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Determination of predictors of non-carious cervical lesions of teeth using logistic regression analysis

Abstract

Relevance. Non-carious cervical lesions of teeth remain the second reason for contacting the dentist after tooth decay and its complications.

Aim. To determine predictors of the occurrence and progression of wedge-shaped defect (WSD) and erosion (E) of tooth enamel in young patients.

Materials and methods. 272 patients (mean age 24.3 ± 6.9 years) were examined, in which potential predictors were collected during the examination and questionnaire method. To analyse the strength of the association between the factors and the outcome, the odds ratio (OR) was used within a 95% confidence interval (CI). Univariate and multivariate logistic regression analysis was used to determine the predictors.

Results. Independent predictors of WSD were salivation rate less than 0.5 mL/min, hygiene habit of applying pressure to the toothbrush, age of 25 and older, the presence of gingival recession and tooth extraction. Latent predictors of WSD development were oral fluid pH (OF) values less than 6.9 C.U., behavioural factors, clinical markers. Potentially protective variables were variables with OR < 1: duration of brushing teeth for three minutes or more, consumption of yoghurt and bananas. Confounding was identified for the "fruit consumption" predictor. Independent predictors of the occurrence of enamel E were the presence of occlusal tooth wear and enamel cracks; modifier factors – OF pH values less than 6.9 C.U., and the habit of brushing teeth before breakfast. However, the broad CI determined for all predictors of the appearance of enamel E in univariate logistic regression analysis, and a small number of observations, indicate the prematurity of the results and the need for their confirmation. Most predictors of the progression of non-carious cervical lesions of teeth were latent and had broad CI in univariate logistic regression analysis, indicating evaluation instability and requiring further studies in larger samples.

Conclusions. The use of the logistic regression analysis method determined statistically independent and hidden predictors that are recommended to be considered in the diagnosis and preparation of a treatment plan for non-carious cervical lesions lesions of teeth in young patients.

Keywords: erosion; wedge-shaped defect; dietary and hygiene habits; oral fluid, cracks.

INTRODUCTION

Non-carious dental pathology in 55% of cases is diagnosed in the cervical region (CR). These are lesions that form in the area of the enamel-cement junction: wedge-shaped defects (WSD) and enamel erosion (E) [1]. Their aetiology is multifactorial, and prevention is difficult in the absence of a clear understanding

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of predictors [2]. Detailed review of aetiopathogenetic factors of non-carious cervical dental pathology, conducted by M. Dioguardi *et al.* [3], showed that they have differences from tooth decay. The occurrence of WSD and E is increasingly associated with the demineralising effect of acids that dissolve enamel minerals. Acids can have different similarities. This refers both to dietary acids found in food and drinks and to acids produced by bacteria. Together, additional conditions are created in the oral cavity (OC) to lower the OF pH. However, according to C.J. Goodacre *et al.* [4], regardless of the mechanism of development of non-carious cervical dental pathology, demineralisation represents the opposite process. Enamel is capable of reversible isomorphic replacement of its ions with saliva ions without destroying the crystal structure and dramatically changing its properties. This minimises its demineralisation and enhances remineralisation, which is carried out by OF, which is oversaturated with ions in relation to tooth enamel [5]. Therefore, saliva is considered as one of the important biological factors that has an intraoral neutralising effect on the action of acid. But this requires favourable conditions in the OC. First of all, the norm should be biophysical indicators of OF: salivation rate (SR), pH, and buffer capacity [6]. The role of other local aetiological factors is actively discussed in contemporary discourse. Increasing attention is being paid to the link between dental occlusion, temporomandibular disorders, parafunctional habits, and non-carious cervical lesions of the teeth. But research findings are sometimes contradictory. Thus, G.A. Fontelle *et al.* [7] did not determine the existence of a significant association between the presence of parafunctional habits (bruxism), stress, and the occurrence of dental pathology in young patients.

The influence of common factors on the appearance of cervical lesions of the teeth has also been proven. Special attention should be paid to the socio-economic and behavioural characteristics of the patient [8-9]. Other variables, such as the region of residence, are likely to influence the occurrence of WSD and E of tooth enamel [10]. Therefore, only a combination of various local and general factors can be crucial in the aetiopathogenesis of non-carious cervical dental pathology. Therefore, timely identification of individual predictors that have a significant impact on the occurrence of dental lesions will minimise their negative impact and include specific measures in a personalised prevention plan. However, this requires a detailed analysis of potential predictors. Most of them have specific consequences in different age groups. The most vulnerable, according to G.A. Fontelle *et al*. [7], are patients over the age of 30. This makes it relevant to determine predictors in young patients and separately consider the factors of their occurrence and progression for WSD and E of tooth enamel. The purpose of the study was to identify predictors of the occurrence and progression of WSD and E of tooth enamel in young patients, their detailing, and further analysis.

MATERIALS AND METHODS

Prim.ary data on potential predictors were collected during a survey of 272 patients (174 women and 98 men) with an average age of 24.3 ± 6.9 years, which included: review of the OC, assessment of the state of hard tissues of teeth, periodontal and hygiene levels, diagnosis of clinical symptoms of musculoskeletal dysfunction of the temporomandibular joint (TMJ) according to the Helkimo Clinical Dysfunction Index (HCDI) [11]; determination of biophysical indicators unstimulated OF (pH and buffer capacity using pH meter AZ-8689 in C.U., SR in mL/min) [12]. The psychoemotional state of the subjects was determined by the level of personal anxiety according to questionnaire by C.D. Spielberger *et al.* in the adaptation of Yu.L. Khanin [13]. A questionnaire was also conducted on the developed "Patient questionnaire/survey", which contained information on self-assessment of parafunctional, dietary, and hygienic habits; the most common complaints about systemic health and the list of diseases according to the International Classification of Diseases, 10th Revision. The criteria for inclusion in the study were young age according to the WHO classification (2016), absence of alcohol and drug addiction, neoplasms, tuberculosis, HIV/AIDS, hepatitis C, mental disorders, pregnancy and lactation, occupational hazards, and written informed consent to participate.

Statistical processing of the source data was performed using Microsoft Excel 2016 spreadsheets (Microsoft Corp., USA) and the Python 3.12 programming language. Univariate analysis (2x2 conjugacy tables) and logistic regression with L1 regularisation (LASSO) were used to determine predictors as the main method of multivariate analysis and the most effective machine learning model according to contemporary researchers [14-15]. LASSO regression models included all variables that had clinical substantiation for inclusion (n = 84). Calculations in Python 3.12 were performed using the pandas libraries for data processing, numpy for numerical calculations, statsmodels for evaluating univariate associations, and scikit-learn for building a LASSO logistic regression model. For each factor, two methods were used to calculate the odds ratio (OR) with the determination of 95% confidence intervals (95% CI) based on the standard error. A factor was considered significant if the CI did not include 1. Multicollinearity control between selected predictors was performed using variance inflation factor (VIF). Values VIF < 5 were considered acceptable. CI for OR in LASSO models was determined by bootstrap resampling (1,000 iterations, percentile method). The stability of variable selection was estimated as the proportion of bootstrap iterations in which the predictor received a

non-zero coefficient and was considered stable under the condition ≥80%.

When analysing the primary data, the presence or absence of a variable and its individual characteristics were taken into consideration. For quantitative indicators, the average values among all respondents were taken as the limit values (n = 272). No additional threshold setting was performed for binary variables (0/1). Analysis of potential predictors of dental pathology progression was performed separately on a subset of patients with WSD (n = 60) and E of tooth enamel (n = 15). Signs that characterise the progression of non-carious cervical lesions of the teeth included an increase in their number and depth in one patient, the appearance of symptoms of dentin hypersensitivity, which indirectly suggests the presence of a pathological process. Interpretation of the results obtained was carried out by the size of the OR, the width of the CI, and the direction of their change during the introduction of the control. The identified predictors were divided into independent (primary aetiological, which is significant in both logistic regression analyses with a change in OR of less than 20%) and latent (modifier factors, which are significant only in LASSO, their effect is manifested after confounder control) [16]. Change in OR of more than 20% was the threshold for establishing confounding [17]. The use of univariate and multi-factor regression analysis helped to simultaneously select the most informative predictors, reducing the coefficients of insignificant variables in the optimisation process to zero. Factors with fewer than 10 observations were excluded from the analysis. The quality of the models was determined by the area under the Receiver Operating Characteristic (ROC)-curve and sensitivity (recall) calculated by stratified cross-validation (CV). It was this approach that provided an unbiased assessment of data that was not used in training the model. For comparison, the Area under the curve (AUC)-ROC values in the training sample were additionally provided. The study was conducted in accordance with the ethical requirements, principles of the Declaration of Helsinki [18], and completely ruled out any compromise of the patient's interests or harm to their health (conclusion of the Bioethics Committee of Donetsk National Medical University No. 43 of 21.01.2021).

RESULTS AND DISCUSSION

The prevalence of cervical dental pathology was 43.3%. 22.1% of those examined (60 people) were diagnosed with WSD, and 5.5% (15 people) – tooth enamel erosion [19]. The restored teeth were not taken into consideration in the CR. Predictors of the occurrence of dental WSD determined by univariate and multivariate analyses are shown in Tables 1 and 2. Independent variables were SR less than 0.5 mL/min, hygienic habit of applying pressure to the toothbrush, and clinical markers: patient age of 25 and older, gingival recession, and impaired dentition integrity due to tooth extraction (Table 1).

The applying of pressure on a toothbrush was determined by the patient's self-assessment and confirmed by the history of its premature renewal due to changes in the appearance of the work surface: less than 30 days for medium bristle roughness and 45 days for stiff bristles [20]. Modifier factors were OF pH values less than 6.9 C.U., the hygienic habit of brushing teeth for three minutes or more, diet features, parafunctional habits (clenching teeth against the background of emotional stress and biting and/or licking the lip mucosa) and clinical markers (Table 2).

Table 1. Independent factors of dental WSD occurrence

Variables	n/%	OR	(95% CI)	OR	(95% CI)
		univariate analysis		multivariate analysis	
OF indicators					
SR	30/50.0	2.12	1.18-3.79	1.23	1.09-1.38
Hygiene habits					
Applying pressure on the toothbrush	19/31.7	2.34	1.22-4.51	1.31	1.16-1.47
Clinical markers					
Age	27/45.0	4.0	2.15-7.45	2.95	2.62-3.32
Gingival recession	20/33.3	5.74	2.76-11.91	6.51	5.78-7.33
Extracted teeth	32/53.3	2.22	1.24-3.97	1.31	1.16-1.48

Note: n/% – number of patients with the corresponding variable and their percentage of the total number of patients with dental WSD
Source: compiled by the authors

Table 2. Hidden factors of dental WSD occurrence

Variables	n/%	OR	(95% CI)	OR	(95% CI)
		univariate analysis		multivariate analysis	
OF indicators					
pH	40/66.7	1.50	0.82-2.75	1.48	1.31-1.67
Hygiene habits					
Duration of brushing teeth	25/41.7	0.90	0.50-1.60	0.86	0.77-0.97

Table 2. *Continued*

Variables	n/%	OR	(95% CI)	OR	(95% CI)
		univariate analysis		multivariate analysis	
Dietary habits					
Consumption of yoghurt	10/16.7	0.76	0.36-1.63	0.89	0.79-1.00
Consumption of bananas	19/31.7	0.65	0.36-1.20	0.56	0.49-0.63
Consumption of tangerines	10/16.7	2.29	0.99-5.32	2.45	2.17-2.76
Fruit consumption	24/40.0	0.92	0.51-1.65	1.43	2.89-3.67
Parafunctional habits					
Habit of clenching teeth tightly	12/20.0	2.05	0.95-4.42	3.26	1.27-1.61
Biting and/or licking lips	11/18.3	1.18	0.56-2.49	1.65	1.46-1.85
Clinical markers					
TMJ musculoskeletal dysfunction	19/31.7	1.54	0.82–2.90	1.43	1.27-1.61
Occlusal tooth wear	39/65.0	1.75	0.97-3.18	1.41	1.25-1.58
History of teeth whitening	12/20.0	1.52	0.72-3.18	1.50	1.34-1.69

Source: ompiled by the authors

Among dietary preferences, the predictors were determined by the consumption of yoghurt, bananas, tangerines, fruits (citrus fruits, apples, kiwis in a total of 2.5 units or more). Clinical markers of the occurrence of dental WSD were musculo-articular dysfunction of the temporomandibular joint lasting more than a year, the presence of occlusal wear facets on the teeth, and a history of teeth whitening. The hygiene habit of "duration of brushing", and dietary features such as consumption of yoghurt and bananas, had OR < 1, indicating their potential protective role in the development of dental WSD. When all fruits were combined in the variable "fruit consumption", the univariate analysis determined OR = 0.92, which corresponds to a negative association with the study result. But in multivariate analysis, OR = 1.43, which indicates a predictor of the occurrence of dental WSD. A change in the direction of association after correction for other variables indicates the existence of confounding. Assessment of the quality of the LASSO model of the occurrence of WSD showed signs of overfitting: AUC-ROC in the training sample was 0.882, while in CV – 0.594 (95% CI (0.506-0.674)), indicating moderate discriminative ability (Table 3). Analysis of the stability of predictor selection by bootstrap resampling (1,000 iterations) confirmed the reliability of key factors: gingival recession was selected in 100% of iterations, patient age ≥25 years – in 97.4%, violation of the dentition integrity – in 79.8%. The hygienic habit of applying excessive pressure to the toothbrush had moderate stability (62.7%), and the OF values (pH – 75.0%, SR – 71.7%) corresponded to a moderate level of reproducibility of selection. Thus, independent predictors of dental WSD occurrence (Table 1) were confirmed as stable associations, while some modifier factors (Table 2) required verification in a larger sample.

Table 3. Quality indicators of LASSO models

Model	n	AUC-ROC training	AUC-ROC cross-validation (95% CI)	Recall
Occurrence of WSD	272	0.882	0.594 (0.506-0.674)	0.183
Increase in the number of WSD	60	0.977	0.662 (0.526-0.805)	0.600
Increase in the depth of WSD	60	0.947	0.404 (0.198-0.642)	0.959
Active WSD progression	60	0.935	0.317 (0.177-0.465)	0.419

Source: compiled by the authors

Factors of tooth enamel erosion were also identified. Independent variables were clinical markers: the presence of occlusal tooth wear and enamel cracks, which are diagnosed during visual examination of the vestibular surface of the teeth under natural and/or artificial lighting and drying. It was found that occlusal tooth wear in univariate analysis increased lice by 5.87 times (95% CI (1.30-26.56)), in multivariate analysis – by 1.24 times (95% CI (1.10-1.39)); enamel cracks on the vestibular surface of teeth increased OR by 5.87 (95% CI (1.30-26.56)) and 1.69 times (95% CI (1.50-1.90)), respectively. Modifier factors were OF pH values and the patient's medical history of brushing teeth before breakfast. Saliva pH values are less than 6.9 C.U. in the univariate analysis increased OR by 2.90 times (95% CI (0.80-10.52)), in the multivariate analysis – by 1.22 times (95% CI (1.08-1.37)); brushing teeth in the morning before meals increased OR by 2.05 (95% CI (0.68-6.16)) and 1.23 times (95% CI (1.09-1.38)), respectively. However, the broad CI determined for all predictors of enamel E occurrence in univariate logistic regression analysis, and the small number of examined teeth with this pathology (n = 15), are direct evidence of instability in the assessment. At the next stage of the study, predictors of dental WSD progression were considered. Only the factors of increasing the number of lesions were independent: age of 25 and older, male gender, and the presence of gum recession (Table 4).

Table 4. Predictors of an increase in the number of WSD

Variables	n/%	OR	(95% CI)	OR	(95% CI)
		univariate analysis		multivariate analysis	
Independent					
Clinical markers					
Age	19/31.7	4.53	1.51-13.65	5.44	4.22-7.02
Gender	15/25.0	3.14	1.03-9.56	1.57	1.22-2.03
Gingival recession	16/26.7	7.14	1.99-25.59	4.25	3.29-5.49
Hidden					
Dietary habits					
Drinking green tea	11/18.3	1.29	0.44-3.80	1.58	1.23-2.04
Drinking black tea	10/16.7	0.54	0.19-1.53	0.51	0.40-0.66
Anatomical features					
Crowding of teeth	17/28.3	0.80	0.28-2.26	0.66	0.51-0.85

Source: compiled by the authors

Hidden factors for increasing the number, depth, and active progression of WSD were diet characteristics, the presence of crowding teeth, the hygienic habit of applying pressure to the toothbrush, and clinical markers. Some of them corresponded to predictors of the occurrence of WSD (the patient's age was 25 years and older, the presence of gingival recession and extracted teeth, applying of pressure on the toothbrush). Age and male gender were factors that simultaneously significantly affected both the increase in the number and depth of lesions in CR. The average daily consumption of green tea more than one cup was variable, which simultaneously increased the number of teeth with WSD and contributed to the active progression of pathology. Both hidden factors of increasing depth of WSD in teeth (Table 5), in univariate analysis, had wide confidence intervals crossing unity, and were not statistically significant. This is a consequence of limited statistical power.

A sub-sample of patients with WSD (n = 60), among whom only a fraction had a progression of lesion depth, was insufficient to identify predictors with moderate effect (OR ~ 1.5-3.0) in a univariate analysis. The multi-factor LASSO model, which simultaneously considers all variables, has a higher sensitivity to such effects, which helped to identify an independent contribution of age and gender. This is why these predictors were classified as hidden rather than independent. Among the hidden factors of the active WSD progression, such a dietary habit as "consuming sour foods" in a daily amount of more than 0.25 of the average serving size was identified (Table 6).

Table 5. Hidden factors of increasing the depth of dental WSD

Variables	n/%	OR	(95% CI)	OR	(95% CI)
		univariate analysis		multivariate analysis	
Clinical markers					
Age	25/41.7	4.17	0.80-21.64	2.74	2.12-3.54
Gender	20/33.3	2.76	0.53-14.38	1.51	1.17-1.95

Source: compiled by the authors

Table 6. Hidden factors of the active WSD progression

Variables	n/%	OR	(95% CI)	OR	(95% CI)
		univariate analysis		multivariate analysis	
Hygiene habits					
Applying pressure on the toothbrush	12/20.0	1.89	0.62-5.81	1.68	1.30-2.17
Dietary habits					
Drinking green tea	14/23.3	3.02	0.96-9.51	2.13	1.65-2.76
Drinking tea with lemon	10/16.7	3.97	0.96-16.33	1.64	1.27-2.12
Consumption of sour foods	15/16.7	2.34	0.80-6.91	1.67	1.29-2.16

Note: foods containing vinegar were considered "sour"
Source: compiled by the authors

Variables such as black tea consumption of more than one cup per day and the presence of crowding teeth had OR < 1, indicating their potential protective role in the progression of dental WSD. Among the identified hidden predictors of the active WSD progression, the greatest effect was demonstrated by the consumption of green tea (OR = 2.13). Applying pressure to the toothbrush (OR = 1.68), drinking lemon tea, and

sour foods (OR = 1.64 and OR = 1.67, respectively) had approximately the same OR values. The difference between the hidden factors of the active WSD progression (Table 6) was that they contained one within the CI interval in univariate analysis, while they did not include one in multivariate CI. This is conditioned by the fact that in a subset of patients with dental WSD, the influence of dietary preferences and the hygiene habit of applying pressure to the toothbrush is masked by stronger predictors and only becomes statistically significant after including a control variable in the LASSO model. The small absolute size of the variables in the sub-sample (patients who consumed green tea had n = 14, lemon tea – n = 10) limited the statistical significance of the univariate analysis. That is why these factors were classified as hidden. The conducted study determined that saliva pH values less than 6.9 C.U. as an independent predictor of the active course of tooth enamel E: in univariate analysis, they increase OR by 29.4 times (95% CI (1.12-772.42)), in multivariate analysis – by 2.47 times (95% CI (1.49-4.10)). Broad CI in univariate analysis indicates instability of the estimate. Other variables that were determined by predictors of the progression of tooth enamel erosion in the subjects were excluded from the analysis, since the number of observations was less than 10. The analysis of factors of occurrence and active course of e enamel due to the small size of the sub-sample (n = 15) is pilot in nature; the corresponding models showed signs of retraining (AUC-ROC training 0.961 and 1.000, respectively) at zero sensitivity and CV, which makes it impossible to interpret them meaningfully. Therefore, the resulting OR and CI reflect associations in the sub-sample under study and can be considered as research hypotheses rather than final prognostic estimates. The results of the study complement the information on the multifactorial aetiopathogenesis of non-carious cervical lesions of teeth [21-22].

The patient's age determined as an independent factor in the occurrence of dental WSD corresponds to the observations of G.A. Fontelle *et al.* [7], L. Sakhabutdinova *et al.* [10] and V. Kolak *et al.* [23]. The results also highlight the significant role of the biophysical properties of OF in the development and progression of non-carious cervical dental pathology. According to V. Kolak *et al.* [23], lower saliva pH values are observed in patients with multiple (≥3) non-carious cervical lesions of teeth. It is known that individual OF characteristics can change the relationship between dietary characteristics and wear of hard tooth tissues [24]. D.W. Bartlett *et al.* [21] and M. Nascimento *et al.* [25] proved the effect of fresh fruit on the appearance of non-carious cervical dental pathology in young patients. According to V. Kolak *et al.* [23], special attention should be paid to the excessive consumption of citrus fruits. The study found that the addition of tangerines to the diet is a hidden predictor of the occurrence of WSD. It is impossible to confirm or refute the potential protective role of banana consumption, as the authors were unable to find any studies in the available literature that examined the effect of this dietary habit on the development of non-carious cervical lesions of the teeth. Therefore, direct comparison of the results obtained is limited. When citrus fruits, apples, and kiwis were combined into the "fruit consumption" variable, it ceased to be a significant factor in the occurrence of WSD in the univariate analysis. However, after recording other variables with higher OR scores in the multivariate logistic model (patient age, presence of gingival recession), a significant association with increased risk was determined. Therefore, these confounders simultaneously affect both the frequency of fruit consumption and the risk of dental WSD. This is probably conditioned by the fact that the relationship between dietary characteristics and the severity of tooth wear is not direct and is influenced by many other variables [24]. The use of yoghurt containing probiotics helps to reduce the number of pathogens in OC, and thus its addition to the diet prevents enamel demineralisation [26]. Research conducted by H. Aidi *et al.* [27] showed that yoghurt consumption was negatively associated with the frequency of erosive tooth wear. This may well explain the protective effect that this dietary factor has on the development of dental WSD. In addition to food preferences, the habit of brushing teeth plays an important role in the appearance, distribution, and structure of cervical dental pathology. Simultaneously, the technique of brushing teeth has a greater impact [22]. B. Hamza *et al.* [28] also drew attention to the application of pressure on the toothbrush as a potential predictor of non-carious cervical lesions of the teeth, which was confirmed by the conducted study. Mechanical injury to the hard tissues of the teeth during brushing, according to M. Dioguardi *et al.* [3], determines the pathological picture of non-carious lesions, which is clinically manifested by wear. According to V. Grover *et al.* [29], manual brushes have a greater negative effect on teeth compared to electric brushes. In addition, the traumatic technique of brushing teeth can become one of the reasons for a certain other independent factor in the occurrence of dental WSD – gingival recession, which was confirmed in the paper by M.A. Cassini *et al.* [30]. According to F.F. Demarco *et al.* [31], gingival recession is a significant clinical indicator of the presence of non-carious cervical lesions of the teeth, as shown by the conducted study.

One of the hidden predictors of the development of tooth enamel erosion was the patient's history of brushing teeth before breakfast. The authors are only aware of one study by D.W. Bartlett *et al.* [21], in which waiting after breakfast before brushing did not significantly affect the degree of tooth wear. But the specifics of dietary and hygienic habits can explain

only a part of cases of non-carious cervical lesions of the teeth [24]. The significant role of parafunctions (clenching teeth tightly and biting nails) and TMJ musculoskeletal dysfunction in their aetiopathogenesis has been proven [32]. The researchers also identified the habit of clenching teeth strongly against the background of emotional stress as hidden predictors of the occurrence of WSD, in addition – biting and/or licking the lip mucosa. But there are also studies that have not revealed the existence of such a relationship [25]. Non-carious cervical pathology of teeth is clinically manifested by facets of occlusal wear, which are significantly more often detected in patients with hyperfunction of the masticatory muscles. This was confirmed in the study by T.S. Carvalho *et al.* [33], which showed that tooth wear and gingival recession are the result of the combined action of many different factors on hard tissues. Enamel cracks are also considered precursors of non-carious pathology [20, 34]. Occlusal wear and cracks are clinical markers of occlusal stress for both WSD and E of tooth enamel [2]. In the case when all occlusal factors were combined, their presence increased the OR of the occurrence of non-carious cervical dental pathology by 4.38 times [35]. M. Giller *et al.* [36] confirmed the existence of a link between occlusal wear and the size of non-carious cervical lesions of the teeth. But clinical practice shows that not all patients with non-carious cervical dental pathology are diagnosed with occlusal wear and vice versa [7, 25]. Using the logistic regression method, R.D. Werneck *et al.* [37] found no correlation between the appearance of WSD and E of tooth enamel and occlusal strength, and with aspects related to brushing and bad habits. But it is important to distinguish physiological changes in the hard tissues of teeth from pathological processes [33]. This distinction should be the basis for making a decision on dynamic monitoring of a patient with non-carious dental lesions. The study found that the presence of extracted teeth is an independent predictor of the occurrence of dental WSD. This was confirmed in the study by D.S. Ramsay *et al.* [24], in which subjects with fewer teeth had a higher chance of hard tissue wear in CR. According to D.C. Penoni *et al.* [38], the average number of non-carious cervical lesions was higher in those individuals with fewer teeth in the OC. As a therapeutic and preventive measure, it was proposed to monitor the condition of CR teeth for at least six months before planning invasive procedures [25]. It is during this period that the OC health of young patients and their quality of life in general can be improved by making significant changes in behavioural habits and treating gingival recession [39]. Restoration of teeth with non-carious pathology should not be considered as a preventive measure to stop the progression of the lesion. Thus, the development of non-carious cervical lesions of the teeth is a multifactorial process due to the interaction of occlusal, behavioural, and hygienic factors, parafunctions and the number of teeth in the oral cavity. Preventing their progression requires a comprehensive risk assessment and dynamic monitoring.

CONCLUSIONS

1. Combination of methods of single- and multivariate logistic regression analysis determined statistically independent and hidden predictors of the occurrence and progression of WSD and E of tooth enamel, and potentially protective factors and a factor with confounding.

2. Independent predictors of WSD occurrence were SR less than 0.5 mL/min, hygienic habit of applying pressure to the toothbrush, age of 25 and older, the presence of gingival recession and extracted teeth. Hidden predictors of WSD development were OF pH values less than 6.9 C.U., dietary, hygienic, and parafunctional habits, clinical markers (duration of temporomandibular joint musculoskeletal dysfunction exceeding one year, presence of occlusal tooth wear, and a history of tooth whitening). Potentially protective variables were variables with OR < 1: brushing teeth for three minutes or more, consumption of yoghurt and bananas. Confounding was identified for the "fruit consumption" predictor. A larger number of dental WSD progression factors were hidden and had broad CI in univariate logistic regression analysis.

3. Pilot analysis of predictors of the occurrence of enamel E identified as independent factors the presence of occlusal tooth wear and enamel cracks, which are diagnosed during visual examination of the vestibular surface under natural and/or artificial lighting and drying; modifier factors – OF pH values of less than 6.9 C.U. and the habit of brushing teeth before breakfast. Saliva pH values are less than 6.9 C.U. were the only detectable predictor of enamel erosion progression that was independent in the number of observations greater than 10. However, broad CI in univariate regression analysis indicates instability in the assessment and prematurity of the results for E of tooth enamel and the need for their confirmation in studies on larger samples.

Limitations of the study. A methodological limitation was the insufficient number of cases of enamel E (n = 15) for multivariate analysis. The inclusion of a significant number of variables (n = 84) in relatively small sub-samples (60 cases of WSD and 15 cases of enamel E) created conditions for retraining LASSO models, which was confirmed by comparing AUC-ROC in the training sample and in CV. There were also limitations in the accuracy of information collected by the questionnaire method. Some differences between the results obtained and the well-known ones were related to the age of the subjects, their socio-economic characteristics, region of residence, etc.

Prospects for further research. In order to provide personalised dental care to patients with non-carious cervical lesions of teeth and a more complete

analysis of the predictors of their occurrence and progression in the future, it is planned to use combined approaches that integrate classical statistical methods with nonlinear machine learning algorithms on a reduced set of primary aetiological predictors with verification on an independent sample. A separate task is to increase the subsample of patients with tooth enamel erosion to confirm the experimental results obtained.

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CONFLICT OF INTEREST

None.

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Визначення предикторів некаріозних пришийкових уражень зубів методом логістичного регресійного аналізу

Анотація

Актуальність. Некаріозні пришийкові ураження зубів залишаються другою після карієсу та його ускладнень причиною звернення до стоматолога.

Мета. Визначення предикторів виникнення і прогресування клиновидного дефекту (КД) та ерозії (Е) емалі зубів у пацієнтів молодого віку.

Матеріали та методи. Були обстежені 272 пацієнта (середній вік 24,3 ± 6,9 роки), в яких потенційні предиктори були зібрані під час огляду та методом анкетування. Для аналізу сили асоціації між чинниками та наслідком був використаний показник відношення шансів (ВШ) у межах 95 % довірчого інтервалу (ДІ). Для встановлення предикторів був застосований однофакторний і багатофакторний логістичний регресійний аналіз.

Результати. Незалежними предикторами виникнення КД були швидкість слиновиділення менша за 0,5 мл/хв, гігієнічна звичка прикладати тиск на зубну щітку, вік 25 років і старше, наявність рецесії ясен і видалених зубів. Прихованими предикторами розвитку КД були показники pH ротової рідини (РР) менші за 6,9 ум. од., поведінкові фактори, клінічні маркери. Потенційно захисними були змінні з ВШ < 1: тривалість чищення зубів протягом трьох хвилин і більше, вживання йогурту та бананів. Для предиктору «вживання фруктів» було визначено існування конфаундингу. Незалежними предикторами виникнення Е емалі були наявність оклюзійної стертості зубів і тріщин емалі; факторами-модифікаторами – показники pH РР менші за 6,9 ум. од. і звичка чистити зуби до сніданку. Але широкі ДІ, визначені для усіх предикторів появи Е емалі при однофакторному логістичному регресійному аналізі, а також незначна кількість спостережень вказують на попередність результатів та необхідність їх підтвердження. Більшість предикторів прогресування некаріозних пришийкових уражень зубів були прихованими та мали широкі ДІ при однофакторному логістичному регресійному аналізі, що свідчить про нестабільність оцінки та потребує подальших досліджень на більших вибірках.

Висновки. Використання методу логістичного регресійного аналізу дозволило визначити статистично незалежні та приховані предиктори, які рекомендовано враховувати при діагностиці та складанні плану лікування некаріозних пришийкових уражень зубів у пацієнтів молодого віку.

Ключові слова: ерозія; клиновидний дефект; дієтичні та гігієнічні звички; ротова рідина; тріщини.