# Polski Merkuriusz Lekarski

POLISH MEDICAL JOURNAL

ISSN 1426-9686

VOLUME LI, 2023, ISSUE 5, SEP– OCT

# EDITORIAL BOARD



Polski Merkuriusz Lekarski cited by PUBMED/MEDLINE, SCOPUS, INDEX COPERNICUS, EBSCO, POLISH MEDICAL BIBLIOGRAPHY, Ministry of Education and Science.


**© ALUNA PUBLISHING**
Z.M. Przesmyckiego 29
05-510 Konstancin-Jeziorna, Poland
tel. +48 604 776 311
a.luczynska@wydawnictwo-aluna.pl

**www.polskimerkuriuszlekarski.pl**

**Distribution and subscription**
Bartosz Guterman
tel. +48 22 245 10 55
prenumerata@wydawnictwo-aluna.pl

# CONTENTS

Pol Merkur Lek, 2023; LI, 5: 533-541 

ORIGINAL ARTICLE

**DOI:** 10.36740/Merkur202305113

# EFFECTS OF PROFESSIONAL ORAL HYGIENE AND TEETH WHITENING ON THE MICROELEMENT COMPOSITION OF ENAMEL

Anna V. Dvornyk, Yaroslav Y. Vodoriz, Oleg A. Pysarenko, Iryna Y. Marchenko, Iryna M. Tkachenko

POLTAVA STATE MEDICAL UNIVERSITY, POLTAVA, UKRAINE

## ABSTRACT

**Aim:** The objective of this study is to investigate the impact of professional teeth cleaning and the substances used in modern dentistry for whitening on the microelement composition of tooth enamel.

**Materials and methods:** To study the morphology and microelement composition of the enamel, scanning electron microscopy was performed using the MiraLM microscope equipped with a Schottky field emission electron gun from Tescan.

**Results:** A comparative analysis between the areas subjected to mechanical cleaning and those where it was not applied revealed a significant difference in the research results, particularly in carbon, which changed from 25.16±1.04 to 32.02±1.8. An analysis of the enamel's chemical composition before and after whitening revealed a decrease in carbon from 45.91±1.20 to 42.46±1.74. The change in phosphorus content was determined to be from 9.77±0.39 to 9.56±0.75. A decrease in calcium from 15.96±0.64 to 15.21±1.22 and magnesium from 0.07±0.01 to 0.01±0.01 was also observed.

**Conclusions:** Professional dental hygiene does not have a direct impact on the microelement composition of enamel, such as the levels of calcium, phosphorus, fluoride, and other microelements. However, it can have an indirect and temporary influence due to the use of abrasive materials that affect dental deposits, pellicle, and the surface layer of enamel. Teeth whitening can affect the microelement composition of enamel, but these changes are mostly temporary and associated with processes of demineralization/remineralization and oxygenation.

**KEY WORDS:** tooth bleaching, teeth whitening, carbamide peroxide, hydrogen peroxide, electron scanning microscopy.

## INTRODUCTION

Oral health and dental care play a crucial role in overall well-being [1]. One key aspect is the regular cleaning of teeth, which includes not only daily brushing at home but also professional cleaning performed by dentists. Professional teeth cleaning is an important procedure aimed at removing plaque, tartar, and other deposits that accumulate on the tooth surfaces [2].

Recently, an increasing number of studies have focused on investigating the impact of professional teeth cleaning on the microelement composition of tooth enamel. Tooth enamel, which is the hardest tissue in the human body, consists of various microelements such as calcium, phosphorus, fluoride, and various trace elements. These microelements play a vital role in dental health by strengthening the enamel and preventing the occurrence of cavities and other dental problems [3].

Moreover, while being a popular procedure teeth whitening can have an impact on the microelement composition of enamel. The majority of whitening methods are based on the use of carbamide peroxide or hydrogen peroxide, which can penetrate the enamel and break down pigments, resulting in a change in tooth color. However, these substances can also affect the microelement composition of tooth enamel, which may lead to potential negative consequences in the future.

Significant attention is being given to studying the changes that occur in the microelement composition of tooth enamel after professional cleaning. However, further research is needed for a deeper understanding of the impact of professional cleaning on the microelement composition of enamel.

In this article, we will examine the impact of professional teeth cleaning and whitening on the microelement composition of tooth enamel, as well as explore the potential consequences of these procedures for dental health [4,5].

## AIM

The objective of this study is to investigate the impact of professional teeth cleaning and the substances used in modern dentistry for whitening on the microelement composition of tooth enamel. Understanding these changes can be of significant importance for improving methods of prevention and treatment of dental diseases.

## MATERIALS AND METHODS

To achieve the objective, 60 previously extracted anterior teeth were investigated. To prevent dehydration of the hard tissues, all samples were stored in a physiological solution under normal conditions [6].

All specimens were divided into three groups:

Group I included extracted teeth that underwent a professional hygiene procedure (10 samples).

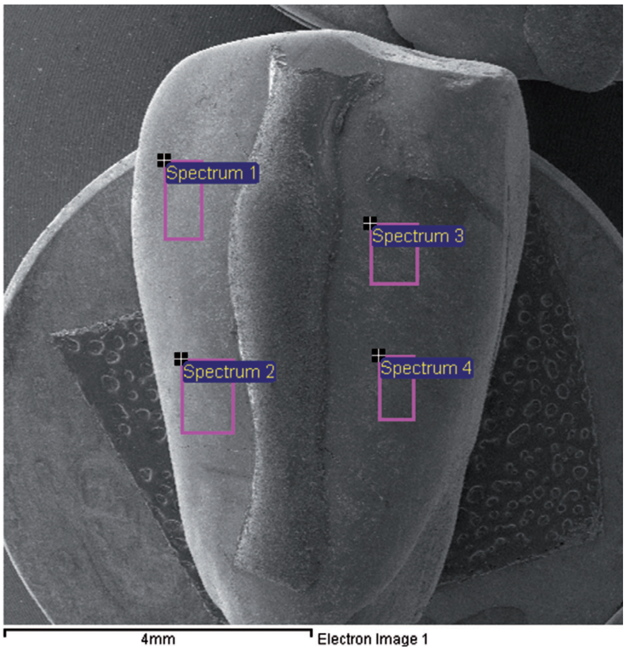



**Fig. 1.** Enamel surface of tooth 21 obtained by SEM with marked areas for surface elemental composition analysis.

Group II consisted of extracted teeth that underwent a prior professional hygiene procedure and were whitened using photoactivation with a 35% hydrogen peroxide (27 samples).

Group III included extracted teeth that underwent professional hygiene and were whitened using photoactivation with a 44% carbamide peroxide (23 samples).

The preparation process of the specimens involved the following steps:

1. Removal of hard and soft dental deposits was performed using an ultrasonic tip.
2. Enamel polishing was conducted using a medium--hardness nylon brush and Cleanic polishing paste (Kerr), with an RDA value of 27.
3 The professional whitening procedure was performed using a cold light lamp to activate the gel with either a 35% hydrogen peroxide concentration or a 44% carbamide peroxide concentration.

After the cleaning and whitening procedures, specific areas for microelement analysis of the enamel were determined (Fig. 1). In the examination of the microelement composition of the enamel, the studied tooth surfaces were divided into zones. The left half (Spectrum 1,2) served as the control zone, while the right half (Spectrum 3,4) served as the experimental zone. The boundary was established using liquid rubber dam.

For a detailed understanding of the changes in enamel morphology resulting from mechanical cleaning, a series of images were taken of the right and left sides of the tooth at various magnifications before and after the professional hygiene procedure (Fig. 2, 3).

After evaluating the morphological changes the determination of the microelement composition was

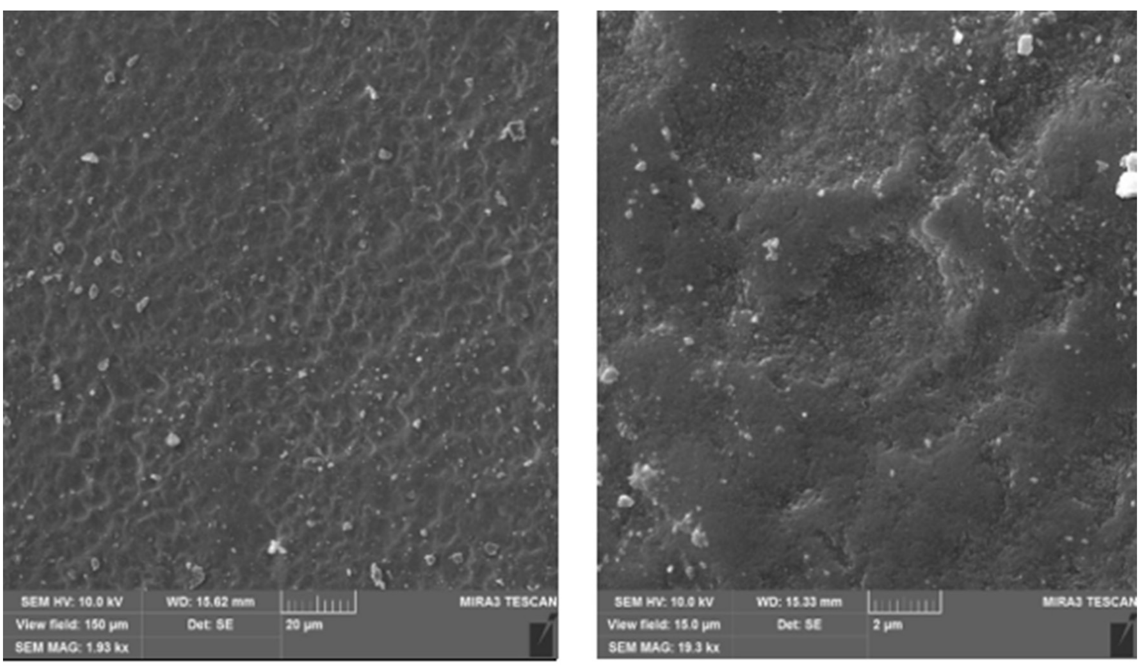



**Fig. 2.** Enamel surface of tooth 21 obtained by SEM (left side, before the mechanical cleaning procedure): A - 150 µm view field; B - field of view 150 µm view field.

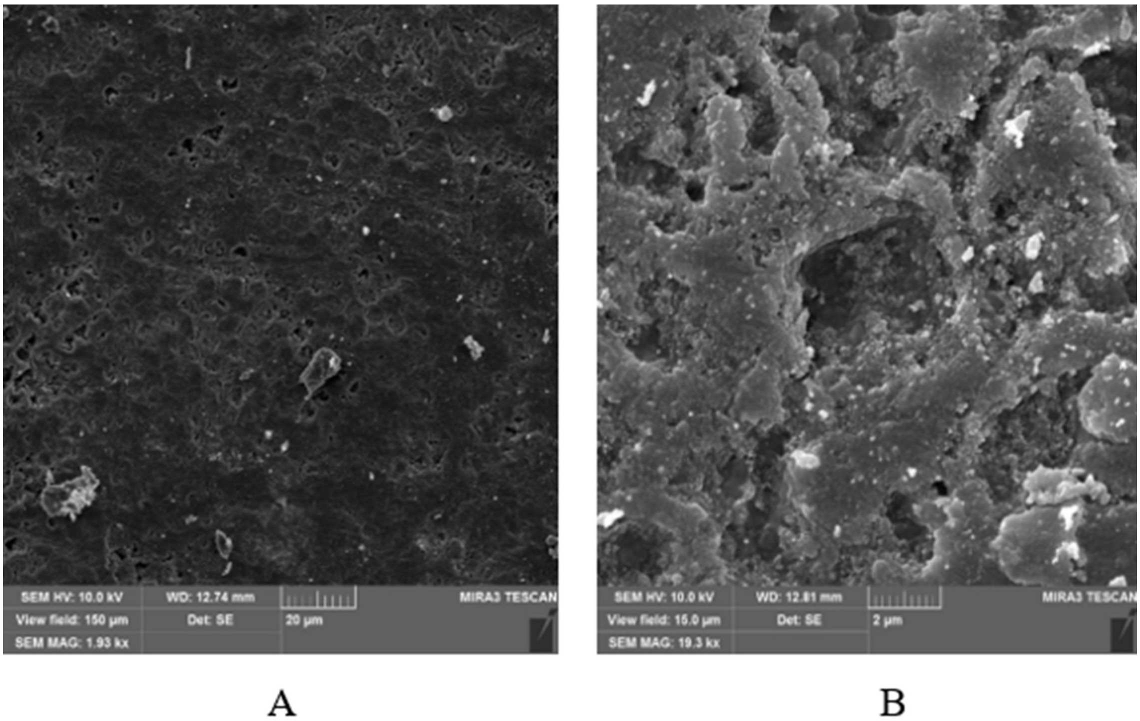



**Fig. 3.** Enamel surface of tooth 21 obtained by SEM (right side, after the mechanical cleaning procedure): A - 150 μm view field; B - field of view 150 μm view field.

carried out in selected areas on the right and left sides (Spectrum 1, 2, 3, 4) (Fig. 1).

To study the morphology and microelement composition of the enamel, scanning electron microscopy was performed using the MiraLM microscope equipped with a Schottky field emission electron gun from Tescan. The areas for microanalysis in the enamel zone were analyzed using the energy-dispersive spectrometer «X-max 80mm2» (Oxford Instruments, UK), which was integrated into the microscope.

After obtaining the results, they were subjected to statistical analysis using the analysis of variance (ANOVA) method. The data were recorded in the «Microsoft Excel 2010» program, and statistical calculations were performed using «IBM SPSS Statistics V22».

## RESULTS

A comparative analysis between the areas subjected to mechanical cleaning and those where it was not applied revealed a significant difference in the research results, particularly in carbon, which changed from 25.16±1.04 to 32.02±1.8. This suggests surface changes in the enamel resulting from mechanical treatment without affecting the crystalline lattice of calcium hydroxyapatite but leading to the formation of free carbon ions that can further participate in chemical reactions. A significant difference was also found in the oxygen level, with initial values of 31.87±0.75 changing to 36.44±0.68, indicating a disturbance in the crystalline lattice of hydroxyapatite and increased activity towards interaction and substitution of certain microelements. This may have implications for the course and activity of chemical reactions with chemical whitening agents that have different compositions and activities, while the oxygen activity, as indicated, increases (Table 1).

For other chemical elements, certain changes in the indicators were observed. There was a slight increase in the amount of phosphorus, aluminum, and gold from 14.4 to 14.54, from 0 to 0.05, and from 0 to 1.37, respectively. Additionally, there was a slight decrease in the amount of chlorine, nitrogen, and magnesium from 0.86 to 0.79, from 0.25 to 0, and from 0.02 to 0, respectively. However, these changes were not statistically significant (Tab. 1, Fig. 3).

Analyzing the obtained data regarding the comparison of groups II and III (Fig. 4, 5), where different bleaching systems were used, the following changes in morphology and elemental indicators can be noted.

When comparing the indicators related to the chemical composition of the enamel before the whitening procedure and after the use of whitening agents such as 35% hydrogen peroxide, an evaluation of the obtained indicators regarding changes in the chemical composition was conducted. An analysis of the enamel's chemical composition before and after whitening revealed a decrease in carbon from 45.91±1.20 to 42.46±1.74. The change in phosphorus content was determined to be from 9.77±0.39 to 9.56±0.75. A decrease in calcium from 15.96±0.64 to 15.21±1.22 and magnesium from 0.07±0.01 to 0.01±0.01 was also observed. On the other hand, an increase was observed in the following elements: oxygen from 23.03 to 26.18, sodium from 0.38 to 0.57, silicon from 0.37 to 0.68, and nitrogen from 2.89 to 4.35.

When examining the statistical differences between the investigated trace elements, no significant differences

**Table 1.** Comparison of the average elemental composition in the studied group of teeth with mechanical cleaning

| Researched trace elements | Native enamel,N = 10 | Enamel after mechanical cleaning, N = 10 | p |
|---|---|---|---|
| C | 25,16±1,04 | 32,02±1,8* | 0,001 |
| O | 31,87±0,75 | 36,44±0,68* | 0,000 |
| Na | 0,49±0,04 | 0,49±0,02 | 0,998 |
| P | 14,40±0,48 | 14,54±0,31 | 0,805 |
| Cl | 0,86±0,07 | 0,79±0,06 | 0,458 |
| Ca | 23,75±0,88 | 23,67±0,52 | 0,941 |
| Si | 0,00±0,00 | 0,05±0,04 | 0,212 |
| N | 0,25±0,25 | 0,00±0,00 | 0,309 |
| Mg | 0,02±0,013 | 0,00±0,00 | 0,152 |
| Al | 0,00±0,00 | 0,01±0,01 | 0,168 |
| Au | 0,00±0,00 | 1,37±0,66* | 0,047 |

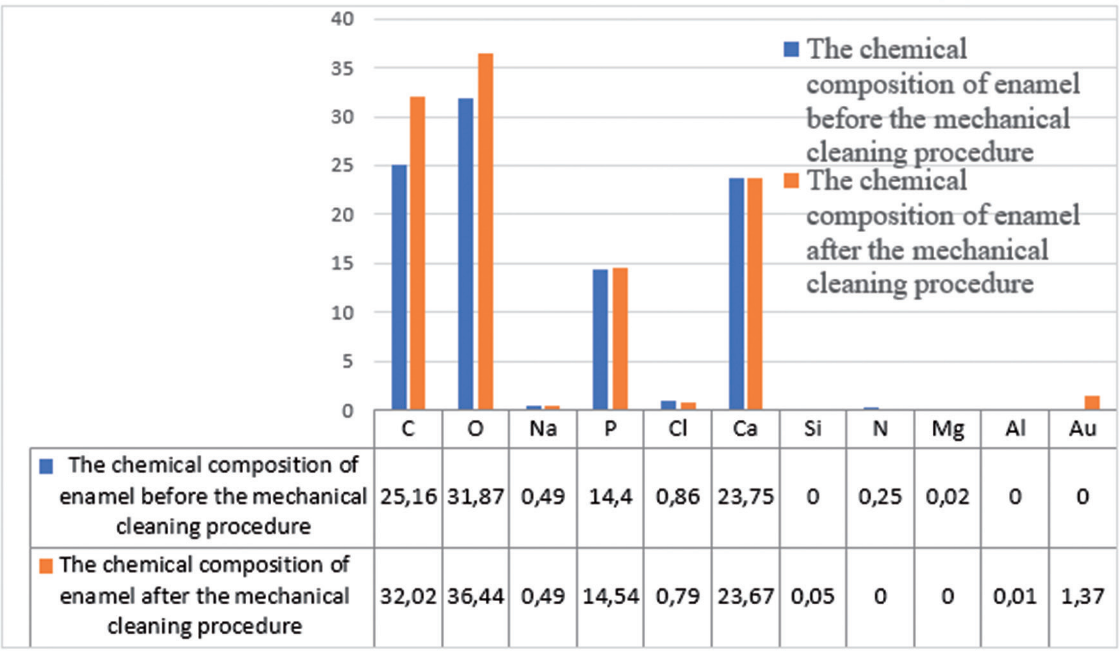



**Fig. 4.** Changes in the chemical composition of enamel before and after the mechanical cleaning procedure.

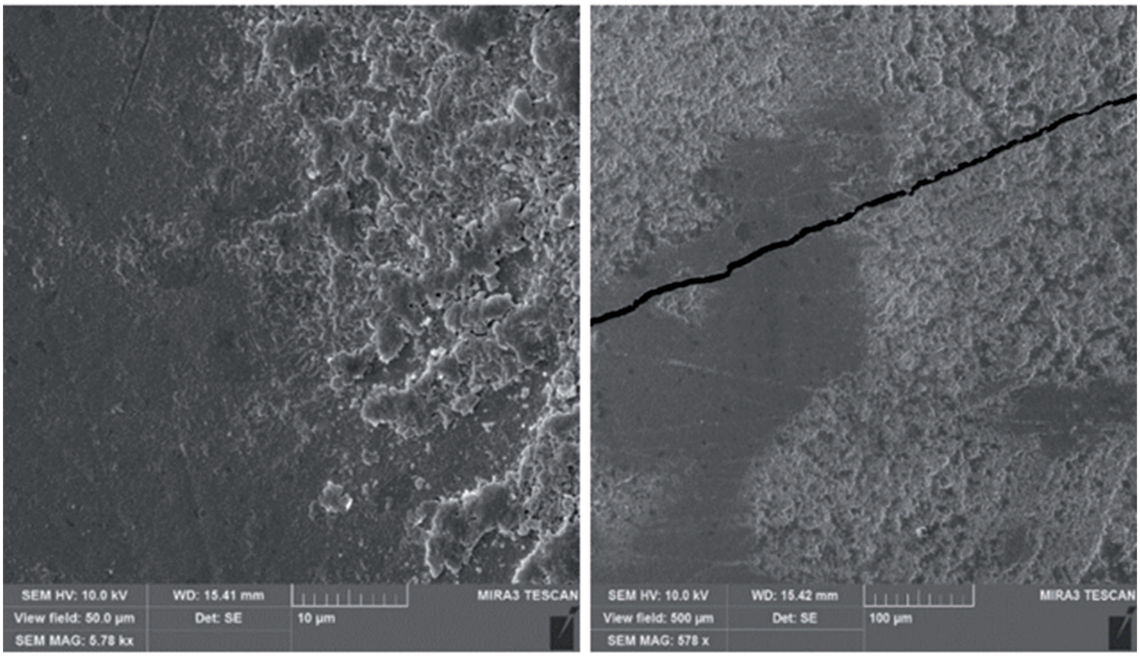
were found for the carbon indicators, which may indicate that carbon enters into a chemical reaction already after mechanical cleaning and the application of hydrogen peroxide as the main component of the whitening system, binding with active trace elements. Differences between the indicators relate to oxygen as one of the most active trace elements (p=0.007), sodium (p=0.06), which is responsible for retaining oxygen and hydrogen, as well as Mg, F, and Ba.

After conducting research using 35% hydrogen peroxide and 44% carbamide peroxide, differences in trace element indicators were observed before the whitening procedure and after its completion. The reliability of changes in trace element indicators and their list varied for the applied components of the whitening systems.

In Figure 6, we present a sample of enamel surface examination after professional tooth cleaning and the application of 44% carbamide peroxide.

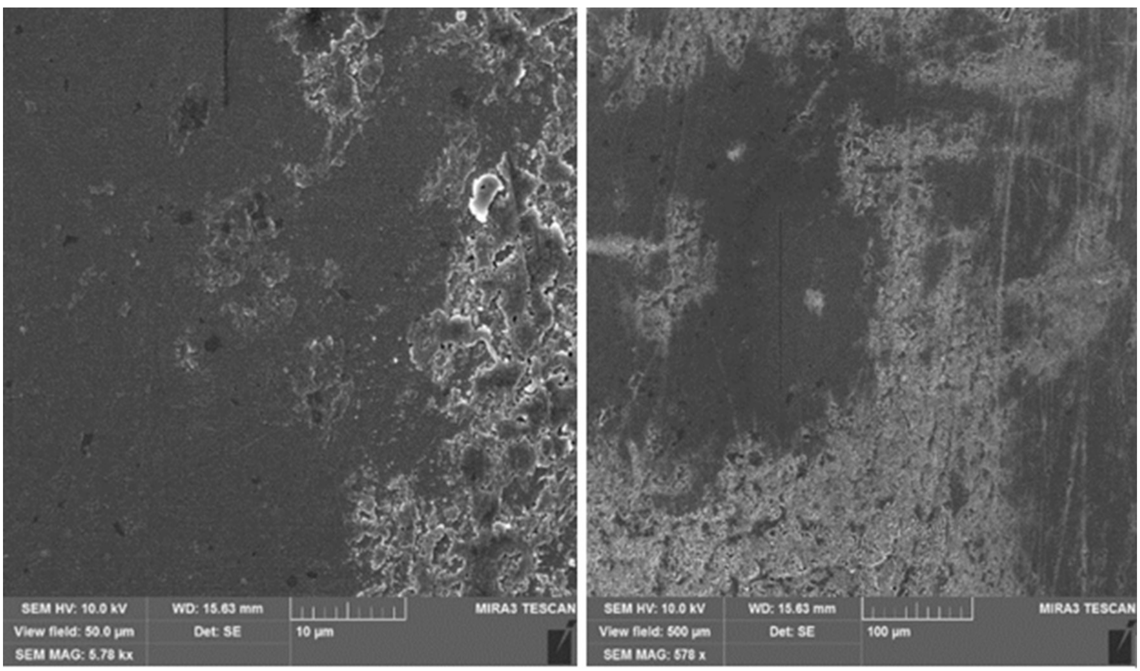
We also observed differences in the morphological characteristics of enamel in the experimental teeth when using different types of whitening systems. The difference was evident when comparing images obtained after tooth whitening. Figures 7 (A and B) and 8 (A and B) present images of teeth treated with 38% hydrogen peroxide and 44% carbamide peroxide as whitening agents, respectively.

The electron micrographs provided show the same magnification but reveal different structures in terms of the distribution of the whitening agent on the enamel




A B

**Fig 5.** Enamel surface of tooth 11 obtained by SEM (control zone): A - field of view 50 µm; B - field of view 500 µm.



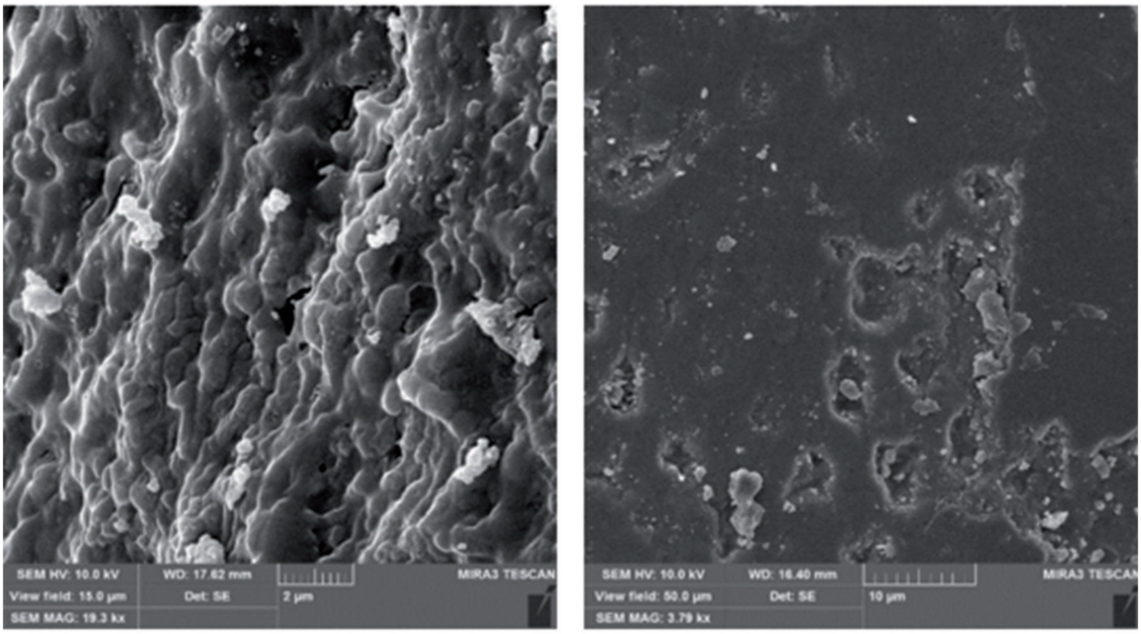

A B

**Fig 6.** Enamel surface of tooth 11, obtained by the SEM method (after professional cleaning and hydrogen peroxide application): A - field of view 50 µm; B - field of view 500 µm.

surface, which will subsequently lead to differences in the quantity of microelements on the enamel surface.

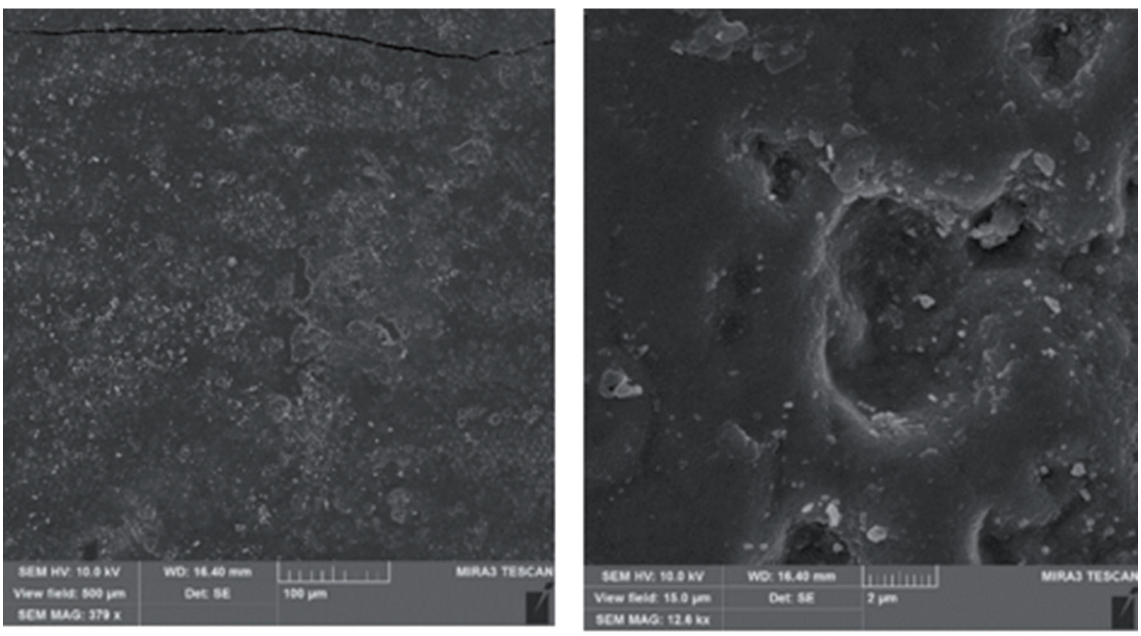
Table 2 presents a comparison of the enamel's chemical composition indicators in normal conditions and when using whitening agents with 44% carbamide peroxide and 35% hydrogen peroxide.

The study revealed a significant decrease in the levels of carbon, oxygen, sodium, chlorine, magnesium, and aluminum ($p \leq 0.05$). There was also a slight decrease in the level of nitrogen from 2.17±0.25 to 1.54±0.47 and an increase in the level of magnesium from 0.04±0.01 to 0.1±0.03. The alteration of these indicators will significantly




A B

**Fig. 7.** Enamel surface of tooth 21 enamel obtained by the SEM method after professional cleaning and application of 44% carbamide peroxide: A - field of view 15 µm; B - field of view 50 µm.




A B

**Fig. 8.** Enamel surface of tooth 11 obtained by the SEM method, the research protocol, the area after professional cleaning and application of carbamide peroxide: A - field of view 500 µm; B – field of view of 15 µm

impact the clinical indicators and manifestations, depending on the characteristics of enamel's functional and structural resistance.

Additionally, the calcium content increased in Group III (18.81±0.48) compared to the experimental samples in Group II (15.21±1.22). As for nitrogen levels, a significant difference was observed: the level for Group II was 4.35±0.76, while for Group III, it was 1.54±0.47.

Through the analysis of microelements in the experimental groups using different whitening systems, statistically significant differences in carbon levels were found: from 42.46±1.74 when using hydrogen peroxide to 44.92±1.90 when using

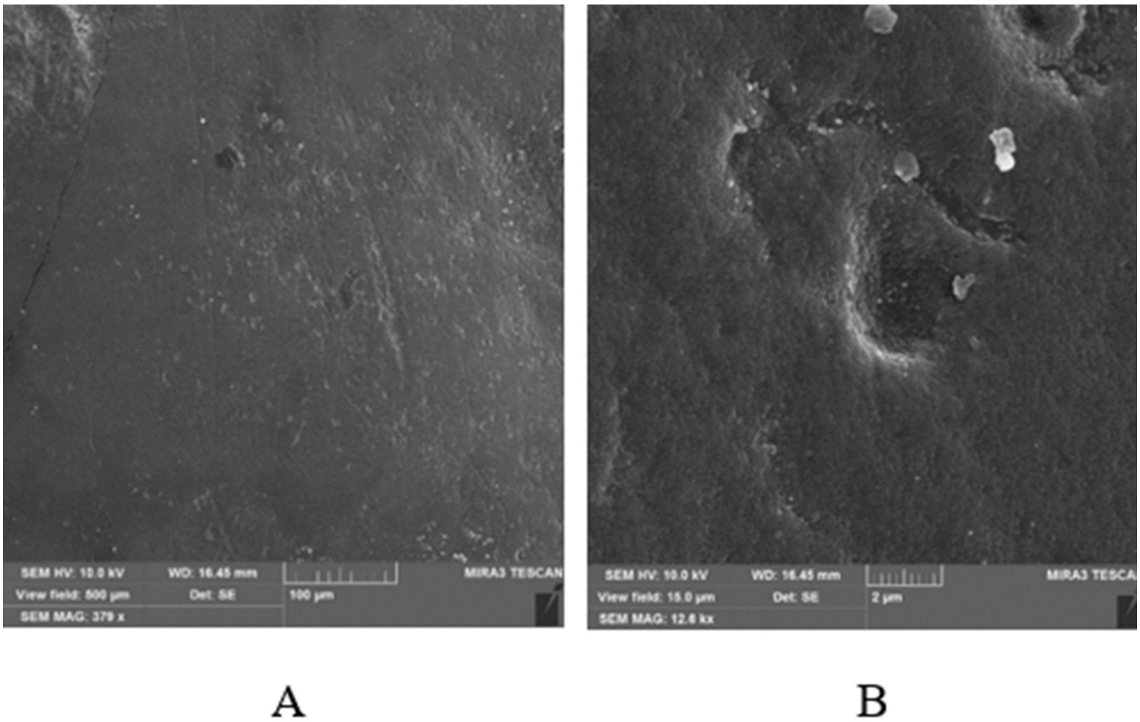



**Fig. 9.** Enamel surface of tooth 21 obtained by SEM, zone after professional cleaning and application of carbamide peroxide: A – field of view 500 µm; B – field of view of 15 µm

**Table 2.** Comparison of the average elemental composition of tooth enamel in normal conditions and after the application of bleaching agents with hydrogen peroxide 35% and carbamide peroxide 44% between the study indicators (M±m), (data are given in weight %)

| Researched trace elements | Microelement composition of enamel before the whitening procedure (N =50) | Microelement composition of enamel after hydrogen peroxide application (N=27) | Microelement composition of enamel after carbamide peroxide application (N=23) | p |
|---|---|---|---|---|
| C | 45,91±1,20 | 42,46±1,74 | 44,92±1,90 | 0,008 |
| O | 23,03±0,63 | 26,18±0,81 | 20,74±1,01 | 0,007 |
| Na | 0,38±0,03 | 0,57±0,05 | 0,224±0,03 | 0,006 |
| P | 9,77±0,39 | 9,56±0,75 | 12,11±0,51 | 0,792 |
| Cl | 0,14±0,03 | 0,16±0,53 | 0,19±0,06 | 0,654 |
| Ca | 15,96±0,64 | 15,21±1,22 | 18,81±0,48 | 0,570 |
| Si | 0,37±0,10 | 0,68±0,30 | 0,16±0,098 | 0,213 |
| N | 2,89±0,40 | 4,35±0,76 | 1,54±0,47 | 0,075 |
| Mg | 0,07±0,01 | 0,01±0,01 | 0,01±0,03 | 0,034 |
| Al | 0,06±0,02 | 0,09±0,04 | 0,01±0,00 | 0,475 |
| Au | 0,37±0,56 | 0,00±0,00 | 0,37±0,66 | 0,143 |
| F | 0,00±0,00 | 0,02±0,01 | 0,05±0,03 | 0,004 |
| Ba | 0,00±0,00 | 0,45±0,25 | 0,38±0,00 | 0,004 |

whiteners based on 44% carbamide peroxide at p=0.008. Changes in oxygen levels were also observed, from 26.18±0.81 to 20.74±1.01, with a significance difference of 0.007. The sodium content changed from 0.57±0.05 to 0.224±0.03 at p=0.006, and the fluoride quantity changed from 0.02±0.01 to 0.05±0.03 with a significance difference of 0.004.

Evaluating the obtained indicators when comparing Groups II and III where different whitening systems were used we can mention changes in the indicators for phosphorus: 9.56±0.75 for Group II and 12.11±0.51 for Group III. There was an increase in the level of calcium in Group III: 18.81±0.48 compared to 15.21±1.22 in the experimental samples of

Group II. A significant difference in nitrogen levels can be observed: the level for Group II was 4.35±0.76, while for Group III, it was 1.54±0.47.

By analyzing the microelement indicators in the experimental groups using different whitening systems, statistically significant differences were obtained for carbon levels, ranging from 42.46±1.74 when using hydrogen peroxide to 44.92±1.90 when using whiteners based on 44% carbamide peroxide ($p=0.008$). There were changes in oxygen levels, from 26.18±0.81 to 20.74±1.01, with a significance difference of 0.007. The sodium content changed from 0.57±0.05 to 0.224±0.03 at $p=0.006$ and the fluoride quantity changed from 0.02±0.01 to 0.05±0.03 with a significance difference of 0.004.

These changes in the indicators will significantly impact the alteration of clinical indicators and clinical manifestations.

## DISCUSSIONS

The observed significant differences in carbon and oxygen levels may indicate surface changes in the enamel that are likely not associated with changes in the microelement composition of tooth enamel but rather with the breakdown of dental plaque (pellicle) and mineralized dental deposits on its surface, as evidenced by electron micrographs (Fig. 1, 2) [7].

After professional teeth cleaning, the temporary increase in the quantity of free carbon and oxygen ions on the tooth enamel should be associated with the process of oxygenation, i.e., improved oxygen access to the tooth enamel. This phenomenon may have a beneficial effect on the condition of the tooth enamel [8]. Free carbon ions can contribute to the neutralization of acidic substances and reduce the risk of developing caries, while oxygen ions can have antimicrobial effects and promote gum healing and overall oral health [9]. Cleaning the enamel surface also improves the access of whitening agents, adhesive systems, and conditioning solutions to the enamel, thereby increasing their effectiveness [10].

Regarding the change in the microelement composition of enamel after whitening, it should be noted that as a result of the chemical reactions of bleaching agents with organic substances in the enamel, the breakdown of carbonates and the removal of carbon from the enamel structure may occur. This leads to a decrease in carbon content in the enamel after whitening [3,11].

During the interaction of hydrogen peroxide with enamel, its molecules decompose, releasing oxygen ($O_2$) molecules. This oxygen can penetrate the structure of tooth enamel, increasing the amount of oxygen present in the enamel. This process occurs through the oxidation of organic compounds contained in the enamel and the alteration of their chemical structure. When carbamide peroxide interacts with enamel and stains on the tooth surface, it breaks down into carbamide molecules and oxides. The oxides can be released in the reaction process, leading to the removal of stains and pigments on the teeth. The formed oxides may contain oxygen, which can result in a decrease in the amount of oxygen in the enamel [3,11].

Tooth whitening with carbamide peroxide may cause a decrease in sodium content in tooth enamel because when carbamide peroxide interacts with enamel and stains on the tooth surface, it breaks down into carbamide molecules and oxides. These oxides can interact with enamel minerals, including sodium, and contribute to their removal from the enamel. This can lead to a reduction in the amount of sodium in the enamel after whitening [12].

## CONCLUSIONS

Professional dental hygiene does not have a direct impact on the microelement composition of enamel, such as the levels of calcium, phosphorus, fluoride, and other microelements. However, it can have an indirect and temporary influence due to the use of abrasive materials that affect dental deposits, pellicle, and the surface layer of enamel.

Mechanical cleaning and teeth whitening with various systems can affect the microelement composition of tooth enamel. The use of hydrogen peroxide during teeth whitening can increase the amount of oxygen in dental enamel. This may be related to the oxidizing properties of hydrogen peroxide, which promote changes in the chemical structure of enamel. The use of carbamide peroxide during teeth whitening can decrease the amount of oxygen in dental enamel. The reasons for this effect may be related to the peculiarities of the chemical reaction that occurs during the interaction of carbamide peroxide with enamel.

For discolorations, both external and internal, mechanical cleaning methods and chemical agents can be used. In our study, a comparison of the chemical composition of the tooth enamel surface was performed when using professional hygiene and the application of carbamide peroxide and hydrogen peroxide as chemical components of the system for influencing tooth enamel.

After conducting experimental research and establishing discrepancies regarding the main elements, we may be able to choose whitening agents in a dental clinic based on clinical and laboratory research data, with appropriate prescription of remineralizing agents with a specified quantity of chemical elements depending on the choice of the whitening component.

Overall, it may be concluded that teeth whitening can affect the microelement composition of enamel, but these changes are mostly temporary and associated with processes of demineralization/remineralization and oxygenation.

### References

1. Vodoriz Y, Lemeshko A, Marchenko I, Shyndryk M, Tkachenko I, Kov. Assessment of quality of life in patients who require treatment in anterior dentition. Visnyk problem biolohiyi i medytsyny. 2019;4(1):296–300.
2. Bali C, Gurdet C, Hauer G, Handler I, Fischer R. Evaluation of the effect of professional dental cleaning and education in dental hygiene in type 1 diabetic patients. Acta Med Austriac. 1999;26(5):159–62.

3. Dvornyk A V, Tkachenko IM, Pysarenko OA, Vodoriz YY, Dvornyk VM, Brailko NM. Experimental study of changes in the chemical composition of tooth enamel when using hydrogen peroxide as the main chemical component in professional bleaching. Wiad Lek. 2022;75(7):1683–7.
4. Reitznerová E, Amarasiriwardena D, Kopčáková M, Barnes RM. Determination of some trace elements in human tooth enamel. Fresenius J Anal Chem. 2000;367(8):748–54. doi:10.1007/s002160000461.
5. Teutle-Coyotecatl B, Contreras-Bulnes R, Rodríguez-Vilchis LE, Scougall-Vilchis RJ, Velazquez-Enriquez U, Almaguer-Flores A, et al. Effect of Surface Roughness of Deciduous and Permanent Tooth Enamel on Bacterial Adhesion. Microorganisms. 2022;10(9).
6. Flores MT, Malmgren B, Andersson L, Andreasen JO, Bakland LK, Barnett F, et al. Guidelines for the management of traumatic dental injuries. III. Primary teeth. Dent Traumatol. 2007;23(4):196–202.
7. Fischer NG, Aparicio C. The salivary pellicle on dental biomaterials. Colloids Surfaces B Biointerfaces. 2021;200:111570.
8. Sundfeld D, Pavani CC, Pavesi Pini NI, Machado LS, Schott TC, Bertoz AP de M, et al. Esthetic recovery of teeth presenting fluorotic enamel stains using enamel microabrasion and home-monitored dental bleaching. Vol. 22, Journal of conservative dentistry : JCD. India; 2019. p. 401–5.
9. Chen H, Gu L, Liao B, Zhou X, Cheng L, Ren B. Advances of Anti-Caries Nanomaterials. Molecules. 2020;25(21):5047. doi: 10.3390/molecules25215047.
10. Mushashe A-M, Coelho B-S, Garcia P-P, Rechia B-CN, da Cunha L-F, Correr G-M, et al. Effect of different bleaching protocols on whitening efficiency and enamel superficial microhardness. J Clin Exp Dent. 2018 Aug;10(8):e772–5.
11. Mayer-Santos E, Maravic T, Comba A, Freitas PM, Marinho GB, Mazzitelli C, et al. The Influence of Different Bleaching Protocols on Dentinal Enzymatic Activity: An In Vitro Study. Molecules. 2022 Mar;27(5).
12. Dvornyk A V., Dvornyk VM, Vodoriz YY, Skripnykov PM, Tkachenko IM. Clinical Features of Influence of Different Groups of Bleaching Agents in the Oral Cavity At Different Periods After the End of the Treatment. World Med Biol. 2022;18(80):56.



**ORCID AND CONTRIBUTIONSHIP**

Anna V. Dvornyk: 0000-0002-3660-3239[A,B]
Yaroslav Y. Vodoriz: 0000-0001-9388-1270[C,D]
Oleg A. Pysarenko: 0000-0002-6104-6745[E,C]
Iryna Y. Marchenko: 0000-0001-7092-1786[A,E]
Iryna M. Tkachenko: 0000-0001-8243-8644[A,E,F]


**CONFLICT OF INTEREST**

The Authors declare no conflict of interest


**RECEIVED:** 27.04.2023
**ACCEPTED:** 03.09.2023



**ADDRESS FOR CORRESPONDENCE**

**Iryna M. Tkachenko**
Poltava State Medical University
23 Shevchenko St., 36011 Poltava, Ukraine
e-mail: tkachenkoirmix@gmail.com




* Contribution: A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval.