the proximal end of the bone to the depth required. The depth of insertion and the site of osteotomy were determined during preoperative planning and measured intraoperatively using the scale on the tube of the endoscopic system. The device was then fixed inside the channel in such a way that the cutter was located next to the wall of the channel. The manipulations were performed during endoscopically assisted surgery (Fig. 3).

Osteotomy was performed by rotating the cutter and moving it inside the canal together with the device using fixators (Fig. 4).

The bone thickness was measured preoperatively to be processed intraoperatively with a cutter (disk) of the required diameter.

The device was tested at the Department of Traumatology and Orthopaedics, the Voronezh State Medical University named after N.N. Burdenko. Simulated femurs fixed to the table were used in the experimental study. Periosteum was simulated by gluing a 0.7 mm polyvinyl chloride film to the models. The study included 40 models with the osteotomy of the femoral shaft performed at a distance of 15 cm from the apex of the greater trochanter.

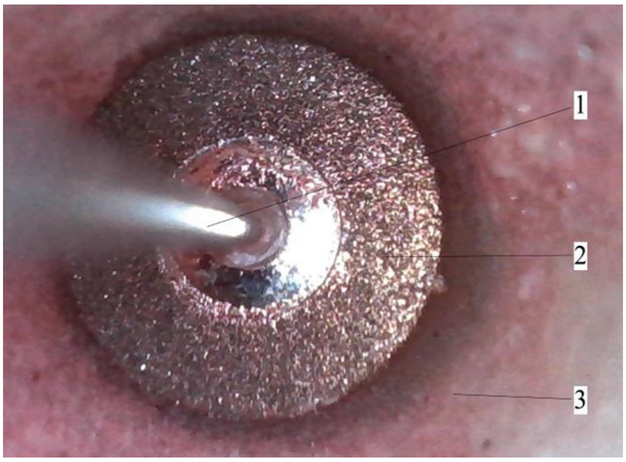

Fig. 3 Endoscopic picture of the femoral canal showing components of the device: cutter holder (1), cutter (disk) (2), femur (3)

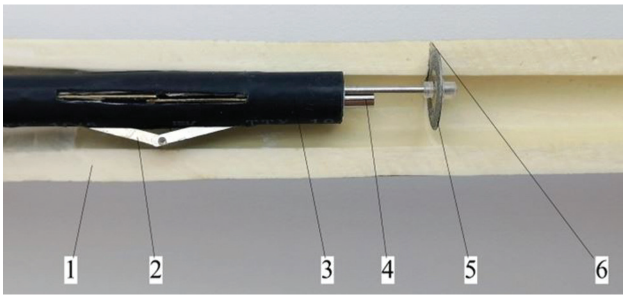

Fig. 4 Cutting the femur at the the upper third using the device placed: femur (1), internal fixator (2), distal end of the device (3), flexible endoscope (4), cutter (disk) (5), femoral bone cut zone (6)

Osteotomy was performed in the experimental group (20 models) using the device developed and femoral shaft of controls (20 models) was osteotomized using standard 10 mm osteotomes. The duration of the manipulation was measured with a SOPpr-2a-3-000 stopwatch. The periosteum was assessed by measuring the length of the partial injury and cuts to the full depth using a ShTs-1-150-0.05 caliper gage. The mean values and standard deviation (M ± m) were calculated using the SPSS Statistics v.26 program. The means were compared using Student's T-test for independent samples (with a normal distribution) and using the Mann-Whitney U-test (with a distribution being different from normal).

RESULTS

The average duration of osteotomy was 482.8 ± 15.4 seconds in the experimental group and was significantly longer than that in the control group measuring 181.3 ± 16.1 (T-score = 60.3; p = 0.00). The bone was cut without surrounding soft tissues in the experimental study. Osteotomy to be performed using a separate surgical approach would require an intraoperative access and suturing the wound. The steps were associated with increased duration of the surgical intervention. The circumference of the simulated femur was 10.4 cm at a distance of 15 cm from the apex of the greater trochanter. The average lengths of partial and complete injuries of the simulated periosteum in the comparison groups are shown in Figure 5.

The mean total length of injury to the simulated periosteum was 1.4 ± 3.0 mm over the entire depth in the experimental group that was significantly less than that in the control group measuring 13.6 ± 3.8 mm (Mann-Whitney U-test = 7.0; p = 0.00). Polyvinyl chloride film ruptures with osteotomes were caused by direct impact of surgical instruments on the film at the beginning of osteotomy and by slipping during crosscut of the cortical bone along the perimeter. The simulated periosteum in the experimental group was damaged by excessive sawing of the cortical bone from the inside using a cutter.

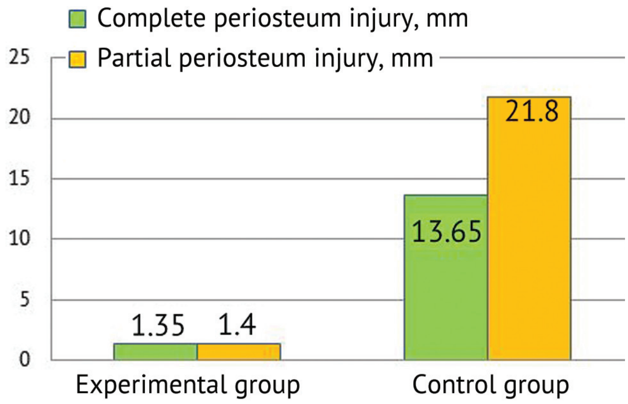

Fig. 5 Average lengths of partial and complete injuries of the simulated periosteum

Similar data were obtained for partial cuts in the film. The average total length of injury to the simulated periosteum was 1.4 ± 2.6 mm in the experimental group that was significantly less than that in the control group measuring 21.8 ± 5.8 mm (Mann-Whitney U-test = 0.0; p = 0.00). The experimental femur was transected without additional injury to the cortical bone. Comminuted fractures at the site of intervention were seen in 6 controls.

DISCUSSION

There is a paucity of publications reporting osteotomies performed from the medullary canal [9]. The interventions require intraoperative radiological control and the availability of special instrumentation with limited functionality. Most surgeries are commonly associated with a separate access required to break bone integrity. Various guides and instruments have been developed to improve the accuracy of osteotomy and ease the performance [10, 11, 12]. Custom-made templates can be used for difficult cases. Despite the high efficiency and accuracy of current devices employed for osteotomy, the use of a separate surgical approach can be accompanied by adverse events including a skin scar at the site of intervention, scars along the surgical approach, intersected periosteum along the certain length and periosteal blood vessels providing nutrition to the bone [13].

The bone was intersected using the device developed and a 0.2 mm cutter (disk) to ensure a minimum cut. The ability to regulate the depth of the cutter (disk) entering the cortical bone with high accuracy allowed intersection to the periosteum. Medulloscope instruments used in modern traumatology and orthopaedics can significantly reduce the invasiveness of interventions and increase the effectiveness [14–17]. The endoscopic system being part of the device provided visual control of the osteotomy and reduced the need for intraoperative radiological control of the manipulation. As opposed to current medulloscopic instruments, the device developed had the ability to move and fix in the medullary canal and can be used for precise interventions including osteotomies.

Multiple osteotomies can be used for significant bone defects to be repaired with the Ilizarov external fixation [18.]. The use of the device developed does not require additional accesses and several osteotomies can be performed at different levels during one operation. Placement of intramedullary constructs is associated with the risk of fat embolism. The use of the device developed for osteotomy can be advocated for cases of involved medullary canal and surgical implantation.

There are various types of surgical interventions aimed at replacing bone defects, limb lengthening with use of nails like in the Bliskunov system and in combination with the Ilizarov apparatus and hexapods [8, 19–21]. Remote-controlled intramedullary lengthening nails can be placed using minimal access to facilitate a good cosmetic effect after surgery. Using the same access, osteotomies can be performed with the device offered. The study showed that the manipulations produced in the femoral canal were technically difficult. The osteotomy performed with the device offered was accompanied by increased length of the procedure. The custom-tailored device used in the study had excessive overall characteristics that made manipulations in the femoral canal difficult to perform.

CONCLUSION

The use of the device developed for processing the femur slightly increased duration of the osteotomy and facilitated minimally invasive intervention retaining periosteum at the osteotomy site, avoiding injury to soft tissues and provided better conditions for bone regeneration.

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