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The use of index teeth vs. full mouth in erosive tooth wear to assess risk factors in the diet: A cross-sectional epidemiological study

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ABSTRACT

Objective: To assess common dietary erosive-tooth-wear (ETW) risk in university students from an exotic-fruit country comparing index teeth vs. full mouth ETW assessment.
Methods: A risk factors' questionnaire was applied on 601 18–25 years old subjects in Bogotá-Colombia. Trained examiners assessed clinically: ETW (BEWE) on all buccal, occlusal and lingual surfaces and ICDAS caries experience (ICDAS-DMFS). Full-arch and index-teeth (buccal of upper-central incisors and occlusal of lower-first molars) maximum-BEWE score categorized patients into: with- (2–3) and without wear (0–1). These were compared in terms of demographic, clinical, dietary and other factors with crude and logistic regression models.
Results: Students' mean age was 20.0 ± 1.9 (77.7% females). Most consumed fruits were erosive/extremely erosive (57%). Prevalence of wear was 73% (full-mouth) vs. 19.6% (index-teeth). Full-mouth-BEWE correlated significantly with teeth-index-BEWE score but low (0.31, $p < 0.001$). Besides anterior-teeth incisal surfaces, occlusal of lower molars (16%) and buccal of upper central incisors (3.3%) showed highest wear frequency. Straw use or 1 -h waiting for toothbrushing didn't show a protective effect. ETW was significantly associated on index teeth with frequent intakes of dietary acids (≥3 daily-acidic drinks and ≥4 daily-fruit portions) (single-variable-logistic regression: OR 4.41, $p = 0.22$ and OR 1.60, $p = 0.035$; multivariable-logistic regression: OR 4.47, $p = 0.022$ and OR 1.63, $p = 0.036$ respectively). No significant differences were noticed between groups when the full-mouth maximum score was used.
Conclusion: This young cohort showed dietary ETW associated with frequent dietary acids' intakes and grading ETW on index teeth vs. full mouth was a more sensitive measurement method to assess underlying ETW risk factors. The teeth index has promising usefulness for the clinic and epidemiology.
Clinical Significance: Using index teeth (buccal of upper central incisors and occlusal of lower first molars) for ETW (BEWE) assessment allowed to show association in young adults between frequent daily exotic fruits/fruit juices dietary-acid consumption and ETW, representing a less time consuming clinical/epidemiological method of ETW measurement than a full mouth examination.

1. Introduction

Erosive tooth wear is the chemical mechanical removal of dental hard tissues which can result in reduced aesthetics, compromised tooth structure and loss of quality of life, possibly resulting in the need for costly restorative intervention [1]. The prevalence and severity of erosive tooth wear is increasing, particularly in the younger population [2]. Causal relationships between diet and erosive tooth wear progression have been established [3] and an acidic diet is believed to be a significant aetiological agent in this increase in prevalence.

There is increasing evidence that small amounts of daily dietary acid intake, particularly when consumed with meals, will not result in pathological erosive tooth wear [4]. On the other hand, it is hypothesized that frequent daily dietary acid intakes are needed for severe erosive tooth wear to occur, which affects only 1–3% of the population [2,5]. A 7-year longitudinal study on 55 participants noted that four or more

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dietary acid intakes were taken by those whose tooth wear had progressed significantly over that period [6]. A case control study on 600 participants observed that three or more dietary intakes per day was associated with those with severe erosive tooth wear [4]. However, it is difficult to confirm these associations as, due to the irreversible nature of erosive tooth wear, the aetiological behaviour may have occurred at a separate time to the dietary data collection and is thus underreported.

Early screening for erosive tooth wear and related risk factors has been advocated. The use of the Basic Erosive Wear Examination (BEWE) is increasing globally as a simple screening tool to assess for the presence of erosive tooth wear in general dental practice and in epidemiological studies [7].

When assessing erosive tooth wear epidemiologically, some authors have examined all surfaces [8–10] whereas others have based the assessment on first molar and incisor teeth [11–13]. Epidemiologically, it has been reported that erosive tooth wear most commonly affects the buccal surfaces of maxillary incisor teeth and the occlusal surfaces of the lower first molar teeth [2]. While the worst affected surface per tooth has been reported to grade the wear [14], there has been a limited number of studies comparing whole mouth wear assessment with the use of index surfaces and underlying risk factors [15].

The aim of this study was to assess common dietary erosive tooth wear risk characteristics in a young cohort from an exotic fruits' country using index teeth in comparison to full mouth. It is hypothesized that erosive tooth wear on the buccal surfaces of the maxillary central incisors and the occlusal surfaces of the lower first molars will be reflective of the wear present in a full mouth erosive tooth wear assessment.

2. Methods

This was a cross-sectional study among students in a university in Bogotá, Colombia. Ethical approval was obtained from Scientific, Technical and Administrative Standards for research in health (007–2016). The present study adheres to the Strengthening the Reporting of Observational Studies (STROBE) statement.

BEWE calibration of the two lead examiners (SM and AMLA) was performed over several days in the UK by two recognised experts in the field (DB and SO). Training was performed until overall inter-/ intra-examiner reproducibility scores of ≥ 0.7 weighted Kappa values were obtained.

The inclusion criteria were adults between the ages of 18–25, not currently wearing orthodontic appliances, no history of reflux, xerostomia, use of medications which could reduce salivary flow and must have at least 24 opposing units with no dentures or crowns on the central incisors or first molar teeth. Around 900 potential participants were approached on a university campus and invited to participate in the study where they would receive an examination of erosive tooth wear and dental caries and would answer a questionnaire. The participants y would be informed of their oral health status, receive a fluoride varnish application and would be referred to treatment if needed. A total of 700 students showed initial interest and were approached, 76 declined to participate and 23 did not meet the inclusion criteria. Data collected was obtained from the remaining 601 young adults.

Following written consent from participants each answered a survey on demographics including age, gender, oral hygiene habits, frequency of fruit and fruit juices intake and number of portions per day, modified from a previous validated questionnaire [4] in addition to the acidity of these fruits. The erosivity of fruits was defined according to Reddy et al. who classified that pH $\geq$ 4.0 as minimally erosive, a pH of 3.0–3.99 as erosive and a pH $<$ 3.0 as extremely erosive [16]. Further data were collected on the frequency of acidic drinks consumed per day, presence of habits such as swishing, sipping or holding drinks in the mouth in addition to whether they used a straw. After the questionnaire was completed, a full mouth basic erosive wear examination was performed by the trained examiners in a reclined position on a dental chair under good lighting conditions. The dentition was air dried with a 3-in-1 syringe and the BEWE scores on the buccal, lingual and occlusal surfaces of all teeth excluding third molars was recorded. BEWE scores corresponded to: 0- No erosive tooth wear; 1- Initial loss of surface texture; 2- Distinct defect, hard tissue loss $<$ 50% of the surface area; 3- Hard tissue loss $\geq$50% of the surface area. Surfaces with restorations covering greater than 50% of the surface were excluded. Afterwards dental caries was assessed visually with the ICDAS-merged criteria including initial (non-cavitated), moderate (microcavities and dentine shadows) and extensive (dentine cavities) caries lesions [17], on all surfaces using same described examination conditions. Assessments were conducted by previously calibrated examiners (ICDAS visual criteria inter-/intra-examiner reproducibility weighted Kappa values $\geq$0.7). Fillings and missing teeth were included to calculate the ICDAS caries experience (ICDAS DMFS).

Statistical Analysis

All analyses were performed in the Statistical Package for Social Sciences version 24 for Windows (IBM Corporation, Armonk, New York, USA) and Stata version 14 (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP) for the Exact Fishers test. Data on each surface was assessed and initially it was analysed using the full mouth maximum BEWE score. The maximum BEWE score identified in the full arch was chosen to categorise the patients into those with moderate/severe wear (maximum BEWE score of 2 or 3) and those with no/minimal wear (maximum BEWE score of 0 or 1).

Additionally, participants were also categorized according to the maximum BEWE score on index teeth: the buccal surfaces of the upper central incisors and the occlusal surfaces of the lower first molars. Again, those with a maximum BEWE score of 2 or 3 on these surfaces were categorized as having wear and compared to those with a maximum BEWE score of 0 or 1 on these surfaces.

Those with and without wear were compared in terms of their demographic and clinical characteristics, using the Chi-square test for categorical variables and the *t*-test for continuous measures. Those with and without wear were also compared in terms of investigated dietary risk and other factors (erosivity of the fruit consumed, time spent consuming each fruit portion, number of portions of fruit consumed daily, number of acidic drinks consumed daily, overall time spent consuming acids, whether or not a straw was frequently used, brushing within an hour of acid consumption, alcohol consumption and previous caries experience) using the Chi-square test or Fishers Exact test for categories with low numbers. Single variable logistic regression analysis of these variables was also performed while controlling for age and gender. Variables chosen to be included in a multivariable logistic regression model were selected as those with a p value less than 0.3 or manual selection based upon prior theory and the research hypothesis.

Spearman correlation was used to assess for correlation between maximum BEWE scores on the index surfaces and a maximum BEWE score on all surfaces. Interpretation of Spearman's correlations were used according to Hinkle et al. 1988 [18], whereby 0-0.3 indicated a negligible correlation, 0.3-0.5 a low correlation, 0.5 to 0.7 a moderate correlation and above 0.7 to be a high correlation. Significance was inferred at $p < 0.05$.

3. Results

The mean age of the sample (n = 601) was 20.0 (SD = 1.9); females represented 77.7% (n = 467). Of the study population 177 (29.5%) reported having dental hypersensitivity. The prevalence of caries experience (ICDAS DMFS) was of 88% with a mean of 8 $\pm$ 7.6 surfaces. When analyzing wear for the whole mouth, 433 participants (72%) had any surface graded a BEWE score of 2 or 3 whereas 118 (19.6%) had a BEWE score of 2 or 3 on the index surfaces. A significant but low correlation (0.31, $p < 0.001$) was observed between the full mouth BEWE score and the index teeth BEWE score.

Table 1
Demographics and clinical characteristics by maximum BEWE Score on all surfaces and on index teeth.

Characteristics	Maximum BEWE Score on all recorded surfaces			Maximum BEWE Score on the index teeth		
	Max BEWE 0/1 n = 168	Max BEWE 2/3 n = 433	p value*	Max BEWE 0/1 n = 480	Max BEWE 2/3 n = 118	p value*
Gender			0.66			0.806
Women	133 (79.2 %)	334 (77.1%)	3	371 (77.3%)	93 (78.8%)	
Men	35 (20.8 %)	99 (22.9%)		109 (22.7%)	25 (21.2%)	
Age			0.004			0.182
Mean (SD)	19.7 (1.7)	20.1(2.0)		20.0 (1.9)	20.2(2.0)	
Range	18–25	18–25		18–25	18–25	
Sum BEWE Score			<			<
Mean (SD)	2.5 (1.31)	6.3 (2.8)	0.00	4.4 (2.2)	8.9 (2.8)	0.001
Range	0–6	3–18	1	0–13	3–18	
Self-reported sensitivity						
No	121 (72%)	303 (70%)	0.69	345 (71.9%)	77 (65.3%)	0.176
Yes	47 (28%)	130 (30%)	0	135 (28.1%)	41 (34.7%)	

Note: index surfaces correspond to buccal surfaces of central incisors and occlusal surfaces of lower first molars.
* Chi square and t-tests used to compare proportions and scores.

From the total score, most wear was observed on the incisal surfaces of the anterior teeth, (n = 305; 50.8%) with a BEWE score of 2 or 3. When these were excluded, most of the severe wear (BEWE Score 2/3) was observed on the occlusal surfaces of lower molar teeth (n = 96; 16%) followed by the buccal surfaces of the central incisors (n = 20; 3.3%), corresponding to the index teeth. Table 1 reports the demographic and clinical data of the study population.

Table 2 reports the crude association between the hypothesized risk factors for both the full mouth BEWE score and the index teeth BEWE score. The majority of fruits consumed were either erosive or extremely erosive (57%). Some participants (11.7%) did not consume fruit and of these, only 4 had a BEWE score of 2 or 3 on the index surfaces. Only 10% of participants spent greater than 30 min consuming acids daily and just under a third of participants frequently used a straw when

Table 2
Crude associations of investigated risk factors using Chi square and Fishers Exact tests.

Characteristics	Maximum BEWE Score on all recorded surfaces			Maximum BEWE Score on the index teeth		
	Max BEWE 0/1 (n = 168) n (%)	Max BEWE 2/3 (n = 433) n (%)	p value	Max BEWE 0/1 (n = 480) n (%)	Max BEWE 2/3 (n = 118) n (%)	p value
Erosivity of fruit consumed			0.868			0.141
Minimally Erosive	7 (4.2)	14 (3.2)		15 (3.1)	6 (5.1)	
Erosive	66 (39.3)	172 (39.7)		184 (38.3)	53 (44.9)	
Extremely Erosive	81 (48.2)	217 (50.1)		241(50.2)	55 (46.6)	
Does not Consume	14 (8.3)	30 (6.9)		40 (8.3)	4 (3.4)	
Time spent consuming each fruit portion			0.821			0.132
< 10 minutes	130(77.4)	343 (79.2)		(78.3)	94 (79.7)	
> 10 minutes	24 (14.3)	60 (13.9)		64 (13.3)	20 (16.9)	
Does not consume	14 (8.3)	30 (6.9)		40 (8.3)	4 (3.4)	
Time spent consuming acids daily			0.734			0.100
< 10 minutes	(62.5)	272 (62.8)		(63.1)	73 (61.9)	
10–30 minutes	39 (23.2)	112 (25.9)		112 (23.3)	37 (31.4)	
> 30 minutes	10 (6.0)	19 (4.4)		25 (5.2)	4 (3.4)	
Does not consume	14 (8.3)	30 (6.9)		40 (8.3)	4 (3.4)	
Use of a straw			0.70			0.667
Uses a glass	145 (86.3)	367 (84.8)	2	410 (85.4)	99 (83.9)	
Uses a straw	23 (13.7)	66 (15.2)		70 (14.6)	19 (16.1)	
Brushing after an acid			0.364[a]			0.775 [a]
Brushes in < 60 min.	10 (6.0)	36 (8.3)		36 (7.5)	10 (8.5)	
Brushes in ≥ 60 min.	157(93.5)	389 (89.8)		427 (91.0)	106 (89.8)	
Does not brush	1 (0.6)	8 (1.8)		7 (1.5)	2 (1.7)	
Numbers of acidic drinks consumed			0.724[a]			0.089[a]
Less than 1/day	133 (79.2)	356 (82.2)		395 (82.3)	91 (77.1)	
1/day	23 (13.7)	54 (12.5)		59 (12.3)	18 (15.3)	
2/day	9 (5.4)	16 (3.7)		21 (4.4)	4 (3.4)	
≥ 3/day	3 (1.8)	7 (1.6)		5 (1.0)	5 (4.2)	
Portions of acids consumed per day			0.757			0.043
< 4 portions per day	126 (75.0)	319 (73.7)		365 (76.0)	79 (66.9)	
≥ 4 portions per day	42 (25.0)	114 (26.3)		115 (24.0)	39 (33.1)	
Alcohol consumption			1.00			0.581
Does not consume	103 (61.3)	266 (61.4)	0	298 (62.1)	70 (59.3)	
At least 1/week	65 (38.7)	167 (38.6)		182 (37.9)	48 (40.7)	
ICDAS Caries experience			1.00			0.231
No	20 (11.9)	52 (12.0)	0	54 (11.3)	18 (15.3)	
Yes	148 (88.1)	381 (88.0)		426 (88.8)	100 (84.7)	

Note: index surfaces correspond to buccal surfaces of central incisors and occlusal surfaces of lower first molars.
[a] Fishers Exact Test used due to low numbers in groups.

Table 3
Single variable logistic regression of investigated risk factors adjusted for sex and age.

Characteristics	Maximum BEWE Score on all recorded surfaces		Maximum BEWE Score on the index teeth	
	OR [95% CI]	p value	OR [95% CI]	p value
Erosivity of fruit consumed				
Minimal	1 [Reference]		1 [Reference]	
Erosive	1.48 [0.56–3.89]	0.426	0.75 [0.27–2.04]	0.570
Extremely Erosive	1.52 [0.59–3.67]	0.389	0.60 [0.22–1.62]	0.301
Does not consume	1.08 [0.35–3.30]	0.896	0.25 [0.06–1.00]	0.050
Time spent consuming each portion				
< 10 minutes	1 [Reference]		1 [Reference]	
> 10 minutes	1.04 [0.62–1.76]	0.874	1.31 [0.75–2.30]	0.342
Does not consume	0.73 [0.37–1.44]	0.370	0.38 [0.13–1.09]	0.070
Time spent consuming acids daily				
< 10 minutes	1 [Reference]		1 [Reference]	
10–30 minutes	1.18 [0.76–1.82]	0.466	1.40 [0.89–2.21]	0.466
> 30 minutes	0.78 [0.35–1.76]	0.549	0.67 [0.24–2.00]	0.549
Does not consume			0.39 [0.14–1.14]	0.085
Use of a straw				
Uses a glass	1 [Reference]		1 [Reference]	
Uses a straw	1.08 [0.64–1.81]	0.774	1.08 [0.62–1.89]	0.788
Brushing after an acid				
Brushes within an hour	1 [Reference]		1 [Reference]	
Brushes after an hour	0.69 [0.34–1.44]	0.327	0.89 [0.43–1.86]	0.759
Does not brush	2.06 [0.23–18.63]	0.519	0.99 [0.18–5.52]	0.986
Numbers of acidic drinks consumed				
Less than daily	1 [Reference]		1 [Reference]	
Once/day	0.84 [0.49–1.44]	0.532	1.36 [0.76–2.45]	0.300
Twice/day	0.61 [0.26–1.43]	0.256	0.81 [0.27–2.43]	0.708
Three or greater/day	0.89 [0.22–3.53]	0.863	4.41 [1.24–15.59]	0.022
Portions of acids consumed per day				
< 4 portions per day	1 [Reference]		1 [Reference]	
≥ 4 portions per day	1.11 [0.73–1.67]	0.637	1.60 [1.03–2.49]	0.035
Alcohol consumption				
Does not consume	1 [Reference]		1 [Reference]	
At least 1/week	0.99 [0.68–1.43]	0.944	1.14 [0.75–1.73]	0.529
ICDAS Caries experience				
No	1 [Reference]		1 [Reference]	
Yes	0.97 [0.56–1.70]	0.917	1.67 [0.37–1.21]	0.182

Note: index surfaces correspond to buccal surfaces of central incisors and occlusal surfaces of lower first molars.

drinking. Those who consumed ≥4 portions of fruit per day were more likely to have wear on the index surfaces (p = 0.043). No significant differences were noticed between groups when the full mouth maximum score was used.

Table 3 reports the adjusted logistic regressions between the hypothetised risk factors and the index teeth BEWE score, controlling for age and gender. Those who consumed ≥3 acidic drinks per day in addition to those who consumed ≥4 portions of fruit per day were more likely to have wear on the index surfaces (p = 0.022 and p = 0.035, respectively). No differences in risk characteristics were observed between those with and without wear when the full mouth maximum BEWE score was used.

Table 4 reports the fully adjusted logistic regression analysis using presence or absence of wear on the index teeth surfaces as the dependent variable. There were no differences in brushing characteristics or the presence of caries between groups. Those who consumed ≥3 acidic drinks per day were 4.47 times more likely to have wear (95% CI: 1.24–16.18, p = 0.022) compared to those who consumed < 1 acidic drink per day and those who consumed ≥4 portions of fruits per day were 1.63 times more likely to have wear (95% CI: 1.03–2.58, p = 0.036) compared to those who consumed < 4 portions of fruits per day. Those who did not consume fruit daily were 84% less likely to have wear on the index surfaces (OR 0.16, 95% CI: 0.03–0.92, p = 0.04) compared to those who consumed minimally erosive fruit.

Table 4
Multivariable logistic regression, adjusted for age and sex.

Characteristics	Maximum BEWE Score of 2/3 on index teeth	
	OR [95% CI]	p value
Erosivity of fruit consumed		
Minimally erosive	1.00 [Reference]	
Erosive	0.71 [0.25–2.00]	0.520
Extremely erosive	0.54 [0.19–1.51]	0.237
Does not consume	0.16 [0.03–0.92]	0.040*
Brushing after an acid		
< 60 minutes	1.00 [Reference]	
> 60 minutes	0.91 [0.43–1.93]	0.806
Does not brush	4.79 [0.51–45.40]	0.172
Daily acidic drinks		
Less than once daily	1.00 [Reference]	
1 per day	1.47 [0.80–2.68]	0.216
2 per day	0.86 [0.28–2.61]	0.791
3 per day	4.47 [1.24–16.18]	0.022*
Portions of acids		
Less than four/day	1.00 [Reference]	
> 4/day	1.63 [1.03–2.58]	0.036*
ICDAS Caries experience		
No	1.00 [Reference]	
Yes	0.65 [0.36–1.19]	0.164

Note: index surfaces correspond to buccal surfaces of central incisors and occlusal surfaces of lower first molars.

* Statistically significant value (p value was with Fisher or with chi^2).

4. Discussion

Increased frequency of drinks and fruit was associated with increased erosive tooth wear on index teeth surfaces but only for ≥3 and ≥4 intakes per day. The fact that associations were observed only with excessive dietary acid intake is to be expected given the age of the participants and limited lifetime exposure to dietary acids. Smaller levels of dietary acid intake may result in wear but at a slower rate of progression [4]. This study confirms that frequent daily quantities of dietary acids results in erosive tooth wear progression and it is promising to note that the numbers consuming at this level were quite small.

Assessing the maximum BEWE score on index teeth surfaces (the buccal surfaces of the central incisor teeth and the occlusal surfaces of the lower first molar teeth) appeared to be a more sensitive method of identifying risk factors than the full mouth maximum BEWE score. In addition, the correlation between the full mouth maximum BEWE score and the index teeth maximum BEWE score was relatively low. The possibility of grading erosive tooth wear on index teeth surfaces instead of examining the full mouth, besides more sensitively being able to identify risk factors, has the advantage of reducing the assessment time and thus resources, both in the clinical practice as in epidemiological studies. This is a wide promising erosive tooth wear assessment simplification.

The BEWE is a simple tool designed to identify wear regardless of the aetiology. It appears that attritional wear on the incisal surfaces of the anterior teeth skewed the data within this study and was not indicative of the erosive risk factors. Other studies have observed no differences between a full mouth score and scores on index teeth [15] although scores on index teeth were lower. There is precedent for using index teeth for epidemiological surveys [11–13] and the data from this study would suggest that this is indicated if erosive risk characteristics are to be investigated.

Delaying brushing one hour after an acid challenge did not appear to have a protective effect in this study population. There is increasing evidence that the general advice to delay brushing after eating is unfounded [4,19]. There is laboratory evidence that suggests that more tooth structure is removed if brushing is performed after an acid challenge [20,21]; however, perhaps our advice should be focused on reducing acid intake, a non-aggressive brushing technique and the use of a fluoridated, low-abrasivity toothpaste [21].

The use of a straw also offered no protective effect in this study. Laboratory investigations have shown that the pH does not drop to the same extent when a straw is used [22] and in situ studies have shown that the use of a straw reduces contact time with the molar and incisor teeth [23]. However, these are small studies with low sample sizes and a reduction in the intraoral pH was observed regardless of whether a straw was used. If a straw is directed at a dental surface rather than towards the back of the mouth, there is potential for greater localized erosive wear [24]. This study would suggest that reducing the intake of acidic drinks would have a greater protective effect.

The questionnaire in this study is similar to the majority erosive tooth wear studies [2,25,26] and was interviewer led as we had trained persons who supported the study, as opposite to self-administered questionnaires [27]. As the multi-factorial nature of erosive tooth wear poses challenges when attempting to capture a comprehensive risk pattern from a patient it is important that the participant fully understands the questions being asked, is able to clarify what aspects of the diet are acidic and can report fully on each risk factor. In this study only 3 participants out of 601 had a habit of sipping, swishing or holding drinks in the mouth which contrasts with a UK study whereby 106 participants out of 601 reported to have the same habit in an interviewer led questionnaire. This could be due to differences in the study population or due to differences in the questionnaire design.

A limitation of this study is that it was carried out on university students who were self-selected to participate in the study. This limits the generalizability of the study to the general population.

5. Conclusion

Dietary erosive tooth wear was observed within this young cohort and was associated with frequent intakes of dietary acids. The use of a straw or waiting until one hour after brushing teeth did not have a protective effect within this study. Grading erosive tooth wear on index dental surfaces appeared to be a more sensitive method of measurement to assess underlying risk factors than a full mouth examination which may save time and resources in future epidemiological studies as well as in the clinical practice.

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