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Comparative analysis of statistical data and oral hygiene indices among different groups of smokers

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Abstract. The aim of the study was to compare the oral hygiene status of individuals consuming different types of tobacco products. The research methodology involved stratification of the sample by type of tobacco use, clinical examination employing standardised indices, comparative statistical analysis, and visual verification of the outcomes. The study was conducted from September 2023 to April 2024 at the private dental clinic of sole proprietor Kravchenko B.I. "GooDDentist". The highest value of the decayed, missing, and filled teeth index was recorded among cigarette smokers (13.0 points), whereas users of heat-not-burn systems exhibited the greatest levels of the soft plaque index (3.05) and calculus index (2.90), indicating intensive biofilm accumulation. Consumers of smokeless (application) tobacco demonstrated the highest gingival index (3.60), reflecting gingival irritation. The proportion of each group in the overall clinical cohort comprised 41.7% (cigarette smokers), 36.1% (users of heat-not-burn systems), and 37.2% (pouch tobacco users). The most clinically relevant adjuncts were the disclosing agent (96%), remineralising gel (94%), and glycine-based air-abrasive powder (92%), confirmed by both objective indicators and patient-reported outcomes. Clinical profiles of tobacco users in Ukraine corresponded to trends documented in Germany, Lithuania, and the Czech Republic, where inflammatory, biofilm-related, or caries-associated alterations predominate depending on the type of tobacco exposure. The findings support the feasibility of implementing personalised preventive protocols tailored to the specific tobacco product type, which may be integrated into dental and clinical hygiene practice as well as inform the development of state-level guidelines for individualised prevention of tobacco-associated oral lesions

Keywords: tobacco use; clinical risk; calculus index; dental prevention; smokeless tobacco; enamel lesions

INTRODUCTION

The growing diversity of tobacco products, including electronic heat-not-burn (HNB) devices, application forms in sachets, and modified cigarettes, has led to a substantial transformation in tobacco-use patterns across many countries. The spread of alternative nicotine-delivery systems is accompanied by the emergence of novel patterns of impact on oral tissues, differing from traditional smoking models. Consequently, there has been an increased need to revise classical approaches to assessing the oral hygiene status of individuals who regularly consume new forms of tobacco products. The issue is further complicated by the fact that, with changes in the chemical composition of smoke, aerosol, or substrate, clinical manifestations may remain undetected when conventional indices are applied without consideration of tobacco-specific effects.

In the study by M. Krawczyk-Suszek & A. Kleinrok [1], it was established that the quality of life of elderly individuals is largely determined by oral health, with oral hygiene indices directly correlating with the level of general somatic health. It was found that disturbances of oral homeostasis contribute to social isolation, loss of appetite, and reduced functional status, underscoring the priority of oral hygiene in geriatric practice. M. Antinozzi *et al*. [2] demonstrated that long-term cigarette smokers exhibited a significant decline in the microbial diversity of the intestinal microbiota, indicating the systemic nature of tobacco-related changes. The authors emphasised that such microbiome alterations may indirectly affect oral health via modulation of the general immune background. However, differences in oral hygiene

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status depending on the type of tobacco exposure were not defined.

S.E. Baumeister *et al.* [3] proved a causal relationship between active smoking and tooth loss, manifested by an increased risk of dentition reduction even after smoking cessation. H.F. Ibrahim & G.S. Hassan [4] identified structural enamel changes in cigarette smokers, including decreased mineralisation and the formation of microcracks, facilitating the penetration of pathogenic agents into deeper tooth layers. A. Beklen *et al*. [5] observed concurrent deterioration of periodontal status and intensification of carious processes in smokers, allowing classical smoking to be regarded as a dual dental hazard factor. However, the authors did not perform comparisons with other tobacco products, such as HNB systems or smokeless (application) tobacco.

R.R. Karanjkar *et al*. [6] provided consolidated evidence of tobacco and nicotine causing persistent discolouration of hard dental tissues, complicating visual diagnostics and adversely affecting patients' psycho-emotional well-being. M.L.S. Souto *et al.* [7] identified a strong correlation between the degree of nicotine dependence and the probability of tooth loss, particularly in individuals over 40 years of age, highlighting the critical role of consumption intensity. In the experimental study by S.H. Lee *et al.* [8], nicotine exposure was shown to accelerate bone resorption, potentially increasing the risk of tooth mobility in users of alternative nicotine products, including electronic devices. These studies, however, lacked a comprehensive approach to assessing integral dental risk through standardised oral hygiene indices.

In the dissertation by A.V. Dvornyk [9], quantitative evidence was obtained confirming that oral hygiene status plays a key role in enhancing the effectiveness of aesthetic dental interventions, particularly tooth whitening. T.O. Yashkina [10] reported that young users of HNB systems exhibited more frequent signs of gingival hyperaemia and superficial gingivitis, indicating an inflammatory component in the relative absence of carious lesions. I. Korzhov & D. Geleta [11] documented that the use of smokeless tobacco ("snus") leads to local mucosal damage, including ulcerative lesions in areas of direct contact. T. Komisova *et al.* [12] identified early respiratory changes among adolescents using electronic cigarettes, suggesting a general inflammatory status capable of influencing oral tissues via systemic immune mechanisms. Nevertheless, the issue of integrating these effects into standardised preventive protocols remains unaddressed.

A review of the current literature revealed an insufficient level of intergroup comparison regarding the hygienic consequences of different types of tobacco products within a single cohort. No comprehensive comparison has been provided simultaneously for the soft plaque index, calculus index, gingival index, and filled teeth (DMFT) index across cigarette smokers, HNB users, and smokeless tobacco consumers. Furthermore, the efficacy of clinical hygiene interventions under conditions of tobacco exposure remains poorly elucidated, limiting the practical applicability of previous research in individualised dental prevention. The aim of this study was to determine the differentiated clinical characteristics of oral status among individuals with various forms of tobacco use, with subsequent justification of the effectiveness of personalised preventive approaches. To achieve this aim, the following objectives were set: to assess differences in soft plaque, calculus, gingival, and DMFT indices depending on the type of tobacco product consumed; to determine localisation and intensity patterns of dental deposits using disclosing agents; to compare the obtained data with elements of preventive dental practice implemented in Germany, Lithuania, and the Czech Republic.

MATERIALS AND METHODS

The study employed a cross-sectional comparative design aimed at assessing oral hygiene status among patients with different models of tobacco use. The investigation was conducted between September 2023 and April 2024. The practical component took place at the private dental clinic of sole proprietor Kravchenko B.I. "GooDDentist". This multidisciplinary platform enabled the formation of a representative sample and ensured coverage of a broad range of clinical cases, thereby enhancing the validity of comparative results. Primary data collection was based on participants' voluntary informed consent.

The research complied with the requirements of the WMA Declaration of Helsinki [13] and the Order of the Ministry of Health of Ukraine No. z1010-09 "On Approval of the Procedure for Conducting Clinical Trials of Medicinal Products and Examination of Clinical Trial Materials and the Model Regulation on Ethics Committees" [14]. A total of 44 participants were enrolled. Inclusion criteria comprised: regular use of only one type of tobacco product for at least one year, absence of severe systemic diseases, and consent to clinical examination. Exclusion criteria included: systemic antibiotic or immunosuppressant intake within the previous three months, pregnancy, and dental treatment within the preceding 30 days. The mean age of participants was 27.7 ± 4.6 years; males accounted for 56.8%, females for 43.2%. Respondents were stratified into three analytical groups according to tobacco product type: cigarette smokers (n = 15), HNB users (n = 14), and smokeless tobacco pouch (snus) users (n = 15). The selection of these three forms was determined by their prevalence among young adults and aligned with World Health Organization recommendations [15] for differentiated assessment of dental risks under tobacco exposure. Each participant completed a standardised questionnaire providing information on duration and frequency of tobacco use, oral hygiene routines, and history of dental interventions. Subjective evaluation of procedural effectiveness and comfort was conducted using a visual analogue scale, where 0 indicated no discomfort and 10 represented maximum discomfort. Participants also rated satisfaction with clinical outcomes. Clinical examination followed a uniform protocol, employing validated index scales and technical tools for visualisation, cleaning, and documentation of oral tissue conditions. For comparative purposes, countries with updated data on risk-oriented preventive protocols – Germany, Lithuania, and the Czech Republic – were included in the analysis. The selection was justified by the availability of publicly accessible hygiene strategies [16-18] adapted to different tobacco-use models and confirmed clinical efficacy of the implemented measures within oral health-care systems [19]. This allowed expansion of the international

context of the findings and facilitated extrapolation of conclusions to the level of practical preventive applications.

The information base of the study comprised clinical examination records, individual anamnesis charts, standardised tobacco-use questionnaires, index registration sheets, summary diagrams, and photographic documentation of oral conditions. The methodological framework was grounded in the application of modified indices by J.G. Greene & J.R. Vermillion [20], and S.L. Fischman [21], adapted to the specific clinical circumstances. Partial and cumulative indicators were calculated in Microsoft Excel, while statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) software, with computation of mean values, standard deviations, and p-values. Interval and ratio scales were applied for metric indices, and nominal variables – for stratified categorical parameters. Clinical examination of oral hygiene status was conducted using five validated indices: the Debris Index Simplified (DI-S), the Calculus Index Simplified (CI-S), the Oral Hygiene Index Simplified (OHI-S), the Modified Gingival Index (MGI), and the Decayed, Missing, and DMFT. The selection of these indices was determined by their international recognition, validation for comparative clinical analysis, and ability to encompass both soft and hard tissue components of oral hygiene impairment. The presence of soft dental deposits was assessed through visual examination of six index teeth following the application of MIRA-2-TON disclosing solution (manufacturer – Hager Werken, Germany), which allowed differentiation between mature (dark violet) and fresh (pink) plaque. Hard deposits were detected by probing the cervical areas using sterile dental instruments. The integrated oral hygiene status was determined by the cumulative scoring of the DI-S and CI-S indices, whereas the condition of the gingivae was evaluated using the non-invasive MGI. The level of dental pathology was determined using the DMFT index, based on the quantitative recording of decayed, filled, and missing teeth.

The calculation of indices was performed according to standardised clinical protocols. The DI-S index was established based on plaque assessment of six index teeth, with each surface scored on a four-point scale depending on the proportion of surface coverage. The CI-S index was computed analogously, recording the presence of calculus in the same regions. The composite OHI-S score was obtained as the sum of DI-S and CI-S values, providing an integrated assessment of oral hygiene status. The MGI index was determined via clinical evaluation of gingival inflammation severity without the use of a probe, taking into account colour, texture, and bleeding tendency. The DMFT index reflected the total number of decayed, filled, and missing teeth recorded during the clinical examination, serving as an indicator of the structural pattern of dental caries experience.

The clinical intervention was implemented according to a standardised sequence of procedures tailored to the individual level of dental risk. The initial stage involved application of the MIRA-2-TON disclosing agent to verify plaque localisation, followed by air-abrasive cleaning using GENTLE glycine powder (particle size 65 µm, Supragingival Glycine). The final stage included application of Fluor Protector Gel (manufacturer – Ivoclar Vivadent, Switzerland) aimed at enamel layer stabilisation and hypersensitivity reduction. The clinical efficacy of each agent was evaluated using a three-point scale (0-3), where 0 – no effect, 1 – mild, 2 – moderate, and 3 – pronounced clinical outcome. The clinical relevance index (%) represented the proportion of participants in whom the respective agent produced a positive effect, as determined by the combination of objective clinical and subjective assessments. All procedures were carried out in compliance with aseptic principles and clinical safety protocols, including the use of sterile metal instruments.

Data collected during the clinical stage were systematised into standardised registration forms and processed using Microsoft Excel and SPSS, version 25.0. Statistical analysis included calculation of means, standard deviations (SD), and intergroup comparisons using one-way analysis of variance (ANOVA). Prior to ANOVA, data normality was verified using the Shapiro-Wilk test [22], and homogeneity of variances assessed via Levene's test [23]. In the presence of statistically significant differences, post hoc analysis was conducted using Tukey's HSD test to identify pairs of groups with reliable distinctions. The threshold of statistical significance was set at $p < 0.05$ [24]. Interpretation of the results accounted for both quantitative indices of oral hygiene across three stratified groups and subjective evaluations of procedural efficacy and comfort by participants. This approach enabled the formation of a differentiated model of clinical risks, integrating data on the actual oral condition with behavioural aspects of hygiene-related compliance. The obtained findings served as a foundation for developing personalised preventive strategies within a risk-oriented dental practice framework.

RESULTS

Comparative characteristics of oral hygiene status in groups of different smoker types. Within the quantitative analysis of oral hygiene status among participants stratified according to tobacco use model, mean values of the principal indices were compared, followed by statistical assessment of intergroup differences. The application of one-way ANOVA confirmed the presence of statistically significant differences, ensuring the reliability of subsequent clinical interpretations. This analytical design enabled determination not only of the direction of changes but also of the effect size, forming the basis for stratified recommendations. The comparison encompassed five standardised indicators: debris index, calculus index, composite hygiene index, MGI, and DMFT index. Table 1 presented mean values and SD for each study group. Corresponding p-values are also provided to assess the statistical significance of intergroup differences within the confidence threshold.

Table 1. Extended intergroup comparison of mean hygiene indices with corresponding p-values

Tobacco use type	DI-S, points ± SD	CI-S, points ± SD	OHI-S, points ± SD	MGI, points ± SD	DMFT, points ± SD
Conventional cigarettes	2.85 ± 0.41	2.06 ± 0.39	4.91 ± 0.62	2.88 ± 0.43	13.0 ± 2.5
HTP	3.05 ± 0.45	2.90 ± 0.37	5.95 ± 0.57	3.20 ± 0.51	8.8 ± 2.1
Smokeless tobacco (Snus)	2.55 ± 0.38	2.20 ± 0.36	4.75 ± 0.55	3.60 ± 0.48	9.4 ± 2.2
p-value	0.032	0.018	0.005	0.021	0.009

Source: compiled by the author based on J.G. Greene & J.R. Vermillion [20], S.L. Fischman [21]

The results presented in Table 1 revealed statistically significant intergroup differences across all five investigated hygiene indices. The highest mean values of DI-S, CI-S, and OHI-S were observed among HNB users, indicating a predisposition to accumulation of both soft and hard deposits despite the absence of combustion. In the group of oral tobacco pouch users, the highest MGI score was recorded, possibly attributable to prolonged chemical irritation of the gingivae in the application zone. Conversely, the highest DMFT levels were found among cigarette smokers, reflecting the cumulative negative effect of smoke exposure.

To enhance interpretation of quantitative results, a clinical visualisation stage was included, providing empirical confirmation of the identified oral hygiene impairments. Visual materials enabled detailed characterisation of deposit morphology, localisation on tooth surfaces, and gingival response patterns. This approach facilitated more precise validation of the DI-S index, ensuring visual correlation with quantitative findings. In this context, Figure 1 illustrated a typical clinical case of a 28-year-old male tobacco user with a two-year history of HNB system use. Following MIRA-2-TON application, areas of soft dental plaque were visualised, confirming a high DI-S score within this stratified group. The image depicts a clinical presentation not fully conveyed by tabulated data, enriching the analysis by combining quantitative assessment with visual verification.

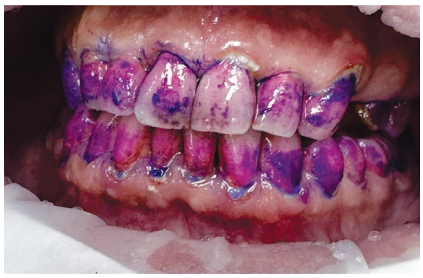

Figure 1. Visualisation of soft plaque after application of the MIRA-2-TON disclosing solution in a patient with a high DI-S index level
Source: photo by the author

Figure 1 demonstrated pronounced accumulation of deposits in the cervical region of anterior teeth and on approximal surfaces, which are typical plaque retention sites in cases of suboptimal oral hygiene practices. Post-application of MIRA-2-TON revealed distinct pink (fresh plaque) and dark violet (mature plaque) staining, providing qualitative insight into the duration of hygiene neglect. Variability in staining distribution across tooth surfaces reflects inconsistent hygiene practices and underscores the necessity for individualised oral hygiene interventions in such patients. The observed visual characteristics correspond to the quantitative values reported in Table 1, where HNB system users exhibited the highest mean DI-S and CI-S indices. The localisation of plaque in cervical and interproximal areas indicates increased self-cleaning difficulty within this user group, justifying the application of more intensive or professionally guided hygiene measures. Thus, the clinical image serves as a visual confirmation of empirical observations, complementing the interpretation of quantitative research data.

Dynamics of clinical response to oral hygiene intervention depending on type of tobacco use. Comparative assessment of DI-S, CI-S, MGI, and DMFT indices among stratified tobacco user groups was conducted based on clinical data collected pre-intervention and at a three-week follow-up visit. The study included cigarette smokers, HNB users, and oral tobacco pouch users. Statistically significant differences between pre- and post-intervention values were determined using analysis of variance, with clarification of intergroup variability. Summarised data are presented in Table 2, showing mean index values, standard deviations, levels of change, and p-values for each group.

Table 2. Dynamics of hygiene index changes in stratified groups of tobacco users (before and after intervention)

Index/User group	Before intervention (Mean ± SD)	After intervention (Mean ± SD)	Δ (Change)	p-level
DI-S				
Cigarette smokers	2.5 ± 0.4	1.7 ± 0.3	-0.8	0.031
HTP system users	2.4 ± 0.3	1.1 ± 0.2	-1.3	0.004
Snus users	2.3 ± 0.5	1.3 ± 0.3	-1.0	0.010
CI-S				
Cigarette smokers	2.1 ± 0.3	1.3 ± 0.3	-0.8	0.038
HTP system users	2.2 ± 0.2	0.9 ± 0.3	-1.3	0.005
Snus users	2.0 ± 0.4	1.0 ± 0.2	-1.0	0.011
MGI				
Cigarette smokers	2.0 ± 0.3	1.6 ± 0.2	-0.4	0.047
HTP system users	1.9 ± 0.3	1.3 ± 0.2	-0.6	0.030
Snus users	2.1 ± 0.2	1.2 ± 0.3	-0.9	0.009

Table 2. Continued

Index/User group	Before intervention (Mean ± SD)	After intervention (Mean ± SD)	Δ (Change)	p-level
DMFT				
Cigarette smokers	5.2 ± 1.1	5.1 ± 1.0	-0.1	0.810
HTP system users	4.8 ± 0.9	4.8 ± 0.9	0.0	1.000
Snus users	5.0 ± 0.8	5.0 ± 0.8	0.0	1.000

Source: compiled by the author based on J.G. Greene & J.R. Vermillion [20], S.L. Fischman [21]

At the three-week follow-up, all stratified tobacco user groups exhibited a significant reduction in mean DI-S, CI-S, and MGI values. In HNB users, DI-S and CI-S decreased by more than 1.3 points, with MGI reduced by 0.6. Among pouch users, MGI decreased by 0.9 points, accompanied by plaque and calculus reductions averaging 1.0 point. In cigarette smokers, DI-S and CI-S declined by 0.8, while MGI showed a mean reduction of 0.4. All three groups demonstrated no change in DMFT values, which remained statistically stable throughout the observation period. The mean DMFT score among HNB users was 4.8 ± 0.9 pre- and post-intervention; pouch users – 5.0 ± 0.8; cigarette smokers – 5.2 ± 1.1 with a negligible 0.1 decrease, which did not reach statistical significance ($p > 0.05$). The absence of DMFT variation reflects structural stability of hard tissue lesions over short-term clinical observation. To systematise outcome dynamics, an integrated clinical response index was developed. The analytical model incorporated absolute changes in DI-S, CI-S, MGI, and DMFT across groups, alongside average percentage reductions for the first three indices. Based on these aggregated parameters, the nature of clinical response was characterised, differentiating intervention efficacy according to tobacco product type (Table 3).

Table 3. Nature of the clinical response to hygienic intervention in stratified groups of tobacco users

Tobacco user group	Total index reduction (points)	Percentage reduction (%)	Response pattern	Intervention type
Cigarette smokers	DI-S (-0.8), CI-S (-0.8), MGI (-0.4), DMFT (-0.1)	~23	Moderate	Air-Abrasive Sanitation + Fluor Protector
HTP system users	DI-S (-1.3), CI-S (-1.3), MGI (-0.6), DMFT (0)	~39	Rapid	Air-Abrasive Sanitation + Fluor Protector
Snus users	DI-S (-1.0), CI-S (-1.0), MGI (-0.9), DMFT (0)	~35	Moderate	Air-Abrasive Sanitation + Fluor Protector

Source: compiled by the author based on World Health Organization [19], J.G. Greene & J.R. Vermillion [20], S.L. Fischman [21]

Summarised quantitative analysis revealed the greatest reduction of hygiene indices among HNB users, with an overall decrease of approximately 40%. Pouch users exhibited comparable reduction levels, predominantly driven by MGI change (-0.9). Cigarette smokers demonstrated the least positive dynamics, with only partial MGI reduction and stable DMFT values. These differences confirm dependence of index dynamics on the nature of tobacco exposure. The presented data may inform recommendations on frequency and intensity of maintenance interventions.

Clinical and preventive implications of differentiated oral hygiene response depending on tobacco use type. Analysis of empirical findings identified distinct effects of various tobacco products on oral hygiene status. Each investigated tobacco user group exhibited a specific structure of hygiene impairment determined by the physicochemical properties of the product, frequency of use, and type of mucosal contact. Smokers demonstrated the highest DMFT scores. HNB users showed predominance of DI-S and CI-S indices, while pouch users exhibited elevated MGI values. Stratification of clinical characteristics within each cohort accounted for both general trends and demographic-behavioural differences. Among cigarette smokers, the majority had a smoking history exceeding 10 years. HNB users typically presented high consumption intensity but shorter usage duration; nevertheless, repeated aerosol exposure contributed to biofilm accumulation in interdental spaces. Pouch users, despite lower mean age, displayed a pronounced inflammatory component in the attached gingiva. To visualise differentiated risk, Table 4 summarised the profile of the highest index values for each study group. The table also outlined corresponding clinical risks and defines hygiene intervention targets relevant to the identified pathological predominance. This summarised format facilitates transition from descriptive clinical observations to structured planning of individualised preventive care.

Table 4. Differentiation of dental risk profiles in tobacco user groups

Profiles in tobacco user groups	Highest index	Clinical risk	Recommended intervention strategy
Cigarette smokers	DMFT	Multiple carious lesions, gingival recession and tooth loss against a background of generalised hygiene impairments.	Restorative and remineralisation therapy, sanitation.
HTP system users	DI-S, CI-S	Accumulation of soft and mineralised deposits.	Chemical biofilm disintegration, regular professional hygiene.
Snus users	MGI	Chronic gingivitis.	Local anti-inflammatory therapy, gingival protection.

Source: compiled by the author

Systematised analysis of the obtained data revealed distinct differences in the clinical and hygienic profiles of tobacco users depending on the type of tobacco product consumed. In the group of cigarette smokers, the highest values of the DMFT index were recorded, which were accompanied by profound hygienic disturbances. Among HNB system users, the highest DI-S and CI-S index values were registered, with localisation of changes in the cervical region. In patients using pouches, the MGI demonstrated the highest values, reflecting alterations within the marginal gingival area. In order to comprehensively evaluate the effectiveness of the clinical agents utilised in the study, a systematic comparison of their functional characteristics was conducted. The assessment encompassed three key components: objective efficacy based on standardised scoring scales, the level of patients' subjective satisfaction, and the compliance of each agent with its designated clinical purpose. Table 5 summarised the findings of this analysis, providing correlation between quantitative indicators and the practical applicability of each product within differentiated hygienic interventions.

Table 5. Comparative characteristics of clinical manifestations and hygienic strategies among tobacco users in Ukraine and European Union (EU) countries

Country	Tobacco user group	Clinical risk	Key index	Preventive measures
Ukraine	Cigarette smokers (dominant group)	High DMFT level, decompensated hygiene.	DMFT	Complex sanitation, remineralisation, chemotherapy.
Germany	HTP users	Predominance of biofilm, gingival hyperplasia.	DI-S, CI-S	Professional cleaning, hygiene education.
Czech Republic	Cigarette smokers	Multiple enamel lesions, deep periodontal pockets.	DMFT, MGI	Periodontal intervention, oral cavity hygiene.
Lithuania	Snus users	Local gingivitis, gingival recession.	MGI	Antiseptic therapy, daily care.

Source: compiled by the author based on World Health Organization [16-18]

Analysis of the clinical agents' effectiveness, presented in Table 5, demonstrated their high functional performance both within standard dental procedures and under risk-oriented preventive conditions among various categories of tobacco users. Each agent fulfilled a specific clinical function within the framework of a sequential hygiene protocol: MIRA-2-TON enabled visualisation of the biofilm, GENTLE glycine powder ensured its gentle removal, and Fluor Protector Gel provided a remineralisation stage completing the procedure. The combined use of these products facilitated a comprehensive approach to clinical debridement, reducing the risk of tissue trauma and enhancing the overall preventive effect. The consistency between objective clinical outcomes and high patient-reported satisfaction scores supports the rationale for incorporating this combination into the recommended toolkit for dental management of individuals with increased hygienic load.

A comparative analysis with existing practices in EU countries revealed convergence in preventive care strategies, grounded in the integration of agents with proven clinical efficacy. In Germany, standard protocols include glycine-based abrasives and remineralising gels targeting users of HNB systems. In Lithuania, active use of plaque-disclosing dyes, particularly MIRA-2-TON, has been integrated into protocols for individuals using smokeless tobacco pouches, with an emphasis on gingivitis prevention. The Czech Republic demonstrated systematic implementation of three-component protocols for cigarette smokers, accounting for the distribution of lesions based on the DMFT index and periodontal tissue dynamics. Considering the structural characteristics of tobacco consumption in Ukraine, sanitising and remineralising interventions, accompanied by verification methods for early detection of pathological areas, remain a priority. The increasing proportion of HNB device and pouch users necessitates the introduction of individualised strategies, particularly involving mild abrasives and anti-inflammatory agents. Such an approach establishes the basis for standardising oral hygiene care in accordance with the epidemiological profile of tobacco use and contributes to the formation of personalised preventive models. To enhance interpretation of the results, key clinical risks associated with predominant forms of tobacco use in four EU countries were systematised. The relationship between the type of tobacco product, characteristic oral health threats, and established preventive strategies was analysed. The synthesis of these indicators enables cross-country assessment of protocol relevance in light of epidemiological burden. Summarised findings were presented in Table 6.

Table 6. Efficacy of clinical agents used in the study

Clinical agent	Target purpose	Efficacy on scale (0-3)	Patient assessment (0-10)	Clinical relevance (%)
MIRA-2-TON	Dental plaque visualisation	2.9	9.1	96
GENTLE glycine powder	Air-abrasive cleaning	2.7	8.7	92
Fluor Protector Gel	Enamel remineralisation	2.8	8.9	94

Source: compiled by the author

The highest clinical relevance within the study was demonstrated by the disclosing agent MIRA-2-TON (96%), which provided precise localisation of plaque-affected areas. Visualisation of both mature and new deposits facilitated prompt identification of intervention sites and improved patient compliance through visual engagement in the hygiene process. The mean efficacy score of the product was 2.9 on a three-point scale, indicating its capacity

to detect lesions even at early stages of biofilm formation. Fluor Protector Gel approached maximum performance indices (2.8 points; 94% relevance), implementing its remineralising function during the final stage of the clinical procedure. Its use contributed to enamel reinforcement, reduction of hypersensitivity, and additional protection for individuals with elevated DMFT values, particularly cigarette smokers. GENTLE glycine powder provided the most delicate cleaning, with an efficacy index of 2.7 points and the highest level of tolerability on the subjective scale (8.7 points). The combined application of these three agents enabled the implementation of a comprehensive hygiene cycle – from diagnostic verification to debridement and remineralisation – with adaptation to the clinical profile of each type of tobacco user.

The oral hygiene status of individuals stratified by tobacco product type demonstrated significant variability across DI-S, CI-S, MGI, and DMFT indices, reflecting diverse pathogenetic mechanisms. Cigarette smokers exhibited the highest DMFT values, indicating a predominance of structural enamel lesions and the need for complex restorative interventions. HNB users presented elevated DI-S and CI-S indices, signifying intensive accumulation of soft and hard deposits. Pouch consumers showed the highest MGI levels, interpreted as a chronic inflammatory response of gingival tissues to direct exposure to tobacco-derived chemical agents. Comparative analysis with clinical practices documented in Germany, Lithuania, and the Czech Republic confirmed the relevance of approaches tailored to specific tobacco-related burdens. In Germany, HNB users are prioritised for protocols combining glycine powders and remineralising gels for biofilm control. In Lithuania, plaque-disclosing dyes are integrated into gingivitis-prevention protocols for pouch users. In the Czech Republic, three-component protocols are adapted to DMFT index distribution among cigarette smokers. In Ukraine, implementation of adaptive protocols remains advisable, considering the predominance of cigarette smoking, thus justifying emphasis on debridement, remineralisation, and visualisation of pathological sites. The integrated use of the investigated clinical agents aligns with these requirements and substantiates a risk-oriented approach to dental prophylaxis.

DISCUSSION

The obtained results confirmed that the form of tobacco use determined the specific pattern of oral hygiene disturbances. The highest values of the DI-S and CI-S were registered among HNB system users, indicating intensive accumulation of both soft and mineralised deposits, attributed to reduced self-cleansing capacity following aerosol tobacco exposure. This deposit profile was associated with the formation of localised biofilm, predisposing to inflammatory processes within marginal tissues. In the group of cigarette smokers, the highest DMFT index values were observed, reflecting prolonged exposure to cariogenic factors and pronounced destruction of hard dental tissues due to the cumulative effects of tar and nicotine. Although soft deposit levels were moderate in this cohort, a tendency towards generalised periodontal pathology was evident. The lowest DI-S and CI-S values were recorded among smokeless tobacco users; however, this group demonstrated predominant inflammatory manifestations in the gingival margin area, reflected by elevated MGI scores. This was attributable to direct and prolonged mucosal contact with tobacco pouches, resulting in chronic irritation and local gingivitis development. Overall, the generalisation of the data revealed a type-specific oral risk profile for each group, supporting the necessity of an individualised approach to prevention and treatment, taking into account both clinical features and behavioural tobacco-use models.

The differentiated impact of various tobacco forms on oral hygiene indicators confirmed a significant deterioration in smokers and moderate changes among HNB users. Increased DI-S and CI-S indices in cigarette users reflected more intense deposit accumulation, consistent with the findings of N. Veiga *et al.* [25], who emphasised the need for early clinical interventions in high-caries-risk patients. That review also highlighted the importance of behavioural stratification in preventive planning, aligning with this study's conclusion regarding the necessity for personalised hygiene strategies according to tobacco exposure type. Particular emphasis was placed on standardisation of assessment methodology, including the use of unified indices (DMF, DI-S, and MGI), ensuring comparability across study groups. Despite this unification, significant differences were identified between smokeless tobacco users and cigarette smokers. According to multifactorial analysis by C. Henschke *et al.* [26], reduced accessibility to dental care is directly associated with higher DMFT levels. Within the context of these findings, such association explains the increased frequency of structural tooth damage among long-term tobacco users.

Further analysis indicated that the highest DI-S and CI-S values were recorded in smokers with extended duration of use, reflecting substantial microbial biofilm accumulation. Research by S. Petrauskienė *et al.* [27] established that even occasional tobacco use among adolescents correlates with deviations from recommended oral hygiene standards. This behavioural determinant predisposes to compromised hygiene status regardless of age, consistent with the outcomes observed in this study. A critical aspect concerned alterations in the oral microbiome associated with different tobacco forms. B. Panariello *et al.* [28] demonstrated that electronic cigarettes and HNB systems modify bacterial composition, promoting predominance of anaerobic pathogenic strains. The present findings corroborate this trend, revealing increased gingivitis prevalence even in the absence of pronounced plaque accumulation, thereby identifying microbiome alteration as a key pathogenetic mechanism.

Analysis of clinical indices further showed that regular cigarette smokers had a statistically higher rate of tooth loss compared with other groups. This relationship indicates the cumulative nature of damage developing under prolonged exposure to tobacco components. M.D.C. Lara-Muñoz *et al*. [29] reported a significant association between tobacco and alcohol consumption frequency and increased tooth loss rates among young adults. The data obtained herein reinforce the multifactorial nature of oral lesions developing in the context of behavioural risks, including hygiene awareness level and access to preventive care. Advanced assessment of periodontal tissues revealed that cigarette smokers predominantly exhibited clinical signs of inflammatory lesions, particularly localised gingivitis,

as reflected in elevated MGI values. Similar findings were reported by R. Shah *et al.* [30], who investigated the effects of prolonged smoking on the periodontal status of young patients. The authors noted a high incidence of gingivitis among individuals with a smoking history, consistent with the clinical patterns identified in the present study.

The fixed variants of dental lesions identified during the clinical stage revealed a close association between the mode of tobacco use and the spectrum of clinical changes. Such a relationship is consistent with the findings of S. Gajendra *et al*. [31], who highlighted the importance of considering both the biological effects of tobacco products and the role of dentists in implementing smoking cessation strategies. The authors emphasised the significance of behavioural modification as an integral component of hygienic intervention, which also corresponds to the results of this study, particularly regarding the need for type-specific preventive algorithms. Within the overall picture of clinical lesions, it was established that the detrimental impact of tobacco products extended to all structural components of the oral cavity – from the soft tissues to the enamel. As demonstrated in the systematic review by B.W. Chaffee *et al*. [32], both traditional cigarettes and alternative forms of tobacco products lead to structural changes in the periodontium and disruption of its functional status. The signs of combined gingival and enamel lesions identified in this study are consistent with the patterns described by the authors and reinforce the argument for a pathogenic effect regardless of the type of tobacco product.

An in-depth stratification of clinical data revealed that the use of heated tobacco systems and electronic cigarettes was accompanied by less pronounced deterioration in hygienic indices compared with traditional cigarettes. However, isolated episodes of mucosal inflammation were recorded in these groups, indicating the chronic influence of aerosol components. Similar findings were reported by M. Ilchyshyn *et al*. [33], who observed that users of heated tobacco systems (GLO and IQOS) exhibited poorer hygiene and higher caries intensity compared to controls, confirming the negative impact of these products on the hard dental tissues and periodontium. A similar dynamic was documented in the systematic review by N. Camoni *et al*. [34], which confirmed the gradual modification of dental status under the influence of alternative tobacco forms without distinct macroscopic lesions. The moderate changes in indices identified in these groups in this study are in agreement with the reported findings. The highest DMFT index values were registered among respondents with long-term cigarette use, indicating an increased risk of tooth loss in this category. In the publication by M.L.S. Souto *et al*. [35], the feasibility of implementing smoking cessation programmes was emphasised as a cost-effective measure for reducing the incidence of periodontal complications. The findings obtained in this study support the necessity of incorporating behavioural interventions into preventive protocols to ensure long-term preservation of oral health.

The assessment of soft dental deposits using the disclosing solution MIRA-2-TON and the DI-S index demonstrated a significant amount of deposits, predominantly among cigarette smokers. This indicates the low effectiveness of current hygienic practices in this group. In the controlled study by J. Milleman *et al.* [36], the effectiveness of comprehensive hygienic care – including a toothbrush, dental floss, and mouthrinses – in reducing plaque and gingivitis manifestations was confirmed. Comparison with the obtained data indicates the necessity of implementing multicomponent hygienic measures to enhance clinical effectiveness in at-risk groups. Additional analysis of the MGI index demonstrated the predominance of moderate forms of gingivitis among young individuals who regularly consumed tobacco products. In the study by S. Kumar *et al.* [37], the influence of behavioural factors, particularly smoking, on oral hygiene status and gingival condition in the adolescent population was demonstrated. The presented results indicated that the development of effective hygienic skills is of critical importance for the prevention of inflammatory lesions, which is fully consistent with the conclusions obtained in this study.

Among individuals who simultaneously used cigarettes and smokeless tobacco (pouches), the highest values of all assessed hygiene and tissue damage indices were recorded, indicating a synergistic effect of combined forms of tobacco use. In the study by A. Ahad *et al.* [38], the impact of dual tobacco product use on periodontal status was analysed, revealing a higher prevalence of deep periodontal pockets and attachment loss. The results obtained are consistent with the clinical picture recorded within this study and confirm the significant pathogenic effect of the combined influence of different tobacco forms. Special attention was given to the evaluation of potential oncological risks arising from prolonged tobacco use. In the study by A. Hernández-Morales *et al.* [39], a statistically significant association was established between the frequency of tobacco consumption and the incidence of lip and oral cavity cancers. Furthermore, it was noted that socio-economic factors modulate the level of risk, which allows the results to be interpreted in a broader context, taking into account the complex interaction of biological and behavioural determinants.

The analysis of changes in hygienic status and tissue damage revealed differences depending on the form of tobacco use, indicating specific mechanisms of influence for each type of product. In the publication by P.J. Ford & A.M. Rich [40], the key pathophysiological mechanisms of tobacco's effects on the oral cavity were summarised, including disruption of the microbiota, altered immune responses, and inhibition of reparative processes. The authors emphasised that regardless of the form of tobacco product, the elevated risk of gingivitis, periodontitis, and preneoplastic changes persists, which corresponds with the clinical data obtained regarding differentiated patterns of damage in the study sample. The obtained results also confirmed an increased need for dental intervention among tobacco users in all groups, manifested in deteriorated hygienic status and increased frequency of lesions. In the study by A. Jebril *et al.* [41], an association between head and neck cancers and poor oral health, including tooth loss and high caries indices, was demonstrated. Such data correspond to the structure of the obtained results and justify the feasibility of early preventive diagnostics in populations with high levels of tobacco consumption.

During the course of the study, standardised indices were employed for the quantitative assessment of oral hygiene status, in line with approaches recommended by the

World Health Organization. In the World Health Organization [42], the use of validated clinical tools was emphasised, ensuring the consideration of behavioural risks, including tobacco use, in the oral health monitoring system. The empirical results obtained correspond with the concept of a differentiated approach to hygiene status assessment, which determines the feasibility of further standardisation of index methodologies in public health. A separate analytical block focused on identifying specific differences in clinical characteristics associated with the use of traditional cigarettes and heated tobacco systems. In the publication by M. Neuberger [43], the particularities of regulatory frameworks for the nicotine product market were considered, with emphasis on the issue of HNB devices. It was noted that the lack of a universally evidence-based approach to defining their risks precludes the establishment of unified clinical strategies, which is a relevant context for interpreting the ambiguous results obtained within this study. The study also analysed the effects of electronic cigarettes, taking into account the clinical characteristics inherent to users of these products. In the systematic review by F. D'Ambrosio *et al.* [44], it was established that although alternative forms of tobacco products demonstrate a relatively lower level of periodontal damage, they are not entirely safe. Adverse effects on both gingival tissues and peri-implant health were confirmed. These findings are consistent with the data obtained, according to which, even in the absence of extensive deposits, a pronounced gingival component persists in the clinical presentation.

The analysis of quantitative indicators confirmed statistically significant differences in oral hygiene status between the study groups, indicating the need for a type-specific approach to assessing dental risks. The clinical results obtained correlated with the trends described in interdisciplinary studies concerning the impact of various types of tobacco products on oral hygiene and periodontal status. The clinical feasibility of employing a set of minimally invasive procedures – including disclosing, glycine air-polishing, and remineralising agents – was also confirmed. The conclusions formed provide a basis for the further development of personalised preventive protocols, taking into account transformations in the structure of tobacco consumption.

CONCLUSIONS

In the framework of this study, a comparative analysis of the clinical and hygienic status of the oral cavity was conducted among representatives of three groups of tobacco users: individuals consuming traditional cigarettes, heated tobacco systems, and smokeless tobacco in the form of pouches. Based on the assessment of the DI-S, CI-S, MGI, and the DMFT index, statistically significant differences between the groups were established ($p < 0.05$). The highest DMFT index was recorded among cigarette smokers (13.0 points), indicating significant dental destruction. Heated tobacco system users showed the highest plaque (3.05 points) and calculus (2.90 points) indices, pointing to active biofilm formation and its mineralisation. Consumers of smokeless tobacco pouches were characterised by the highest MGI (3.60 points), indicating chronic gingival inflammation.

Structural analysis showed that cigarette smokers contributed the most to the overall caries index (41.7%), heated tobacco users to plaque (36.1%) and calculus (40.5%), and smokeless tobacco users to the MGI (37.2%). This indicates differential effects of products on oral health status. The evaluation of preventive agents confirmed their effectiveness: plaque-disclosing agent – 96%, remineralising gel – 94%, and air-abrasive powder – 92%. Their combined application ensured a full cycle of hygienic support depending on the type of tobacco exposure. Taking the obtained results into account, it seems appropriate to implement personalised preventive approaches stratified by type of tobacco load. It is recommended to adopt combined clinical protocols encompassing detection, mechanical cleaning, and remineralisation support, with adjustment depending on the dominant clinical risk.

The study encountered a number of methodological limitations that may affect the generalisability of the results. In particular, the sample size in certain groups of tobacco users limited statistical power during intergroup comparisons. An additional limitation was the varying duration of tobacco use among participants, which may have influenced the severity of clinical indicators. The objective assessment of the tolerability of dental interventions was accompanied by variability in subjective evaluations, which also impacted data homogeneity. Promising directions for future research include the investigation of oral hygiene status dynamics over long-term observation, the inclusion of biomarker monitoring of inflammatory processes, and the deepening of cross-national comparative analyses considering social and behavioural factors.

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CONFLICT OF INTEREST

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Порівняльний аналіз статистичних даних, гігієнічних індексів у різних групах курців

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Анотація. Метою дослідження було порівняти гігієнічний стан порожнини рота у споживачів різних типів тютюнових виробів. Методологія дослідження передбачала стратифікацію вибірки за типом тютюнокористування, клінічне обстеження з використанням стандартизованих індексів, порівняльну статистичну обробку та візуальну верифікацію результатів. Дослідження проводилось з вересня 2023 року по квітень 2024 року на базі приватної стоматології ФОП Кравченко Б.І «GooDDentist». Найвищий рівень індексу карієсу, пломб і втрат зубів спостерігався серед курців сигарет (13,0 бала), тоді як користувачі систем нагрівання тютюну мали максимальні показники індексу м'якого нальоту (3,05) та зубного каменю (2,90), що свідчило про інтенсивне накопичення біоплівки. У споживачів аплікаційного тютюну зафіксовано найвищий рівень індексу стану ясен (3,60), що вказувало на гінгівальне подразнення. Частка кожної групи у загальному клінічному навантаженні становила 41,7 % (курці сигарет), 36,1 % (користувачі систем нагрівання) та 37,2 % (використання паучів). Найвищу клінічну релевантність продемонстрували фарбувальний розчин для виявлення нальоту (96 %), ремінералізуючий гель (94 %) і повітряно-абразивний порошок на основі гліцину (92 %), що підтверджено як об'єктивними показниками, так і оцінками пацієнтів. Клінічні профілі тютюнокористувачів в Україні відповідали тенденціям, зафіксованим у Німеччині, Литві та Чехії, де домінують запальні, біоплівкові або карієсогенні зміни залежно від типу тютюнового навантаження. Отримані результати підтвердили доцільність впровадження персоніфікованих профілактичних протоколів із урахуванням типу тютюнового виробу та можуть бути інтегровані в практику стоматологів і клінічних гігієністів, а також використані при формуванні державних протоколів індивідуалізованої профілактики тютюново-асоційованих уражень

Ключові слова: тютюнокористування; клінічний ризик; індекс зубного каменю; стоматологічна профілактика; аплікаційний тютюн; ураження емалі