
PATHOGENETIC MECHANISMS UNDERLYING THE RELATIONSHIP BETWEEN CALCIUM-PHOSPHORUS METABOLISM AND THE CONDITION OF PERIODONTAL TISSUES

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INTRODUCTION

Estrogen deficiency is an important pathogenetic factor in the development of disturbances in bone metabolism leading to osteoporosis. Osteoporotic changes resulting from a reduction or loss of ovarian function in women affect various parts of the skeleton, including the bone tissue of the periodontal complex. Impairment of bone remodeling processes and a decrease in the mineral density of periodontal bone under conditions of estrogen deficiency may play a significant role in the increased prevalence and severity of periodontal diseases observed with advancing age in women^{1, 2}.

Laboratory methods play an important role in assessing the pathogenetic mechanisms of osteoporosis development, allowing determination of which bone remodeling process predominates – reduced bone formation or increased bone resorption. Analysis of biochemical parameters contributes to a deeper understanding of the nature of metabolic disorders in bone tissue and helps clarify the mechanisms underlying bone mass loss.

Currently, a number of biochemical markers of bone metabolism are identified, the concentrations of which are measured in serum and urine. Most of these markers reflect the intensity of bone tissue remodeling processes, since bone formation and resorption are closely interconnected and physiologically coupled processes. Under normal conditions, these processes are in a state of dynamic equilibrium; however, in pathological conditions, the rate of one of them may significantly predominate over the other. Accordingly, some markers primarily

¹ Areal-Quecuty V., Cantiga-Silva C., Simón-Soro A. et al. Apical periodontitis in osteoporotic postmenopausal women: systematic review and meta-analysis. *Medicina Oral, Patología Oral y Cirugía Bucal*. 2024. Vol. 29. No. 5. P. e711–e718.

² Горб-Гаврильченко І. В. Вплив тривалості штучної менопаузи на клінічні прояви генералізованого пародонтиту у жінок після оваріоектомії. *Український стоматологічний альманах*. 2010. С. 33–35.

characterize osteoblastic activity and bone formation processes, whereas others serve as indicators of osteoclastic activity and the intensity of bone resorption. The determination of these parameters makes it possible to assess the direction and severity of disturbances in bone metabolism, as well as to use them for diagnosis, disease monitoring, and evaluation of treatment efficacy.

Osteocalcin is a specific non-collagenous protein of the bone matrix and is recognized as one of the most reliable markers of bone formation. Synthesized by osteoblasts, it participates in bone tissue mineralization and serves as an indicator of the functional state of bone-forming cells. Changes in serum osteocalcin concentration reflect the intensity of bone formation and the characteristics of bone remodeling.

According to several authors, a decrease in serum osteocalcin levels is considered a characteristic marker of impaired bone formation in patients with generalized periodontitis. This parameter may indicate disturbances in bone tissue metabolism and represent one of the pathogenetic links in progressive alveolar bone resorption in inflammatory and destructive periodontal diseases³.

One of the most widely used laboratory methods for assessing bone-forming activity in patients with generalized periodontitis is the measurement of total and bone-specific alkaline phosphatase activity. Although this biochemical marker is less specific than osteocalcin, it is extensively used to characterize bone metabolic status and bone tissue remodeling processes.

The bone-specific isoenzyme of alkaline phosphatase is produced by osteoblasts and is directly involved in the mineralization of the bone matrix, which allows it to be considered an indicator of the functional activity of bone-forming cells. Changes in the level of this enzyme may reflect disturbances in both bone formation and bone tissue mineralization. Therefore, the determination of alkaline phosphatase activity retains important diagnostic value in assessing metabolic disorders of bone tissue and the pathogenetic mechanisms of destructive changes in the periodontal complex.

The intensity of metabolic processes in bone tissue is largely characterized by parameters of calcium–phosphorus metabolism, particularly the concentrations of calcium and phosphorus in blood and urine. Assessment of these parameters makes it possible to evaluate the state of mineral metabolism and the characteristics of bone remodeling under both physiological and pathological conditions.

According to current understanding, one of the key factors in the development of osteoporosis is insufficient calcium supply to the body. It is known that approximately 99% of the total calcium content in the human

³ Schini M., Vilaca T., Gossiel F., Eastell R. Bone turnover markers. *Endocrine Reviews*. 2023. Vol. 44. No. 3. P. 417–476.

body is localized in bone tissue, which not only performs a structural function by providing mechanical strength to the skeleton but also serves as the main reservoir of this macroelement. Maintenance of stable calcium concentrations in the body is ensured by a complex regulatory system governing its intake, deposition, and mobilization from bone tissue^{4, 5}.

Calcium deficiency is regarded as an important pathogenetic factor contributing to reduced bone mineral density and the development of osteoporosis, particularly in the elderly. In women during early postmenopause, calcium deficiency is often combined with estrogen deficiency, which leads to increased bone resorption, disruption of bone remodeling processes, and accelerated loss of bone mass. As a result of these changes, the risk of osteoporotic skeletal lesions and associated structural and functional disorders of bone tissue increases.

Phosphorus also plays a significant role in bone remodeling processes alongside calcium, with approximately 85–90% being stored in bone tissue. The mineral component of bone tissue is composed not only of crystalline hydroxyapatite structures but also of an amorphous calcium phosphate phase, which forms a non-crystalline component of the mineral matrix in the form of dense granular structures. The content of the amorphous calcium–phosphate component in bone tissue is subject to age-related changes. During early ontogenesis, the proportion of the amorphous phase is relatively high, reflecting active processes of bone growth and remodeling. As bone tissue matures, there is a gradual increase in the proportion of crystalline hydroxyapatite, which becomes the predominant form of the mineral component in mature bone. These changes reflect the processes of mineralization and structural stabilization of the bone matrix during aging and development. Amorphous calcium phosphate is regarded as a labile reservoir of calcium and phosphorus ions in bone tissue. Its hydrolysis contributes to the maintenance of a stable calcium concentration in the interstitial fluid of bone tissue, thereby supporting mineral metabolism processes. Under the influence of cellular active transport mechanisms, the concentrations of calcium and phosphorus ions may reach a state of supersaturation, creating conditions for the subsequent precipitation of amorphous calcium–phosphate compounds. Amorphous calcium phosphate is characterized by high metabolic activity, and its content is determined both by age-related factors and by the nutritional status of the organism. Inadequate dietary intake of vitamin D, calcium, and phosphorus contributes to disturbances

⁴ Rizzoli R. Calcium and bone health: updated evidence and future directions. *Nutrients*. 2024. Vol. 16. No. 5. P. 681.

⁵ Compston J. E., McClung M. R., Leslie W. D. Osteoporosis. *The Lancet*. 2024. Vol. 403. No. 10428. P. 1092–1107.

in mineral metabolism and alters the balance between the amorphous and crystalline phases of calcium–phosphate compounds in bone tissue.

Bone tissue contains both amorphous and crystalline forms of calcium phosphate, which constitute its principal mineral component. Cellular and enzymatic regulatory mechanisms maintain a dynamic equilibrium between these mineral phases, thereby determining the structural organization and metabolic activity of the bone matrix, as well as its adaptive properties under changing physiological and pathological conditions.

There is evidence indicating the influence of estrogens on intestinal calcium absorption processes. According to most researchers, the regulatory effects of estrogens on calcium metabolism and bone tissue metabolism are mediated indirectly, including through the parathyroid hormone system, which in turn influences the metabolism of the active form of vitamin D – 1,25-dihydroxycholecalciferol⁶.

Estrogen deficiency is accompanied by a reduction in calcitonin production and altered sensitivity of bone cells to parathyroid hormone, leading to dysregulation of bone remodeling processes and increased bone resorption. In vitamin D deficiency, enhanced bone resorption is driven by a compensatory increase in parathyroid hormone secretion, aimed at maintaining physiological serum levels of calcium and phosphorus through mobilization of mineral components from bone tissue. However, this compensatory mechanism does not always ensure complete normalization of mineral homeostasis, thereby contributing to the development and progression of bone metabolic disorders.

The degree of bone resorption can be assessed by measuring urinary levels of several collagen degradation markers, including proline, hydroxyproline, and deoxypyridinoline. These compounds are breakdown products of collagen structures and to some extent reflect the intensity of bone tissue resorption processes.

Particular interest is given to hydroxyproline as one of the most extensively studied biochemical markers of bone metabolism. Since collagen contains a significant amount of hydroxyproline, and a substantial proportion of it is localized in bone tissue, which is characterized by a higher turnover rate compared to soft tissues, urinary excretion of hydroxyproline is regarded as a relatively objective indicator of the intensity of bone matrix degradation.

It should be noted that hydroxyproline and its derivatives, being components of collagen in bone and cartilage tissue, allow for an indirect assessment of the degree of degradation of the connective tissue matrix. Accordingly, their determination is used not only to evaluate the extent of bone resorption but also

⁶ Khosla S., Oursler M. J., Monroe D. G. Estrogen and the skeleton. *Trends in Endocrinology & Metabolism*. 2022. Vol. 33. No. 9. P. 645–658.

for the dynamic monitoring of treatment efficacy in diseases associated with impaired bone remodeling.

Thus, the planned investigation of biochemical markers – including calcium, phosphorus, osteocalcin, alkaline phosphatase, and hydroxyproline levels in peripheral blood and urine – will make it possible to assess the intensity of bone metabolism in postmenopausal women suffering from generalized periodontitis. The obtained data are of significant importance for understanding the pathogenetic mechanisms of osteoporotic changes in the bone structures of the periodontal complex and for clarifying the role of impaired bone remodeling in the development of this pathology.

1. Biochemical markers of electrolyte metabolism in the assessment of the activity of osteoporotic lesions in the alveolar bone in patients after oophorectomy

The conducted studies indicate that in the long-term period after total oophorectomy, women with generalized periodontitis develop pronounced osteoporotic changes in bone tissue. Within the first six months after surgical intervention, most patients exhibit foci of “probable” osteoporosis in the alveolar process, which in a relatively short time transform into “definite” osteoporosis, usually without the formation of peripheral zones of hypermineralized rim. The absence of compensatory zones of excessive calcium deposition along the periphery of bone tissue is accompanied by an intensification and acceleration of resorptive processes in the interdental alveolar septa, thereby contributing to the progression of destructive changes in the periodontal complex.

The identified patterns in the formation of “probable” and “definite” osteoporotic changes in patients after oophorectomy allow for early prediction of an increased susceptibility to activation of the osteoporotic process in periodontal bone structures at early postoperative stages, as well as the identification of high-risk groups for the progression of resorptive changes.

The use of an osteoporosis activity index in women who have undergone oophorectomy enables quantitative assessment of individual risk for the development and progression of osteoporotic changes, as well as stratification of patients into groups with favorable and unfavorable courses of osteoporosis in the bone structures of the periodontium⁷.

To elucidate the mechanisms underlying the formation of low-, moderate-, and high-activity osteoporotic foci in the interdental alveolar septa of women after oophorectomy, a study was conducted to assess the levels of various

⁷ Горб-Гаврильченко І. В. Активність остеопорозу кісткової тканини пародонту у жінок з гіпоестрогенією, хворих на генералізований пародонтит. *Новини стоматології*. 2002. № 1. С. 58–59.

electrolytes in blood and urine, including total and ionized calcium, phosphorus, as well as their urinary excretion under fasting conditions. These parameters, which are of key importance for bone tissue mineral metabolism, were used to evaluate the features of systemic calcium–phosphorus homeostasis across different degrees of osteoporotic activity.

Phosphorus excretion in the morning urine sample was determined relative to creatinine levels using the phosphomolybdic acid reduction method. Urinary calcium was measured by titration using a murexide indicator, based on the formation of a colored complex.

Biochemical studies were performed in 128 women. Based on the obtained data, patients after total oophorectomy (108 women) suffering from generalized periodontitis were divided into three clinical groups.

The first group included 32 women with low activity of the osteoporotic process. The second group consisted of 31 patients with a moderate degree of osteoporosis activity. The third group comprised 45 patients with high activity of osteoporotic changes in the interdental alveolar septa.

The control group included 20 practically healthy women with intact periodontium.

Analysis of the results of total serum calcium levels (Table 1) showed that in women of Groups I and II, the values were 2.26 ± 0.04 mmol/L and 2.09 ± 0.04 mmol/L, respectively, with no statistically significant differences compared with those of the control group.

In patients with high osteoporotic activity in the periodontal bone structures, a significant decrease in total serum calcium concentration was observed, with a mean level of 2.02 ± 0.20 mmol/L.

Table 1

Calcium–phosphorus metabolism parameters in women after ovariectomy with generalized periodontitis ($M \pm m$)

Parameter (mmol/L)	Osteoporosis Activity Index < 7 points (n = 32)	Osteoporosis Activity Index > 7–< 13 points (n = 31)	Osteoporosis Activity Index > 13 points (n = 45)	Control Group (n = 20)
Total serum calcium	2.26 ± 0.04	$2.09 \pm 0.04^*$	$2.02 \pm 0.02^*$	2.20 ± 0.03
Serum phosphorus	1.20 ± 0.02	1.34 ± 0.04	$1.40 \pm 0.04^*$	1.30 ± 0.01
Urinary calcium	$3.23 \pm 0.08^*$	$5.03 \pm 0.20^*$	$8.27 \pm 0.20^*$	2.10 ± 0.02
Urinary phosphorus	$20.80 \pm 2.10^*$	$22.30 \pm 2.00^*$	$27.50 \pm 2.00^*$	18.50 ± 1.20
Ionized serum calcium	$1.04 \pm 0.01^*$	$0.92 \pm 0.02^*$	$0.85 \pm 0.02^*$	1.25 ± 0.04

Notes:

1. $p < 0.05$ – statistically significant difference compared with the control group.
2. n – sample size (number of patients).

Since the concentration of total serum calcium does not reflect the actual level of the biologically active fraction of the cation directly involved in metabolic processes, the level of ionized calcium was additionally determined.

The results of the study demonstrated that the mean ionized calcium level in women after total oophorectomy was 0.92 ± 0.01 mmol/L, which was significantly lower than that observed in the control group (1.25 ± 0.04 mmol/L; $p < 0.05$) (see Table 1).

Furthermore, it was established that as the activity of the osteoporotic process in the periodontal bone structures increased, a significant decrease in serum ionized calcium concentration was observed. Thus, in patients with low-activity osteoporotic lesions in the interdental septa, the mean ionized calcium level was 1.04 ± 0.01 mmol/L, whereas in patients with patchy osteoporotic lesions this parameter decreased to 0.85 ± 0.02 mmol/L.

Urinary calcium excretion was significantly elevated in all examined women following total oophorectomy. In patients with generalized periodontitis and low-activity osteoporotic changes in the interdental alveolar septa, the mean urinary calcium excretion was 3.23 ± 0.08 mmol/L, which was 1.5 times higher than that observed in the control group ($p < 0.05$) (see Table 1).

As the activity of osteoporotic changes in the interdental alveolar septa increased, a further statistically significant rise in urinary calcium excretion was observed, which may be associated with the increasing duration of surgically induced menopause.

Determination of serum inorganic phosphorus levels (see Table 1) showed that the mean value in the study group was 1.30 ± 0.02 mmol/L, which was within the reference range (1.32 ± 0.01 mmol/L).

At the same time, women with pronounced osteoporotic activity in the periodontal bone structures exhibited elevated phosphorus concentrations corresponding to hyperphosphatemia, with a mean level of 1.40 ± 0.04 mmol/L ($p < 0.05$).

In contrast, in patients after total oophorectomy with signs of low-activity osteoporosis in the interdental alveolar septa, the mean serum phosphorus level was 1.20 ± 0.02 mmol/L ($p > 0.05$), which was slightly lower than that observed in the control group.

Urinary phosphorus excretion in women with surgically induced menopause suffering from generalized periodontitis was elevated compared with the control group and averaged 24.20 ± 0.04 mmol/L.

A relationship was established between the level of phosphaturia and the activity of the osteoporotic process in the periodontal bone structures. Thus, urinary phosphorus excretion was 20.80 ± 0.01 mmol/L in patients with inactive disease, 22.3 ± 2.0 mmol/L in those with moderate activity, and increased to

27.5 ± 2.0 mmol/L in patients with pronounced osteoporotic changes in the interdental alveolar septa. These findings indicate a progressive deterioration of phosphorus metabolism associated with increasing osteoporotic activity.

The obtained results indicate that the parameters of calcium–phosphorus metabolism in women with surgically induced menopause are largely dependent on the severity of osteoporotic changes in the periodontal bone structures. As the activity of the osteoporotic process increases, a more pronounced and statistically significant decrease in serum ionized calcium levels is observed, accompanied by an increase in urinary calcium excretion.

At the same time, a reduction in serum phosphorus concentration was identified, the extent of which increased with the progression of osteoporotic changes in the interdental alveolar septa. These alterations were accompanied by the development of hyperphosphaturia (Table 2), reflecting the systemic nature of disturbances in phosphorus metabolism.

The statistically significant differences identified in the levels of ionized calcium and phosphorus, as well as in their urinary excretion, among women after total oophorectomy suffering from generalized periodontitis, depending on the severity of osteoporotic changes in the periodontal bone structures, suggest that biochemical parameters of calcium–phosphorus metabolism may be considered potential markers of bone resorption activity.

Table 2

Correlation between osteoporosis activity index and calcium-phosphorus metabolism parameters

Osteoporosis Activity Index (points)	Total Serum Calcium (mmol/L)	Serum Phosphorus (mmol/L)	Urinary Calcium (mmol/L)	Urinary Phosphorus (mmol/L)	Ionized Serum Calcium (mmol/L)
Group 1 (< 7 points) → 5	2.26	1.20	3.23	20.80	1.04
Group 2 (7–13 points) → 10	2.09	1.34	5.03	22.30	0.92
Group 3 (> 13 points) → 15	2.02	1.40	8.27	27.50	0.85

2. Endocrine mechanisms of impaired bone remodeling in women with long-term surgically induced menopause

The obtained results suggest that one of the key mechanisms underlying the enhancement of bone resorption in women with long-term surgically

induced menopause is a disruption in the regulation of the calcium-regulating hormonal system. A deficiency of hormones involved in maintaining calcium homeostasis and bone remodeling processes may contribute to the progression of osteoporotic changes in the periodontal bone structures⁸.

To clarify the role of endocrine disorders in the development of the described changes in women after total oophorectomy suffering from generalized periodontitis, a study was conducted to assess the serum levels of key calcium-regulating hormones, including parathyroid hormone (PTH), calcitonin, and growth hormone (somatotropin).

The results of the study of serum hormone levels in women after oophorectomy are presented in Table 3. The analysis of the obtained data was performed both for the overall sample of the main group and separately according to the activity of the osteoporotic process in the interdental alveolar septa.

Table 3

Blood levels of calcium-regulating hormones in women after ovariectomy according to the activity of the osteoporotic process in periodontal bone structures ($M \pm m$)

Blood Hormones (pg/mL)	Osteoporosis Activity Index < 7 points (n = 20)	Osteoporosis Activity Index > 7– < 13 points (n = 20)	Osteoporosis Activity Index > 13 points (n = 20)	Control Group (n = 19)
Parathyroid hormone (PTH)	24.9 ± 1.4*	28.7 ± 0.5*	39.20 ± 0.70*	16.9 ± 0.9
Calcitonin	14.1 ± 0.4*	11.3 ± 0.3*	8.10 ± 0.40*	18.2 ± 0.7
Growth hormone (Somatotropin)	2.4 ± 0.2*	1.3 ± 0.2*	0.70 ± 0.04*	3.6 ± 0.6

Notes:

1. $p < 0.05$ – statistically significant difference compared with the control group.
2. n – number of patients.
3. Values are presented as mean ± standard error of the mean ($M \pm m$).

As shown in Table 3, the mean parathyroid hormone concentration in women after total oophorectomy suffering from generalized periodontitis was 30.9 ± 0.9 pg/mL, which was significantly higher than in the control group

⁸ Машенко І. С., Горб І. В. Роль гормональних змін у розвитку остеопорозу альвеолярної кістки у хворих на генералізований пародонтит. *Вісник стоматології*. 2001. № 2. С. 19–20.

(16.9 ± 0.9 pg/mL; $p < 0.05$). Comparative analysis of subgroups with different degrees of osteoporotic activity revealed a more than twofold increase in parathyroid hormone levels in patients with patchy osteoporotic lesions, where its concentration reached 39.20 ± 0.70 pg/mL^{9, 10}.

In patients with low osteoporotic activity, the parathyroid hormone level was 24.9 ± 1.4 pg/mL. In cases of moderate osteoporotic activity in patients with generalized periodontitis, a significant increase in its concentration was observed, reaching 28.7 ± 0.5 pg/mL ($p < 0.05$).

Considering that the activity of osteoporotic changes in the alveolar process, as previously noted, depends on the duration of surgically induced menopause, the pronounced hypersecretion of parathyroid hormone in the long-term period after total oophorectomy appears to be a natural phenomenon and is consistent with the findings of other clinical studies.

The serum calcitonin level in the examined patients was 11.2 ± 0.5 pg/mL, which was significantly lower than the control values ($p < 0.05$).

Analysis of calcitonin levels in relation to the activity of the osteoporotic process in the interdental alveolar septa showed that the most pronounced decrease was observed in patients with an activity index exceeding 13 points, whereas the least reduction was noted in those with an index below 7 points (see Table 3).

Similar changes in women after total oophorectomy were also observed regarding the serum concentration of growth hormone (somatotropin). A pronounced relationship was established between the level of this hormone and the degree of activity of the osteoporotic process in the periodontal bone structures.

Thus, in cases of minimal osteoporotic activity, a decrease in somatotropin concentration to 2.4 ± 0.2 pg/mL was observed, whereas in moderate and high activity its level decreased more markedly—to 1.3 ± 0.2 pg/mL and 0.70 ± 0.04 pg/mL, respectively.

A pronounced deficiency of growth hormone was noted in women after total oophorectomy already by the third year following the establishment of surgically induced menopause. The correlation analysis between the levels of calcium-regulating hormones and the index of osteoporotic activity revealed a positive correlation between the index values and parathyroid hormone levels ($r = 0.58$ in Group I, $r = 0.70$ in Group II, and $r = 0.85$ in Group III). At the same time, an inverse correlation was established with the concentrations of

⁹ Eastell R., Szulc P. Use of bone turnover markers in postmenopausal osteoporosis. *Endocrine Reviews*. 2023. Vol. 44 (3). P. 417–476.

¹⁰ Marino S., Bellido T. PTH receptor signalling, osteocytes and bone disease induced by diabetes mellitus. *Nature Reviews Endocrinology*. 2024. Vol. 20. P. 661–672.

somatotropin and calcitonin ($r = -0.57$, $r = -0.62$, and $r = -0.77$ in Groups I, II, and III, respectively) (Table 4).

Table 4

Correlation between osteoporosis activity index and calcium-regulating hormone levels in women after ovariectomy

Osteoporosis Activity Index (points)	Parathyroid hormone (pg/mL)	Calcitonin (pg/mL)	Somatotropin (pg/mL)
Group 1 (< 7 points) → 5	24.9	14.1	2.4
Group 2 (7–13 points) → 10	28.7	11.3	1.3
Group 3 (> 13 points) → 15	39.2	8.1	0.7

Thus, the obtained results indicate more pronounced disturbances in calcium-regulating hormones in women after oophorectomy in the presence of active osteoporotic lesions in the interdental alveolar septa.

One of the leading mechanisms of increased parathyroid hormone secretion appears to be hypocalcemia, which, in turn, develops as a result of a cascade of pathophysiological changes associated with decreased calcitonin levels and a reduced anabolic effect of growth hormone (somatotropin).

CONCLUSIONS

The conducted studies indicate that the concentration of inorganic phosphorus in the blood, as well as the excretion of calcium and phosphorus in this group of patients, is directly related to the severity of the osteoporotic process in the alveolar bone tissue. As osteoporosis activity increases, there is an increase in the excretion of these macroelements and in the level of inorganic phosphorus in the blood serum, which indicates a positive correlation between these parameters.

The hypercalciuria observed in all study groups, as well as the tendency toward increased urinary phosphorus excretion, appears to reflect a state of negative calcium balance and suggests an intensification of bone resorption processes.

At the same time, the levels of total and ionized calcium show an inverse relationship with the activity of osteoporotic changes in the periodontal bone structures: as the severity of the pathological process increases, these parameters decrease, confirming a negative correlation between these indicators and the degree of osteoporosis.

The obtained data indicate pronounced disturbances in calcium–phosphorus metabolism in women with induced menopause suffering from generalized periodontitis. Metabolic alterations caused by estrogen deficiency have a direct

effect on bone tissue, promoting an increase in bone resorption processes, which in turn leads to a secondary rise in urinary excretion of calcium and phosphorus.

An inevitable consequence of enhanced urinary calcium loss is its compensatory mobilization from bone tissue, which further aggravates disturbances in mineral metabolism and contributes to the progression of osteoporotic changes.

Pronounced changes are also observed in the endocrine system, which regulates calcium and phosphorus homeostasis. As the activity of the osteoporotic process increases, the concentration of parathyroid hormone rises, indicating a direct correlation. This increase in secretion is likely stimulated by the development of hypocalcemia. Parathyroid hormone, in turn, enhances bone resorption through the activation of osteoclasts, thereby contributing to the maintenance of total and ionized calcium levels in the blood.

The concentrations of calcitonin and somatotropin show an inverse relationship with the severity of osteoporotic changes. Their decrease is most likely associated with estrogen deficiency, which normally exerts a stimulatory effect on the production of these hormones.

SUMMARY

The study examined the characteristics of calcium–phosphorus metabolism and endocrine regulation in women with induced menopause suffering from generalized periodontitis, depending on the activity of the osteoporotic process in the alveolar bone tissue. It was found that serum inorganic phosphorus levels, as well as urinary excretion of calcium and phosphorus, are directly related to the severity of osteoporosis. As the activity of the pathological process increases, there is an elevation in the excretion of macroelements and an increase in serum inorganic phosphorus concentration. This indicates a positive correlation between these parameters and the degree of osteoporotic changes. The detected hypercalciuria and the tendency toward increased phosphaturia reflect a negative calcium balance and enhanced bone resorption. At the same time, a decrease in total and ionized calcium levels confirms their inverse relationship with osteoporosis activity. The obtained data indicate pronounced disturbances in calcium–phosphorus metabolism caused by estrogen deficiency. These metabolic changes contribute to increased bone resorption and the progression of osteoporotic processes. Significant alterations in endocrine regulation were also observed, manifested by elevated parathyroid hormone levels. In contrast, decreased concentrations of calcitonin and somatotropin are associated with estrogen deficiency and further aggravate disturbances in bone metabolism.

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