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MORPHOFUNCTIONAL CHANGES IN BONE TISSUE STRUCTURE IN EXPERIMENTAL OSTEOPOROSIS

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Abstract

Osteoporosis (OP) represents a major health concern in the aging population, characterized by reduced bone mass and deteriorated bone microarchitecture due to estrogen deficiency and impaired calcium metabolism. This experimental study aimed to investigate the morphofunctional effects of organic calcium compounds on bone tissue structure in a rat model of osteoporosis. OP was induced by ovariectomy in white outbred female rats, which were subsequently divided into intact, control, comparison (calcium chloride), and experimental (calcium) groups. Bone samples were examined histologically using hematoxylin and eosin staining after standard fixation and decalcification procedures. Morphological analysis of untreated osteoporotic rats revealed bone rarefaction, trabecular thinning, and signs of osteomalacia. In contrast, administration of calcium demonstrated significant restorative changes, including improved trabecular organization and reduced resorptive activity. These findings suggest that organic calcium in the form of calcium alginate promotes bone tissue regeneration and may serve as an effective therapeutic approach for managing osteoporosis.

Keywords: osteoporosis, bone tissue, outbred rats, calcium, ovariectomy, bone regeneration, calcium alginate

Introduction

As the average life expectancy worldwide increases and the proportion of elderly and senile population grows, the incidence of osteoporosis (OP) also rises [6, 8]. One of the factors influencing the pharmacodynamic and pharmacokinetic parameters of calcium preparations used in OP treatment can be the characteristics of metabolic activity and hormonal background [9]. It is known that the use of substances containing naturally occurring calcium can have a positive effect on the hormonal background of experimental subjects, as well as on calcium absorption, which depends on the condition of the gastrointestinal tract (GIT) [5]. In OP, the qualitative structure of bone tissue changes, which is associated with a decrease in bone mass and its mechanical insufficiency. Estrogen deficiency is known to be one of the main causes of accelerated bone loss and OP development. Consequently, the occurrence of OP is characteristic of women in the postmenopausal period, as well as in cases of hyperprolactinemia, hypogonadism, after ovarian removal, and with the development of amenorrhea caused by hypoestrogenemia [8].

The aim of the study is to investigate the morphofunctional changes in bone tissue structure in rats when using organic calcium compounds in the treatment of experimental osteoporosis.

Materials and methods

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Experiments were conducted on 10 white outbred rats weighing 170-220 g, in which a model of experimental osteoporosis (OP) was reproduced using the standard ovariectomy method. The experimental animals underwent ovary removal, and the study was conducted after 2 months. The animals were kept in the vivarium of the Tashkent Pharmaceutical Institute with free access to water and food. The research was carried out in accordance with the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (Strasbourg, March 18, 1986) [1]. The study adhered to the basic ethical principles of animal care and the main provisions of the Helsinki Declaration [1, 10]. At the end of the experiment, the animals were euthanized under light ether anesthesia. The animals were divided into equal groups: Group I - before the induction of experimental OP (intact), Group II (control) - animals with experimental OP without treatment, Group III (comparison) - with experimental OP after the administration of calcium chloride, and Group IV (main, experimental) - with experimental OP after the administration of calcium alginate. Confirmation of osteoporotic changes in bone tissue was carried out by morphological examination of skeletal bone sections using the method of preparing bone tissue specimens and their microscopy according to the standard protocol [3]. For histological examination, bone tissue fragments were placed in a 4% neutral formalin solution, then decalcified in 15% nitric acid, and subsequently fixed in alcohols. After sufficient fixation, paraffin blocks were prepared from the materials. The prepared sections were stained with hematoxylin and eosin.

Results and discussion

As demonstrated by the morphological studies of rat bones, in group II (control) - animals with experimental osteoporosis (OP) without treatment - samples from the epiphyseal part of the tibia taken after ovariectomy showed bone tissue resorption, areas of rarefaction due to calcium salt leaching, increased porosity, and softening of bone tissue with the presence of primitive weakly calcified bone trabeculae (Fig. 1), which aligns with the findings of authors [4, 6, 7]. Additionally, bone tissue resorption processes, lysis foci, and osteomalacia were observed in the central areas. Microscopic examination revealed a predominance of formed elements and weakly calcified primitive bone trabeculae [2].

The introduction of calcium alginate in group IV led to the restoration of bone tissue structure, as evidenced by the absence of clear morphological signs of osteoporosis (OP)

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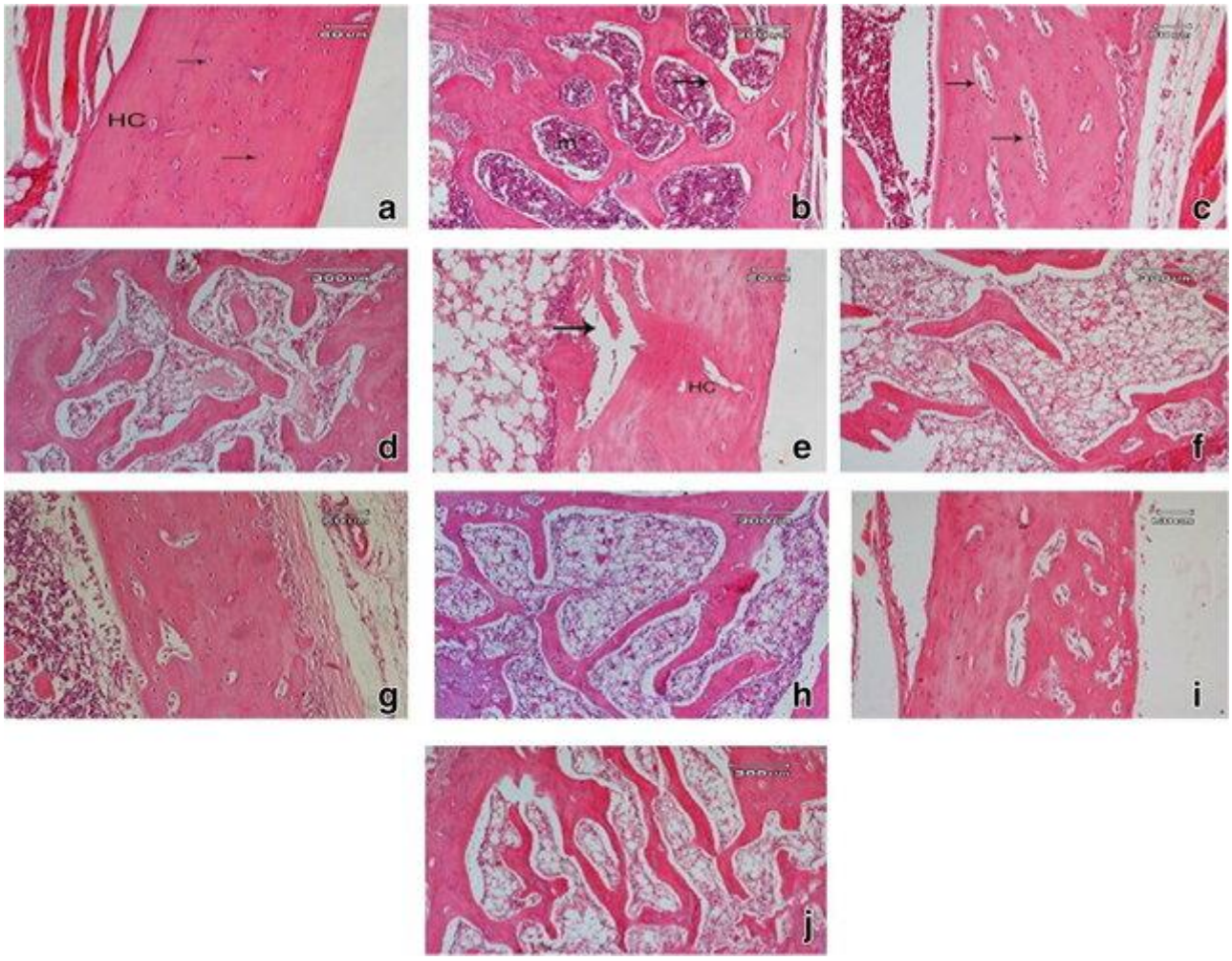

(Fig. 1). In group IV, osteogenic fibrous tissue growth was observed with subsequent compaction of compact bone tissue, including areas of repair, disappearance of porosity, and resolution of osteomalacia due to calcium salt saturation as a result of calcium alginate therapy (Figure 2). Areas of compact bone tissue lack porosity and display uniform coloration. The proliferation of fibrous connective bone tissue is one of the main indicators of the intensity of restorative processes. Thickening of bone trabeculae, which ensures the strength characteristics of the bone, is also observed, indicating the effectiveness of calcium alginate therapy. All of this points to the positive effect of calcium alginate therapy on bone tissue structure (confirmed by the proliferation of osteogenic connective tissue - the foundation of future bone). Thus, during the treatment of experimental OP with calcium alginate, areas of bone trabeculae compaction were observed, which may result from replenishing calcium deficiency. Additionally, foci of osteogenic fibrous connective tissue proliferation were noted, indicating osteogenic restoration processes [7]. Furthermore, fragments of dense bone tissue and layers of cartilage plates alternate with areas of osteogenic fibrous tissue growth, suggesting regenerative processes in the bone occurring in response to calcium alginate therapy.

Conclusion

The obtained results demonstrate that experimental osteoporosis induced by ovariectomy causes pronounced structural deterioration of bone tissue, reflected in reduced calcification and increased porosity. Treatment with calcium alginate led to marked restoration of bone microarchitecture, highlighting its potential to enhance bone mineralization and mitigate

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osteoporotic changes. Compared to inorganic calcium chloride, the organic calcium alginate compound exhibited superior efficacy in promoting structural recovery of bone tissue. These results suggest that calcium alginate may represent a promising alternative for the prevention and treatment of osteoporosis, warranting further investigation into its biochemical and clinical mechanisms.

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