STIMULATION OF REPARATIVE OSTEOGENESIS BY MILLIMETER BAND ELECTROMAGNETIC RADIATION IN EXPERIMENTAL TRAUMATIC DEFECTS OF THE MANDIBLE

Ch. R. Ragimov, G. P. Ter-Asaturov, M. B. Golant, K. A. Rogov, and L. Z. Balakireva

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Traumatic injuries of the maxillofacial region, according to data obtained by different authors, account for between 6 and 16.4% of all peacetime injuries, and their frequency in recent years has shown a tendency to increase [1, 2]. The high percentage of post-traumatic complications and the unsatisfactory nature of the final outcome attach particular importance to the development of new effective methods and improvement of existing methods of treatment of fractures of the mandible. The solution of this problem is closely bound up with the search for substances stimulating regeneration of bone tissue in order to optimize and speed up the processes of osteogenesis.

The aim of this investigation was to study the effect of millimeter band electromagnetic radiation (EMR) of nonthermal intensity on reparative regeneration of bone in the region of a traumatic defect using experimental models in order to determine the possibility of using this method in the treatment of patients with fractures of the mandible.

The theoretical basis for the use of this new type of radiation, little known in medicine, consisted of research conducted during the last 20 years under the direction of Academician N. D. Devyatkov, in the course of which information has been obtained on the possibility of applying nonthermal effects of EMR on living organisms [3, 4, 6] and, in particular, on bone tissue [5].

EXPERIMENTAL METHOD

Experiments were carried out on 60 chinchilla rabbits aged 4-5 months (weight 2.2-2.5 kg), divided into three groups: 2 experimental groups and 1 control, each consisting of 20 rabbits. Under intravenous anesthesia (1.5 ml callipsol solution into the external vein of the ear) and local procaine anesthesia (1%, 3.0 ml), with aseptic precautions, the skin was divided in layers along the lower border of the body of the mandible, down to bone. Soft tissues were stripped off the outer surface of the body of the mandible, after which a circular defect 6 mm in diameter was formed through the bone by means of a drill. The wound was then sutured in layers: the periosteum and muscle with cat/gut and the skin with silk sutures. At the end of the experiment the rabbits were kept under identical conditions and received the same animal house diet together with tap water. In experimental group 1 the rabbits were exposed to EMR starting from the first day after the operation. The previously shaved area of skin in the occipital region of the rabbit's head was irradiated for 1 h at a fixed wavelength (5-6 mm), from an apparatus made by the "Istok" Research and Production Combine (Fryazino), and intended for experimental research on biological objects. The distance between the irradiating mouthpiece and the occipital skin was 3.4 mm and the power of the generator did not exceed 25 mW, the cross section of the output circuit on the flange being 2 cm. A course of irradiation consisted of 7 sessions in the course of two weeks. Control group 2 was irradiated under the same conditions but with a change of the time schedule: 0.5 h instead of 1 h. The animals were taken from the experiment by injecting air from a syringe into the marginal vein of the ear after preliminary general anesthesia, 7, 14, 21, and 28 days after the operation, with five animals from each group. The mandible was disarticulated

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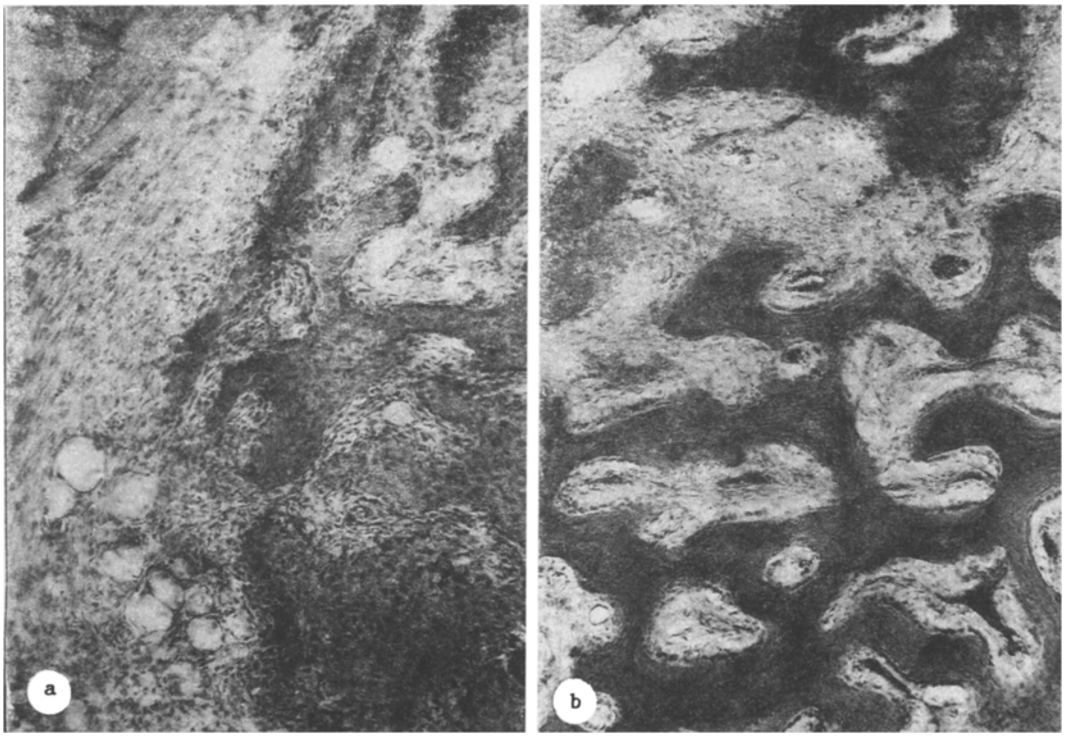

Fig. 1. Morphological changes in region of body defect 3 weeks after trauma: a) control, 3 weeks. Here and in Fig. 2, staining with hematoxylin and eosin, 100×; b) exposure to EMR for 1 h, 3 weeks. Formation of spongy bone. Newly formed blood vessels in intertrabecular spaces.

and roentgenograms of it were taken on the "Infantoscope-18" apparatus (West Germany) on ORWO x-ray film, with an automatic program of 25 mA and 38 kV in one projection.

The outer compact laminar of the mandible was taken for histologic investigation. For this purpose a fragment of the mandible measuring 1.5 × 1.5 cm × 1.5 mm was removed with a saw in the region of the defect, and after decalcification it was fixed in 10% neutral formalin and embedded in celloidin. Sections were stained with hematoxylin and eosin and with picrofuchsine by Van Gieson's method.

EXPERIMENTAL RESULTS

The course of healing of the bone wound was assessed on the basis of roentgenograms and morphological data. During our investigations and comparison of the time course of formation of bony callus in the experimental and control groups of animals the following results were obtained.

On the 7th day after the operation no significant difference could be observed in the pattern of reparative osteogenesis in the different groups. Morphologically a circular defect with smooth edges could be identified. The cavity of the defect was filled with undifferentiated connective tissue containing newly formed vessels of capillary type, focal hemorrhages with signs of organization, and small fragments of bone tissue with no sign of osteoclasis. In the peripheral zones delicate collagen fibers formed a network of small loops. The roentgenograms also revealed a circular defect of bone tissue, consisting of a zone of translucency and completely deprived of any structure. The bone tissue adjacent to the defect had the ordinary structure and density. The edges of the defect were distinct and smooth.

Morphological investigations on the 14th day showed that the lumen of the defect in animals of the control group was filled with granulation tissue rich in fibroblasts. The compact bone at the edges of the defect, just like fragments of bone tissue in its lumen, showed evidence of osteoclasis. In the peripheral zones close to the defect, foci of the formation of fibrous connective tissue could be seen, among which masses of osteoid were found in some areas.

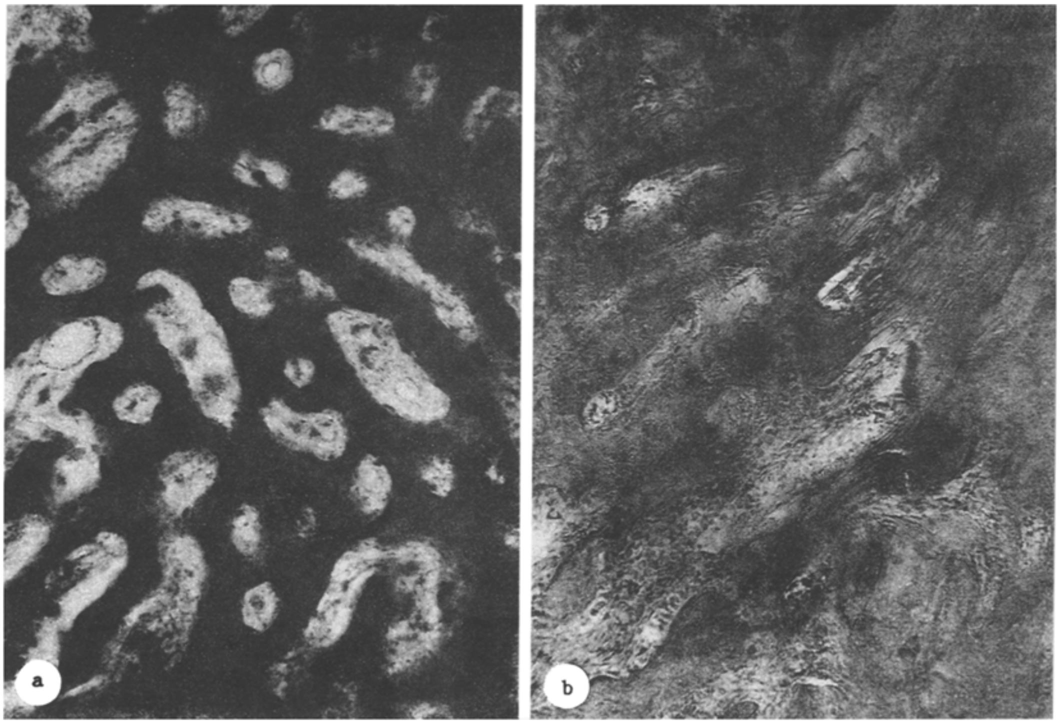

Fig. 2. Morphological changes in region of bony defect 4 weeks after trauma. a) Control, 4 weeks; b) exposure to EMR for 1 h, 4 weeks. Newly formed compact bone in edges of defect.

After exposure to EMR for 1 h, more distinct evidence of osteoclasis of the edges of the wound canal and of the bony fragments discovered in the zone of the defect were more marked at this time of observation. Extensive areas of vascularized fibrous connective tissue with large foci of osteoid could be identified in the same area. In the peripheral zones of the wound canal individual bony trabeculae were being formed, with osteoblasts arranged in one or two layers on their surface.

The roentgenographic picture on the 14th day in animals of the control group was as follows: in the peripheral zones of bone tissue adjacent to the defect areas of osteoporosis were distinguishable. The edges of the bony defect appeared distinct. The zone of translucency corresponding to the bony defect, just as previously, contained no radio opaque inclusions. After exposure to EMR for 1 h, the edges of the bony defect were no longer smooth, and delicate amorphous cloudlike shadows could be seen in some places adjacent to the edges of the wound defect. After exposure to 30 min the roentgenologic picture of repair processes was less clear than in the preceding experimental group, but comparison with the control group showed more marked areas of osteoporosis in the bone tissue adjacent to the defect, and a zone in which they were found was wider.

By the 21st day after the operation the control morphological investigations revealed deep lacunae, formed by osteoclasts, in the bone tissue at the edges of the defect. The cavity of the defect was filled with vascularized connective tissue, with numerous areas of osteoid. Single bony trabeculae were forming in the peripheral part of the wound canal, with one or two rows of osteoblasts on their surface (Fig. 1e). After exposure to EMR for 1 h, by this time the whole space of the defect was filled with bony trabeculae, which joined together in the peripheral parts to form spongy bone. The spaces between the trabeculae were filled with loose connective tissue, containing one or two small vessels (Fig. 1b). After exposure to EMR for 30 min the formation of new spongy bone was observed in certain areas of the peripheral zone of the defect. In the central parts, small bony trabeculae were lying separately among the connective tissue.

Roentgenograms taken 3 weeks after the operation showed a zone of irregular osteoporosis in the bone tissue adjacent to the defect. The edges of the defect were indistinct, blurred, and uneven. The region of the bone defect did not differ in appearance from the previous times of observation. After exposure to EMR for 1 h the zone of the bony defect had the appearance of a shadow of varied intensity, which, in regions adjacent to the edges of the defect, acquired the structure of bone tissue. The porosity of the peripheral parts of the bone adjacent to the defect concealed the boundary between the latter and the newly formed bone tissue, thus creating the indistinctness or, at times, the indistinguishability of the boundary of the bone defect. After exposure to EMR for 30 min, amorphous shadows of varied intensity were seen in the region of the bony defect, adjacent to its edges. The lumen of the bony defect was not completely filled with them.

By the 28th day, the formation of new spony bone could be observed in the control morphological sections only at certain parts of the peripheral zone of the former defect. In its central part, separately arranged bony trabeculae could be identified among the connective tissue (Fig. 2a). After exposure to EMR for 1 h, immature basophilic compact bone with newly formed vascular canals was being formed on the surface of the preexisting mature compact bone. The boundary between the preexisting and newly formed compact bone was clearly distinguishable along the cementation lines. In the central parts, spony bone with narrow intertrabecular spaces and with marked proliferation of osteoblasts could be found. Signs of mineralization of the newly formed bone tissue also were seen (Fig. 2b). After exposure to EMR for 30 min the newly formed compact bone could be seen in the form of a narrow band, covering the edges of the former defect only in certain parts. The rest of the space consisted of spongy bone with narrow intertrabecular spaces. In the central parts scattered bony trabeculae, distributed among fibrous connective tissue, were identified in some places.

At these same times after the operation, bony tissue adjacent to the edges of the defect in the control group preserved indistinctly visible areas of osteoporosis on the roentgenograms. The edges of the bony defect were blurred, it became smaller in size, and under these circumstances it lost the regularity of its geometric shape. After exposure for 1 h the region of the previous defect consisted of bone tissue with the ordinary structure and the boundaries of the region of the operation could not be identified. After irradiation for 30 min the region of the operation consisted of bony tissue, where some parts of the boundary of the former bony defect were hardly distinguishable from the ordinary structure in the background.

In all preparations studied, from both control and experimental groups, foci of suppurative inflammation, of a varied degree of severity, could be identified in the zone of regeneration of bone tissue. Suppurative inflammation had an inhibitory effect on the course of reparative regeneration of bone tissue, and the more extensive the microabscesses discovered, the more inhibitory their effect on the course of reparative regeneration of bone tissue.

Thus the investigations revealed the stimulating effect of EMR of this particular waveband and intensity of irradiation on reparative regeneration of the bony tissue of the mandible. Sessions of exposure to EMR for 1 h to the occipital region, carried out at intervals of 1 day on the experimental group of animals in our experiments accelerated repair of bony tissue by about one week compared with the control. Exposure to EMR for 30 min under the same conditions also had a stimulating effect on reparative regeneration of bone tissue, but the effect was weaker.

The effectiveness of the use of EMR on the course and intensity of reparative osteogenesis allow this method to be recommended for the treatment of injuries to the bones of the facial skeleton, in conjunction with other methods of conservative and operative treatment. It must be pointed out that the mechanism of the action of EMR on reparative regeneration of bone tissue is not yet fully known and requires profound study.

LITERATURE CITED

1. P. Z. Arzhantsev, G. M. Ivashchenko, and T. M. Lur'e, Treatment of Facial Injuries [in Russian], Moscow (1975).
2. Yu. I. Bernadskii, Traumatology and Reconstructive Surgery of the Maxillofacial Region [in Russian], Kiev (1985).
3. N. D. Devyatkov (ed.), Medico-Biological Aspects of Milimeter Band Radiation [in Russian], Moscow (1987).
4. N. D. Devyatkov (ed.), Nonthermal Effects of Millimeter Radiation [in Russian], Moscow (1981).
5. A. A. Podkolzin, N. V. Stepanova, V. I. Tonkonozhenko, et al., The Use of Millimeter Band Low-Intensity Radiation in Biology and Medicine [in Russian], ed. by N. D. Devyatkov, Moscow (1985), pp. 91-100.
6. N. D. Devyatkov (ed.), Effects of Nonthermal Action of Millimeter Band Radiation on Biological Objects [in Russian, Moscow (1983).