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EFFECT OF A THERAPEUTIC AND PREVENTIVE COMPLEX ON THE BIOCHEMICAL INDICATORS OF RAT BLOOD SERUM UNDER CONDITIONS OF A CARIES-INDUCING DIET AND DIETARY VITAMIN D DEFICIENCY ON THE BACKGROUND AND DESTRUCTION OF JAW BONE TISSUE

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This study was devoted to assessing the effect of the proposed therapeutic and prophylactic complex on the biochemical parameters of rat serum under conditions of a cariogenic diet and dietary vitamin D deficiency against a background of jawbone destruction. Experimental studies were conducted on 30 four-month-old male Wistar rats. During the experiment, the animals were divided into three groups of 10 rats each: Group 1 – intact animals; Group 2 – trauma to the lower jaw region in the projection of the molar roots and modeling of dietary vitamin D deficiency against a background of a high-sucrose cariogenic diet; Group 3 – pathology model and administration of the therapeutic and prophylactic complex. Modeling of the pathological condition resulted in a 27.8 % decrease in total calcium concentration, a 19.8 % decrease in inorganic phosphorus concentration, a 14.3 % decrease in total vitamin D level, a 1.5-fold reduction in magnesium concentration, and a 1.4-fold decrease in osteocalcin level, accompanied by a 1.4-fold increase in parathyroid hormone concentration. Administration of the proposed therapeutic and prophylactic complex contributed to the correction of the identified disorders and normalization of the studied parameters toward the values observed in intact animals.

Key words: bone destruction, rats, vitamin D deficiency, dental caries, blood serum, experiment.

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ВПЛИВ ЛІКУВАЛЬНО-ПРОФІЛАКТИЧНОГО КОМПЛЕКСУ НА БІОХІМІЧНІ ПОКАЗНИКИ СИРОВАТКИ КРОВІ ЩУРІВ ЗА УМОВ КАРІЄСОГЕННОЇ ДІЄТИ ТА АЛІМЕНТАРНОГО ДЕФІЦИТУ ВІТАМІНУ D НА ТЛІ ДЕСТРУКЦІЇ КІСТКОВОЇ ТКАНИНИ ЩЕЛЕП

Робота була присвячена оцінці впливу запропонованого лікувально-профілактичного комплексу на біохімічні показники сироватки крові щурів за умов карієсогенної дієти та аліментарного дефіциту вітаміну D на тлі деструкції кісткової тканини щелеп. Експериментальні дослідження були проведені на 30 чотиримісячних щурах-самцях лінії Wistar. У ході експерименту тварин було розподілено на три групи по 10 щурів у кожній: 1-ша група – інтактні тварини; 2-га група – травма ділянки нижньої щелепи в проєкції коренів молярів та моделювання аліментарного дефіциту вітаміну D на тлі високосахарозної карієсогенної дієти; 3-тя група – модель патології та застосування лікувально-профілактичного комплексу. У сироватці крові визначали концентрацію загального кальцію, неорганічного фосфору, магнію, загального 25-гідроксивітаміну D, паратгормону та остеокальцину. Моделювання патологічного стану призвело до зниження концентрації загального кальцію на 27,8 %, неорганічного фосфору – на 19,8 %, загального вітаміну D – на 14,3 %, концентрації магнію – в 1,5 раза та рівня остеокальцину – в 1,4 раза, що супроводжувалося підвищенням концентрації паратгормону в 1,4 раза. Застосування запропонованого лікувально-профілактичного комплексу сприяло корекції виявлених порушень і нормалізації досліджуваних показників у напрямку значень інтактних тварин, що свідчить про відновлення кальцій-фосфорного обміну, зниження активності резорбції кісткової тканини, стимуляцію функціональної активності остеобластів та посилення мінералізації альвеолярної кістки.

Ключові слова: деструкція кісткової тканини, щури, дефіцит вітаміну D, карієс, сироватка крові, експеримент.

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Chronic apical periodontitis is an inflammatory lesion of periodontal structures caused by pulp necrosis and penetration of infected and toxic root canal contents through the apical foramen. Its destructive forms are clinically significant because they may act as foci of odontogenic infection and reduce the immunological defence of the body [13, 14]. Apical periodontitis associated with root canal infection is one of the most common jaw lesions, usually manifesting as periapical granulomas or cysts. Understanding its pathogenesis and identifying inflammatory biomarkers may improve diagnosis and treatment.

Bone tissue is the main depot of calcium, magnesium, and phosphorus [4]. Calcium is essential for skeletal mineralisation and is supplied exclusively through dietary intake. Its homeostasis is maintained by bone metabolism, intestinal absorption, and renal reabsorption, regulated by parathyroid hormone (PTH), calcitonin, fibroblast growth factor 23, calcium concentration, calcium-sensing receptors, and local processes in bone, intestine, and kidneys

[10]. Only ionised calcium is physiologically active, while calcium and phosphorus form the mineral basis of bone tissue; vitamin D is a key regulator of calcium metabolism [1].

Vitamin D metabolites directly influence calcium transport and stimulate its intestinal absorption; therefore, vitamin D deficiency may cause calcium insufficiency even with adequate mineral intake [6, 8]. Magnesium is also important for bone metabolism: approximately 60 % of Mg is located in bone, where it participates in mineral matrix formation and vitamin D activation to calcitriol, which stimulates calcium and phosphorus absorption. Calcitriol deficiency slows bone repair and impairs remodelling [9, 15].

Experimental magnesium deficiency is associated with reduced osteoblast activity, decreased alkaline phosphatase and osteocalcin levels, and increased osteoclast numbers. Its probable mechanisms include collagen degradation, impaired collagen synthesis, altered apatite structure, changes in PTH and 1,25-(OH)2D levels, low-grade inflammation, and endothelial dysfunction [7]. Vitamin D3 deficiency disrupts calcium-phosphate homeostasis, induces compensatory hyperparathyroidism, and activates bone resorption, whereas cholecalciferol correction stabilises mineral balance. Combined calcium and vitamin D therapy remains an important approach to correcting calcium homeostasis [3].

PTH regulates calcium-phosphorus metabolism, jawbone density, dental tissue mineralisation, and regeneration. Bone remodelling and repair are mediated by bone cells and periosteal osteogenic cells, while magnesium additionally supports osteogenesis by stimulating osteoblast activity and increasing receptor sensitivity to PTH [12]. Osteocalcin, synthesised by osteoblasts, is one of the most informative serum markers of bone formation.

Bone healing after apical periodontitis treatment depends not only on root canal disinfection and filling materials but also on systemic metabolic status. Therefore, treatment of destructive periodontitis should combine elimination of infection with stimulation of reparative processes in the area of bone destruction. Thus, improving conservative methods for optimising reparative osteogenesis remains a relevant objective of contemporary dentistry.

The purpose of the study was to assess the effect of the proposed therapeutic and prophylactic complex on the biochemical parameters of rat blood serum under conditions of a cariogenic diet and dietary vitamin D deficiency against a background of jawbone destruction.

Materials and methods. Experimental studies were conducted using 30 male Wistar rats of herd breeding, 4 months old with an average body weight of 214.8±3.2 g. Inclusion criteria were: confirmed Wistar strain and male sex; age exactly 16±1 weeks (verified from breeding records); body-weight falling within cohort mean at baseline (214.8±3.2 g); absence of visible injury, malocclusion, or systemic/oral pathology on veterinary inspection; no previous exposure to experimental procedures or pharmacological agents. Exclusion criteria, applied immediately prior to random assignment, included: clinically detectable disease or behavioral abnormalities; weight outside the predefined range; wounds or oral lesions; aggressive behavior; modeling errors; and failure to adapt during the 7-day acclimatization period. Only male Wistar rats were enrolled to minimize biological variability introduced by sex-specific endocrine cycles.

The study was conducted from July 1, 2025, to August 2, 2025. All animals were maintained in the accredited barrier-type vivarium of State Establishment "The Institute of stomatology and maxilla-facial surgery National academy of medical sciences of Ukraine" under the husbandry conditions specified in the institute's standard operating procedure, which fulfils both Ukrainian legislation and ARRIVE 2.0 recommendations. Briefly, rats were group-housed (4–5 per cage) in individually ventilated Euro-Type IV polycarbonate cages (floor area ≈ 1500 cm²; internal dimensions 425×266×185 mm) fitted with stainless-steel wire lids and placed on ventilated racks delivering 12±2 air changes h^{-1}. Cages contained 3 cm of autoclaved aspen-wood shavings (LIGNOCEL® Hygienic Animal Bedding, JRS GmbH) that were replaced twice weekly. Environmental enrichment was provided ad libitum and comprised shredded paper nesting material (Nestlets), hardwood gnawing blocks (2×2×6 cm), and a cardboard tunnel (⌀ 9 cm, length 12 cm) per cage; items were refreshed at each cage change.

The room was held at 21±2 °C with 55–75 % relative humidity and a 12:12 h light/dark cycle (lights on 07:00–19:00). Noise was <50 dB SPL outside scheduled stress-exposure periods. Reverse-osmosis-filtered water was supplied in polycarbonate bottles with stainless-steel sipper tubes and replaced thrice weekly.

Daily husbandry included visual health checks and removal of soiled enrichment; full cage sanitisation (hot-water wash and autoclave) was performed weekly.

Each rat was weighed, assigned an individual code, and allocated to an experimental arm by simple computer-generated randomisation carried out with Microsoft Excel software. Animals were assigned to three experimental groups:

1. Intact group – rats that underwent no surgical procedures and received no drug administration; they were fed a complete balanced diet, n=10;

2. Pathology (TLJ) – trauma to the lower jaw region in the projection of the molar roots and modeling of dietary hypovitaminosis D against the background of a high-sugar cariogenic diet (CD), n=10;

3. Treatment (TLJ+TPC) – trauma to the

mandibular region in the projection of the molar roots, administration of a therapeutic and prophylactic complex (TPC) against a background of simulated dietary hypovitaminosis D using a high-sugar cariogenic diet, n=10.

No animal met any exclusion criterion, and there were no deaths or withdrawals after group allocation. consequently, the composition of all three groups remained unchanged throughout the 33-day observation period, and data from every animal were included in the final analysis.

Experimental studies were conducted at the "Laboratory of Biochemistry and Vivarium" of the SE "The Institute of stomatology and maxilla-facial surgery National academy of medical sciences of Ukraine" (SE "ISMFS NAMS"). All experiments on rats were conducted according to standard operating procedures approved by SE "ISMFS NAMS", developed in accordance with the Guidelines of the Pharmacological Committee of the Ministry of Health of Ukraine, the "General Ethical Principles of Animal Experiments" adopted by the Seventh National Congress on Bioethics (Kyiv, 2019) and was guided by the recommendations of the European Convention for the Protection of Vertebrate Animals for Experimental and Other Scientific Purposes (Strasbourg, 1985). Studies recommended by the Commission on Bioethical Expertise (conclusion of the bioethics commission of the ONMedU, protocol No. 26 of 23/10/2024).

Injuries to the lower jaw were induced in a laboratory setting using a portable dental drill and a sterile carbide bur under thiopental anesthesia.

To study the effect of cariogenic factors on the recovery of the injured jaw, the cariogenic diet developed by M.S. Bugayova and S.A. Nikitin, as modified by I.V. Khodakov et al. (2023) [7], was used.

The reduction of oil content by 0.5 % was justified by the use of this oil for dosing retinol acetate (34.4 mg (100,000 IU)/ml. Manufacturer: PJSC "Technolog," Uman, Ukraine). Vitamin A was administered to rats at a rate of 0.048 ml per 100 g of feed (48,000 IU). The removal of "Undevit" from the diet was justified by the use of vitamins A and D3 in the study. The reduction in oil content in the feed was compensated for by increasing the content of breadcrumbs by 0.5 %, resulting in the following composition of the cariogenic diet: refined sugar (57 %); skimmed cow's milk cheese (18.5 %); white wheat bread crumbs (19 %); unrefined sunflower oil (4.5 %); table salt (1 %).

Animals first received "Mumie" gel (centaury infusion + echinacea infusion + sage infusion + mumie + 0.05 % chlorhexidine), developed by the Laboratory for the Development and Research of Oral Hygiene Products of the State Establishment "The Institute of Stomatology and Maxillofacial Surgery of the National Academy of Medical Sciences of Ukraine" (State Sanitary and Epidemiological Expertise Conclusion No. 1378/16 dated 10 December 2019): 0.3 mL per 200 g of body weight, administered per os once daily, to provide anti-inflammatory, adaptogenic, regenerative, osteotropic, anticoagulant, antibacterial, haemostatic, and immunomodulatory effects, as well as to increase salivation rate. Immediately afterwards, the animals received "Osteovit" (glucosamine sulfate + chondroitin sulfate + Boswellia sarca extract + vitamin D3 + calcium carbonate; LLC "Elite-Pharm", Dnipro, Ukraine): 150 mg/kg of body weight, administered to reduce inflammation, support cartilage and bone tissue regeneration, provide calcium required for bone mineralisation, and promote calcium and phosphorus absorption while supporting immune function. The animals also received Aquadetrim Vitamin D3 water solution (INN Cholecalciferol; Medana Pharma S.A., Poland): 0.000297 mL per 100 g of body weight (4.45 IU of vitamin D3), administered per os to regulate calcium and phosphate metabolism, promote proper skeletal mineralisation and growth, and participate in immune-system function. In addition, the animals received "Forteza" 0.15 % oral spray (INN Benzydamine hydrochloride; Abdi Ibrahim Ilaç Sanayi ve Ticaret A.Ş., Istanbul, Türkiye): 0.3 mL per 200 g of body weight, administered for its analgesic, anti-inflammatory, antiexudative, and disinfectant properties, as benzydamine penetrates the epithelial layer and reaches effective concentrations in inflamed tissues.

At the conclusion of the experiment, the animals were euthanized on the 33rd day of the study under thiopental anesthesia (20 mg/kg) by total exsanguination from the heart.

Although 1,25-(OH)2D represents the biologically active form of vitamin D, it is widely recognised that measurement of circulating 25-OH D provides more accurate information regarding the vitamin D status of patients and can therefore be used in the diagnosis of hypovitaminosis D.

Mineral metabolism and bone tissue metabolism were assessed in the Biochemistry Laboratory of the State Establishment "The Institute of Stomatology and Maxillofacial Surgery of the National Academy of Medical Sciences of Ukraine" in Odesa based on the results of biochemical analyses of blood serum. Total calcium, inorganic phosphorus, and magnesium concentrations were determined using a VVmini-1240 spectrophotometer (Shimadzu) and reagent kits manufactured by Filisit-Diagnostics, Ukraine. Total 25-OH vitamin D (D2+D3), PTH, and osteocalcin concentrations were determined using a Multiskan EX enzyme-linked immunosorbent assay analyser manufactured by Labsystems in accordance with the manufacturer's protocol.

Data processing was carried out with MS Excel 2010. Prior to parametric testing, the Shapiro-Wilk normality test was applied to each continuous variable; none showed significant deviation from a

Gaussian distribution (p>0.05). Therefore, inter-group comparisons were performed with the two-tailed Student's t-test. When pair-wise contrasts were required (Control × Comparison, Control × Intervention, Comparison × Intervention), the family-wise type-I error rate was controlled with the Bonferroni adjustment. [2].

Results of the study. The assessment of mineral metabolism was performed to determine the systemic biochemical changes associated with experimental jawbone destruction under conditions of a cariogenic diet and dietary vitamin D deficiency. Particular attention was paid to calcium, inorganic phosphorus, magnesium, and total 25-hydroxyvitamin D, as these parameters reflect the state of calcium-phosphorus homeostasis and the metabolic prerequisites for bone tissue repair. Comparison of the experimental groups made it possible to evaluate both the severity of mineral imbalance in the pathology model and the corrective effect of the proposed therapeutic and prophylactic complex.

As shown by the data presented in Table 1, the serum total calcium concentration in Group 2 animals, in which jawbone destruction was modelled under conditions of a cariogenic diet and dietary vitamin D deficiency, decreased by 27.8 %.

Table 1

Indicators of mineral metabolism in the blood serum of rats receiving the TPC under conditions of a cariogenic diet and dietary vitamin D deficiency against a background of jawbone destruction, M±m

Indices / Group	Total calcium concentration, mmol/L	Inorganic phosphorus concentration, mmol/L	Magnesium concentration, mmol/L	Total vitamin D concentration, 25-OH (D_2+D_3), ng/mL
1. Intact group, n=10	2.30±0.10	2.27±0.15	1.48±0.11	32.43±1.82
2. Pathology + CD, n=10	1.66±0.09 p<0.001	1.82±0.10 p<0.02	0.98±0.06 p<0.002	27.80±1.10 p<0.05
3. Pathology + CD + TPC, n=10	2.52±0.11 p>0.2 p_1<0.001	2.12±0.11 p>0.4 p_1>0.1	1.35±0.09 p>0.4 p_1<0.002	40.27±2.15 p<0.01 p_1<0.001

Note: p – significance relative to the intact group; p_1 – significance relative to the group 2.

In our opinion, the decrease in serum calcium concentration, or hypocalcaemia, is not a direct cause of alveolar bone destruction but rather indicates profound metabolic disturbances in which the body is no longer capable of maintaining homeostasis. Determination of total vitamin D concentration in the serum of animals with jawbone destruction showed that dietary vitamin D deficiency resulted in a statistically significant 14.3 % decrease in total serum vitamin D in rats (p<0.05). Based on the experimental findings, vitamin D deficiency may be considered a risk factor that impairs bone regeneration.

It is known that, in addition to calcitonin, PTH and the active vitamin D metabolite calcitriol participate in the maintenance of calcium-phosphorus homeostasis. The mechanism of action of vitamin D involves increasing the synthesis of proteins responsible for the intestinal transport of calcium and phosphorus. Vitamin D deficiency impairs intestinal phosphorus absorption. In Group 2 animals, inorganic phosphorus concentration decreased by 19.8 %. PTH stimulates the release of calcium from bone but simultaneously increases the renal excretion of phosphorus, thereby reducing its concentration in the blood.

Magnesium also plays an important role in bone metabolism. Its biological role is associated with its unique ability to act as a natural calcium antagonist and thereby regulate the wide range of vital functions that depend on the presence of calcium ions. The 1.5-fold magnesium deficiency observed in Group 2 rats compared with the intact group reduces calcium bioavailability, contributes to hypocalcaemia and decreased calcitriol levels, and delays bone tissue restoration in the area of inflammatory destruction. Magnesium deficiency is accompanied by reduced activity of several enzymes, including phosphatases and ATPases, the formation of inactive forms of vitamin D, and, consequently, decreased intestinal calcium absorption.

Table 2 presents the biochemical parameters of the blood serum of rats receiving the TPC under conditions of a cariogenic diet and dietary vitamin D deficiency against a background of jawbone destruction.

Table 2

Biochemical parameters of the blood serum of rats receiving the TPC under conditions of a cariogenic diet and dietary vitamin D deficiency against a background of jawbone destruction, M±m

Indices / Group	Parathyroid hormone concentration, pg/mL	Osteocalcin concentration, ng/mL
1. Intact group, n=10	30.84±1.45	16.91±0.85
2. Pathology + CD, n=10	41.72±2.10 p<0.001	11.84±0.52 p<0.001
3. Pathology + CD + TPC, n=10	33.42±1.75 p>0.2 p_1<0.002	15.52±0.68 p>0.25 p_1<0.002

Note: p – significance relative to the intact group; p_1 – significance relative to the group 2.

Assessment of the dynamics of osteocalcin, a biochemical marker of bone formation, showed that its concentration in Group 2 animals decreased 1.4-fold, indicating reduced activity of osteoblasts, the cells responsible for bone formation and renewal. Vitamin D is required for osteocalcin synthesis. Vitamin D insufficiency impairs osteoblast function, resulting in a decrease in the level of this protein.

The function of PTH is to normalise serum calcium levels under conditions of hypocalcaemia. PTH concentration in Group 2 rats increased 1.4-fold, indicating a secondary response of the animals to reduced calcium levels, vitamin D deficiency, or the process of alveolar bone destruction. The parathyroid glands respond to a decrease in calcium concentration by increasing PTH secretion to stimulate calcium mobilisation from bone and maintain its normal concentration in the blood, thereby stabilising homeostasis. PTH stimulates osteoclasts, the cells responsible for bone resorption, resulting in breakdown of the bone matrix and the release of calcium.

Assessment of mineral metabolism and bone tissue metabolism in rat blood after administration of the TPC demonstrated normalisation, manifested as a 1.5-fold increase in calcium concentration ($p1<0.001$), a 1.2-fold increase in phosphorus concentration ($p_1>0.1$), and a 1.4-fold increase in magnesium concentration ($p_1<0.002$).

After 33 days of TPC administration, total vitamin D concentration increased by 31 % ($p_1<0.001$), which was 1.2-fold higher than the baseline value recorded in the intact group.

TPC administration contributed to a 20 % reduction in serum PTH concentration in rats. Normalisation of PTH concentration indicates restoration of calcium metabolism and a decrease in the activity of bone destruction due to reduced osteoclast stimulation.

The 24 % increase in osteocalcin concentration in Group 3 rats ($p_1<0.002$) indicates a favourable trend, namely activation of bone formation. The TPC stimulated osteoblast activity, resulting in increased osteocalcin levels and enhanced mineralisation of the alveolar bones.

The results of the present study demonstrate that mandibular bone injury combined with a high-sucrose cariogenic diet and dietary vitamin D deficiency induces marked disturbances in systemic mineral metabolism and bone remodeling. In the pathology group, serum total calcium decreased by 27.8 %, inorganic phosphorus by 19.8 %, total 25-hydroxyvitamin D by 14.3 %, magnesium by 1.5-fold, and osteocalcin by 1.4-fold, whereas parathyroid hormone concentration increased by 1.4-fold. The simultaneous occurrence of hypocalcemia, hypophosphatemia, reduced vitamin D status, and elevated parathyroid hormone indicates disruption of the integrated endocrine mechanisms responsible for maintaining calcium-phosphate homeostasis.

Discussion. The present findings demonstrate that mandibular bone destruction induced under conditions of a cariogenic diet and dietary vitamin D deficiency is accompanied by pronounced disturbances in systemic mineral metabolism. The observed reductions in serum calcium, phosphorus, magnesium, vitamin D, and osteocalcin, together with elevated parathyroid hormone (PTH), indicate disruption of the mineral-regulatory axis rather than a purely local response to bone injury. This interpretation is consistent with the concepts of calcium homeostasis proposed by Matikainen et al. [10].

The decrease in total 25-hydroxyvitamin D agrees with the observations of Tsyriuk et al. [6], who associated vitamin D deficiency with multiple metabolic disturbances. In our study, a 14.3 % reduction in vitamin D was accompanied by a 27.8 % decrease in calcium, a 19.8 % decrease in phosphorus, and a 1.4-fold increase in PTH, indicating the development of compensatory hyperparathyroidism aimed at maintaining extracellular calcium concentrations. Magnesium deficiency also appears to play an important role. Previous studies identified magnesium as an essential regulator of vitamin D activation, osteoblast function, mineral matrix formation, and PTH activity [5, 7, 9, 12, 15]. The simultaneous reduction in magnesium and osteocalcin observed in our experiment supports the concept that magnesium deficiency may contribute to impaired osteoblast activity and delayed bone regeneration, although its independent effect cannot be separated from the concurrent disturbances in calcium, phosphorus, and vitamin D metabolism.

The 1.4-fold reduction in osteocalcin, accompanied by elevated PTH, reflects an imbalance between bone formation and resorption. This observation agrees with the concept proposed by Quintero et al. [11] that systemic metabolic disturbances may enhance susceptibility to bone loss and impair bone remodeling.

Administration of the therapeutic and preventive complex markedly improved the investigated parameters. Compared with untreated animals, calcium increased 1.5-fold, magnesium 1.4-fold, total vitamin D by 31 %, osteocalcin by 24 %, whereas PTH decreased by 20 %, indicating restoration of mineral homeostasis and activation of osteoblast-dependent bone formation. These findings support previous evidence that combined calcium, vitamin D, and magnesium supplementation may improve skeletal metabolism [7], although the individual contribution of each component cannot be determined.

The present results also complement the microbiological concept of apical periodontitis proposed by Siqueira and Rôças [13]. Considering the high prevalence of apical periodontitis reported by Tibúrcio-Machado et al. [14], correction of systemic metabolic disturbances may represent an important adjunctive therapeutic strategy.

Limitations. A limitation of this study is that the experimental design was focused on the assessment of serum biochemical markers; therefore, the findings characterize mainly the systemic mineral metabolism and bone remodeling without direct morphological evaluation of jawbone tissue.

Conclusions

1. Analysis of the biochemical parameters of rat blood serum showed that modelling jawbone destruction in experimental caries complicated by dietary vitamin D deficiency resulted in hypocalcaemia, manifested by a statistically significant 27.8 % decrease in serum calcium, a 14.3 % decrease in total vitamin D, and a 19.8 % decrease in inorganic phosphorus. The 1.5-fold magnesium deficiency observed in Group 2 rats compared with the intact group reduced calcium bioavailability, contributed to hypocalcaemia and decreased calcitriol levels, and delayed bone tissue restoration in the area of inflammatory destruction. A 1.4-fold decrease in osteocalcin concentration indicated reduced osteoblast activity. The 1.4-fold increase in PTH concentration in Group 2 rats reflected a secondary response to decreased calcium levels and vitamin D deficiency and was associated with the process of alveolar bone destruction.

2. Administration of the proposed therapeutic and prophylactic complex inhibited the identified disturbances under conditions of a cariogenic diet and dietary vitamin D deficiency against a background of jawbone destruction, bringing the studied parameters towards the values observed in intact animals. These changes indicate restoration of calcium metabolism and a reduction in bone destruction due to decreased osteoclast stimulation, activation of bone formation, and stimulation of osteoblast activity, which resulted in increased osteocalcin levels and enhanced mineralisation of the alveolar bones.

3. Further investigation of the effect of the proposed TPC on the oral cavity may provide clinicians with an opportunity to positively influence bone healing in areas of destruction. The effectiveness of these measures primarily depends on early diagnosis, which enables correction of the identified disturbances, supports the normal physiological restoration of bone tissue, and improves patients' oral health.

Prospects for further research. Further research should focus on developing an effective method for preventing complications and accelerating healing in chronic destructive periodontitis according to serum vitamin D levels, with the use of an appropriate therapeutic and prophylactic complex.

References

1. Babienko VV, Mokiienko AV, Poliuliakh OA. Mahniy yak esentsiynyy mikronutriyent: hihiyenichni ta medyko-biolohichni aspekty: monohrafiya. Odesa: Pres-kurier; 2024. 300 p. [in Ukrainian].
2. Holovanova IA, Bielikova IV, Liakhova NO. Osnovy medychnoyi statystyky: navch. posib. dlya aspirantiv ta klinichnykh ordynatoriv. Poltava; 2017. 113 p. [in Ukrainian].
3. Kovalchuk AV, Zinych OV, Korpachev VV, Kushnareva NM, Prybyla OV, Shishkan-Shishova KO. Osteokaltsyn: vzayemozvyazok mizh kistkovym metabolizmom ta homeostazom hlyukozy pry tsukrovomu diabeti. Mizhnarodnyy endokrynolohichnyy zhurnal. 2021;17(4):322–328. DOI: 10.22141/2224-0721.17.4.2021.237347. [in Ukrainian].
4. Litovka IH, Berezovskyi VYa. Vplyv mahniyu na remodelyuvannya kistkovoyi tkanyny. Fiziolohichnyy zhurnal. 2018;64(3):91–99. DOI: 10.15407/fz64.03.091. [in Ukrainian].
5.Poladych IV, Avramenko SO. Vplyv defitsytu vitaminu D3 na kaltsiyevo-fosfatnyy obmin ta spivvidnoshennya RANKL/OPG v eksperymenti. Visnyk problem biolohiyi i medytsyny. 2025;4(179):178–186. DOI: 10.29254/2077-4214-2025-4-179-178-186. [in Ukrainian].
6. Tsyriuk OI, Tseisler YuV, Strubchevska KR, Kozyk MO, Ostapchenko DI, Korotkyi OH, Tymoshenko IO. Vzayemozvyazok defitsytu vitaminu D z metabolichnymy porushennyamy. Mizhnarodnyy endokrynolohichnyy zhurnal. 2023;19(1):45–52. DOI: 10.22141/2224-0721.19.1.2023.1241. [in Ukrainian].
7. Capozzi A, Scambia G, Lello S. Calcium, vitamin D, vitamin K2, and magnesium supplementation and skeletal health. Maturitas. 2020;140:55–63. DOI: 10.1016/j.maturitas.2020.05.020.
8. Göring H. Vitamin D in nature: a product of synthesis and/or degradation of cell membrane components. Biochemistry (Mosc). 2018;83(11):1350–1357. DOI: 10.1134/S0006297918110056.
9. Matek Sarić M, Sorić T, Juko Kasap Ž, Lisica Šikić N, Mavar M, Andruškienė J, Sarić A. Magnesium: health effects, deficiency burden, and future public health directions. Nutrients. 2025;17(22):3626. DOI: 10.3390/nu17223626.
10. Matikainen N, Pekkarinen T, Ryhänen EM, Schalin-Jäntti C. Physiology of calcium homeostasis: an overview. Endocrinol Metab Clin North Am. 2021;50(4):575–590. DOI: 10.1016/j.ecl.2021.07.005.
11. Quintero S, Ait-Aissa K, Munkhsaikhan U, Sahyoun AM, Hoque Apu E, Abidi AH, Kassan M. Exploring the relationship between periodontal diseases and osteoporosis: potential role of butyrate. Biomed Pharmacother. 2025;182:117791. DOI: 10.1016/j.biopha.2024.117791.
12. Rondanelli M, Faliva MA, Tartara A, Gasparri C, Perna S, Infantino V, Riva A, Petrangolini G, Peroni G. An update on magnesium and bone health. Biometals. 2021;34(4):715–736. DOI: 10.1007/s10534-021-00305-0.
13. Siqueira JF Jr, Rôças IN. Present status and future directions: microbiology of endodontic infections. Int Endod J. 2022;55 Suppl 3:512–530. DOI: 10.1111/iej.13677.
14. Tibúrcio-Machado CS, Michelon C, Zanatta FB, Gomes MS, Marin JA, Bier CA. The global prevalence of apical periodontitis: a systematic review and meta-analysis. Int Endod J. 2021;54(5):712–735. DOI: 10.1111/iej.13467.
15. Zhang W, Zhao Y. Global dietary magnesium deficiency: prevalence, underlying causes, health consequences, and strategic solutions. Int J Vitam Nutr Res. 2025;95(6):46828. DOI: 10.31083/IJVNR46828.

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