



Prognostic Significance Of The Immune-Stress Index In Assessing Dental Risk In Children With Hearing Impairment

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Abstract: Significant correlations were identified between the Immune-Stress Index (ISI) and the OHI-S, PLI, PMA, and SBI indices ($r = 0.59-0.67$; $p < 0.001$), as well as with the level of dental anxiety and negative behavior ($r = 0.62-0.66$; $p < 0.001$). At high ISI values, the risk of unfavorable dental outcomes increased by 3.9–5.6 times. ROC analysis confirmed the high prognostic value of ISI (AUC = 0.86). The findings allow ISI to be considered an integral marker for predicting the risk of developing an unfavorable dental status in children with hearing impairment.

Keywords: Immune-stress index, children with hearing impairment, salivary cortisol, secretory IgA, dental anxiety, gingivitis.

1. Introduction: Preserving oral health in children with disabilities and hearing impairment remains one of the pressing and insufficiently resolved issues in modern pediatric dentistry and preventive medicine. According to domestic studies, this group of children demonstrates a higher prevalence of dental caries and inflammatory periodontal diseases, characterized by early onset, a tendency toward chronicity, and the insufficient effectiveness of standard preventive measures [6]. Similar patterns are confirmed by international studies, which show that children with hearing impairment have a more unfavorable dental status and a reduced oral health-related quality of life

[8].

Traditionally, the leading role in the development of dental diseases in children with hearing impairment has been attributed to limitations in hygienic behavior, insufficient dental literacy, and difficulties in communication with medical personnel. At the same time, it has been shown that even with the implementation of preventive programs, a high frequency of inflammatory changes in periodontal tissues persists, indicating the involvement of additional pathogenetic factors [3,4]. The family and social context is also of significant importance in this regard: the level of parental involvement, the availability of specialized dental care, and the adaptation of preventive measures to the child's communicative abilities [4].

In recent years, increasing attention has been paid to the role of chronic psychoemotional stress that develops in children with hearing impairment as a result of sensory deprivation and limitations in social communication. Prolonged stress exposure is accompanied by activation of the hypothalamic–pituitary–adrenal axis and an increase in cortisol levels, a universal biochemical marker of stress load. Elevated salivary cortisol levels have been found to be associated with increased dental anxiety, reduced cooperativeness, and unfavorable behavioral reactions during dental examination [7].

Along with neuroendocrine changes, the mucosal immune system plays a key role in maintaining oral homeostasis, the central component of which is secretory immunoglobulin A. Secretory IgA provides anti-adhesive protection of the mucous membrane, participates in the regulation of microbial biocenosis, and limits the development of inflammatory processes. Systematic reviews and meta-analyses indicate that decreased salivary sIgA concentration is associated with an increased prevalence of dental caries and inflammatory oral diseases in children and adolescents [2]. In addition, the secretion of sIgA has been shown to be highly sensitive to psychoemotional stress, especially in childhood and adolescence [9].

Individual domestic studies indicate changes in the biochemical composition of saliva in children with hearing impairment already at the stage of forming hygienic skills, reflecting tension in the adaptive and immune mechanisms of the oral cavity [1]. However, most existing studies focus on the analysis of isolated clinical, immunological, or behavioral factors without integrating them into a unified pathogenetic model of dental pathology in children with hearing impairment

[3,5,6,8].

In this context, the use of integral indicators that allow an objective assessment of the balance between stress-adaptive and local immune mechanisms appears promising. The Immune-Stress Index, which combines indicators of neuroendocrine activity (cortisol) and the state of mucosal immunity (sIgA), makes it possible to move from the isolated evaluation of individual markers to a comprehensive analysis of stress-associated immune imbalance. Importantly, this index potentially reflects not only biological changes but also clinical, behavioral, and psychoemotional manifestations of dental status, including the quality of oral hygiene, the severity of inflammatory processes, and the level of dental anxiety in children with hearing impairment [7,9,10].

Thus, an in-depth study of the relationship between the Immune-Stress Index and clinical, behavioral, and psychoemotional indicators represents a relevant scientific and practical task aimed at improving approaches to dental risk stratification and optimizing preventive care for children with disabilities and hearing impairment.

Objective of the study: to investigate the relationship between the Immune-Stress Index and the clinical, behavioral, and psychoemotional indicators of dental status in children with hearing impairment and to assess its prognostic significance.

2. Methods

The study included 131 children aged 7 to 15 years. The sample was formed using a purposive selection method, taking into account the homogeneity of age distribution and the absence of severe somatic diseases that could affect the condition of the oral cavity. The main group consisted of 94 children with varying degrees of hearing impairment (congenital or early-acquired) studying in specialized schools and boarding institution. The control group consisted of 37 practically healthy children comparable in age and sex, studying in general education schools. The control group was used to compare hygienic skills, functional salivary parameters, and the prevalence of dental pathology.

Inclusion criteria: age 7–15 years; consent of parents/legal representatives to participate; the child's ability to undergo examination; absence of acute infectious diseases.

Exclusion criteria: severe concomitant diseases (endocrine, oncological, systemic); severe intellectual

disability (grade III–IV); mental disorders; aggressive or non-contact behavior preventing examination; ongoing orthodontic treatment affecting plaque indices.

The mean age in the main group was 10.2 ± 0.22 years, while in the control group it was 9.27 ± 0.32 years. Analysis of the sex distribution of the examined children showed a predominance of boys in both the main and control groups. In the main group, boys accounted for 66.0% and girls for 34.0%; in the control group, 67.6% and 32.4%, respectively.

In terms of the severity of hearing impairment, children with grade III–IV hearing loss predominated (43.6%), while the proportion of children with complete deafness was 27.7%, indicating a high severity of sensory deficit in the main group.

Hearing rehabilitation devices were used by 71.2% of the children, of whom 52.1% used hearing aids and 19.1% had cochlear implants. At the same time, nearly one third of the examined children (28.8%) did not use technical means of hearing correction, which significantly limited the possibilities for verbal communication and aggravated difficulties in interaction with medical personnel.

A clinical and laboratory examination of children with hearing impairment was conducted. The levels of cortisol and secretory immunoglobulin A in saliva were determined, and the Immune-Stress Index was calculated. Dental status was assessed using the hygienic indices OHI-S (Greene–Vermillion), PLI (Silness–Löe), and the periodontal indices PMA and SBI.

Psychoemotional state and behavioral reactions were evaluated using validated scales of dental anxiety and behavioral assessment. Spearman's correlation analysis, odds ratio (OR) calculation, and ROC analysis were applied. Study results: The total DMF index in children of the main group was 3.84 ± 0.21 , which was significantly higher than the corresponding value in the control group — 2.17 ± 0.18 ($p < 0.001$), indicating a higher intensity of the caries process in children with hearing impairment. Analysis of the DMF index structure showed that the leading contribution in the main group was made by the "D" component (decayed teeth): the mean number of decayed teeth reached 2.41 ± 0.17 , which was more than twice the value in the control group (1.02 ± 0.12 ; $p < 0.001$). These data indicate a predominance of untreated caries and insufficient effectiveness of preventive measures. The number of filled teeth did not differ statistically

between the groups (1.19 ± 0.11 and 1.03 ± 0.10 ; $p > 0.05$). Against the background of higher caries intensity in children with hearing impairment, this suggests an insufficient volume of therapeutic dental care. The "M" component (missing teeth) was significantly higher in the main group (0.24 ± 0.05 vs. 0.12 ± 0.04 ; $p < 0.05$), reflecting a more unfavorable course of the caries process and delayed dental visits.

Assessment of oral hygiene status using the OHI-S

index revealed an unsatisfactory level of hygiene in children of the main group. The mean OHI-S value was 2.61 ± 0.14 , which was significantly higher than in the control group (1.32 ± 0.11 ; $p < 0.001$). The increase in the total OHI-S index in children with hearing impairment was mainly due to the accumulation of soft dental plaque: the DI-S value reached 1.92 ± 0.10 , which was almost twice as high as in the control group (0.96 ± 0.08 ; $p < 0.001$). The CI-S component was also higher in the main group (0.69 ± 0.06 vs. 0.36 ± 0.05 ; $p < 0.01$), reflecting prolonged retention of dental deposits and insufficient effectiveness of professional hygiene. Analysis of the distribution by hygiene levels showed that among children with hearing impairment, the proportion of individuals with satisfactory and unsatisfactory hygiene reached 85.1%, with unsatisfactory hygiene detected in 34.0% of the examined children. In the control group, nearly half of the children (45.9%) had a good level of hygiene, while unsatisfactory hygiene was recorded in only 5.5%, confirming a more favorable hygiene profile.

3. Results of PLI, PMA, SBI, and dental anxiety assessment:

Assessment using the Plaque Index (PLI) confirmed the previously identified patterns. The mean PLI in the main group was 1.94 ± 0.10 , corresponding to an unsatisfactory level of oral hygiene and significantly higher than the control value (1.02 ± 0.08 ; $p < 0.001$). In the main group, the proportion of children with unsatisfactory or poor hygiene according to PLI reached 62.7%, whereas in the control group, most children demonstrated good or satisfactory hygiene. Poor hygiene (PLI > 2.5) was observed exclusively in children with hearing impairment (17.0%), and no such cases were recorded in the control group.

Analysis of periodontal tissue condition using the PMA index showed significantly more pronounced inflammatory changes in children of the main group. The mean PMA value was $34.7 \pm 2.1\%$, corresponding to moderate gingivitis and nearly twice as high as the control group ($17.9 \pm 1.8\%$; $p < 0.001$). Among children

with hearing impairment, moderate and severe forms of gingivitis predominated: moderate gingivitis was diagnosed in 43.6%, severe in 12.8%, whereas severe forms were absent in the control group. Gingival bleeding assessed by the SBI index was also significantly higher in the main group (1.82 ± 0.09 vs. 0.86 ± 0.07 ; $p < 0.001$). Moderate and pronounced gingival inflammation was observed in 71.3% of children with hearing impairment, whereas mild forms predominated in the control group. Severe gingival inflammation (SBI > 2.0) occurred exclusively in children of the main group (21.3%).

Analysis of dental anxiety levels revealed pronounced

intergroup differences. In the main group, only 19.1% of children had low dental anxiety, whereas in the control group this proportion exceeded half of the participants, reaching 51.4%. The largest category in the main group consisted of children with moderate dental anxiety, accounting for 48.9% of those examined. This level of anxiety manifested as cautious behavior, the need for additional adaptation, and delayed development of cooperative behavior during dental examination.

Of particular clinical significance is the high proportion of children with high dental anxiety in the main group — 31.9%, nearly four times higher than in the control group (8.1%).

Distribution of children by dental anxiety levels (n, %)

Level of dental anxiety	Main group (n = 94)	Control group (n = 37)
Low anxiety	18 (19.1%)	19 (51.4%)
Moderate anxiety	46 (48.9%)	15 (40.5%)
High anxiety	30 (31.9%)	3 (8.1%)
Total	94 (100%)	37 (100%)

Children in the main group exhibited pronounced negative behavioral reactions, refusal to cooperate, emotional tension, and difficulty following the dentist’s instructions.

Salivary cortisol levels in children with hearing impairment were significantly higher than in the control group (7.18 ± 0.34 vs. 4.92 ± 0.29 nmol/L; $p < 0.001$), while remaining within age-related reference values, indicating chronic stress-adaptive tension.

Table 2.
Integral Immune-Stress Index (ISI) in examined children (M ± m)

Parameter	Main group (n = 94)	Control group (n = 37)	p
Cortisol, nmol/L	7.18 ± 0.34	4.92 ± 0.29	<0.001
sIgA, mg/L	112.6 ± 5.8	148.3 ± 6.2	<0.001
ISI	6.38 ± 0.32	3.32 ± 0.22	<0.001

Salivary sIgA concentration in the main group was significantly lower (112.6 ± 5.8 vs. 148.3 ± 6.2 mg/L; $p < 0.001$), indicating reduced local mucosal immune resistance. The Immune-Stress Index in children with hearing impairment was 6.38 ± 0.32 units, nearly twice as high as in the control group ($p < 0.001$).

High and very high ISI values were observed in 54.2% of the main group compared to 18.9% in controls ($\chi^2 = 21.6$; $p < 0.001$).

Significant positive correlations were found between ISI and all studied hygiene and periodontal indices, with correlation coefficients ranging from $r^2 = 0.59$ to 0.67 ($p < 0.001$). The strongest association was observed between ISI and PMA index ($r^2 = 0.67$), reflecting the prevalence and severity of gingival inflammation. Increased ISI was accompanied by enlargement of inflamed tissue areas and more severe clinical gingivitis.

Significant correlations with OHI-S ($r^2 = 0.63$) and PLI ($r^2 = 0.59$) indicate a link between stress-immune imbalance and worsening individual oral hygiene and plaque accumulation. Correlation with SBI ($r^2 = 0.61$) confirms the relationship between stress-hormonal load and inflammatory activity.

At high and very high ISI levels (> 6.0 units), the risk of unfavorable dental outcomes increased substantially. The likelihood of unsatisfactory or poor oral hygiene increased 4.26 times, pronounced plaque — 3.88 times, and moderate to severe gingivitis — 5.12 times ($p < 0.001$). The risk of moderate to pronounced gingival inflammation according to SBI increased 4.47 times. Correlation analysis revealed a strong positive association of ISI with dental anxiety ($r^2 = 0.66$; $p < 0.001$) and frequency of negative behavioral reactions ($r^2 = 0.62$; $p < 0.001$). At high ISI, the risk of pronounced dental anxiety increased 5.33 times, and the likelihood of negative or strongly negative behavior — 5.63 times.

ROC analysis demonstrated high diagnostic accuracy of the Immune-Stress Index (AUC = 0.86; 95% CI: 0.79–0.92; $p < 0.001$). The optimal ISI threshold was 6.1 units, at which sensitivity reached 82.4% and specificity 78.1%.

These findings confirm that the Immune-Stress Index reflects not only biochemical changes but also clinical, behavioral, and psychoemotional aspects of dental health. High ISI values create a self-perpetuating pathogenic cycle in which chronic stress and immune disturbances exacerbate behavioral maladaptation, which in turn aggravates inflammatory processes in

the periodontal tissues.

4. Conclusions

The Immune-Stress Index correlates significantly with hygienic, periodontal, behavioral, and psychoemotional indicators ($r^2 = 0.59–0.67$; $p < 0.001$), reflecting the integral clinical-functional state of the oral cavity in children with hearing impairment.

High ISI values are associated with a 3.9–5.6-fold increased risk of unfavorable dental status and demonstrate high prognostic significance (AUC = 0.86), supporting the recommendation to use ISI for risk stratification and preventive care in children with disabilities and hearing impairment.

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