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PECULIARITIES OF THE STRUCTURAL AND FUNCTIONAL STATE OF TOOTH ENAMEL IN INTERNALLY DISPLACED CHILDREN UNDER VARIOUS PSYCHOEMOTIONAL CONDITIONS

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Introduction. It is well-established that psychoemotional stress can alter physiological processes, including the remineralization dynamics of dental enamel, thereby influencing its resistance to carious lesions. However, the specific relationship between wartime psychological stressors and the structural and functional characteristics of enamel in children remains insufficiently explored.

The aim of the study: to assess the state of structural and functional enamel resistance, the level of reactive anxiety, and the severity of depressive symptoms in children, with consideration of age, sex, and migration status.

Materials and methods. A total of 375 school-aged children (6–13 years old) were examined, comprising a main group (149 internally displaced children) and a comparison group (226 permanent residents). Psycho-emotional status was assessed using the Spielberger-Hanin Inventory (reactive anxiety) and the M. Kovacs Children's Depression Inventory (CDI) (depressive symptoms). The structural and functional resistance of dental enamel was determined using the TER-test.

Results. Internally displaced children demonstrated a high level of psychoemotional maladjustment, evidenced by a significantly elevated prevalence of depressive disorders – 96.64% and reactive anxiety – 95.30%. These indicators exceeded those in the comparison group by 1.2-fold and 1.12-fold, respectively, $p < 0.05$. Furthermore, the mean structural-functional enamel resistance score, determined by the TER-test, was 4.74 ± 0.10 , in the main group, which was significantly higher than the comparison group's value of 3.69 ± 0.09 , $p < 0.01$.

Conclusions. Thus, as a result of the conducted research, it was found that internally displaced children aged 6 to 13 years (the main study group) exhibited significantly higher frequencies of moderate to high levels of reactive anxiety and depressive symptoms, with a marked predominance among girls. Notably, the TER-test scores in this cohort exceeded those observed in the comparison group by a factor of 1.3, $p < 0.01$.

Keywords: children, internally displaced persons, psycho-emotional state, dental caries, enamel resistance.

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ОСОБЛИВОСТІ СТРУКТУРНО-ФУНКЦІОНАЛЬНОГО СТАНУ ЕМАЛІ ЗУБІВ У ВНУТРІШНЬО ПЕРЕМІЩЕНИХ ДІТЕЙ ЗА РІЗНИХ ПСИХОЕМОЦІЙНИХ СТАНІВ

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У статті наведено результати клінічного аналізу психоемоційних показників та структурно-функціональної резистентності емалі у дітей віком 6–13 років з урахуванням віку, статі та міграційного статусу. Встановлено, що у внутрішньо переміщених дітей (основна група) віком 6–13 років спостерігався високий рівень психоемоційної дезадаптації, який проявлявся високою частотою депресивних розладів (96,64%) та реактивної тривожності (95,30%). Порівняно з показниками у дітей, які постійно проживають на території міста Тернопіль та області (порівняльна група), ці значення були вищими в 1,2 та 1,12 раза відповідно, $p < 0,05$. Оцінка структурно-функціональної резистентності емалі за допомогою ТЕР-тесту показала, що середній бал у дітей основної групи становив $4,74 \pm 0,10$, що в 1,3 раза перевищувало аналогічний показник у порівняльній групі – $3,69 \pm 0,09$, $p < 0,01$.

Ключові слова: діти, внутрішньо переміщені особи, психоемоційний стан, карієс зубів, резистентність емалі.

Introduction

In the 21st century, war at the heart of Europe has resulted not only in extensive humanitarian losses but also in unprecedented challenges for Ukraine's healthcare system. Among the most vulnerable populations are internally displaced children who have been forced to leave their

homes due to the proximity to active combat zones. The loss of home, forced relocation, disruption of familiar environments, absence or death of family members and peers, coupled with the persistent exposure to an alarming information environment (sirens, explosions, distressing news), together pose a multifaceted threat to both the somatic and psycho-emotional health of these children. These factors collectively hinder normal development and impair physiological functioning [1].

Of particular concern within the context of psycho-emotional stress is dental enamel, a highly sensitive tissue that undergoes formation and mineralization in close

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Стаття поширюється на умовах ліцензії



interrelation with the endocrine, immune, and nervous systems [2; 3]. War-induced emotional distress can significantly affect salivary flow rate, oral microbiome balance, salivary pH, and consequently, the enamel's resistance to demineralization [4]. Internally displaced children – especially those of early school age – face an increased risk of developing dental caries, the most prevalent pediatric oral disease, particularly in conditions of diminished hygiene standards and limited access to fluoride-containing preventive agents [5; 6].

The psycho-emotional state of children, including levels of reactive anxiety and depressive symptoms, serves as a critical mediator in the relationship between adverse social context and both systemic and oral health outcomes [7–9]. Empirical studies reveal that children exposed to war exhibit markedly elevated anxiety levels, which correlate with poor oral hygiene indicators, reduced salivary pH, and decreased enamel resistance to acid erosion [10; 11].

To date, the relationship between the psycho-emotional condition of internally displaced children and the structural-functional state of dental enamel under prolonged stress remains insufficiently explored. Investigating this connection is of paramount importance for the development of effective interdisciplinary prevention and rehabilitation programs targeting children affected by armed conflict – underscoring both the timeliness and the critical relevance of our research.

The aim of the study: to assess the state of structural and functional enamel resistance, the level of reactive anxiety, and the severity of depressive symptoms in children, with consideration of age, sex, and migration status.

Materials and Methods

The evaluation of dental health and psycho-emotional status in the study cohort was conducted at the Department of Pediatric Dentistry, I. Horbachevsky Ternopil National Medical University of the Ministry of Health of Ukraine, as well as at the dental clinics “OrthoXperts” and “Dental Cosmetology” in Ternopil. In accordance with the aims of the study, a total of 375 school-aged children (aged 6 to 13 years) were examined. Participants were stratified into two groups: the main group – consisted of 149 internally displaced children (72 boys and 77 girls), the comparison group – included 226 children (113 boys and 113 girls) who were permanent residents of Ternopil and the surrounding region.

To assess affective disorders in children, two validated psychological instruments were employed: the Spielberg-Hanin State Anxiety Inventory [12], and the Children's Depression Inventory (CDI) by M. Kovacs [13].

Reactive (State) Anxiety, as measured by the Spielberg-Hanin Inventory, reflects the magnitude of emotional reactivity to acute stress and may vary in severity, duration, and intensity. The instrument comprises 20 items, with responses rated on a four-point scale: 1 – “almost never”, 2 – “sometimes”, 3 – “often”, and 4 – “almost always”. A cumulative score ≤ 30 is considered within the normal range. Scores of 31–45 suggest moderate anxiety, while ≥ 46 is indicative of high anxiety levels.

The Children's Depression Inventory (CDI) is a psychometrically robust tool for quantifying the range of

depressive symptoms in children and adolescents aged 6–17 years. It explores core components of affective pathology, including: depressed mood, anhedonia (inability to experience pleasure), somatic and vegetative dysfunctions, low self-esteem, impaired interpersonal relationships, and overall severity of depressive symptoms. The CDI contains 27 items, each with three response options scored 0, 1, or 2, corresponding to increasing symptom severity. The self-reported responses reflect the child's subjective experience over the preceding two weeks.

To assess the structural-functional resistance of dental enamel, the TER-test was employed [14]. The procedure involved the application of a single drop of 1N hydrochloric acid to the labial surface of the maxillary central incisor. After 5 seconds, the acid was rinsed with distilled water, the surface dried with a cotton pellet, and stained with a 1% aqueous solution of methylene blue. The intensity of dye uptake was directly proportional to the depth of acid etching, thereby indicating enamel resistance. It should be noted that the analysis of the structural-functional resistance of enamel (TER-test) was performed in a subgroup of children with dental caries (DMF + df ≥ 1). Accordingly, this stage of the study included 135 children of the main group and 144 children of the comparative group.

This investigation was conducted in full accordance with the ethical principles outlined in the Declaration of Helsinki for research involving human participants. All necessary precautions were taken to ensure patient confidentiality and informed consent. The study protocol was approved by the Bioethics Committee of I. Horbachevsky Ternopil National Medical University, Ministry of Health of Ukraine (Protocol No. 81, dated April 03, 2025).

Statistical analysis of the data was performed using Microsoft Excel and Statistica software. Student's t-test was used for comparative analysis. Differences were considered statistically significant at $p < 0.05$.

Research results and their discussion

The study findings demonstrated that among internally displaced children aged 6 to 13 years (main group), the absence of depressive symptoms (score < 30) was observed in only $3.36 \pm 1.47\%$ of respondents (Fig. 1). This was 6.6 times lower than the corresponding proportion in the comparison group of same-aged peers residing in Ternopil and its surrounding region – $22.12 \pm 2.76\%$, $p < 0.01$.

At the same time, mild depression was recorded in $51.68 \pm 4.09\%$ of children in the main group, which was 1.3 times less prevalent than in the comparison group – $65.05 \pm 3.17\%$, $p < 0.05$. Moderate depression (scores 41–50) was found in $41.60 \pm 4.03\%$ of internally displaced children, a figure 3.2 times higher than among children in the comparison group – $13.07 \pm 2.52\%$, $p < 0.01$. Notably, only the group of internally displaced children included cases of severe depression (scores > 55), identified in $3.36 \pm 1.47\%$ of respondents, $p < 0.01$.

More detailed stratification of depressive symptoms by age and gender is presented in Table 1 and Table 2.

According to Table 1, no cases of severe depression were recorded among boys or girls in either group aged 6–9 years. However, among internally displaced children, $2.30 \pm 1.60\%$ of boys were found to exhibit no signs of

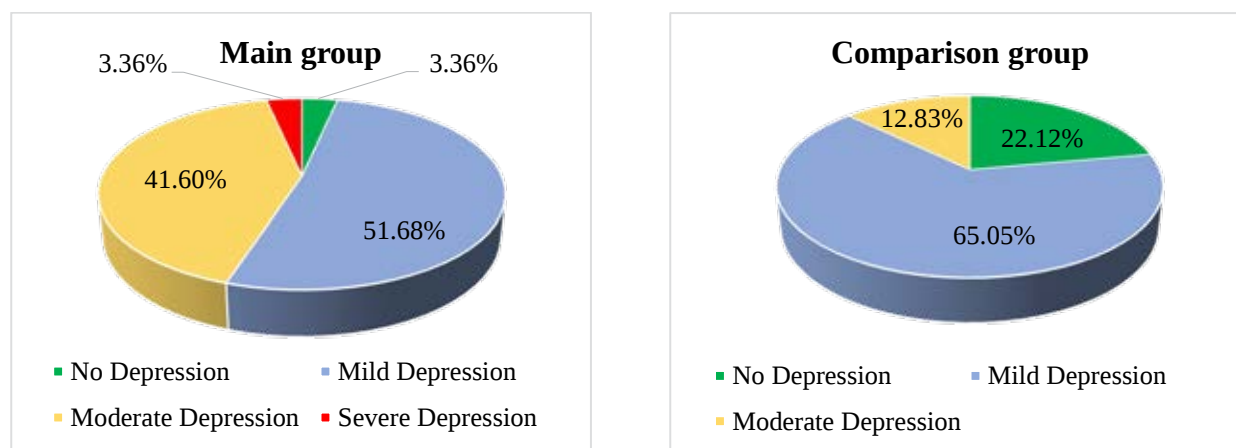


Fig. 1. The structure of depressive disorders in children aged 6 to 13: findings from a clinical cohort study

depression (score < 30), while no cases of depression-free girls were observed in the same group.

In contrast, the proportion of boys without depressive symptoms in the comparison group was 6.3 times higher than in the main group, $p_1 < 0.01$. Additionally, $8.33 \pm 2.82\%$ of girls in the comparison group scored below 30 on the depression inventory, indicating no depressive symptoms.

Mild depression (30–40 points) was recorded in $37.93 \pm 5.20\%$ of boys and $27.59 \pm 4.79\%$ of girls in the main group, $p > 0.05$, compared to $30.21 \pm 4.68\%$ and $31.25 \pm 4.73\%$ of boys and girls, respectively, in the comparison group, $p_1 > 0.05$.

Moderate depression (41–55 points) was observed in $9.20 \pm 3.09\%$ of boys in the main group, versus $5.20 \pm 2.26\%$ in the comparison group, $p_1 > 0.05$. In contrast, moderate depression among girls in the study group was 2.2 times more frequent than among their peers in the comparison group, $p_1 < 0.05$.

For children aged 10–13 years (Table 2), the absence of depression was observed in $4.83 \pm 1.72\%$ of internally displaced boys, compared to $12.30 \pm 2.88\%$ of boys in the comparison group – 2.5 times higher. Meanwhile, $9.23 \pm 2.53\%$ of girls in the comparison group were free

from depressive symptoms, whereas no such cases were identified among girls in the study group, $p, p_1 < 0.01$.

Mild depression (30–40 points) was found to be more common in the comparison group than the main group: 2.2 times more frequent in boys, and 2.0 times more frequent in girls, $p > 0.05$, $p_1 < 0.05$. Conversely, moderate depression was significantly more prevalent among displaced children: 3.9 times higher in boys and 6.6 times higher in girls, compared to the comparison group, $p < 0.01$.

Importantly, severe depression (scores > 55) was observed exclusively among children aged 10–13 in the main group: $3.23 \pm 1.24\%$ of boys and $4.84 \pm 2.72\%$ of girls, $p < 0.01$.

An evaluation of reactive anxiety (RA) levels among children aged 6 to 13 years (Fig. 2) revealed that the absence of reactive anxiety (score < 30) was identified in $4.70 \pm 1.73\%$ of internally displaced children (main group), compared to a significantly higher proportion – $15.04 \pm 2.37\%$ – among children permanently residing in Ternopil and the surrounding region (comparison group), a difference of 3.2-fold, $p < 0.01$.

Moderate levels of reactive anxiety (scores between 31–45) were observed in the majority of participants across both cohorts: $69.13 \pm 3.78\%$ in the main group and

Table 1

Quantitative and gender distribution of children aged 6 to 9 years with depressive disorders in the study cohort

Level of depression	Main group (n = 87)		Comparison group (n = 96)	
	Boys (n = 43)	Girls (n = 44)	Boys (n = 48)	Girls (n = 48)
Less than 30 points (no depression)	2 $2,30 \pm 1,60$ *	–	14 $14,53 \pm 3,59$	8 $8,33 \pm 2,82$
30–40 points (mild depression)	33 $37,93 \pm 5,20$	24 $27,59 \pm 4,79$	29 $30,21 \pm 4,68$	30 $31,25 \pm 4,73$
41–55 points (moderate depression)	8 $9,20 \pm 3,09$	20 $23,0 \pm 4,51$ ••, **	5 $5,2 \pm 2,26$	10 $10,41 \pm 3,11$
More than 55 points (severe depression)	–	–	–	–

Notes: •• $p < 0,01$ – a statistically significant difference in values relative to data for boys;

* $p_1 < 0,01$; ** $p_1 < 0,05$ – a statistically significant difference in values relative to data in the comparison group.

Table 2

Quantitative and gender distribution of children aged 10 to 13 years with depressive disorders in the study cohort

Level of depression	Main group (n = 62)		Comparison group (n = 130)	
	Boys (n = 29)	Girls (n = 33)	Boys (n = 65)	Girls (n = 65)
Less than 30 points (no depression)	3 $4,83 \pm 1,72$ **	—	16 $12,30 \pm 2,88$	12 $9,23 \pm 2,53$
30–40 points (mild depression)	9 $14,51 \pm 4,47$ **	11 $17,74 \pm 4,85$ **	41 $31,54 \pm 4,07$	47 $36,16 \pm 4,21$
41–55 points (moderate depression)	15 $24,19 \pm 5,43$ *	19 $30,66 \pm 5,85$ *	8 $6,15 \pm 2,10$	6 $4,62 \pm 1,84$
More than 55 points (severe depression)	2 $3,23 \pm 1,24$	3 $4,84 \pm 2,72$	—	—

Notes: * $p_1 < 0,01$; ** $p_1 < 0,05$ – a statistically significant difference in values relative to data in the comparison group.

72.12 $\pm$ 2.98% in the comparison group, with no statistically significant difference between them, $p > 0.05$. High reactive anxiety levels (≥ 46 points) were documented in 26.17 $\pm$ 3.60% of the internally displaced children – twice as frequent as in their peers from the comparison group, where the figure stood at 12.83 $\pm$ 2.22%, $p < 0.01$.

According to Table 3, the absence of reactive anxiety was noted in 3.45 $\pm$ 0.94% of boys aged 6–9 years in the main group, compared to 7.29 $\pm$ 2.65% of boys in the same age bracket in the comparison group, $p > 0.05$. Notably, in the comparison group, only girls demonstrated complete absence of anxiety – 3.13 $\pm$ 1.77%, $p < 0.01$.

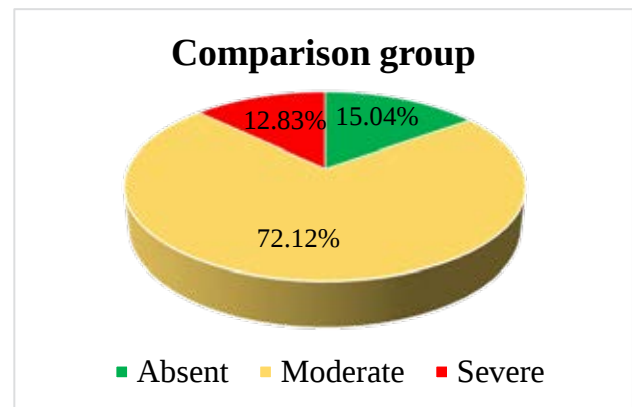
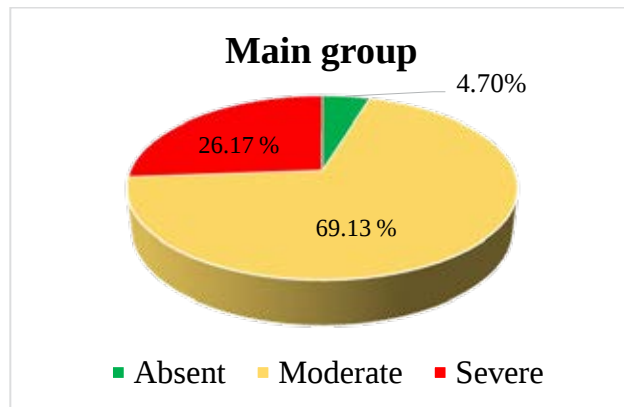


Fig. 2. Structure of reactive anxiety in children aged 6 to 13: comparative analysis across study groups

Table 3

Quantitative and gender-based distribution of children aged 6 to 9 years in the study groups according to levels of reactive anxiety

Level of reactive anxiety	Main group (n = 87)		Comparison group (n = 96)	
	Boys (n = 43)	Girls (n = 44)	Boys (n = 48)	Girls (n = 48)
Up to 30 points (absent)	3 $3,45 \pm 0,94$	—	7 $7,29 \pm 2,65$	3 $3,13 \pm 1,77$
31–45 points (moderate)	34 $39,08 \pm 5,23$	27 $31,03 \pm 4,95$	39 $40,63 \pm 5,01$	38 $39,58 \pm 4,99$
46 points (high)	6 $6,90 \pm 2,71$ **	17 $19,54 \pm 4,25$ **	2 $2,08 \pm 0,95$	7 $7,29 \pm 2,65$

Note: ** $p < 0,01$ – a statistically significant difference in values relative to data for boys;

** $p_1 < 0,05$ – a statistically significant difference in values relative to data in the comparison group.

Moderate anxiety in children aged 6–9 was found in $39.08 \pm 5.23\%$ of boys and $31.03 \pm 4.95\%$ of girls in the main group, $p > 0.05$, while similar values were observed among their counterparts in the comparison group: $40.63 \pm 5.01\%$ in boys and $39.58 \pm 4.99\%$ in girls, $p, p_1 > 0.05$.

However, high reactive anxiety (≥ 46 points) was more prevalent among children aged 6–9 in the main group compared to their counterparts in the comparison group – 3.3 times more frequent in boys and 2.7 times in girls, though this difference reached statistical significance only in the latter, $p > 0.05$ for boys, $p_1 < 0.05$ for girls.

Among older children aged 10–13 years, the absence of anxiety was observed only in $6.45 \pm 3.12\%$ of boys in the main group, $p < 0.01$, and in $11.53 \pm 2.80\%$ of boys, $p > 0.05$, and $6.92 \pm 2.22\%$ of girls, $p < 0.01$ in the comparison group (Table 4).

Moderate levels of reactive anxiety predominated in both groups across sexes in this age range. In the main group, these figures ranged from $35.48 \pm 6.07\%$ in boys to $32.26 \pm 5.93\%$ in girls, $p, p_1 > 0.05$, while in the comparison group, the rates were $35.38 \pm 4.19\%$ and $30.77 \pm 4.04\%$ for boys and girls, respectively, $p > 0.05$.

Importantly, high reactive anxiety in the 10–13 age group was more frequently observed among girls across both cohorts. Within the main group, this rate exceeded that of the comparison group by a factor of 1.7 ($20.96 \pm 5.16\%$ vs. $12.32 \pm 2.88\%$, $p < 0.05$, $p_1 > 0.05$). Conversely, among boys aged 10–13, high anxiety was recorded in $4.84 \pm 2.72\%$ in the main group versus $3.08 \pm 1.51\%$ in the comparison group, $p > 0.05$.

Thus, it can be asserted that children aged 6 to 13 years with dental caries in both study cohorts exhibited elevated

levels of psychoemotional stress. However, internally displaced children in the main study group were more frequently diagnosed with moderate to high levels of depressive states and reactive anxiety. It is also noteworthy that among girls aged 6–13 years, moderate to high-intensity psychoemotional disturbances were observed more frequently than among boys in both the main and comparison groups.

The structural-functional condition of enamel in children aged 6–9 years from the study groups is presented in Table 5. The highest TER-test values – 5.12 ± 0.11 and 5.03 ± 0.10 points – were recorded among 6- and 7-year-old children in the main group, respectively, $p_1 > 0.05$. These TER-test values in 6- and 7-year-olds indicated a medium level of enamel structural-functional resistance. In contrast, their peers in the comparison group showed slightly lower TER-test scores – 4.07 ± 0.09 and 3.92 ± 0.09 points, respectively, $p < 0.01$ – although, by test criteria, these too fell within the medium resistance range.

Among 8- to 9-year-old internally displaced children in the main group, TER-test values showed a declining trend: from 4.86 ± 0.08 points at age 8, $p_1 > 0.05$, to 4.75 ± 0.06 points at age 9, $p_1 < 0.05$. Simultaneously, age-matched children from the comparison group residing in Ternopil city and region demonstrated TER-test values that were, on average, 1.3 times lower than those in the main group, $p < 0.01$.

According to TER-test criteria, the structural-functional enamel condition in 8-9-year-old children indicated medium resistance in the main group and high-to-medium resistance in the comparison group. Notably, TER-test values among 6–9-year-old children in the main group

Table 4

Quantitative and gender-based distribution of children aged 10 to 13 years in the study groups according to levels of reactive anxiety

Level of reactive anxiety	Main group (n = 62)		Comparison group (n = 130)	
	Boys (n = 29)	Girls (n = 33)	Boys (n = 65)	Girls (n = 65)
Up to 30 points (absent)	4 6.46 ± 3.17	–	15 11.53 ± 2.80	9 6.92 ± 2.22
31–45 points (moderate)	22 35.48 ± 6.07	20 32.26 ± 5.93	46 35.38 ± 4.19	40 30.77 ± 4.04
46 points (high)	3 4.84 ± 2.72	13 20.96 ± 5.16 ••	4 3.08 ± 1.51	16 12.32 ± 2.88 ••

Note: •• $p < 0.05$ – a statistically significant difference in values relative to data for boys.

Table 5

The significance of enamel resistance test indices in children aged 6–9 years with dental caries (DMFT + df)

Research groups	Age, years				Average value
	6 years	7 years	8 years	9 years	
Main group (n = 77)	$5.12 \pm 0.11^*$	$5.03 \pm 0.10^*$	$4.86 \pm 0.08^*$	$4.75 \pm 0.06^*$	$4.94 \pm 0.09^*$
Comparison group (n = 55)	4.07 ± 0.09	3.92 ± 0.09	3.84 ± 0.08	3.73 ± 0.05	3.89 ± 0.08

Notes: * $p < 0.01$ – a statistically significant difference in values relative to data in the comparison group.

were 1.3 times higher than in their counterparts in the comparison group, $p < 0.01$.

In children aged 10–13 years from the main group, TER-test values ranged from 4.63 ± 0.14 points at age 10 to 4.23 ± 0.09 points at age 13, $p_1 > 0.05$. Throughout all age subgroups, children in the main cohort consistently exhibited higher TER-test scores than their peers in the comparison group, $p < 0.01$. On average, children aged 10–13 years in the main group demonstrated TER-test scores that were approximately 1.3 times higher than those in the comparison group – 4.54 ± 0.13 vs. 3.49 ± 0.11 points, respectively, $p < 0.01$ (Table 6).

The findings of this study revealed a markedly high level of psycho-emotional maladjustment among internally displaced children (main study group) aged 6 to 13 years. This was evidenced by an exceptionally high prevalence of depressive disorders (96.64%) and reactive anxiety (95.30%). When compared to their peers residing permanently in the city of Ternopil and its surrounding region (comparison group), these indicators were 1.2 times and 1.12 times higher, respectively, $p < 0.05$.

Assessment of the structural and functional resistance of enamel using the TER-test demonstrated that the mean score in the main group was 4.74 ± 0.10 , significantly

Table 6

The significance of enamel resistance test indices in children aged 10–13 years with dental caries (DMFT + df)

Research groups	Age, years				Average value
	10 years	11 years	12 years	13 years	
Main group (n = 58)	$4,63 \pm 0,14^*$	$4,75 \pm 0,16^*$	$4,56 \pm 0,11^*$	$4,23 \pm 0,09^*$	$4,54 \pm 0,13^*$
Comparison group (n = 89)	$3,62 \pm 0,12$	$3,70 \pm 0,13$	$3,42 \pm 0,09$	$3,21 \pm 0,08$	$3,49 \pm 0,11$

Notes: * $p < 0,01$ – a statistically significant difference in values relative to data in the comparison group.

exceeding that of the control group – 3.69 ± 0.09 , $p < 0.01$. This suggests the presence of reactive compensatory changes in enamel structure, likely associated with adaptive remodeling under conditions of chronic psycho-emotional stress.

These findings are consistent with prior studies demonstrating the impact of war-related or displacement-induced psychological stress on mental, somatic, and oral health [15; 16]. For example, Ponomarenko and Kaifie (2023) reported that over 80% of Ukrainian refugee children in Germany exhibited clinically significant symptoms of depression [17]. Similarly, Urbanski et al. (2024) found significantly higher levels of depression and anxiety among displaced Ukrainian children in Poland compared to their local counterparts [18]. In turn, Golanska et al. (2021) emphasized the link between chronic stress and compromised enamel integrity, including microdamage and increased dental hypersensitivity [19]. A comprehensive review by Jankovic-Rancovic and Pantar-Brick (2024) concluded that war and displacement exert both neuropsychological and somatic effects on children, particularly influencing endocrine mechanisms involved in enamel remineralization [20].

Our results confirm a multifactorial relationship between children's psycho-emotional condition, migratory status, and the structural-functional parameters of dental enamel. War-induced psychological stress appears to be a significant risk factor not only for mental health but also for oral health outcomes in children.

Conclusions

Thus, as a result of the conducted research, it was found that internally displaced children aged 6 to 13 years (the main study group) exhibited significantly higher frequencies of moderate to high levels of reactive anxiety and depressive symptoms, with a marked predominance among girls. Notably, the TER-test scores in this cohort exceeded those observed in the comparison group by a factor of 1.3 ($p < 0.01$), indicating a meaningful contribution of psycho-emotional stress to the alteration of enamel's structural and functional resistance.

Prospects for Further Research. Future research aims to identify genetic markers or polymorphisms that underlie individual variability in salivary gland responses to psycho-emotional stress.

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