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PROBIOTIC CORRECTION OF PERIODONTAL SYNDROME IN ANIMALS UNDER CONDITIONS OF OBESITY AND CHRONIC STRESS

*The **aim** of this study was to investigate the effect of obesity and chronic stress on periodontal tissues, both separately and in the combined comorbidity of these conditions in rats, and the role of the probiotic Lactobacillus casei in the correction of periodontal syndrome under these conditions. **Methods.** The development of periodontal syndrome and the effectiveness of the probiotic Lactobacillus casei IMV B-7280, administered to rats from one month of age intragastrically in a volume of 1 mL ($5 \cdot 10^8$ CFU) in two-week courses with breaks of 2 weeks, were studied in a model of glutamate-induced obesity and chronic stress — in combination and separately. In periodontal tissues, the total proteolytic and antitryptic activity, free fucose and glycosaminoglycans (GAG) content, catalase activity, thiobarbiturate active products (TBA reagents), and the content of oxidatively modified proteins (OMP) and molecules of average mass (AMM) were determined; in bone tissue, the molar root exposure coefficient was calculated. The anthropometric parameters of the animals and the Selye triad were studied. **Results.** We have substantiated the development of periodontal syndrome in animals with glutamate-induced obesity against the background of chronic stress, as evidenced by the activation of free radical oxidation of lipids and proteins, depolymerization of fucoproteins and proteoglycans of periodontal connective tissue, which causes exposure of molar roots by almost 65%. The administration of the probiotic Lactobacillus casei in two-week courses with intervals of 2 weeks to obese rats with chronic stress prevented the development of obesity, as evidenced by a significant decrease in visceral fat mass, Li index, and BMI, as well as the severity of stress syndrome, as evidenced by a decrease in ulcer formation, thymus involution, and adrenal hypertrophy. The periodontoprotective effect of Lactobacillus casei under the combined influence of obesity and chronic stress was proved by significant changes in oxidative stress, free fucose, and GAG content and a 1.5-times decrease in the molar root exposure ratio. **Conclusions.** Periodic administration of Lactobacillus casei to rats treated with sodium glutamate in the neonatal period against the*

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background of chronic stress prevented the development of obesity, the severity of stress syndrome6 and damage to periodontal tissues, as evidenced by the prevention of oxidative stress, increased catabolism of extracellular connective tissue proteins and antiresorptive effect.

Keywords: *periodontal tissues, obesity, stress, probiotic Lactobacillus casei IMV B-7280, proteases, antiradical protection, fucose, glycosaminoglycans.*

Obesity and overweight have become epidemic problems worldwide, and health experts now consider them chronic inflammatory diseases (WHO, 2021). Currently, numerous scientific studies have proven that the intestinal microbiome can be considered an environmental factor that modulates the development of obesity (Tang et al., 2021).

Over the past 30 years, there has been much evidence of a link between oral diseases, such as periodontitis, and various systemic diseases. The Canadian Association of Dental Hygienists notes that there is a weak association between periodontitis and rheumatoid arthritis, kidney disease, tumors, and cognitive impairment/Alzheimer's disease; there is a stronger association between periodontal disease and obesity for patients of all ages (Lavigne, 2022). A systematic review with a meta-analysis showed that overweight and obese people have 27% and 81% higher chances of periodontitis, respectively, than people with normal weight (da Silva et al., 2021).

Periodontitis is a multifactorial chronic inflammatory disease of periodontal tissues characterized by progressive destruction of the supporting apparatus of the tooth and is the main cause of tooth loss, it is the sixth most common disease in the world. According to current estimates, 796 million people worldwide suffer from its severe form. The link between periodontal tissue diseases and non-communicable diseases has been the subject of many studies over the past few years. It is known that the leading factor in the development of generalized periodontitis is dysbiosis of the oral microbiota, so we believe that the use of probiotic correction can be effective in preventing the development of periodontal syndrome in the case of obesity with chronic stress. Probiotics are a set of living microorganisms that, when consumed, improve or restore the recipient's microflora, in particular the gastrointestinal tract, thereby affecting the metabolism of the body as a whole. There is still no complete understanding of the impact of the microbiome on the human body. At the same time, probiotics as bacterial cultures exhibit interspecies interaction, which is well documented in the oral cavity, in particular, by *Lactobacillus casei* IMV B-7280. Its local effect on the oral cavity is cohesion and coaggregation mediated by adhesin receptors, as well as a succession of periodontal pathogens and a powerful antagonistic effect (Wen et al., 2017). It has also been proven that periodontal pathogenic microflora is not only a key source and plays a triggering role in the development of local and systemic chronic inflammation but also acts as an independent risk factor for coronary heart disease (Vesnina et al., 2015).

The **aim** of this study was to investigate the effect of obesity and chronic stress on rat periodontal tissues, both separately and in combination, the comorbidity of these conditions in rats, and the role of the probiotic *L. casei* IMV B-7280 in the correction of periodontal syndrome under these conditions.

Materials and Methods. The object of research was the probiotic *Lactobacillus casei* IMV B-7280 from the Ukrainian Collection of Microorganisms (UCM, Zabolotnyi Institute of Microbiology and Virology (IMV), NAS of Ukraine).

The experimental studies were performed in compliance with bioethical standards on 103 nonlinear rats of both sexes, which were divided into 8 groups: Group 1 (n = 11) — intact rats, Group 2 (n = 11) — obese rats, Group 3 (n = 16) — obese rats exposed to stress, Group 4 (n = 15) — stressed rats, Group 5 (n = 10) — intact

rats injected with probiotic, Group 6 (n = 12) — obese rats with probiotic treatment, Group 7 (n = 16) — obese rats exposed to stress and probiotic treatment, and Group 8 (n = 10) — obese rats exposed to stress against the background of obesity and probiotic treatment. Glutamate-induced obesity was modeled by subcutaneous injection of sodium glutamate (4 mg/g) in a volume of 8 μL/g of rat body weight to newborn rats on days 2, 4, 6, 8, and 10 of life, followed by standard vivarium chow. Chronic stress modeling was performed according to Selye G. For this purpose, the experimental rats were fixed on their backs for 1 hour for 5 days at the age of 4 months. The probiotic *L. casei* IMV B-7280 was administered to rats starting from one month of age intragastrically in a volume of 1 mL ($5 \cdot 10^8$ colony forming units (CFU)) every 14 days with a break of 2 weeks. Under the influence of sodium thiopental, 4-month-old rats were withdrawn from the experiment by bleeding, visceral fat, thymus, adrenal glands, and stomach, and periodontal tissues were removed and weighed. Body length was measured, and body mass index (BMI) (the ratio of body weight in grams to the square of body length in square centimeters) and the Lee index (the ratio of the cube root of body weight in grams to body length in centimeters) were calculated. The development of stress syndrome was assessed by the state of the gastric mucosa, and the relative weight of the thymus and adrenal glands was calculated.

The objects of the study were soft periodontal tissues of rats, in the homogenate of which general proteolytic activity was observed (Ugolev, 1969); the general antitryptic activity (Veremeenko, 1988); the content of secondary TBA-active products, which are markers of lipid peroxidation and oxidative stress, (Steel & Garishvili, 1977); the content of oxidatively modified proteins (OMB), which is an early marker of oxidative stress; the content of molecules of average mass, which is a marker of endotoxicosis (Dubinina,1995) and catalase activity (Korolyuk, 1988), and the content of free fucose (Sharaev, 1997) and glycosaminoglycans (GAG) (Sharaev, 1987). To assess the degree of resorption of the alveolar ridge of the jaws, the molar root exposure coefficient was calculated (using a binocular microscope), which is equal to

$$\frac{\Delta L}{L} \cdot 100$$

where L is the distance from the marginal edge of the alveolar process to the upper edge of the tooth crown, and ΔL is the distance from the marginal edge of the alveolar ridge to the lower edge of the crown.

The results were statistically processed using the IBM SPSS Statistics 26 2020 software package. The Kruskal-Wallis test was used to determine a statistically significant difference between the groups.

Results. Analyzing the anthropometric parameters of the studied animals, we found that postnatal administration of sodium glutamate to newborn rats causes a significant increase in visceral fat mass, BMI, and Body Mass Index in 4-month-old animals compared to intact animals (Table 1). The combined effect of obesity and chronic stress contributes to a significant increase in the Li index and the amount of visceral adipose tissue depot compared to Group 1 of rats. No significant changes in the studied anthropometric parameters were found in the animals modeled with chronic stress. The administration of *L. casei* IMV B-7280 in two-week courses to rats with glutamate-induced obesity leads to a significant decrease in the Lee index, BMI, and visceral fat content compared to animals modeled with obesity without correction. The probiotic *L. casei* IMV B-7280 prevented the development of obesity in animals with comorbid conditions, as evidenced by a significant decrease in the Li index, BMI, and the absence of visceral fat in these animals compared to rats modeled with obesity on the background of stress syndrome without correction (Table 1).

Thus, the probiotic *L. casei* IMV B-7280 is effective in correcting obesity in animals under

conditions of modeling isolated obesity and obesity against the background of a general adaptation syndrome.

The experimental efficacy of the probiotic *L. casei* IMV B-7280 was proved by analyzing the indicators reflecting the severity of stress, namely, the development of gastric mucosal ulceration: complete absence in obese rats with correction and a decrease in the frequency, severity, and multiplicity of ulcers in animals with stress, obesity with stress on the background of correction compared to the corresponding control (Table 2).

In animals modeled with obesity and obesity on the background of stress syndrome, thymus involution decreased under the conditions of administration of the probiotic *L. casei* IMV B-7280 as evidenced by significant changes in the relative weight of the thymus gland compared to the corresponding control animals (Table 2). Probiotic correction of animals treated with sodium glutamate on the 2nd, 4th, 6th, 8th, and10th days of life prevented the development of obesity in rats both alone and in combination with chronic stress and contributed to the prevention of stress syndrome

Table 1. **Anthropometric indicators of the studied animals under conditions of obesity, chronic stress, and correction with the probiotic *L. casei* IMV B-7280 *(M±m)***

Animal groups **N**=103	Li index	Visceral fat mass, g	BMI
1. Intact n=10	0.254±0.003	0.50±0.26	0.35±0.01
2. Obesity n=14	0.268±0.003*	11.42±1.30*	0.43±0.01*
3. Obesity + stress n=17	0.263±0.002*	12.90±0.74*	0.39±0.01
4. Stress n=10	0.258±0.002	0.09±0.09	0.37±0.01
5. Probiotic n=10	0.250±0.001	2.45±0.36	0.33±0.005
6. Obesity+probiotic n=12	0.253±0.003*#	7.38±0.85#	0.39±0.01* #
7. Stress+probiotic n=16	0.260±0.004	3.18±0.38	0.39±0.004
8. Obesity+stress+probiotic n=10	0.243±0.004*,**	—	0.36±0.01**

*P < 0.05 compared to intact animals, # P_{2-6} <0.05; ** P_{3-8} <0.05

Table 2. **Indicators of the severity of the stress syndrome of the studied animals under conditions of obesity, chronic stress, and correction with the probiotic *L. casei* IMV B-7280 (M±m)**

Animal groups N=103	Relative weight of the thymus, mg/g	Relative weight of the adrenal glands, mg/g	Indicators of GM		
			Frequency of ulcers, %.	The number of ulcers, number of ulcers per 1 rat	Severity, points
1. Intact n=10	1.08±0,17	0.21±0.02	—	—	—
2. Obesity n=14	1.10±0,07	0.16±0.02	—	—	—
3. Obesity + stress n=17	0.99±0,09	0.20±0.02	59.2	0.93	5
4. Stress n=10	0.77±0,16	0.30±0.04*	75	1.79	6
5. Probiotic n=10	1.17±0,18	0.20±0.03	—	—	—
6. Obesity+probiotic n=12	1.49±0,11#	0.20±0.03	—	—	—
7. Stress+probiotic n=16	0.85±0,10	0.22±0.05#	14.3	0.14	1
8. Obesity+stress+probiotic n=10	1.29±0,09**	0.25±0.02	15.3	0.31	2

*P < 0.05 compared to intact animals; # P_{2-6} <0.05; ** P_{3-8} <0.05

based on significant changes in ulcer formation, adrenal hypertrophy, and thymus involution.

We found that under the conditions of comorbidity of experimental obesity and chronic stress in periodontal tissues, the content of TBA-active products, OMP, and AMM significantly increased by more than 2 times against the significant decrease in catalase activity compared to these indicators in intact animals (Table 3). Thus, the combined effect of obesity and stress syndrome causes the activation of free radical oxidation in periodontal tissues against the inhibition of antiradical defense. Analyzing the separate effects of obesity and immobilization of animals on the development of oxidative stress, we found a significant increase in the content of OMP and AMM in periodontal tissues under obesity compared to control as well as in the content of TBA-reactants and OMP along with a decrease in catalase activity in animals with chronic stress compared to these indicators in intact rats.

The probiotic *L. casei* IMV B-7280 prevented the development of oxidative stress in the periodontal tissues of rats with obesity and chronic stress, both separately and with **c**omorbid conditions, as evidenced by a significant decrease in the content of TBA-reactants, OMP, and AMM compared to the corresponding groups of animals

Table 3. **Indicators of oxidative stress in rat periodontal tissues under conditions of obesity, chronic stress, and correction with probiotic *L. casei* IMV B-7280 (M±m)**

Animal groups N=103	TBA reagent content, μmol/g	OMP content, n.u.	Catalase activity, μkat/g	Content of AMM, n.u.
1. Intact n=10	10.00 ± 2.13	0.036 ± 0.003	0.34 ± 0.02	0.042 ± 0.014
2. Obesity n=14	12.43 ± 3.03	0.076 ± 0.007#	0.37 ± 0.01	0.145 ±0.017#
3. Obesity + stress n=17	22.77 ± 5.25*	0.082 ± 0.004*	0.16 ± 0.02*	0.086 ± 0.021*
4. Stress n=10	21.04 ±8.27**	0.108 ± 0.005**	0.10 ± 0.02**	0.042 ± 0.012
5. Probiotic n=10	12.91 ± 3.19	0.039 ± 0.021	0.40 ± 0.01	0.049 ± 0.019
6. Obesity+probiotic n=12	6.13 ± 1.38^	0.010 ± 0.005^	0.44 ± 0.01	0.019 ± 0.007^
7. Stress+probiotic n=16	11.48 ± 1.21&	0.088 ± 0.009&	0.37 ± 0.01	0.030 ± 0.019
8. Obesity+stress+pro-biotic n=10	7.52 ± 1.38^^	0.416 ± 0.091^^	1.11 ± 0.12^^	0.049 ± 0.042^^
Statistical indicator	P_{1-3} <0.05* P_{1-4} <0.05** P_{1-2} <0.05# P_{2-6} <0.05^ P_{3-8} <0.05^^ P_{4-7} <0.05&			

Table 4. **Proteinase-inhibitory potential of rat periodontal tissue under conditions of obesity, chronic stress, and correction with probiotic *L. casei* IMV B-7280 (M±m)**

Animal groups N=103	Total antitryptic activity, g/kg	Total proteolytic activity, μmol/g×min
1. Intact n=10	27.88 ± 4.52	1.61 ± 0.09
2. Obesity n=14	56.12 ± 11.09*	1.60 ± 0.07
3. Obesity + stress n=17	98.27 ± 14.95**	1.80 ± 0.06
4. Stress n=10	22.56 ± 2.23	1.54 ± 0.08
5. Probiotic n=10	34.7 ± 6.36	1.51 ± 0.06
6. Obesity + probiotic n=16	111.6 ± 19.81^	1.85 ± 0.13
7. Stress + probiotic n=12	28.8 ± 5.11	1.61 ± 0.08
8. Obesity+stress+probiotic n=14	76.9 ± 14.27#	1.31 ± 0.36
Statistical indicator	P_{1-2} <0.05* P_{1-3} <0.05** P_{2-6} <0.05^ P_{3-8} <0.05#	

without correction. Analyzing the antioxidant protection of periodontal tissues in animals, a significant increase of almost 7 times was obtained in rats modeled with the combined effect of obesity and chronic stress compared to the corresponding group of animals without correction (Table 3).

Thus, under the combined effect of obesity and chronic stress, periodontal syndrome develops, the leading link in the development of which is oxidative stress, which is effectively prevented by probiotic *L. casei* IMVB-7280 correction. Analyzing the total proteolytic activity in periodontal tissues of the studied animal groups, we found no significant changes. The total antitryptic activity was significantly increased by 3.5 times in the periodontal tissues of rats under the combined effect of obesity and chronic stress compared to the control and by 1.8 times compared to the animals with modeled obesity (Table 4). Thus, under conditions of comorbidity of stress and obesity in animals, the activation of proteolysis in periodontal tissues is decompensated by the increase in protease inhibitors. Under the conditions of probiotic administration, we observed a significant increase in the total antitryptic activity by almost 2 times in periodontal tissues of obese animals compared to this indicator in rats that were modeled with obesity without correction.

Investigating the content of free fucose and GAG in periodontal tissues as informative markers of the depolymerization of fucoproteins and connective tissue proteoglycans, we found significant changes only in rats with combined effects of obesity and chronic stress: the content of fucose increased by 1.6 times and the content of GAG — by 1.7 times compared to control animals (Table 5). Thus, the combination of the effects of experimental obesity and chronic stress is accompanied by increased breakdown of biopolymers of periodontal connective tissue. The administration of *L. casei* IMV B-7280 for two weeks to rats with glutamate-induced obesity and chronic stress contributes to a significant decrease in the content of free fucose by 1.7 times and the content of GAG by 2.5 times compared to animals under these conditions without correction.

Thus, probiotic correction effectively prevented the destruction of periodontal tissues under the combined effect of obesity and chronic stress. When studying the resorption coefficient of the alveolar ridge of rats of all study groups, we obtained the following results (Fig. 1).

We obtained a statistically significant difference between the group of intact rats and the rats with induced obesity, the group of rats exposed to chronic stress, and the group of rats with comorbidity of these conditions (Fig. 1). The results obtained indicate a resorptive effect of obesity and chronic stress on the bone tissue of the alveolar process of the jaws. At the same time, no statisti-

Table 5. **The content of free fucose and GAG in rat periodontal tissues under conditions of obesity, chronic stress, and correction with the probiotic *L. casei* (M±m)**

Animal groups N=103	Free fucose content, μmol/g	GAG content, μmol/g
1. Intact n=10	2.98 ± 0.71	1.94 ±0.37
2. Obesity n=14	2.53 ± 0.30	1.57 ± 0.39
3. Obesity + stress n=17	4.75 ± 0,32*	3.29 ± 0.37*#
4. Stress n=10	3.99 ± 0.42	2.08 ± 0.15
5. Probiotic n=10	2.40 ± 0.46	2.14 ± 0.25
6. Obesity + probiotic n=16	1.39 ± 0.34	2.95 ±0.59
7. Stress + probiotic n=12	2.75 ± 0.43^	2.17 ±0.21
8. Obesity+stress+probiotic n=14	2.81 ± 0.91**	1.29 ±0.23**
Statistical indicator	P_{1-3} <0.05* P_{3-8} <0.05** P_{4-7}<0.05^ P_{2-3} <0.05#	

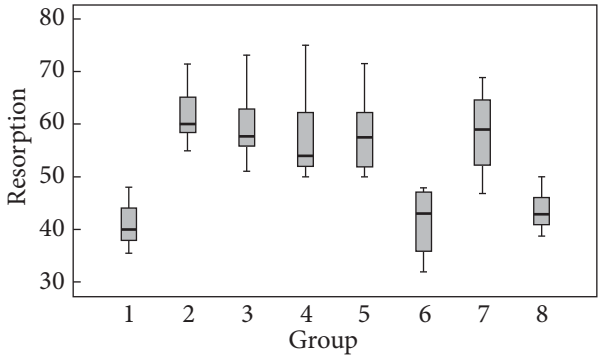

Fig. 1. The coefficient of molar root exposure (%): Group 1 — intact rats; Group 2 — obese; Group 3 — obese + stress; Group 4 — stress; Group 5 — probiotic; Group 6 — obese + probiotic; Group 7 — stress + probiotic; Group 8 — obese + stress + probiotic

cally significant difference was found between the groups of rats with obesity, stress, and obesity on the background of stress, indicating approximately the same effect of obesity, stress, and their combination on the resorption of alveolar bone of the jaws of the studied animals. Analyzing the effectiveness of the probiotic *L. casei*, we found significant changes between the group of rats modeled with obesity and animals with comorbidity of these conditions compared to the corresponding control (Fig.1). Thus, in the groups of obese rats and obese rats with chronic stress, probiotic correction showed an antiresorptive effect, which is confirmed by a statistically significant difference in the coefficient of molar root exposure compared to the corresponding groups without correction.

Discussion. Stress and obesity are linked through several interacting pathways that span cognition, behavior, physiology, and biochemistry. First, stress interferes with cognitive processes such as executive function and self-regulation. Second, stress can affect behavior by leading to overeating and consumption of high-calorie foods; by reducing physical activity; and by reducing sleep. Third, stress causes physiological changes in the hypothalamic-pituitary-adrenal system, reward processing in the brain, and possibly the gut microbiome. Finally, stress can stimulate the production of hormones and peptides such as leptin, ghrelin, and neuropeptide Y. Obesity itself can be a stressful condition due to the high prevalence of weight stigma. (Tomiyama, 2019). Research in this area is important because it targets two major problems: stress and obesity, which are very prevalent in modern society. While there is growing scientific attention to the complex interactions between stress, energy balance, appetite regulation, food reward, and motivation and their impact on the obesity epidemic, there are significant gaps in our understanding of these relationships (Sinha et al., 2013; van der Valk et al., 2018). Indeed, future research to improve our understanding of the neurobehavioral and metabolic mechanisms underlying generalized adaptive disorder and its relation to obesity will be of great benefit in the understanding of pathogenesis and the search for new prevention and treatment methods.

In the model of glutamate-induced obesity and chronic stress in rats, we obtained a significant increase in visceral fat mass, BMI, and Li index compared to intact animals. The probiotic *L. casei* prevented the development of obesity in animals with comorbid conditions, as evidenced by a significant decrease in the Li index, BMI, and the absence of visceral fat in these animals compared to rats modeled with obesity on the background of stress syndrome without correction. It is now well known that the microbiota plays a crucial role in the pathogenesis of many diseases (Mohajeri, et al., 2018; Amedeo Amedei et al., 2018), so the use of probiotic therapy is effective.

Probiotic correction of rats treated neonatally with sodium glutamate prevented the development of obesity in rats both alone and in combination with chronic stress and contributed to the prevention of stress syndrome, as evidenced by significant changes in the ulcer formation, adrenal hypertrophy, and thymus involution.

Based on clinical parameters, levels of reactive oxygen metabolites (ROM), resistin in gingival fluid and blood serum in obese or overweight

individuals with and without periodontitis, the development of oxidative stress as a leading mechanism of periodontal tissue damage in obesity has been substantiated (Suresh et al., 2022).

The probiotic *L. casei* prevented the development of oxidative stress in periodontal tissues of rats with obesity and chronic stress both separately and with comorbid conditions, as evidenced by a significant decrease in the content of TBA-reactants, OMP, and AMM compared to these indicators in the corresponding groups of animals without correction. Analyzing the antioxidant protection of periodontal tissues in animals, a significant increase by almost 7 times was obtained in rats modeled with the combined effect of obesity and chronic stress compared to this indicator in the corresponding group of animals without correction.

We have proved that the combination of experimental obesity and chronic stress is accompanied by the increased breakdown of fucoproteins and proteoglycans of periodontal connective tissue: the fucose content increases by 1.6 times and the GAG content by 1.7 times compared to the control animals. The introduction of *L. casei* IMV B-7280 under the conditions of glutamate-induced obesity and chronic stress prevents the depolymerization of extracellular proteins of periodontal tissues, as evidenced by a significant decrease in the content of free fucose and GAG compared to the rats that were modeled with the combined effect of obesity and stress without correction. Thus, probiotic correction effectively prevented the destruction of periodontal tissues under the combined effect of glutamate-induced obesity and chronic stress.

The alveolar process of the jaws is characterized by a high turnover rate, a complex association with the tooth and periodontium, as well as high sensitivity to oral pathogenic lesions and mechanical stress, which increases its difficulty in protecting the body and remodeling periodontal bone tissue. The main mechanisms associated with the activation of inflammation during alveolar ridge resorption include the activation of osteoclastogenesis, M1-like polarization of macrophages, inflammation of periodontal tissues, pyroptosis of osteoblasts, macrophages, and fibroblasts, as well as reduced osteogenesis (Li et al., 2021). Alveolar bone loss is also involved in systemic bone destruction and is affected by local or systemic pathological factors, so it is important to investigate the mechanisms involved in the dysregulation of jaw alveolar remodeling in the case of obesity with chronic stress. Our results indicate a resorptive effect of obesity and stress on the bone tissue of the alveolar process of the jaws in rats. At the same time, we did not find a statistically significant difference between the groups of rats with obesity, stress, and obesity with chronic stress, which indicates the same pathogenetic links that are realized in obesity, stress, and their combination on the resorption of alveolar bone of the jaws of the studied animals. The introduction of the probiotic *L. casei* IMV B-7280 promotes significant differences between the group of rats modeled with obesity and animals with comorbidity of these conditions compared to the corresponding control. Thus, in the groups of obese rats and obese rats with chronic stress, probiotic correction showed an antiresorptive effect, which was confirmed by a statistically significant difference in the coefficient of molar root exposure compared to the corresponding groups without correction. To date, numerous studies using various animal models to determine the effectiveness of lactobacilli in reducing both primary and secondary osteoporotic bone loss have proven the effectiveness of their use (Zhang et al., 2015; Zaiss et al., 2019; Rastogi et al., 2022).

Most studies have shown that the potential pathogenic mechanism underlying the relationship between obesity, chronic stress, and periodontitis may rely on a common and potentially interrelated low-grade inflammation involving several cytokines, adipokines, and oxidative stress. In any case, although several putative molecular pathogenic links between obesity, chron-

ic stress, and periodontitis have been identified, further studies with longer follow-up are needed to better understand the putative link between obesity and periodontitis, general adaptation syndrome and periodontitis to possibly pave the way for new biomarkers of obesity, stress and periodontitis, as well as for innovative preventive strategies and special recommendations for individuals with obesity and periodontal disease in the setting of stress. Although the pathogenesis of inflammatory and metabolic disorders is multifactorial and very complex, recent modern literature suggests the modulation of the intestinal microbial flora and immune responses by probiotics as a major therapeutic intervention.

Conclusions. Periodic administration of *L. casei* IMV B-7280 to rats treated with sodium glutamate in the neonatal period against the background of chronic stress prevented the development of obesity, the severity of stress syndrome and damage to periodontal tissues, as evidenced by the prevention of oxidative stress, increased catabolism of extracellular connective tissue proteins, and antiresorptive effect.

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КОРЕКЦІЯ ПРОБІОТИКОМ ПАРОДОНТАЛЬНОГО СИНДРОМУ
У ТВАРИН ЗА УМОВ ОЖИРІННЯ І ХРОНІЧНОГО СТРЕСУ

Метою даної роботи було дослідження впливу ожиріння та хронічного стресу на тканини пародонта як окремо, так і в поєднанні коморбідності цих станів у щурів та ролі пробіотика *Lactobacillus casei* IMV B-7280 в корекції пародонтального синдрому за цих умов. **Методи.** На моделі глутаматіндукованого ожиріння та хронічного стресу у поєднанні та окремо досліджували розвиток пародонтального синдрому та ефективність пробіотику *L. casei* IMV B-7280, який вводили внутрішньошлунково щурам, починаючи з одномісячного віку в об'ємі 1мл ($5{\cdot}10^8$ КУО) двотижневими курсами з перервами у 2 тижні. У тканинах пародонта визначали загальну протеолітичну та антитриптичну активність, вміст вільної фукози та ГАГ, каталазну активність, вміст ТБК-реактантів, ОМБ, МСМ; у кістковій тканині розраховували коєфіцієнт оголення коренів молярів. Досліджували антропометричні показники тварин та тріаду Сельє. **Результати.** Нами обґрунтовано розвиток пародонтального синдрому у тварин за умов глутаматіндукованого ожиріння на тлі хронічного стресу, про що свідчить активація вільно-радикального окиснення ліпідів та білків та деполімеризація фукопротеїдів та протеогліканів сполучної тканини пародонта, що спричиняє оголення коренів молярів майже на 65%. Введення пробіотику *L. casei* IMV B-7280 двотижневими курсами з перервами у 2 тижні щурам за умов ожиріння на тлі хронічного стресу запобігало розвитку ожиріння, про що свідчить вірогідне зменшення маси вісцерального жиру, індексу Лі та ІМТ, а також тяжкості стрес-синдрому, на що вказує зменшення виразкоутворення, інволюції тимусу та гіпертрофії надниркових залоз. Пародонт-протекторна дія *L. casei* IMV B-7280 за умов поєднаного впливу ожиріння та хронічного стресу доведена вірогідними змінами показників оксидативного стресу, вмісту вільної фукози і ГАГ та зменшенням коефіцієнту оголення коренів молярів у 1,5 рази. **Висновки.** Періодичне введення *L. casei* IMV B-7280 щурам, що отримували глутамат натрію в неонатальному періоді на тлі хронічного стресу попереджало розвиток ожиріння, тяжкість стрес-синдрому та ушкодження тканин пародонту, про що свідчить запобігання розвитку оксидативного стресу, підвищений катаболізм екстрацелюлярних білків сполучної тканини та антирезорбтивний ефект.

***Ключові слова**: тканини пародонту, ожиріння, стрес, пробіотик, Lactobacillus casei IMV B-7280, протеази.*