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ORIGINAL ARTICLE

Multicenter study to develop and validate a risk assessment tool as part of composite scoring system for erosive tooth wear

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Abstract

Objectives (i) To develop, validate, and apply in practice a new risk assessment tool for erosive tooth wear (ETW) including a risk factors questionnaire and a saliva secretion evaluation, which combined with a clinical index, can be part of an ETW composite scoring system; (ii) to assess ETW lesions and current and past erosive challenges in younger age groups.

Methods The Tooth Surface Loss/Erosion Working Group of the European Association of Dental Public Health consisted of an international panel of experts designed the survey component of the new tool (Erosive Wear Assessment of Risk—EWAR) and confirmed its construct and content validity. After receiving ethical approvals and informed consents, the EWAR tool (questionnaire + saliva secretion evaluation) was applied in a multicenter cross-sectional study with 207 participants aged 15–21 years old from four countries (Finland, Greece, Romania, the USA). BEWE score was used for the clinical assessment of ETW.

Results A total of 58.5% of participants had ETW. 10.9% and 20.3% of participants had low secretion of stimulated (< 1 ml/min) and unstimulated saliva (< 0.25 ml/min), respectively. The following factors were bivariately significantly associated with ETW: energy drink consumption, low secretion of stimulated saliva, juices consumption, erosive drink consumption for quenching thirst between meals, erosive drink kept in the mouth, feeling pain/icing after consuming something acidic or cold, and co-existence of other type of tooth wear. In regression analysis, only energy drink consumption (OR = 3.5, 95% CI: 1.39, 8.9), low secretion of stimulated saliva (OR = 36.3, 95% CI: 4.71, 78.94), and feeling pain/icing (OR = 8.8, 95% CI: 1.92, 40.04) remained significant.

Conclusions The examiners of the study reported that the EWAR tool appeared to be an affordable and easy-to-use instrument. Some challenges occurred during the saliva collection process. Inferential analysis revealed that the risk factors/indicators of low stimulated salivary flow, energy drink consumption, and pain/icing with ETW were considered the most important in ETW occurrence.

Clinical relevance EWAR tool combined with the BEWE clinical index can be used for ETW risk assessment for epidemiological studies and chairside use.

Keywords Erosive tooth wear · Risk assessment · Erosive risk factors · Saliva flow · BEWE

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Introduction

Erosive tooth wear (ETW), which is the chemical loss of mineralized tooth substance caused by the exposure to acids not derived from oral bacteria [1], remains in the spotlight of the dental scientific community. This oral health condition appears to be a prevalent and maybe of increasing clinical concern [2] especially in younger populations. ETW can be a challenging condition to measure or score, mostly due to the fact that some wear will occur naturally. The ideal ETW scoring system should be adequate; simple with well-defined clinical criteria; reflective of the etiology of the condition; accurately categorizing shape, area, and depth of affect; and able to assess only ETW as it usually co-exists with other types of tooth wear (TW) [3]. Such a scoring system is required for the accurate diagnosis and monitoring of ETW. With the exception of the basic erosive wear examination (BEWE) [4], no index appears to meet all of the above criteria. However, BEWE per se is a clinical index and does not provide information on the etiology of the ETW lesion; therefore, it does not contribute to the differential diagnosis nor to the secondary prevention of ETW [3]. Also, researchers suggested that as-yet unidentified ETW etiological or pathogenic factors remain to be determined and validated, such as interaction between erosive factors (e.g., dry mouth and consumption of acidic consumption) [5, 6].

A composite scoring system using both clinical and dietary/behavioral/biological criteria could be more accurate to detect lesions where ETW is the principle etiological factor [3]. This would be the first step of ETW risk assessment and management. A complete ETW risk assessment includes risk factor identification and characterization, exposure assessment, and risk level estimation [1]. In this way, having an accurate ETW diagnosis and risk assessment significantly increases the chances to also have successful ETW risk management at both population and individual level. There is limited literature on ETW risk assessment tools with the aforementioned characteristics. A useful suggestion toward this direction was the Dental Erosive Wear Risk Assessment tool (DEWRA) suggested by Young et al. [7]. This tool includes a history-taking regarding dietary and oral hygiene habits, social and lifestyle habits, and general health conditions, as well as BEWE and saliva measurements. However, there are some limitations of this tool, e.g., there is no detailed record of the potentially erosive challenges (e.g., it records all the potentially erosive beverages in one category "acidic drinks" without assessing in detail the drink type, consumption frequency, number of servings per day, etc.), there is no specific record of past and current erosive challenges, and there is no specific protocol of saliva secretion collection to achieve replicable results; therefore, further research is needed in this area to design and validate an ETW risk assessment tool.

Within the context of these efforts, the Special Interest Working Group (SIWG) on Tooth Surface Loss/Erosion of the European Association of Dental Public Health (EADPH) held in Budapest, Hungary in 2016, reached to the following two main conclusions [8]: (a) at that time the BEWE was considered as the most reliable and convenient clinical index to assess ETW and (b) to generate a brief but content and construct validated survey with the main potential ETW risk factors, which would address the difficulty of differentiating erosion from other wear types and to achieve ETW risk assessment/management as successfully as possible. The proposed questionnaire should also ideally include some ETW risk indicators, which are attributes or exposures that are significantly associated with ETW development, but not considered as part of the causal chain [1]. When possible biological data related to ETW, such as saliva flow rate, are available, they can also be integrated to the assessment. The role of saliva related to ETW has been extensively discussed in the literature and it can be summarized as following according to Buzalaf et al. [9]: "salivary clearance gradually eliminates the acids through swallowing; saliva's buffering capacity contributes to the neutralization of dietary acids; salivary flow permits dilution of the acids; saliva can be supersaturated with respect to tooth mineral, resulting in remineralization with calcium phosphate and fluoride; and salivary proteins can further protect teeth through buffering, binding tooth mineral and lubrication." Thus, a risk assessment tool including a survey on ETW risk factors/indicators plus a salivary secretion evaluation can be used together with the BEWE index to provide a composite scoring system that can be used relatively easily both in epidemiological studies and in daily practice. Considering and discussing the above during the Budapest meeting, the members of Tooth Surface Loss/Erosion SIWG decided to collaborate in order to develop, validate, and apply a new risk assessment tool in young populations by conducting an international multicenter study. In consequence, this study's main research question was: how a convenient and affordable risk assessment tool can be developed, validated, and applied in practice to accurately detect and evaluate specific, current, and past potentially ETW risk factors and indicators? Also, how the use of this tool can contribute to a precise estimation of the magnitude of the effect of these ETW factors/indicators? We assume that this new risk assessment tool can be used in addition to the BEWE index to accurately assess ETW lesions, and it can assist in differentiating erosion from other wear types and in achieving ETW risk assessment/management as successfully as possible.

The aims of this multicenter cross-sectional study were (i) to develop, validate, and evaluate in practice a new risk assessment tool for erosive tooth wear (ETW) (entitled Erosive Wear Assessment of Risk (EWAR) tool) including a risk factors questionnaire and a saliva secretion evaluation and (ii) to apply this tool as part of an ETW composite scoring system (EWAR

tool + BEWE) to accurately assess ETW lesions and current and past potentially erosive challenges in younger age groups.

Materials and methods

Ethical approvals and research sites

Prior to data collection, the relevant ethics committee for each research site approved the study. More specifically, the approval was provided in Finland by the Ethical Committee of the Northern Ostrobothnia Hospital District (11.9.2017, #70/2017 240§); in Romania, by the Research Ethics Committee of the University of Medicine and Pharmacy of Tirgu-Mures (27.09.2017, #312); and in both the USA and Greece, by the Walden University Institution Review Board (#03-01-17-6274274). Informed consent forms were received from all the participants and parents/guardians when needed and confidentiality of the data was confirmed. The data were collected in a public high school (Finland), a dental school (Romania), and two private dental clinics (Greece and the USA).

Study sample

The sample of this cross-sectional multicenter study consisted of 207 participants aged 15–21 years old from four countries (Table 1). This age group was suggested as the most suitable for the purposes of this study, since abrasion and attrition of the permanent teeth are less probable to be present in younger age groups [10]. Therefore, erosion is likely to be the dominant etiology for TW in this specific age group. In addition, the permanent dentition of the examined young individuals has been exposed to erosive effects for 9–15 years, which probably permitted the development of erosive lesions [11]. Finally, participants with visible carious lesions were excluded to avoid confusion with dentine hypersensitivity symptoms. Random and convenience samples were used in this multicenter study. More specifically, for the schools of Finland and Romania, respectively, dental students were invited to participate in the study (convenience sample), while in Greece and the USA, young individuals were randomly selected and then invited to participate from patients' lists provided by two private dental clinics within strata of sex; a random replacement was used for participants who did not meet the inclusion criteria or did not agree to participate in the study. For the purposes of this study, it was attempted to have equal erosion/no erosion groups in all study sites. The participation rate ranged from 35 to 85% among countries and locations (Table 1). All 207 participants were examined between October 2017 and May 2019.

Formulation and validation of the risk assessment questionnaire

As mentioned above, the EWAR tool (Table 2) consists of two components: a survey including ETW risk factors/

Table 1 Sample demographics, number of BEWE examiners, and BEWE sum score of the international multicenter study by country (n = 207)

	Finland	Greece	Romania	United States	Total
Gender					
Males	35	37	9	20	101
Females	30	38	21	17	106
Age group					
15–18 years	65	30	3	13	111
19–21 years	0	45	27	24	96
Participation rate (%)	85	75	35	46	60.3
Number of BEWE examiners	2	1	1	1	5
BEWE sum score	Frequency %				
0	18.5	46.7	86.7	35.1	41.6
1	15.4	16.0	10.0	8.2	13.6
2	30.8	13.3	3.3	29.7	20.3
3	10.8	4.0	0.0	18.9	8.2
4	9.2	4.0	0.0	2.7	4.8
5	7.7	5.3	0.0	5.4	5.3
6	1.5	1.3	0.0	0.0	1.0
7	1.5	2.7	0.0	0.0	1.4
10	3.1	4.0	0.0	0.0	2.4
12	1.5	2.7	0.0	0.0	1.4

Table 2 The Erosive Wear Assessment of Risk (EWAR) tool generated by the Special Interest Working Group of European Association of Dental Public Health

Erosive Wear Assessment of Risk tool
For use additionally to the application of B.E.W.E. clinical assessment
Dentist or dental team member should complete this according to participant's responses

Potential erosive behavior	Frequency/assessment	Number of glasses, cups or fruits per day/week based on the response on the left	Time of occurrence of the erosive behavior		Please specifically provide the type(s)/name(s) of the soft drink, energy/sport drink, juice, alcohol, fruit you usually consume based on the response on the left
			Currently (Since when?)	In the past (Please determine the time period of occurrence)	
1. Consumption of soft drinks	- More than once a day - Once a day or almost once a day - Occasionally during the week - Never or hardly ever				
2. Consumption of energy or/and sport drinks	- More than once a day - Once a day or almost once a day - Occasionally during the week - Never or hardly ever				
3. Consumption of juices	- More than once a day - Once a day or almost once a day - Occasionally during the week - Never or hardly ever				
4. Consumption of alcohol	- More than once a day - Once a day or almost once a day - Occasionally during the week - Never or hardly ever				
5. Consumption of fruits	- More than once a day - Once a day or almost once a day - Occasionally during the week - Never or hardly ever				

We would now like to ask whether you have particular habits when consuming your drinks (Q.6,7)

Table 2 (continued)

6. Erosive drinks (soft, sport, energy drinks, juices) kept in the mouth for longer period when consumed	- More than once a day - Once a day or almost once a day - Occasionally during the week - Never or hardly ever	**NA**			
7. Erosive drinks (soft, sport, energy drinks, juices) for quenching thirst between meals	- More than once a day - Once a day or almost once a day - Occasionally during the week - Never or hardly ever	**NA**			
We would now like to ask whether you have particular problems with your digestive system (Q.8, 9):					
8. GERD symptoms, such as regurgitation and heartburn	- Daily - Weekly - At least once a month - Never or hardly ever	NA			NA
9. Vomiting (for any reason)	- More than once a day - Once a day or almost once a day - Occasionally during the week - Never or hardly ever	NA			NA
10. Do you feel pain or "icing" after eating or drinking something acidic or cold?	- More than once a day - Once a day or almost once a day - Occasionally during the week - Never or hardly ever	NA			NA
11. Unstimulated[1,2] saliva secretion	- Low secretion - Normal secretion	NA	NA		NA
12. Stimulated[1,2] saliva secretion	- Low secretion - Normal secretion	NA	NA		NA
13. Co-existence of other type of tooth wear	- Yes (please provide the type and rationale for this type assumed by dentist/dental professional. Which relevant signs/symptoms you see, please briefly explain) - No				
14. Brushing frequency	- More than once a day - Once a day or almost once a day - Occasionally during the week	NA	NA	NA	

indicators and an unstimulated and stimulated saliva flow evaluation. A panel of experts on ETW and members of the EADPH Tooth Surface Loss/Erosion SIWG from six countries (Finland, Greece, Hungary, Ireland, Romania, and the USA) worked between October and December 2016 to formulate the ETW survey and then to confirm its construct (relating the survey to the general theoretical framework of ETW) and content validity (please see clinical assessment of ETW section below for more information). All the experts were dentists (researchers or academic faculty) with extensive clinical experience in ETW. The final version of the Erosive Wear Assessment of Risk (EWAR) tool is presented in Table 2 and it was developed in English. The EWAR tool consists of two main parts; questions on erosive risk factors and indicators and a saliva collection protocol. The tool also assesses both current and past ETW behaviors, which is a unique characteristic of this survey, asking "if currently; since when?", "if in the past; please determine the time period of occurrence." Finally, this survey is not self-administrated (interview mode) and it is designed to be completed with the assistance of a dentist or dental team member to limit bias in responses as much as possible. The survey questions were pilot tested in 15 individuals with similar characteristics with the final sample to ensure that the questions were well defined, comprehensible, and presented in a consistent manner, and then the final version was applied in all research sites of the study. The interviews using the questionnaire were performed with the help of dental team members (dentist, dental nurse, or dental hygienist) depending on the resources of each research site.

Collection of stimulated and unstimulated saliva

Stimulated and unstimulated saliva secretion was recorded according to a protocol with the shortest collection time possible for patients' convenience (Table 3). This combined protocol was based on the saliva measurement procedures suggested by the American Dental Association [12] and the Oral Health Services Research Centre of University College Cork [13]. The cutoff value for low salivary flow rate was < 0.25 ml/min for unstimulated saliva and < 1.0 ml/min for stimulated saliva, respectively [14, 15]. Saliva flow rates were recorded in the same time of the day (morning hours) to avoid differences of the saliva flow and in the same light conditions. For statistical analysis, hyposalivation and reduced salivary flow cases were merged into one category (low secretion).

Clinical assessment of ETW and training of the examiners

The clinical assessment of ETW was completed using the BEWE score [4] as the most reliable clinical index available for erosive tooth wear. Prior to the data collection, all the

Table 2 (continued)

	- Never or hardly ever
15. Type of toothbrush (soft, medium, hard)	

[1] for the saliva flow measurement, a combined protocol was used suggested by the American Dental Association and the Oral Health Services Research Centre of University College Cork

[2] the cutoff value for low salivary flow rate is < 0.25 ml/min for unstimulated saliva and < 1.0 ml/min for stimulated saliva, respectively

Table 3 The collection of whole mouth saliva protocol as part of the Erosive Wear Assessment of Risk (EWAR) tool based on the American Dental Association and the Oral Health Services Research Centre of University College Cork suggestions

Collection of unstimulated whole mouth saliva
• Unstimulated saliva is collected via passive drool
• Small groups of participants (4–5) sit quietly in a circle with their heads tilted a little forward and their backs to each other to minimize embarrassment and afford some privacy
• Each participant is provided with a pre-weighed labeled tube, a funnel, and a disposable wipe
• Participants swallow the saliva in their mouths, and then when asked drool* all saliva that collects into the test tube via the funnel for at least 5 min or until at least 2 ml of saliva is collected
• The tube is closed and collected from participants
• Check cap is secure and that the name, date of birth, sample type, and date and duration of time are all recorded on the tube
• Record the length of time over which the sample is collected
• Weigh tube with saliva
Collection of stimulated whole mouth saliva
• Participants remain seated
• Each participant is provided with a new pre-weighed labeled test tube, a funnel and a disposable wipe
• Each participant is provided with a paraffin wax pellet to chew for 1 min
• The participant is asked to swallow the saliva that has collected in the mouth. Participants continue to chew on the wax pellet and drool* the saliva into the test tube via the funnel for a 3- to 5-min time period
• The tube is closed and collected from participants
• Check cap is secure and that the name, sample type, and date details are on the test tube
• Record the length of time over which the sample is collected
• Weigh tube with saliva

*Saliva collection by drooling was suggested for the convenience of the participants

examiners (dentists with considerable clinical and research experience in ETW) agreed on specific ETW clinical criteria and were trained and calibrated according to the ETW/BEWE photos ("gold standard") generously provided by Professor Carolina Ganss, one of the co-creators of BEWE. In addition, as part of this training, in Finland and Greece, 6 and 10 dental students, respectively, were clinically examined and the BEWE score of all the sextants was assessed. This training was supervised by the principal researcher in each research site and it was coordinated by the chair of the SIWG. In this way, both face content validity (researcher's subjective evaluation of the appropriateness for measuring ETW) and reliability of the measurements (the extent to which an instrument contains errors that appear between observations, measured either for one observer at different times or between multiple examiners at points in time) were confirmed in all study sites. Inter-/intra-examiner agreement on detecting ETW lesions was very satisfactory (Cohen's kappa> 0.90). To avoid overestimation of the recorded ETW, in case of doubt between two grades, the less advanced grade was chosen. The clinical examination (BEWE data) was carried out under artificial light using dental mirrors by the participating dentist, blind to the results of salivary tests and the participants' questionnaire. Cotton rolls and gauze were available for moisture control and removal of plaque when necessary.

Data analysis

The outcome variables were BEWE cumulative score and the presence of erosion (no erosion when BEWE = 0, erosion when BEWE ≥ 1). The Chi-square and Cramer's V (effect size) tests were used to test the strength of associations between independent and categorical or quantitative sample proportions. Also, the estimates of relative risks of ETW are reported by calculating odds ratios and the corresponding 95% confidence interval (CIs) using binomial logistic regression. Finally, pairwise comparisons of estimated marginal means were conducted to investigate potential associations between interaction effects/variables. All reported probability values (p values) were compared with a significance level of 5% ($p < 0.05$). The analysis of coded data was carried out using the IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp (Released 2017).

Results

The demographic characteristics and BEWE sum score of the sample are presented in Table 1. Regarding the prevalence of ETW, 121 (58.5%) participants had ETW of some degree (BEWE sum score > 0), and 51 (24.5%) were in need of more specific preventative measures (BEWE sum score > 2) according to creators of the BEWE [4]. According to Chi-square test results, the majority of the factors included in the EWAR tool were found to be significantly associated with ETW. These factors are the following in order of effect size (Cramer's V) (Table 4); energy drink consumption ($V = 0.317$, $p < 0.0001$), low secretion of stimulated saliva ($V = 0.298$, $p < 0.0001$), juices consumption ($V = 0.278$, $p < 0.0001$), erosive drink consumption for quenching thirst between meals ($V = 0.168$, $p < 0.053$), and erosive drink kept in the mouth ($V = 0.157$, $p < 0.024$). Additionally, the symptom/risk indicator of feeling pain/icing after consuming something acidic or cold food was significantly related to ETW with medium effect size ($V = 0.225$, $p < 0.001$). The co-existence of other types of TW was also found to be significantly associated with ETW ($V = 0.240$, $p < 0.001$). Attrition was the most commonly reported other type of TW.

On the other hand, logistic regression analysis (Table 4) revealed that participants with low secretion of stimulated saliva were approximately 36 times more likely to have ETW compared with those with normal secretion of

Table 4 Bivariate (Chi-square) and multivariable (binomial logistic regression) analysis for risk factors/indicators in association with ETW occurrence of the sample ($N = 207$)

	Erosion			Chi-square test			Binomial Regression*
ETW risk factor or indicator	BEWE = 0 *N* (%)	BEWE ≥ 1 *N* (%)	Total	χ^2	*p*	Cramer's V	OR [95% CI]
Total	86 (41.5)	121 (58.5)	207				
Soft drinks consumption				1.428	NS	-	
At least once a day	7 (38.9)	11 (61.1)	18				
Occasionally during the week	37 (37.8)	61 (62.2)	98				
Never or hardly ever	42 (46.2)	49 (53.8)	91				
Energy drink consumption				20.823	0.0001	0.317	
At least once a day	0 (0)	3 (100)	3				
Occasionally during the week	8(16)	42 (84)	50				3.523 [1.390, 8.927]
Never or hardly ever	78 (50.6)	76 (49.4)	154				
Juices consumption				15.963	0.0001	0.278	
At least once a day	13 (29.5)	31 (70.5)	44				
Occasionally during the week	51 (57.5)	38 (42.5)	89				
Never or hardly ever	22 (29.7)	52 (70.3)	74				
Erosive drink kept in the mouth				5.123	0.024	0.157	
Occasionally during the week	6 (13.3)	12 (66.7)	18				
Never or hardly ever	115(60.2)	74 (39.8)	189				
Erosive drink for quenching thirst between meals				5.83	0.053	0.168	
At least once a day	3 (21.4)	11 (78.6)	14		.		
Occasionally during the week	48 (49.5)	49 (50.5)	97				
Never or hardly ever	35 (36.5)	61 (63.5)	96				
Pain/icing after cold or acidic diet				10.472	0.001	0.225	
Occasionally during the week	5 (15.6)	27 (84.4)	32				8.770 [1.921, 40.038]
Never or hardly ever	81 (46.3)	94 (57.7)	175				
Unstimulated saliva secretion				0.039	NS	-	
Low (< 0.25 ml/min)	17 (48.6)	18(51.4)	35				
Normal (≥ 0.25 ml/min)	64 (46.7)	73(53.3)	137				
Stimulated saliva secretion							
Low (< 1 ml/min)	2 (10.5)	17 (89.5)	19	15.545	0.0001	0.298	36.254 [4.712, 78.942]
Normal (≥ 1 ml/min).	91 (58.3)	65 (41.7)	156				
Co-existence of other wear type							
Yes	19 (25.7)	55 (74.3)	74	11.945	0.001	0.240	
No	67 (50.4)	66 (49.6)	133				

*All the survey predictors in different combinations were included in multiple logistic regression models and the model with the best fit was selected to report significant ORs (Nagelkerke R^2 = 0.292, Hosmer & Lemeshow test $p < 0.321$), outcome variable erosion (yes/no)

stimulated saliva (OR = 36.3, 95% CI: 4.71, 78.94, $p < 0.001$). Also, participants who consumed energy drinks occasionally during the week were approximately 3.5 times more likely to have ETW compared with the young individuals who never or hardly ever consumed energy drinks (OR = 3.5, 95% CI: 1.39, 8.9, $p < 0.008$). Further, participants who experienced pain/icing after consuming erosive food occasionally during the week were approximately 9 times more likely to have ETW compared with those who experienced this symptom never or hardly ever (OR = 8.8, 95%CI: 1.92, 40.04, $p < 0.005$). Also, a post hoc power analysis was conducted to confirm the adequacy of the sample size. The achieved statistical power was found satisfactory 0.90 > 0.80, using as effect size the lowest significant odds ratio estimated in the regression model (OR = 3.5, $a = 0.05$, G*Power Calculator).

In this multicenter study, another interesting finding was the impact of the current erosive effect of some erosive behaviors (Table 5); first, there was a statistically significant difference of probability of erosion of 0.28 ($p < 0.018$) between those who kept erosive drink in their mouth currently and

Table 5 Report of pairwise comparisons of estimated marginal means of significant associations between interaction effects/variables to investigate combinations between current and past ETW erosive behaviors

Interaction effect		MD (a–b)	SE	df	*p*	95% Wald CI for Difference	
a	b						
Erosive drink kept in the mouth currently and not in the past	Erosive drink kept in the mouth neither currently nor in the past	0.28	0.17	1	0.018	0.05	0.50
Erosive drinks for quenching thirst between meals currently and not in the past	(i) Erosive drinks for quenching thirst between meals both currently and in the past	0.26	0.113	1	0.022	0.04	0.48
	(ii) Erosive drinks for quenching thirst between meals in the past and not currently	0.42	0.165	1	0.011	0.09	0.74
	(iii) Erosive drinks for quenching thirst between meals neither currently nor in the past	0.31	0.096	1	0.001	0.12	0.49

MD mean difference, *SE* standard error, *df* degrees of freedom

not in the past and those who never demonstrated this behavior (currently or in the past). Second, there was a statistically significant difference of probability of erosion between those who consumed erosive drinks for quenching thirst between meals currently and not in the past and (i) those who have this behavior currently and in the past (MD = 0.26, $p < 0.022$), (ii) those who demonstrate this behavior only in the past and not currently (MD = 0.42, $p < 0.011$), and (iii) those who never had this behavior, currently or not in the past (MD = 0.31, $p < 0.001$).

Finally, another noteworthy finding was the relatively high number of the participants who demonstrated low secretion of saliva despite their young age. More specifically, 10.9% and 20.3% of the participants with valid measurements had low secretion of stimulated and unstimulated saliva, respectively. On the other hand, several participants (for stimulated saliva measurement, 32 out of 207 (15.5%); for unstimulated saliva measurement, 35 out of 207 (16.9%)) did not have the time or felt uncomfortable to participate in the saliva collection process. In total, 49 out of the 207 participants (23.6%) did not participate in at least one (for stimulated or unstimulated) saliva collection process.

Discussion

Validating and applying a new risk assessment tool can be a challenging but also an enlightening process. The applicability of a new survey should be evaluated and discussed. After the completion of the international multicenter study, all the involved researchers and examiners sent to the chair of the SIWG a detailed report on the data collection process they followed and on their experience about the applicability and feasibility of this new risk assessment tool. These reports revealed that all researchers and examiners agreed that the survey component of the EWAR tool was relatively easy and convenient to use and the questionnaire took approximately 5 to 10 min to complete. The interview mode of this survey usually results in higher item response and greater control of the interviewer, by ensuring that questions are answered and not missed, recording responses accurately [16]. On the other hand, the fact that this survey tool is not self-administrated can be considered as a limitation, in terms of human resources and most importantly for potential social desirability bias [16]. Respondents often tend to give more socially desirable responses in face to face surveys than in self-administration surveys [17, 18]. For example, participants may underreport the frequency of soft drinks consumption due to the fact that the negative dietary consequences of these drinks are known. This potential limitation is partly addressed by including different questions per risk factor to crosscheck the responses; e.g., juices consumption is assessed by asking frequency, number of glasses, and occurrence time (currently, past) for this consumption, as well as type/name of the preferred juice. Further, saliva collection was the most challenging and time-consuming process (can take at least 15–20 min to collect both stimulated and unstimulated saliva according to the suggested protocol) reported by the examiners when using the EWAR tool, and this can be also a drawback in daily practice and large epidemiological studies. Although we highlight the importance of saliva collection when assessing ETW, which was also supported by the results of this multicenter study, depending on time constraints, the EWAR tool can be used by responding only to the survey questions (ETW risk factors and indicators) and collecting BEWE data (ETW screening), to at least assess erosive behaviors that are preventable.

Looking at the results of the inferential analysis of this multicenter study, three risk factors/indicators were considered the most important in ETW occurrence. To begin with, a low stimulated salivary flow (< 1 ml/min) was found to be the risk factor with the largest effect size on ETW occurrence (OR = 36.3, $p < 0.0001$). As discussed earlier, the protective role of saliva for dental hard tissues has been well documented in the literature, with respect to both dental caries and TW. A low stimulated salivary flow rate and subjective dry mouth

feeling have been significantly associated with erosive lesions with or without the simultaneous presence of an acidic diet [6, 19–22]. While low flow rate does not have a direct erosive effect on tooth surface, it is more likely that dental hard tissues are unprotected and exposed to strong and direct erosive challenges such as an acidic diet. Therefore, we suggest that a low flow rate of stimulated saliva can be considered as an ETW risk indicator but not automatically a risk factor, meaning that its presence can flag for a high ETW probability, without necessarily being part of the causal chain. In addition, a surprising result of this multicenter study was the frequency of low stimulated (10.9%) and unstimulated saliva (20.3%) flow in this young population. This frequency can be considered as relatively high since it is similar to the overall estimated prevalence (22%) of dry-mouth (hyposalivation and xerostomia) from adult population-based studies [23]. Unfortunately, no population-based studies have been conducted in children or adolescents to have comparable results; however, it is known that increasing age has been associated with an increase of dry mouth prevalence [23]. The frequency of low saliva flow in the young population of this study is a distressing finding probably due to potentially undetected or neglected health conditions that may also affect general health of children and adolescents, such as type 1 of diabetes mellitus, obesity [24], asthma [25], drugs (prescribed or illicit) [26], and anxiety/depression [26]. Nevertheless and despite the efforts by all the examiners to collect saliva as accurately as possible, it should not be underestimated that there are potential limitations of the saliva collection protocol; for example, the standardized time of 1 min to chew the paraffin wax pellet and the convenient for participants collection time period of 3 to 5 min, as well as the fact that collection was performed by drooling instead of expectoration of the saliva into the test tube (although examiners were encouraged to keep the 3 min for comparable results). These procedures may have resulted in less precisely measured stimulated saliva rates in this study.

Energy drink consumption demonstrated one of the highest effect sizes in both bivariate and multivariable analysis. The impact of this type of drink on tooth surface has been already well documented in the literature. In brief, energy drinks are characterized by low pH and calcium concentration and high titratable acidity, which all are significant ETW conditions [27]. In addition, these conditions result in significant decrease of the enamel surface hardness and severe demineralization [28]. These severe erosive consequences may partly explain the high erosive potential of energy drinks, even when they are occasionally consumed during the week, as found in this study; hence, patients should be advised to limit energy drink consumption as much as possible. On the other hand, energy drinks have been also significantly associated with cardiac arrest, myocardial infarction, spontaneous coronary dissection, coronary vasospasm, and high blood pressure, mostly due to the acute caffeine toxicity [29]. Despite the negative general and oral health consequences of energy drink consumption, these beverages are a growing industry with a market value predicted to reach $61 billion by 2021. In Europe, 68% of adolescents (aged 10–18 years old), 30% of adults, and 18% of children (< 10 years old) consume energy drinks on a regular basis [30], while in the USA about 30% of teenagers (aged 12–17 years old) often consume these beverages [31]. Additionally, energy drinks are a significant part of the partying subculture among young people who commonly mix these beverages with alcohol [31, 32]. Therefore, dental community can contribute in formulating collaborative public health policies to minimize the harmful effects of energy drink consumption, such as restriction of sales to children and adolescents and appropriate labeling of these products to highlight their unhealthy content.

The third finding of this multicenter study pertaining to significant ETW risk factors is the significant association of pain/icing with ETW when consuming something cold or acidic. This symptom in this young population is most probably attributed to dentin hypersensitivity (DH) and not to exposed tooth roots. DH has also been significantly associated with relatively severe ETW lesions, since these lesions are very often located in dentine. However, DH pain mechanisms are not well understood and many theories, such as hydrodynamic theory, attempt to explain them but there are no evidence-based data for this [33]. Although toothbrushing or other abrasive behaviors may be solely responsible for a small percentage of DH, it is likely that erosive components exacerbate the condition, resulting in tissue loss and tubular opening [34]. This is supported by the results of this study, since brushing frequency and type of toothbrush were not significantly associated with ETW and those with carious lesions were excluded from the study. Further, bivariate analysis revealed the synergistic action of other types of TW like attrition, on ETW lesions, although this result was not confirmed when conducting regression analysis (Table 4). In conclusion, according to the results of this study, DH can be considered as a main ETW risk indicator and can be used to assess the severity of erosive lesions.

Sometimes the absence of reported acid exposure does not necessarily mean that a given lesion is not caused by acids; in many cases, acid exposure may lie in the past, or the patient is not aware of or does not report in adequate detail the exact time period of the acid exposure [11]. To address this significant limitation of already published ETW surveys, the EWAR tool includes specific questions about the time of occurrence of each potentially erosive behavior ("currently; since when?", "in the past; please determine the time period of occurrence"). This risk assessment is important since it assists to prioritize the management of past and current erosive behaviors and lesions; if the erosive challenge was in the past, the erosive lesions are most probably inactive and any

potential treatment depends on esthetic or DH or acute endodontic complications [35]. But if the erosive effect is current, the management should be first focused on successfully identifying and modifying the erosive behavior, and secondly to treat any noncarious tooth surface loss and potential endodontic issues if needed [36]. For example, when analyzing relevant data from the present multicenter study, it was revealed that for two erosive behaviors ("erosive drink kept in the mouth" and "erosive drinks for quenching thirst between meals currently and not in the past") the participants who demonstrated these behaviors only currently and not in the past had a higher probability of more severe erosive lesions. This can reflect that an active erosive effect may exist (high acidic exposure due to these behaviors) possibly resulting in steady progression of the erosive lesion, and thus increasing its severity. In dental practice, this means that for these two behaviors a special management should be designed and provided, comparing with other erosive behaviors that occurred only in the past. In consequence, due to the interview mode of the EWAR tool, it can be considered as part of a motivational interviewing, behavioral change and adopting preventive advice, probably increasing the clinical benefits of this risk assessment. This type of interviewing can be also helpful when this tool is used in older adults and elders to assist them report erosive behaviors which may lie far in the past.

The present study has several limitations. To begin with, this multicenter study was initially designed to have more and equal number of participants from each country, as well as random samples, but this was difficult due to lack of economic and human resources. Thankfully, the strict inclusion criteria, such as the age of the participants, contributed to have a total relatively overall homogenous sample, which contributed to achieve satisfactory statistical power and validity. Second, although all the examiners followed the same specific protocol for saliva secretion evaluation, saliva collection was sometimes time-consuming and challenging; therefore, for some participants, saliva data were not collected (about 25% of the total sample), although they completed the questionnaire of the EWAR tool. Finally, although the questionnaire was administrated by a dental team member to increase the validity of the responses, participants can be subjected to recall bias to some degree.

Conclusions

According to the experience of the researchers and examiners who applied the EWAR tool (questionnaire + saliva secretion evaluation) in the study population, this tool appeared to be a convenient, affordable, and easy-to-use instrument. The only reported challenges pertained to the collection of the saliva, but the examiners also stated that following the provided saliva collection protocol, potential errors can be limited. Further, bivariate and multivariable analysis revealed that low stimulated salivary flow, energy drink consumption, and pain/icing when consuming something cold or acidic were the risk factors/indicators found to be mostly associated with ETW. More research is needed to evaluate the applicability of this tool in different population groups and to modify it as needed (e.g., to assess in more detail the other types of TW as risk factors) in order to be applicable to all age groups and tooth types (deciduous, permanent).

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in this study were in accordance with the ethical standards of the institutional research committee of each research site (in Finland by the Ethical Committee of the Northern Ostrobothnia Hospital District (11.9.2017, #70/2017 240§); in Romania, by the Research Ethics Committee of the University of Medicine and Pharmacy of Tirgu-Mures (27.09.2017, #312); in the USA/Greece by the Walden University Institution Review Board (#03-01-17-6274274)) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent forms were received from all the participants and parents/guardians when needed and confidentiality of the data was confirmed.

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