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THE REACTION OF SPONGY BONE TISSUE TO THE USAGE OF MOTOR SYSTEMS IN TRAUMA AND MAXILLOFACIAL SURGERY

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ABSTRACT

The problem of drilling spongy bones for setting fixing structures is very relevant in traumatology and maxillofacial surgery. A number of experiments have been carried out to determine the optimal method of spongy bone drilling without additional cooling. A morphological study of the reaction of spongy bone tissue to drilling in different conditions was carried out. Clinical recommendations for optimal drilling of the spongy bone without additional cooling were determined.

Keywords: Internal fixation, spongy bone drilling, morphological pattern of the spongy bone, twist drill needle

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INTRODUCTION

Trauma surgery issues are one of the leading in medicine and, in particular, in maxillofacial surgery. The data in native and foreign literature allow us to see that among all skeletal injuries, the frequency of fractures of facial bones is from 3.2 to 8.0% [1-4, 6-8, 12-14, 17, 25, 26], and in the Chuvash Republic - 17% [21].

There are two directions in the bone fractures treatment: conservative-orthopedic and surgical (Internal fixation), its combinations are also possible [1-12, 14, 17-19, 24-26]. In the research, we consider surgical methods as in this case, it is necessary to affect directly on the bone tissue, leading to its additional trauma in varying degrees.

Discussing the tactics and methods of treating patients with facial fractures, it is necessary to remember the bones structure of maxillofacial area. It is well known that facial bones are represented by a spongy tissue covered with a cortical layer, and in some parts of the face, the so-called "weakness" zones, which Dr. Le Fort established in 1901, the bones are flat and mainly consist of a cortical plate. Nutrition in the "weakness" zones is carried out only by the periosteum, and therefore its additional trauma, as in case of bone Internal fixation, disrupts the nutrition process and the process of bone regeneration [5]. Performing open bone internal fixation, injury can be caused using the motor system. Unlike motor cooling systems used in dental implantology, external cooling is practically not used in traumatology, and in some cases it is simply impossible. For example, performing intraosseous internal fixation of the condylar process of the lower jaw [6, 8, 10-12, 14, 18, 24, 26], where the retaining needle has to pass a way in a large fragment of at least 4 cm [20, 24].

During internal fixation, we exert both mechanical and thermal effects on the bone. With the development of a high speed rotation, it is possible to overheat the bone tissue, which leads to bone necrosis and, accordingly, to its lysis along the channel formed by the needle. This, in turn, leads to the migration of needles [26]. For today, the optimal speed of rotation is not determined with the insertion of locking pin-needles using motor systems without the possibility of additional cooling.

The temperature effect on bone tissue during drilling affects humoral and cellular responses. It is known that in bone tissue at a temperature (t°) above 41°C, blood vessels, blood flow, fat cells and bone beams begin to undergo significant changes, and heating the bone to 52°C leads to permanent stop of blood flow and tissue necrosis [15, p .89].

So, for bone tissue, the safest is to increase t° without additional cooling from the original (body t°) not more than 5°, as the lower threshold for the occurrence of changes in tissues.

Temperature of heating depends on the sharpness of the cutting edge of the tool, the speed of insertion, pressure and additional cooling. Since we cannot use additional cooling during intraosseous holding of the needle and cannot monitor the force of pressure, it remains for us to choose the optimal rate of insertion of the needle, based on the degree of heating of the bone tissue around the cutting end of the needle and along its length, not exceeding the mentioned above parameter of 5°.

MATERIALS AND METHODS.

Heating of the bone tissue at the point of entry of the needle into the bone and along the length of the channel formed by the needle was checked to determine the optimal speed and method of introduction of spokes into the spongy bone during internal fixation. For this, a series of experiments was carried out.

In the first experiment (Exp-1), we selected the optimal technique for introducing needles. To do this, in Exp-1a, the needle was inserted into the bone under a thin cortical layer intermittently with an interval of 1 after 1 second. In this case, we were interested in the t° of heating the cortical layer of the bone along the canal. Intermittent insertion of the needle allows the tissues and the tool to cool. This statement was borrowed from the therapeutic dentistry, where intermittent preparation of the cavity is recommended to prevent tissue overheating [16].

In Exp-1b, a continuous rotation of the needle was made in the previously formed channel. In this case, the heating was determined by friction of the needle against the channel walls, excluding the pressure factor and the cooling time of the tissues and the tool, in order to determine the methodology for holding the needle in the bone more accurately.

In previous articles [21, 22], the optimal - feather sharpening of the needle retainers was selected. Therefore, all subsequent studies were carried out precisely with the use of this type of sharpening of the cutting edge of the needles.

For Exp-1 a needle-pin with a diameter of 1.5 mm with feather sharpening, a clamping device for needles for internal fixation of facial bones [23], an NSK brand physiological dispenser of the "Surgic Pro" model, a "Digital multimeter DT838" thermocouple, and a non-contact infrared thermometer "TemPro 300" were used. As bone material, we used dissected cadaver lamb ribs with a cortical layer thickness of 0.9 mm and a spongy layer of up to 1.5 mm.

In Exp-1a, the needle fixed in a clamping device was inserted into the bone under the cortical layer to a depth of 2 cm, at 50, 100, 300 and 400 rpm with a torque of 0.8 N*m provided by the physiological dispenser. In Exp-1b, a needle rotated in a preformed channel in the bone under the cortical layer at the same rotations per minute, but without pressure. In both experiments, before the insertion of the needle, a thermocouple and non-contact infrared, the initial t° of the needle-pin and bone was measured. Then, using the same instruments, while inserting the needle into the bone at a distance of 2 cm, the t° of the needle, the bone at the entry point, and the cortical layer at a distance of 2 cm were measured for each of the given speeds.

Conducting experiments on speciments using devices with a sufficient error is justified by the fact that the living human body has thermoregulation due to the constant blood flow in all vessels, including the small capillary bed, which is available in all tissues. Therefore, during the experiments, we chose a minimum increase in t° of heating bone tissue, not exceeding 5°, which can be compensated by a living organism without the occurrence of severe inflammation, leading to lysis of the bone tissue.

It is a known fact that during drilling the formation of a traumatic layer of necrotic tissue is inevitable, the thickness of which depends on the heating of the bone and the duration of the thermal injury [15 p. 312]. But this judgment is valid only for working with a drill, where the chips are removed. While drilling with needles, the thickness of the necrotic layer may also depend on the degree of compression of the bone marrow that occurs, since the needle passing through the bone forms a channel equal to its diameter. Bone chips, however, are not removed, unlike working with a drill, but distributed in the spongy substance. To find out the depth of penetration of bone chips into the spongy substance of the bone, and therefore to assess the degree of compression of the red bone marrow, the second experiment was conducted (Exp-2). This experiment will help to evaiuate the mechanical effect on bone tissue.

Exp-2: the needle was inserted into the bone at 300 rpm, after preliminary washing down the compact layer with a milling cutter in the place of the proposed needle, at low speeds. Lamb vertebrae were used as bone material. In this experiment, the yield of chips from the channel at the insertion point was visually evaluated. The chips did not come out of the channel. With prolonged (more than 20 seconds) continuous drilling, bone marrow boiling was determined around the point of insertion of the needle. This fact led us to the need of another or the third experiment (Exp-3), to determine the volume of primary denaturation of bone marrow cells when conducting the needles at different speeds of the available modern motor systems used in maxillofacial surgery.

In Exp-3, to assess the denaturation of red bone marrow cells along the edge of the canal formed by the needle, at 300 - 600 rpm with a torque of 0.8 N*m, a needle with feather sharpening was inserted into the bone. As bone material, dissected cadaver lamb vertebrae were used (4-5 hours from the time of slaughter). The needle was inserted into the bone intermittently with an interval of 1-1 second before jamming in the cortical layer of the opposite side, that is, the entire height of the vertebra, for each of the speeds. In this case, for the purity of the experiment, the needles were replaced every two drills. The bone, since slaughter, was stored in an isotonic sodium chloride solution to prevent drying. Immediately after carrying out the needles, preparations with formed channels were placed in a solution of neutral (10%) formalin, where they were stored for 10 days at t° = 4°C.

After a predetermined time, the vertebrae were sawn into bone blocks 1 cm in diameter with a channel in the center. Then, the bone blocks were sent for decalcification using ethylene diamine tetraacetate, after this histological preparations of longitudinal sections of the canal stained with the hematoxylin-eosin method were made to further evaluate the depth and uniformity of penetration of bone chips into the bone marrow cells of the spongy bone.

RESULTS

Exp-1 allowed us to obtain data that in addition to heating the bone, the needle itself was heated when it was inserted into the bone, but its heating at the injection site did not exceed 3° in all cases. Averaged data on the degree of heating of bone tissue around the cutting part of the needle during intermittent administration (Exp-1a) are presented in Table 1.

Table 1. Changes of the t° in the bone tissue with intermittent insertion of needles with feather sharpening using different speeds

Rotation speed	Initial bone temperature, °C	t° of the bone tissue with the insertion of needles at the entry point, °C	t° of the bone tissue with the insertion of the needle at a distance 2cm, °C	Heating of the bone tissue around the cutting part, °C
300 rmp, torque 0,8 N*m	20,66±0,86	23,8±0,8	24,95±0,8	**4,25±0,42**
100 rmp, torque 0,8 N*m	20,25±0,34	22,7±0,56	23,7±0,48	**3,45±0,48**
50 rmp, torque 0,8 N*m	22,75±0,46	23,95±0,5	24,7±0,59	**2,95±0,28**

Data of the heating degree of the bone tissue around the needle during continuous rotation, obtained during Exp-1b, are presented in table 2.

Table 2. Changes in the bone tissue t° with continuous rotation of the needles in the bone channel using different speeds

Rotation speed	Initial bone temperature, °C	t° of the bone tissue with the insertion of needles at the entry point, °C	t° of the bone tissue with the insertion of the needle at a distance 2cm, °C	Heating of the bone tissue around the cutting part, °C
300 rmp	20,7±0,87	32±1,2	32,7±1,03	**12,1±0,45**
100 rmp	20,25±0,34	27,15±0,41	29±0,33	**8,75±0,46**
50 rmp	21,75±0,46	26,35±0,75	26,95±0,72	**5,4±0,57**

From tables 1 and 2, we purposely excluded the speed of insertion and rotation of the needle equal to 400 rotations per minute, because its continuous rotation caused a visual "burning", and while introducting with an interval of 1 after 1 second, the heating significantly exceeded the mark of 12°.

Histological sections obtained by sagittal cuts of demineralized fragments of vertebral bodies were morphologically researched. Histological preparations were stained with hematoxylin-eosin and photographed in no less than 3-5 fields of view using a Carl Zeiss microscope and an AxioLab.1 camera. Morphometry was performed using the ZEN program (Carl Zeiss, Germany).

With an increase of 100, a bone matrix matching to the structure of the reticulofibrotic bone, which was penetrated by longitudinally oriented bone channels, was revealed in the histological sections of the samples. We measured the depth of damage to the bone matrix from the edge of the canal formed by the needle to the first undamaged bone trabecula.

When the needle rotates with the speed of 300 rpm at the bottom of the canal, fragments of the bone matrix or bone "shavings", which are formed during the mechanical insertion of the needle, are determined (Fig. 1).

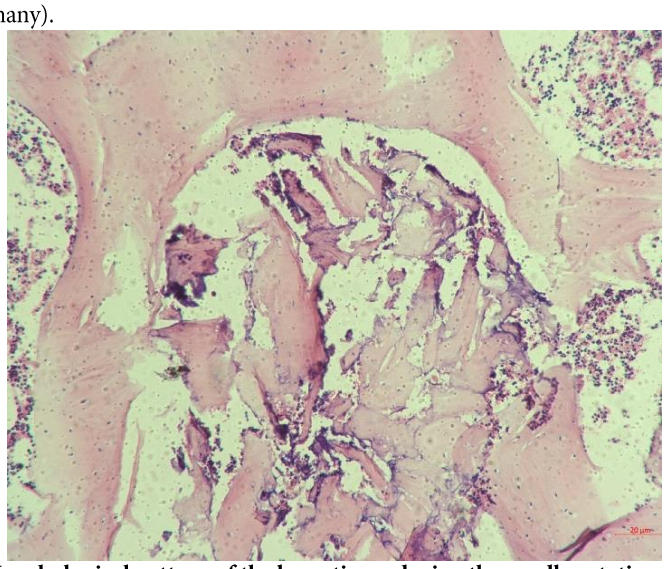

Figure 1. Morphological pattern of the bone tissue during the needle rotations at 300 rpm

The canal side is smooth, with a weakly basophilic border zone. The structure of the bone trabeculae, limiting the cavity filled with bone marrow is not broken. Bone trabeculas have homogenous oxyphilic staining. Osteocytes are determined in bone lacunae. Hematopoietic cells that are located in the intertrabular cavities do not have signs of morphological and functional disorders. Thus, when the needle rotates at speed 300 rpm, there is no violation of the structure of the spongy bone of the vertebra and there are no signs of destruction of bone tissue. Hematopoietic cells retain functional activity.

When the needle rotates at speed 400 rpm, the bone tissue of the vertebra located along the forming channel has distinct basophilia (Fig. 2). This is due to coagulation of collagen as a result of thermal effects during the insertion of the needles. The depth of the damage is 145.49 ± 4.37 μm, which significantly differs from the indicators of the depth of the damage during rotation of the needle with the lower number of rotation moves. The structure of the bone trabeculas outside the exposure zone is not broken. Hematopoietic cells are not damaged.

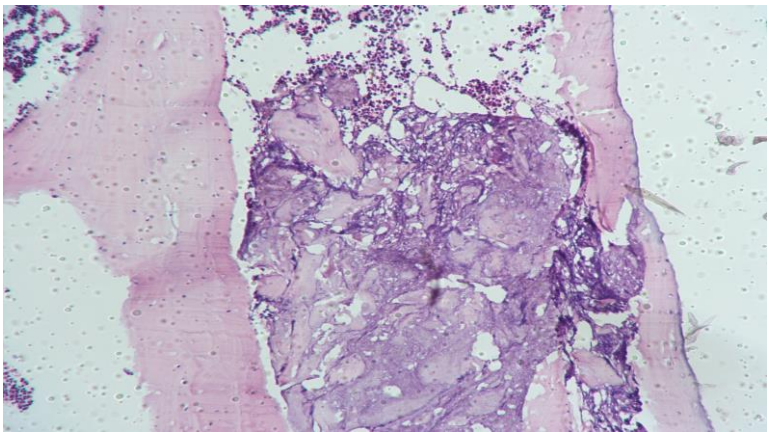

Figure 2. Morphological pattern of the bone tissue during rotation of the needle at 400 rpm

The rotation of the needle at speed 500 rpm leads to deeper destructive changes in the bone tissue of the vertebrae in comparison with the affect from 300 and 400 rpm, (Fig. 3).

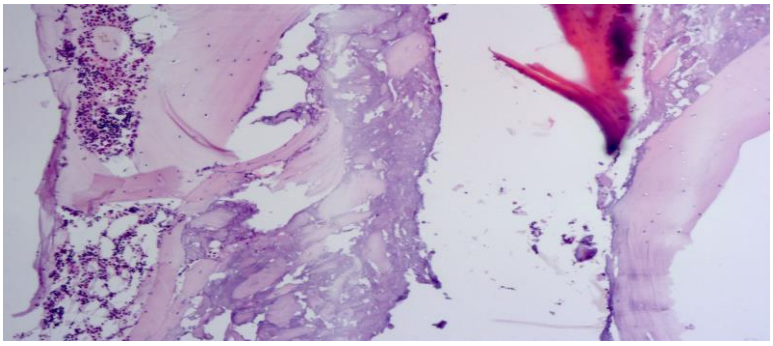

Figure 3. Morphological pattern of the bone tissue during rotation of the needle at 500 rpm

The depth of damage in this group exceeds this parameter twice, compared with 400 rpm and it is 361.41 ± 48.19 μm. It should be noted that in this case there is a violation of the structure of the bone tissue; part of the bone lacunae does not contain osteocytes. Hematopoietic cells expose partial damage and death.

In bone preparations obtained by rotating the needles at speed 600 rpm, the destruction of the bone trabeculas occurs along the channel wall, which is formed by the insertion of the needles. Opened cavities between bones trabeculas are filled with necrotic damaged tissues with hyperchromic basophilic staining (Fig. 4). They are formed by dead hematopoietic cells and deformed bone trabeculas, which look like polychromatophilically stained crossbars with lacunae containing fragments of osteocyte nuclear. Here, the depth of damage is 2563.31 ± 391.20 μm.

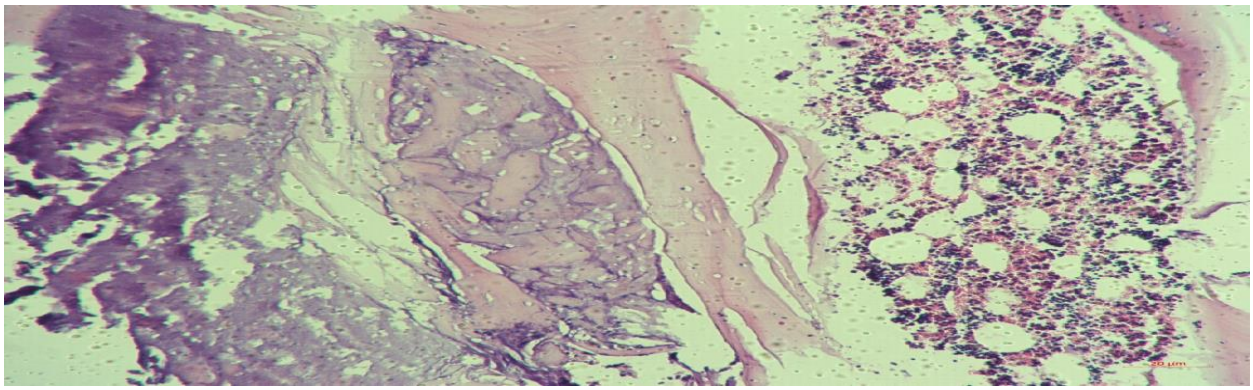

Fig.4. Morphological pattern of the bone tissue during rotation of needles at 600 rpm

The formation of the canal during the needle rotation at a speed of 500 and 600 rpm has a damaging effect on the structure of the bone vertebrae, which is shown in the thermal destruction of the collagen matrix of the bone tissue, coagulation necrosis of the bone marrow tissue.

DISCUSSION

Based on the results obtained in Exp-1, we were able to prove that the twist drill needle without the possibility of additional cooling should be inserted intermittently, which means, with stops, it allows the retainer and the bone to not overheat.

Continuous rotation without overheating of the bone tissue is possible with the insertion of the needle into the bone at speed up to 50 rpm. Intermittent insertion allows you to increase the speed of the needles retainers up to 300 rpm. A subsequent increase in the number of rpm leads to overheating of the bone tissue around the cutting edge of the needles retainers as well as death of hematopoietic cells and the bone marrow necrosis.

The main damaging factor in the bone tissue around the needle is thermal. The mechanical factor, that is, compression of bone chips, can also affect the viability of the bone marrow, and therefore the possibility of developing lytic processes around the retainer. But when drilling, the spread of bone chips occurs only in the opened bone marrow cells along the channel formed by the retainer. herefore, the influence of this factor is negligible.

CONCLUSION

Spongy bone drilling without additional cooling should be carried out either continuously at speed 50 rpm, or intermittently with intervals 1 after 1 second at speed up to 300 rpm.

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