

ORIGINAL ARTICLE

CONTENTS

Influence of elemental composition on the stability of restorative structures in permanent teeth in children from different geographical areas of residence

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ABSTRACT

Aim: To evaluate the correlation between the mineral composition of the hard tissues of the teeth and the percentage of defects and loss of various restorative materials in permanent teeth in children living in the lowland and mountainous geographical zones of Transcarpathian region.

Materials and Methods: 1050 permanent teeth of different groups filled with different materials were studied. An ultra-microscopic examination by the method of raster electron microscopy was carried out and the mineral composition of the teeth was evaluated. On the AZtecOne microanalytical accelerator complex with the X-MaxN20 detector.

Results: Improbable differences in indicators were established in children living in lowland and mountainous areas of Zakarpattia region, when using glass ionomer cements both after 6 months (6.7%; 7.2%; p>0.05) and after 12 months. months (20.0%; 16.3%; p>0.05); with direct composite restorations after 6 months (4.4%; 6.0%; p>0.05) and after 12 months (9.6%; 11.1%; p>0.05); with indirect composite restorations after 6 months (2.1%; 4.0%; p>0.05) and after 12 months (10.5%; 10.0%; p>0.05).

Conclusions: The reason for the higher percentage of fillings made of glass ionomer cements in the permanent teeth of children from mountainous areas is the significantly lower calcium content and their mineral composition (p>0.05)

KEY WORDS: permanent teeth, restorative structures, glass ionomer cements, light-curing composites, indirect restorations

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INTRODUCTION

The restoration of the lost hard tissues of the teeth is carried out by direct and indirect fixed structures made of various types of restorative materials according to the indications [1]. Direct restorations mean fillings using glass ionomer cements (GC) and composites, mostly light-cured, and indirect restorations include inlays, veneers, and when more than 2/3 of the tooth tissue volume is lost, crowns [2]. With strict adherence to manufacturing technologies, all types of modern structures are durable, which will satisfy aesthetic and functional requirements. However, even in the absence of manufacturing errors, defects may occur in restorative structures, even their complete loss [3, 4]. An important etiological role in this is played by the condition of the hard tissues of the teeth, in particular, the mineral composition [5-7]. The mineral state of permanent teeth largely depends on the intake of minerals into the human body with drinking water and food [8]. Drinking water has physical and chemical characteristics specific to different geographical zones and regions of residence [9]. The Transcarpathian region, which is a natural zone of biogeochemical deficiency of fluorine and iodine, is an unfavorable background for the formation of a dental prosthesis system in children who live permanently in these territories and consume drinking water available for these territories [10].

The question of the influence of the mineral composition of the hard tissues of permanent teeth and the stability of restorative structures has not been given sufficient importance in the scientific literature, which served the purpose of our study.

AIM

The aim of the study was to assess the correlation between the mineral composition of the hard tissue of the teeth and the percentage of defects and the loss of various restorative structures in the permanent teeth of children living in the lowland and mountainous geographical zones of the Transcarpathian region.

MATERIALS AND METHODS

525 medical records of dental patients (form 043) of patients of lowland (Uzhgorod) and mountain (Rakhiv) geographic areas of residence in the Transcarpathian region were subjected to paraclinical content analysis to evaluate the performed restorative structures in permanent teeth and their dispensary observation after 6 and 12 months after treatment. Statistical analysis was carried out on the basis of 1050 filled permanent teeth (630 in children from the lowland area of residence and 420 from the mountain area), their distribution was carried out by group affiliation and by the material from which the filling was made. An ultra-microscopic study was carried out by the method of raster electron microscopy (electron microscope SEO-SEM Inspect S50-B) and the mineral composition of the teeth was assessed (characteristic X-ray radiation induced by a proton beam (PIXE, μ-PIXE methods) was carried out on the AZtecOne microanalytical accelerator complex with the X-MaxN20 detector (manufacturer Oxford Instruments plc) B, (Sumy State University, Ukraine). Statistical research was carried out using the standard program Microsoft Excel, 2010 and the package of statistical programs «Statistica 13.0» [11-13].

RESULTS

Restorative structures in permanent teeth are represented by direct restorations, that is, fillings made of light-curing composite materials and glass ionomer cements, and indirect restorations in the form of inlays and veneers.

The percentage distribution in relation to the material of restorative structures was as follows: fillings made of light-curing composite materials accounted for 88.1%, of which 38.1% were in molars, 30.2% in incisors, 12.7% in premolars, 7.1% in canines ; fillings made of glass ionomer cements accounted for 2.4%, of which in molars - 1.6%, in premolars - 0.8%; indirect restorations accounted for 9.5%, of which 3.9% in molars, 3.2% in incisors, and 2.4% in canines.

Figure 1 shows the percentage ratio of the number of filled permanent teeth with different types of materials in lowland and mountainous geographical zones (Fig. 1).

Therefore, the number of permanent teeth treated with glass ionomer cements in the lowland geographical area (the city of Uzhhorod) is different compared to the mountainous geographical area (the city of Rakhiv). Yes, incisors and canines were not filled with this material; premolars filled (5-4.7=) by 0.3 percent more in Rakhiv; molars - by (10-8.3=) 1.7 percent more in the lowland zone. Regarding the use of direct composite restorations: incisors filled more in Uzhhorod by 13.5 percent; canines - by 1.2 percent, molars - by 1.2 percent; premolars filled 2.8 percent less. Regarding indirect restorations, inlays or veneers: mainly molars were treated in the city of Rakhiv - a mountainous geographical area with an index of 7.2 - the maximum compared to other teeth and a lowland geographical area.

In general, the percentage of teeth treated with the materials analyzed above is higher compared to such treatment carried out in Uzhhorod for incisors and canines and in Rakhiv for premolars and molars (Fig. 2).

Figure 3 shows the total percentage of filled teeth in the two geographical areas studied for permanent teeth. From the figure, there is an obvious advantage of using direct composite restorations in Uzhhorod and a slightly lower percentage of the use of this treatment in Rakhiv (Fig. 3).

Thus, the share of permanent teeth filled with different types of restorative materials relative to the two studied geographical areas and types of teeth is presented as follows: in general, the share of use of these materials for the treatment of permanent teeth is different in different geographical areas. In all cases, the difference is small, from 0.5 to 1.8, and in total up to 5.0 for indirect restorations - inlays, veneers.

Figure 4 presents the results of the obtained data regarding the placed fillings and their defects in permanent teeth for the lowland and mountainous geographical zones of the Transcarpathian region, which were treated with glass ionomer cements (Fig. 4).

It is noticeable that in both geographical zones the defects and loss of teeth are similar quantitatively and after a year they prevail mainly in the lowland zone. It is also evident that the rate of filling defects or loss increases by 12 months in both geographic areas for all types of teeth.

Figure 5 shows the percentage distribution of fillings placed for direct composite restorations in two geographic areas (Fig. 5).

The number of defects and loss of fillings increases reliably up to 12 months in molars.

Figure 6 shows the results of teeth treatment through indirect restorations - inlays, veneers in percentage. Also shown are the indicators of fillings and defects after 6 and 12 months with this material. It is obvious that premolars and molars were treated the least with this material (Fig. 6).

The number of defects is the highest after 12 months in both geographical areas.

According to the results of the correlation analysis of the relationship between the materials used for the treatment of permanent teeth in terms of the prevalence of tooth defects after 6 and 12 months, the following pairs were established that showed a reliable

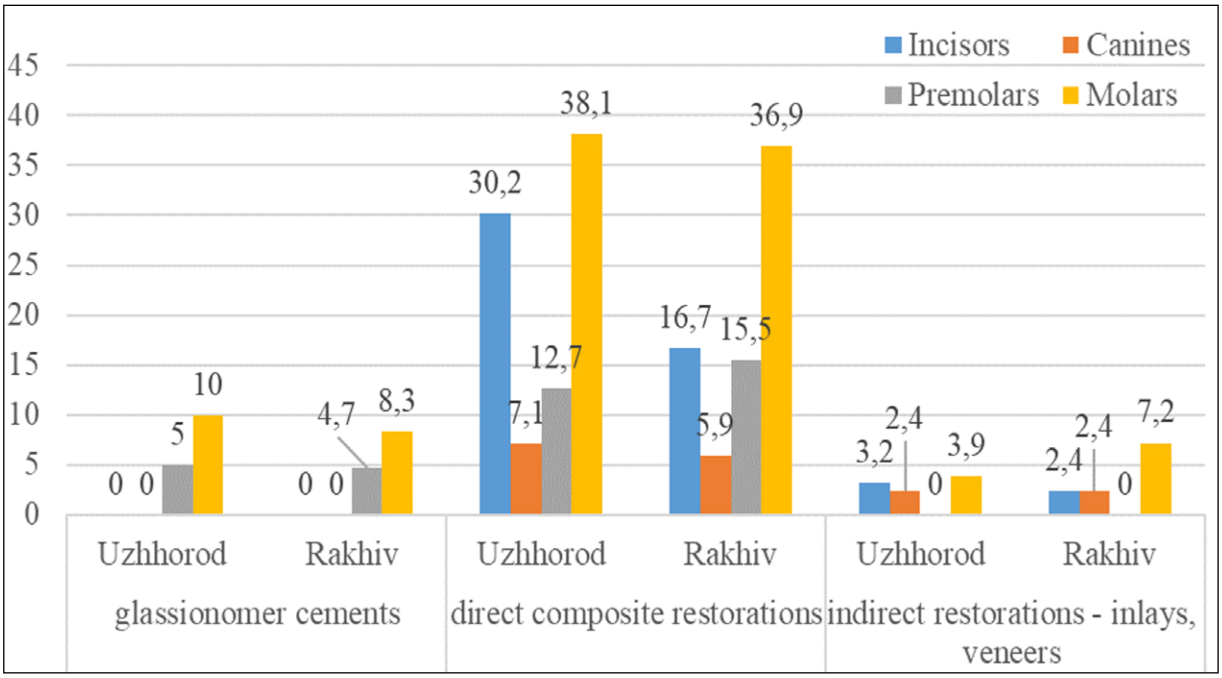

Fig. 1. The percentage ratio of the number of filled permanent teeth with different types of materials in lowland and mountainous geographical zones.

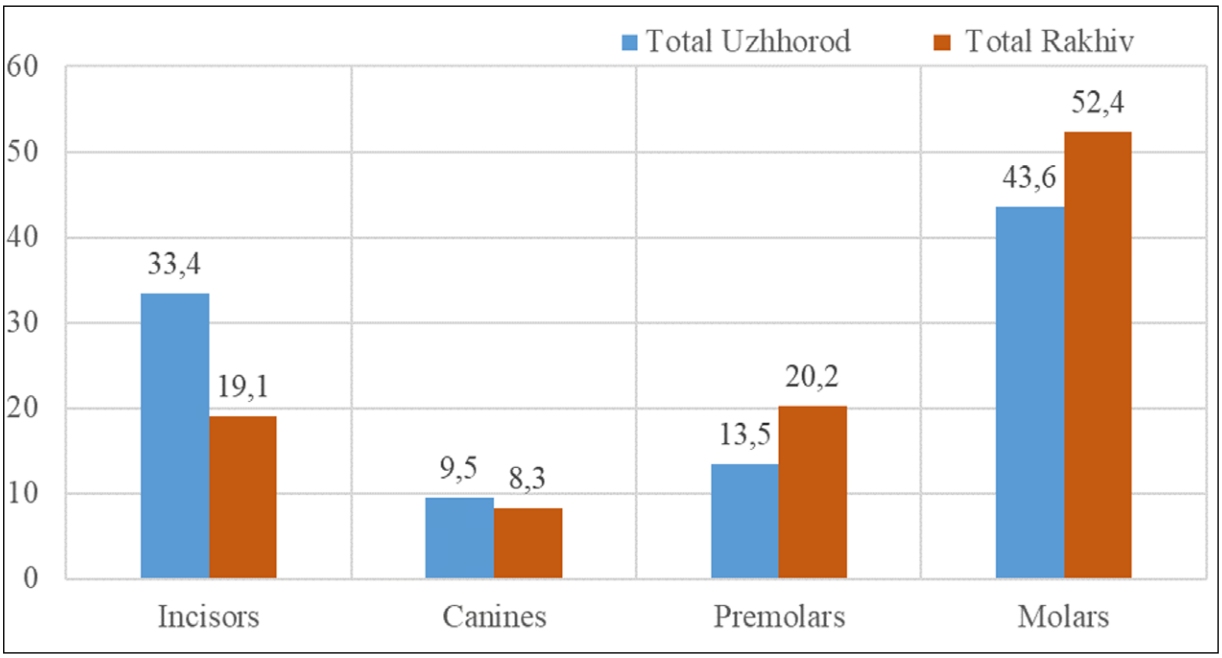

Fig. 2. Total percentage of filled permanent teeth with different restorative materials.

relationship, where GC – Glass ionomer cements; DCR - Direct composite restorations; IR – Indirect restorations, LZ - lowland zone, MZ - mountain zone.

GC, placed fillings (LZ) and GC, defects 6 months (LZ), IR, defects 6 months (LZ), IR, defects 6 months (MZ) with R=0.88; P<0.05 and DCR, defects 6 months (MZ), DCR, defects 12 months (MZ) with R=0.92; P<0.05.

GC, placed fillings (MZ) and GC, defects 6 months (LZ), IR, defects 6 months (MZ), IR, defects 6 months (MZ) with R=0.88; P<0.05 and DCR, defects 6 months (MZ), DCR, defects 12 months (MZ) with R=0.92; P<0.05.

DCR, placed fillings (LZ) and DCR, defects 6 months (MZ), DCR, defects 12 months (MZ) with R=0.97; P<0.05; and IR, placed fillings (IR) with R=0.90; P<0.05.

DCR, placed fillings (MZ) and DCR, defects 6 months (MZ), DCR, defects 12 months (MZ) with R=0.97; P<0.05; and IR, placed fillings (IR) with R=0.90; P<0.05.

IR, placed fillings (LZ) and DCR, placed fillings (LZ), DCR, placed fillings (MZ), DCR, defects 6 months (LZ), DCR, defects 12 months (LZ), IR, defects 12 months

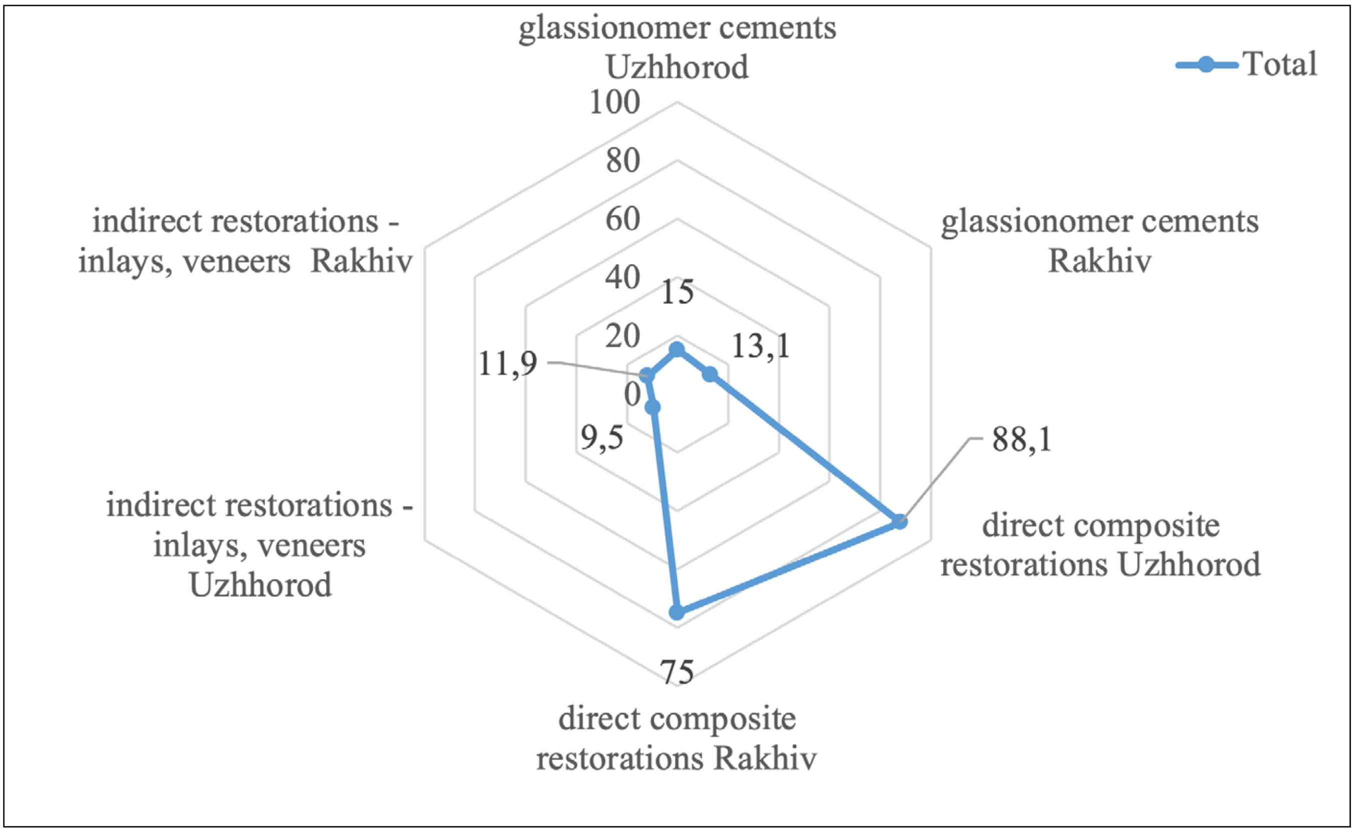

Fig. 3. Distribution of the prevalence of various restorative structures and fillings in permanent teeth by group affiliation of teeth in children who live in two geographical zones together.

(LZ) with R=0.90; P<0.05; and IR, placed fillings (MZ), IR, defects 12 months (MZ) with R=0.97; P<0.05.

IR, placed fillings (MZ) and GC, defects 6 months (LZ), IR, defects 6 months (LZ), IR, defects 6 months (MZ) with R=0.89; P<0.05; and IR, fillings placed (LZ), IR, defects 12 months (LZ) with R=0.97; P<0.05.

Thus, it can be seen that the correlation indicators are very high and amount to R=0.90 with a statistical significance level of p<0.05. Figure 7 presents the results of the cluster analysis, which shows the degree of difference or similarity between the studied indicators. It is noticeable that there is a certain similarity between the group of materials - glass ionomer cements and compomers and their difference from light curing composite materials. The figure shows only the presence of two separate groups - placed seals and defects (Fig. 7).

Somewhat separately, forming a subgroup, defects were placed after 12 months in the lowland and mountain zone for teeth treated with glass ionomer cements, which may indicate some difference relative to all other materials and defects.

Table 1 shows the results of spectral measurement of the weight of elements present in the enamel and dentin of permanent teeth in children from lowland and mountainous geographical areas (Table 1).

Only 9 elements are observed in different quantities. All elements are present in the teeth of both geographical areas. It can be seen from the table that in the enamel and dentin of the patients' teeth, carbon C (51.34%; 45.79%; p<0.05) prevails in the lowland zone and oxygen O (52.13%; 52.42%; p< 0.05) in the mountain zone. Figure 8 shows the average weight of microelements of enamel and dentin in % (Fig. 8).

Al is also present everywhere, the indicators of which prevail in the mountainous zone. Regarding Mg, which is present everywhere in a relatively small amount relative to all other trace elements, and S is not observed in permanent teeth. Thus, sulfur in the patients' temporary teeth can be considered an indicator of the mountainous area of their residence, and a high calcium index can be a characteristic of the patients' permanent teeth. When comparing the percentages of the appearance of defects of various restorative structures and their loss in permanent teeth of children living in the lowland and mountain areas of the Transcarpathian region, differences were found when using glass ionomer cements after 6 months (6.7%; 7.2%; p>0.05) and after 12 months (20.0%; 16.3%; p>0.05); with direct composite restorations after 6 months (4.4%; 6.0%; p>0.05) and after 12 months (9.6%; 11.1%; p>0.05); with indirect composite restorations after 6 months (2.1%; 4.0%; p>0.05) and after 12 months (10.5%; 10.0%; p>0.05).

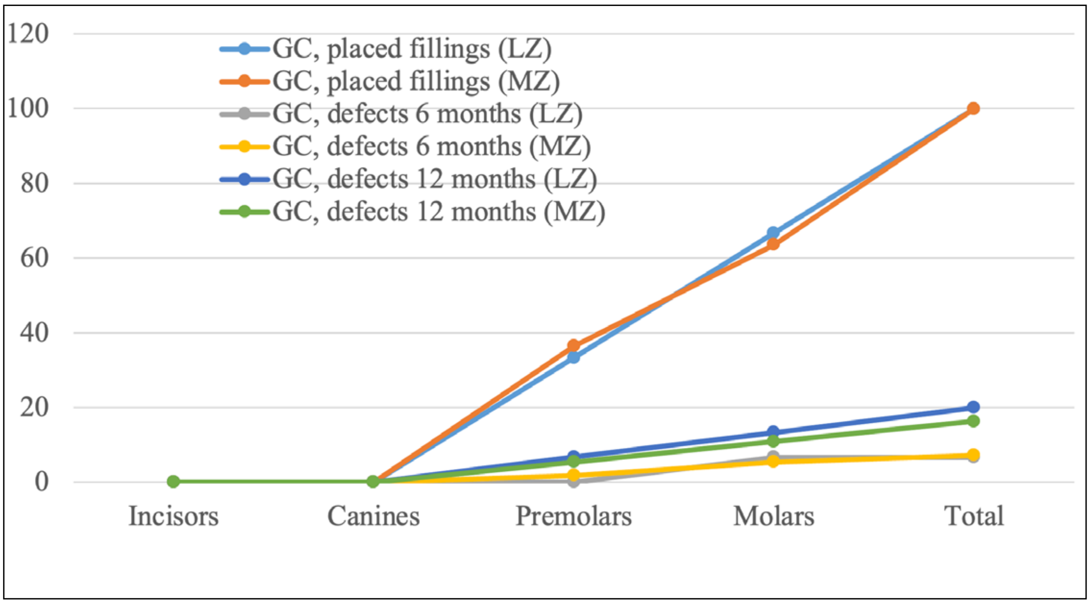

Fig. 4. Percentage of placed fillings in permanent teeth that were treated with glass ionomer cements in two geographical areas.

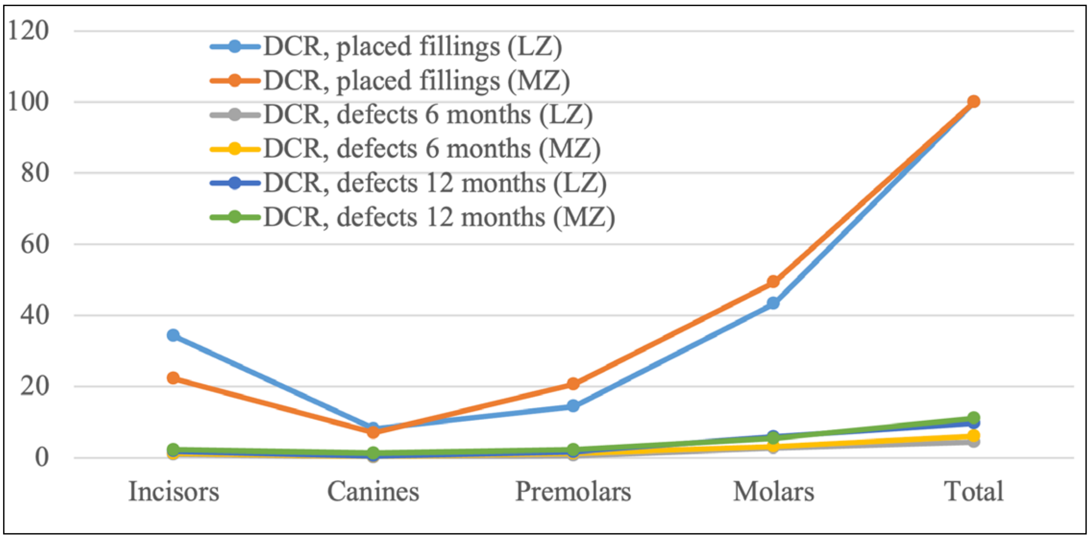

Fig. 5. Percentage of fillings placed in permanent teeth where direct composite restorations were performed in two geographic areas.

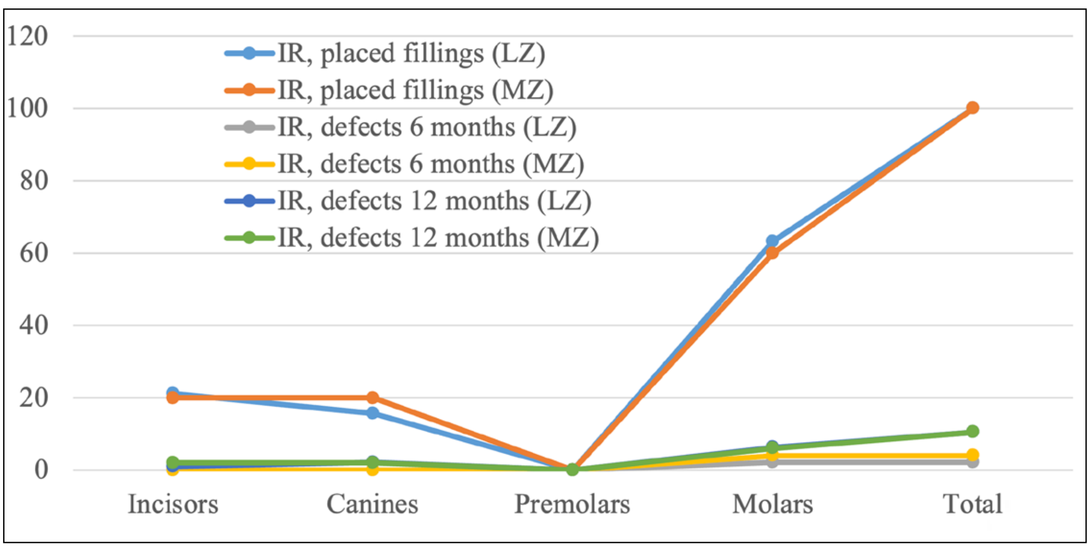

Fig. 6. Percentage of placed fillings and defects after 6 and 12 months in permanent teeth that were treated through indirect restorations - inlays, veneers in percentages in two geographical areas.

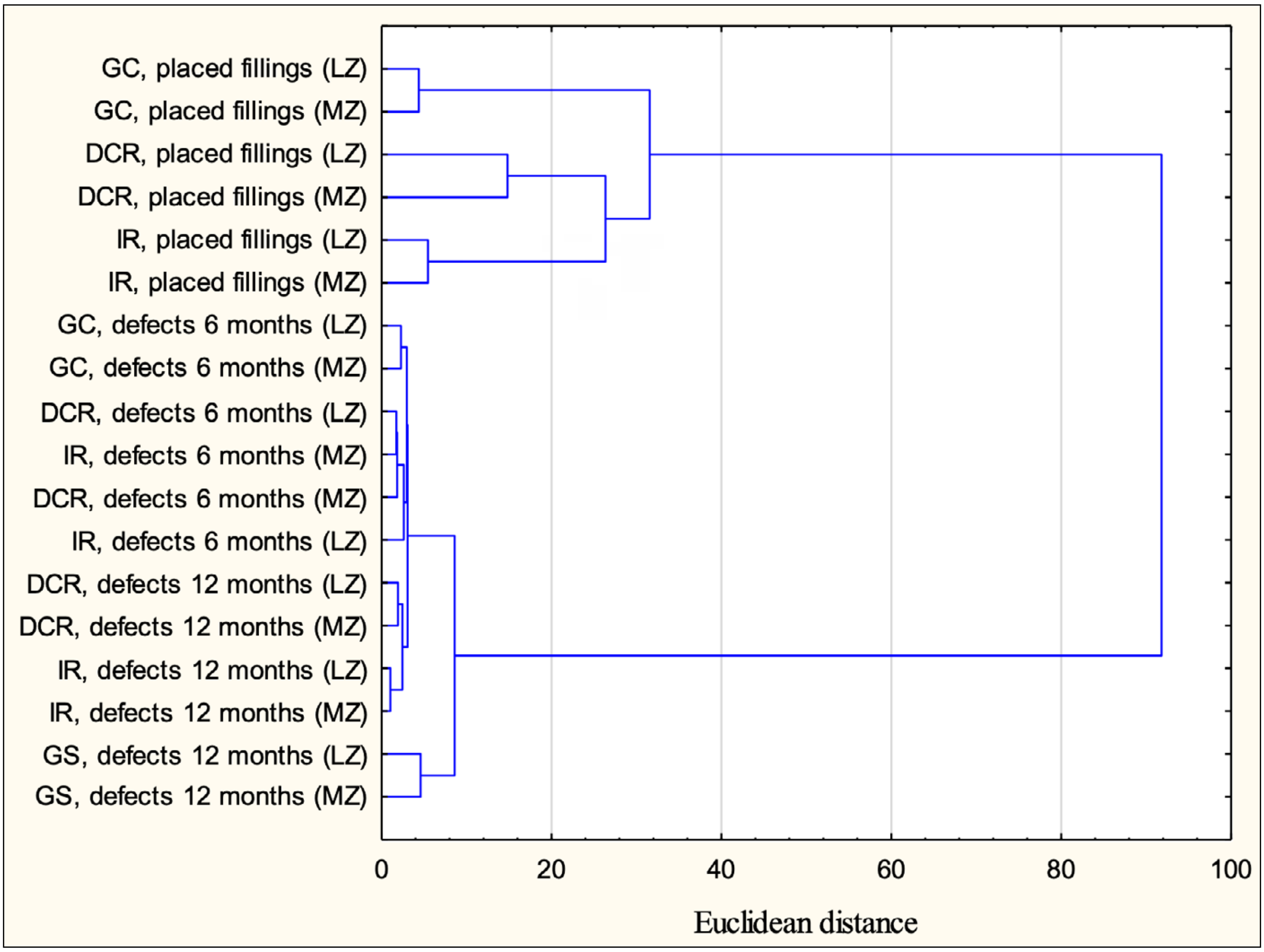

Fig. 7. Results of cluster analysis showing the degree of difference or similarity between the studied indicators.

According to Figure 9, we can hypothesize that, probably, in the permanent teeth of children in the mountain zone, in a higher percentage of cases, fillings also made of glass ionomer cements fall out, which manifests itself mainly after 12 months, because the mineral composition of their teeth is recorded statistically reliably (p>0, 05) lower calcium content (Fig. 9).

DISCUSSION

Despite the rather complete and perfect study of the macroelement composition of the hard tissues of the teeth, the importance of microelements in maintaining the health of the oral cavity is still a subject of research and debate. Some microelements are etiological factors of the occurrence and progression of caries, while others, on the contrary, contribute to the remineralization of hard tooth tissues. The influence of metals on the condition and functioning of the hard tissues of the teeth has been studied by a number of authors.

Researches related to the layer-by-layer, zonal distribution of essential microelements in the dentin and enamel of intact teeth and the distribution of such cariostatic elements as calcium, fluorine, and phosphorus on the surface of the enamel and in the parapulpous dentin attracted the attention of scientists. Thus, Mamaladze M. et al. (2022) conducted an X-ray spectral analysis of 6 intact extracted teeth using scanning electron microscopy (SEM) in order to identify trace elements in the structures of human teeth and determine their localization and concentration in 6 areas of these teeth: surface enamel, enamel thickness, enamel-dentin border, parapulpal dentin, root dentin and cementum. The researchers found that the distribution of essential trace elements in the hard tissues of the teeth is uneven, and fluoride in the hard tissues is contained only in minimal concentrations [14].

To improve the optical properties of restorative materials, Pink K. et al. 2022 applied collimated transmission spectroscopy, in particular, determined the extinction coefficient of human tooth enamel to

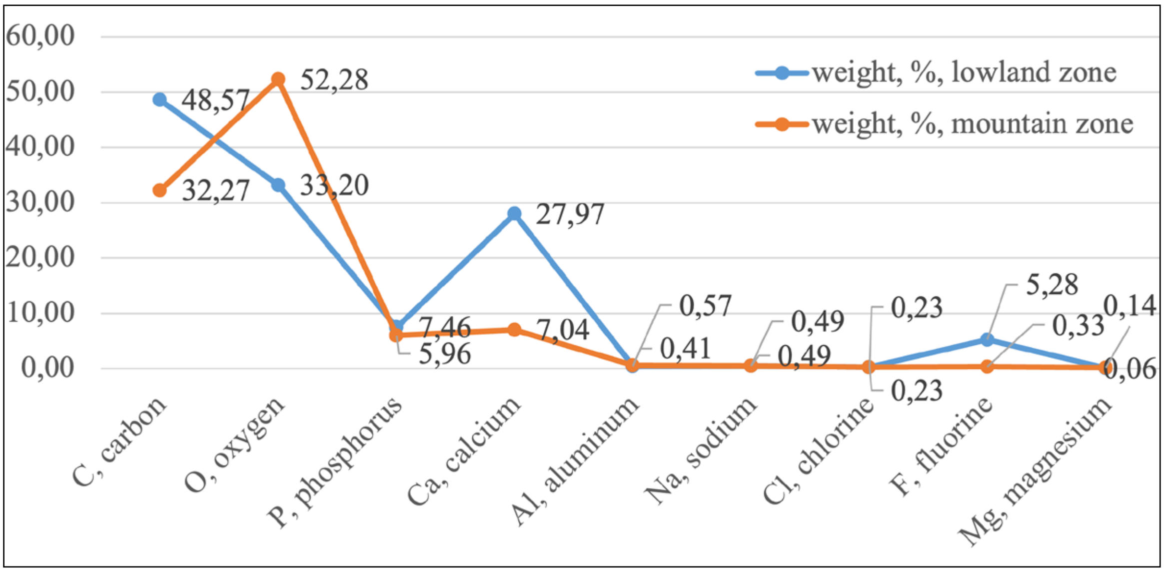

Fig. 8. Average weight values of microelements of enamel and dentin, %.

Table 1. Interrelationship of the elemental composition of permanent teeth of patients from the lowland and mountain areas of residence of the patients

Element, permanent teeth	Weight, %, enamel, lowland	Weight,%, dentin, lowland	Weight,%, enamel, mountain zone	Weight,%, dentin, mountain zone
C, carbon	51,34±6,32	45,79±0,25	27,53±2,35	37,00±4,34
O, oxygen	34,14±3,35	32,26±0,20	52,13±5,27	52,42±5,78
P, phosphorus	8,34±2,01	6,58±0,12	7,79±1,09	4,13±0,12
Ca, calcium	31,62±4,03	24,31±0,12	9,96±1,26	4,11±0,24
Al, aluminum	0,29±0,01	0,52±0,01	0,49±0,01	0,64±0,03
Na, sodium	0,53±0,02	0,45±0,04	0,53±0,02	0,45±0,02
Cl, chlorine	0,28±0,01	0,17±0,01	0,28±0,01	0,17±0,01
F, fluorine	5,48±0,93	5,07±0,21	0,48±0,01	0,17±0,01
Mg, magnesium	0,06±0,01	0,05±0,01	0,16±0,01	0,12±0,01
P<0,05				

provide additional optical properties of enamel and improve the propagation of light in teeth and improve the optical properties of restorative materials. The authors determined the uniqueness of the optical behavior of each sample, which is of great importance in the development of restorative dental materials [15].

Fischer A. et al. 2009 studied the concentration of metals (Cd, Pb, Mn, Cu, Cr, Fe, Zn, Na, K, Mg, Ca) in temporary and permanent teeth, taking into account their location in the oral cavity, that is, on the upper or lower jaw and found that the concentration of metals in temporary teeth is probably higher than in permanent teeth, and the relationship between the concentration of metals in permanent and temporary teeth and their location on the jaw was revealed, higher metal concentrations were found in the teeth of the upper jaw than in the lower jaw [16].

Shaik I. et al. 2021, reviewed the presence of trace elements in teeth and their role in dental health and development. The role of elements such as calcium and phosphate has been carefully studied, unlike elements that are present in small amounts in the enamel and dentin of the teeth, although their absence can disrupt the healthy development of enamel and dentin and lead to defects in the development of teeth, as well as caries. In addition, excessive consumption of some trace elements can adversely affect the development and health of teeth [17].

The exact impact of micronutrients on dental and oral health is still unknown. Researchers have found that lead ions replace calcium, as well as calcium and phosphorus in bone mineral crystals, causing hypercalcemia and hyperphosphatemia, meaning lead

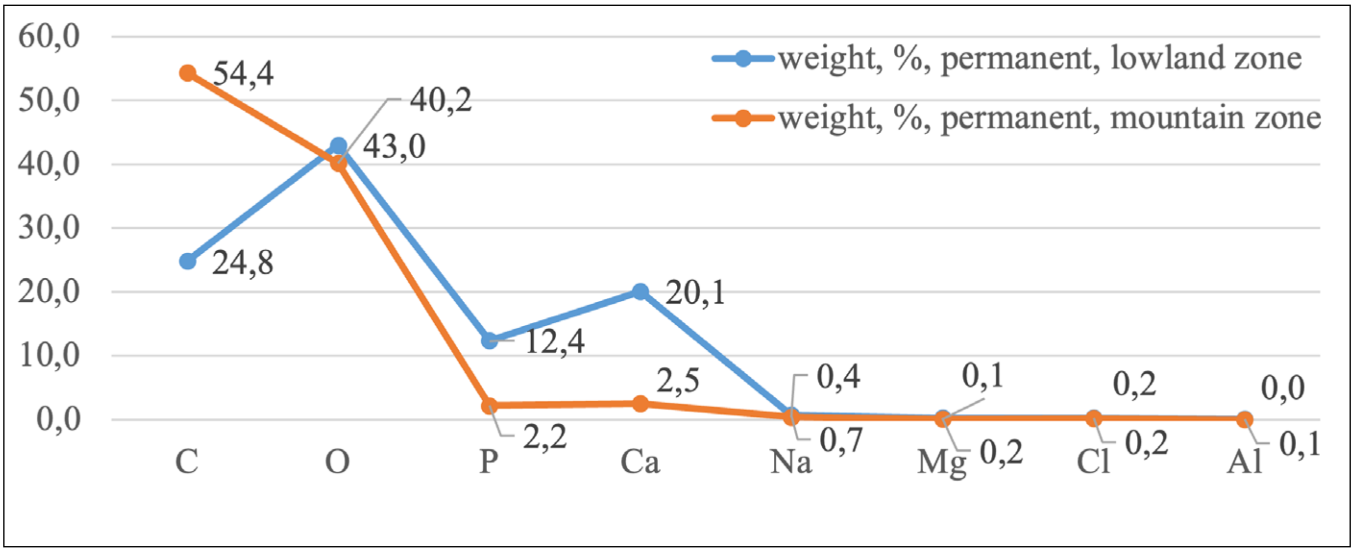

Fig. 9. Average values of the weight of trace elements and the percentage of defects in permanent teeth in two geographical areas, %.

is considered a caries-promoting element. A direct link between enamel hypoplasia and lead exposure in children was found [18].

For the first time, we conducted studies that determined the relationship between the mineral composition of enamel and dentin of permanent teeth and the stability of restorative structures made of different restorative materials. For this, a paraclinical content analysis and statistical analysis was carried out on the basis of 1050 filled permanent teeth (630 in children from the lowland area of residence and 420 from the mountain area), their distribution was carried out by group affiliation and by the material from which the filling was made. It was determined that permanent teeth were dominated by direct restorations in permanent molars made of light-cured composite materials in 38.1% of cases (240 units) in children from the lowland zone and in 36.9% of cases (155 units) in children from the mountain zone.

The percentage of loss or defects of fillings in permanent teeth made of glass ionomer cements and light-curing composite materials in children living in the mountainous area does not significantly differ from similar indicators in children living in the lowland area, namely after 6 months ($p>0.05$), and after 12 months ($p>0.05$); indicators regarding indirect restorations differ significantly after 6 months ($p<0.05$) and not significantly after 12 months ($p>0.05$). The appearance of defects or loss of fillings made of glass ionomer cements prevails after both 6 and 12 months.

Improbable differences in the appearance of instability of restorative structures in the permanent teeth of children from the mountain zone made of glass ionomer cements, light-curing composites on indirect restorations were determined after 6 months (7.2%; 6.0%; 4.0%; $p>0.05$), and after 12 months (16.3%; 11.1%; 10.0%; $p>0.05$); in children of the lowland zone, the differences are probable, and are after 6 months (6.7%; 4.4%; 2.1%; $p<0.05$) and after 12 months (20.0%; 9.6%; 10 .5%; $p<0.05$).

Estimation of the mineral composition of tooth enamel using spectrometry is an interesting and modern type of research that will allow with a high degree of probability to establish the micro- and macroelemental composition of enamel and determine the optimal ways of normalizing its composition. In addition, during restorative manipulations with the hard tissues of the teeth, the determination of the mineral composition of the teeth and the study of the relationship between the mineral composition of the hard tissues and the adhesive properties of the restorative filling materials with a high degree of efficiency will improve the quality of caries treatment.

The results of a spectral study of the hard tissues of the teeth will help to choose a filling material taking into account its adhesive properties, which will improve the long-term results of caries treatment and the quality of the performed restoration work.

CONCLUSIONS

Improbable differences in the stability of restorative structures in the permanent teeth of children living in the lowland and mountain areas of the Transcarpathian region were established when using glass ionomer cements both after 6 months (6.7%; 7.2%; $p>0.05$) and after 12 months (20.0%; 16.3%; $p>0.05$); with direct composite restorations after 6 months (4.4%; 6.0%; $p>0.05$) and after 12 months (9.6%; 11.1%; $p>0.05$); with indirect composite restorations after 6 months (2.1%; 4.0%; $p>0.05$) and after 12 months (10.5%; 10.0%; $p>0.05$).

According to the analysis of the mineral composition of the enamel and dentin of the teeth and its relationship with the prevalence of defects, the loss of fillings in different geographical areas, it is possible to hypothesize that, probably, fillings made of glass ionomer cements fall out in a higher percentage of cases in the permanent teeth of children in the mountainous area, because a statistically significantly ($p>0.05$) lower calcium content was recorded in the mineral composition of their teeth. Also, the loss of fillings will correlate with these indicators at an average or high level ($R=0.6-0.8$; $p<0.05$) and with the content of magnesium and sodium at a low or average level ($R=0.3-0.6$; $p<0.05$).

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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