Original Article

Evaluation of Tooth Wear and Associated Risk Factors: A Matched Case–Control Study

C Atalay, G Ozgunaltay

Department of Restorative Dentistry, School of Dentistry, Hacettepe University, Ankara, Turkey

Abstract

Aim: The aim of this case–control study was to compare the associated risk factors between adults with tooth wear (TW) and age- and sex-matched controls without TW. **Methods:** Fifty participants with TW and 50 age- and sex-matched controls participated in this study. A questionnaire was prepared to assess oral healthcare and consumption of erosive food and drinks. All participants completed the diet analysis forms. Saliva characteristics were evaluated with GC Saliva-Check BUFFER test. Examiners measured the TW of case patients, using the TW index. Data were statistically analyzed using Chi-square and Mann–Whitney *U*-tests ($P < 0.05$). **Results:** Individuals in the case group brush their teeth more often ($P < 0.05$). The difference in erosive food consumption between the case and control groups was significant ($P < 0.05$). There was no erosive effect of acidic food when consumed as a main meal or a snack ($P > 0.05$). Although there was no difference between stimulated saliva flow rate and buffering capacity between groups, the difference between the resting saliva flow rates and pH values was significant ($P < 0.05$). Although some wear was seen on buccal/labial surfaces of teeth, cervical and occlusal/incisal surfaces were scored higher. No TW was observed on palatal/lingual surfaces. The cervical surfaces of mandibular premolars and incisal surfaces of anterior teeth were most affected. **Conclusion:** Of the factors investigated, TW in the case group was correlated with consumption of acidic foods, lower salivary flow rate, and pH.

Keywords: *Diet, oral hygiene, risk factors, saliva, tooth wear*

Date of Acceptance: 02-Aug-2018

Introduction

The number of individuals with natural teeth has increased due to increased life span, spread of protective dentistry services, and improvements in oral and dental health. However, this positive development is accompanied by tooth wear (TW), the loss of tooth structure due to a chemical or physical attack of non-bacterial origin.[1] The etiology of TW is often multifactorial, and individual sensibility to TW may be modified by other chemical, biological, and behavioral factors.

Some people are at greater risk due to their eating and brushing habits. Poor oral health behaviors and malnutrition are the leading causes of tooth surface loss in adults.[2] Beverage consumption trends have altered, and while consumption of dairy products has decreased, consumption of carbonated drinks and packaged products has increased.[2] Frequent and faulty brushing with abrasive oral hygiene products can also increase TW.

Saliva is considered the biological factor with the greatest potential to modify the progression of TW.[3] There are several potential mechanisms by which saliva may protect enamel from dietary acid erosion. Saliva protection mechanisms include the dilution of erosive

Address for correspondence: Dr. C Atalay, Department of Restorative Dentistry, School of Dentistry, Hacettepe University, Ankara 06100, Turkey. E-mail: cansuatalaydr@gmail.com

Access this article online

Quick Response Code:

Website: www.njcponline.com

DOI: 10.4103/njcp.njcp_203_18

How to cite this article: Atalay C, Ozgunaltay G. Evaluation of tooth wear and associated risk factors: A matched case–Control study. Niger J Clin Pract 2018;21:1607-14.

agents in the mouth, neutralization, effects of calcium and phosphate ions, and slowing of the rate of enamel dissolution.[4]

The loss of dental tissue can change the structure of enamel, and in advanced stages the dentin surface can be exposed. TW is initially painless and unrecognizable. In the next stage, complaints often include tenderness and nonaesthetic factors.[5,6] It is difficult to recognize the signs of TW and very important to avoid premature diagnosis. Correct diagnosis is an important part of the treatment and will help the dentist determine recommendations for the patient.

Although many causes of TW are known, the risk levels associated with individual wear-causing factors and their effects in populations have not yet been determined. The aims of this study were to (1) evaluate oral hygiene behavior, dietary habits, and saliva characteristics as risk factors of TW and (2) compare the associated risk factors between adults with TW and age- and sex-matched controls without TW.

Methods

Study participants

The study was conducted from November 2014 to January 2016. Ethics approval was granted by the Local Ethics Commission; written informed consent was signed by each subject. We used a multistage, stratified sampling method to obtain a representative sample of the adult population between the ages of 18 and 65 years, attending general practices. A total of 100 participants were recruited following referral by other departments for generalized TW or general treatment. Inclusion criteria included participants having a minimum of six eligible teeth (without restorations) showing TW on different surfaces (cases, n = 50), though the number of teeth scored per patient was usually far higher (mean 12.3, range 6–20). At the same time, age- (year and as close as possible to month) and sex-matched subjects without TW were selected for the control group (controls, n = 50). The selection was obtained from the consecutive list of patients who were to be given an appointment for a routine check-up. Conditional logistic regression analysis was used for individual matching. The target sample size was calculated to have an 80% power of demonstrating a significant difference between groups at a 5% level.

After screening, consenting patients who were in good health and able to understand and read the questionnaire were included. Subjects were excluded if they were currently wearing orthodontic appliances, had crowns or partial dentures, or had eating disorders. Patients on medications that affect the salivary system such as antihistamines, diuretics, antidepressants, antipsychotics, and sedatives were not included.

Questionnaire

A trial questionnaire was developed that reflected the putative factors associated with TW and was tested with a pilot group of 15 randomly selected patients. A final questionnaire was thereafter prepared to collect participants' personal data and determine the risk factors that could cause TW. The questionnaire had the following components: (1) sociodemographic characteristics of participants (gender, birth date); (2) tooth brushing frequency, technique, toothbrush type; and (3) frequency of intake of citrus fruits, citrus-flavored sweets/gums, fruit juices, sports drinks, soft drinks.

Nutritional analysis

Individuals were given nutritional analysis forms to record their complete dietary intake. They recorded all foods and drinks ingested and the consumption time for 2 weekdays and 2 weekend days which are consecutive. The examiner evaluated the erosive potential of the different acidic foods and drinks and the frequency of ingestion during main meals and snacks at the next appointment.

Saliva analysis

Resting and stimulated saliva samples were collected from individuals using a Saliva-Check BUFFER kit (GC Corp., Leuven, Belgium). Subjects were not allowed to eat or drink 1 h before their appointments (always between 9 and 10 a.m.), and adherences were confirmed by asking the subjects before saliva analysis. First, unstimulated saliva was collected. Individuals were asked to expectorate into the collection cup until approximately 5 mL was obtained. Subjects were instructed not to speak during collection of unstimulated saliva. One end of the pH strip was placed into the sample and then the color was checked to estimate the pH. According to the color of strip, samples were classified as acidic saliva, moderately acidic saliva, or healthy saliva. To stimulate saliva, subjects were given a piece of wax to chew; saliva was collected for 5 min in a measuring cup and the volume was measured. One drop of the stimulated saliva was dispensed onto each of the three buffering test pads, left for 2 min. After that, the three scores were added and the results recorded.

Tooth wear detection

The four visible surfaces of all teeth except third molars were examined for TW by drying the teeth with an air syringe and visually inspecting them with a mouth mirror and a dental probe under good lighting. Surfaces were scored in accordance with the Smith and Knight's tooth wear index (TWI) [Table 1].[7] Evaluations were conducted by two calibrated examiners (CA and GO); only teeth without restorations were examined.

Statistical analysis

Data were entered into spreadsheets and imported into SPSS Statistics for Windows Version 22.0 (IBM Corp., Armonk, NY, USA). Categorical variables were shown by number and percentage. The normality of the numerical variables was tested by Shapiro–Wilks test and the homogeneity of variances by Levene's test. Chi-square test was used to compare categorical variables and a Mann–Whitney *U*-test was used to compare numeric variables between the case and control groups. All levels of significance were set at $P < 0.05$.

Results

The age range of the participants was 18–65 years (mean = 45.82 ± 9.88 years); 46% were males and 54% were females.

Oral hygiene practices

In the case group, most adults reported a tooth brushing frequency of ≥ 2 times/day [Table 2]; the results showed that participants in the case group brushed their teeth more often than controls. Waiting time after meals before tooth brushing was 34.05 (±32.69) min in the case group and 45.19 (±33.12) min for control group. Brushing immediately after meals and acid exposure did not differ between groups ($P > 0.05$). Electric toothbrush use was not declared in either group. Subjects chose more than one option for toothbrush type and brushing movement; medium toothbrushes were most commonly used in both groups. The vertical brushing movement showed the highest rate of TW ($P > 0.05$), but the difference was not significant.

Consumption of potentially erosive foods and drinks

According to questionnaire results, 44% (n = 44) of the subjects in the case group and 42% (n = 42) of subjects in the control group consumed potentially erosive foods and/or beverages between meals. The distribution of food/beverage consumption frequency between groups is shown in Table 3. No individual in either group reported between-meal eating more than three times per day ($P > 0.05$).

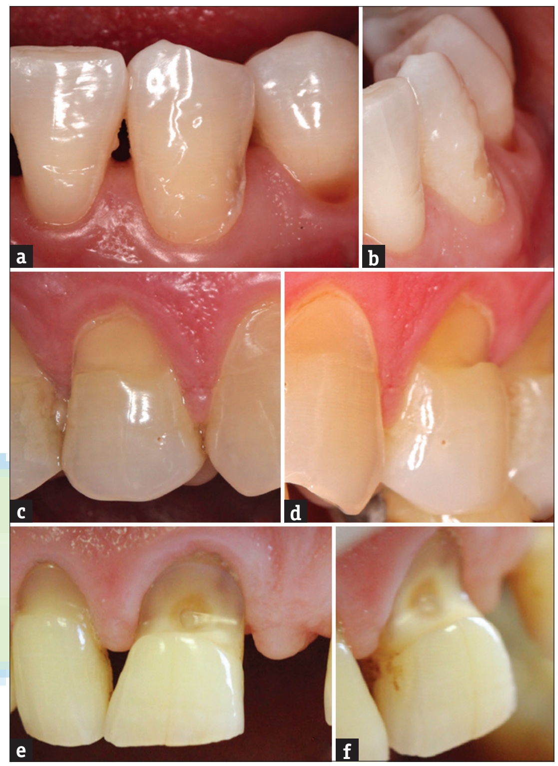

Figure 1: Examples of TW on the cervical surfaces and scores: (a) Score 2; defect <1 mm (buccal aspect), (b) Score 2 (aproximal appearance), (c) Score 3; defect 1–2 mm (buccal aspect), (d) Score 3 (aproximal appearance), (e) Score 4, defect more than 2 mm (buccal aspect), and (f) Score 4 (aproximal appearance)

Table 1: Smith and Knight's tooth wear index

Score	Surface	Criteria
0	Buccal/lingual/palatal/occlusal/incisal	No loss of enamel surface characteristics
	Cervical	No loss of contour
1	Buccal/lingual/palatal/occlusal/incisal	Loss of enamel surface characteristics
	Cervical	Minimal loss of contour
2	Buccal/lingual/palatal/occlusal	Loss of enamel exposing dentine for less than one third of surface
	Incisal	Loss of enamel that minimally exposes dentine
	Cervical	Defect <1 mm deep
3	Buccal/lingual/palatal/occlusal	Loss of enamel exposing dentine for more than one third of the surface
	Incisal	Loss of enamel and substantial loss of dentine
	Cervical	Defect <1-2 mm deep
4	Buccal/lingual/palatal/occlusal	Complete enamel loss, pulp exposure, secondary dentine exposure
	Incisal	Pulp exposure or exposure of secondary dentine
	Cervical	Defect >2 mm deep pulp exposure, secondary dentine exposure

Among case group participants, the frequency of drinking straw use was reported as follows: 68% never, 28% rarely, and 4%, sometimes. In the control group, the frequencies were as follows: 42% never, 34% rarely, and 24% sometimes.

When nutritional analysis was performed, the difference between groups was statistically significant ($P < 0.05$) except for weekday main meals ($P > 0.05$). In both groups, consumption frequency of acid-containing foods was the highest between meals on weekend days.

Saliva parameters

Flow rate and pH values are included in Table 4. No difference was detected between groups in terms of stimulated saliva flow rate and buffering capacity ($P > 0.05$). There were statistically significant differences between case and control groups in terms of the resting saliva flow rate and pH value ($P < 0.05$). The pH results showed that 36% of the individuals in the case group had a healthy pH and 64% had moderately acidic saliva. In the control group, 82% had a healthy pH and 12% had moderately acidic saliva ($P < 0.05$).

Table 2: Oral hygiene practices of the study population (*n*=100)

Oral hygiene practices	Case (*n*=50), *n* (%)	Control (*n*=50), *n* (%)	OR	95% CI	*P*
Tooth brushing					
Frequency					
Once a day	7 (14)	20 (40)	3.21	0.71-1.01	0.012
Twice a day	38 (76)	27 (54)	2.29	0.49-0.76	
≥3 times per day	5 (10)	3 (6)	1.40	0.55-1.26	
Technique*					
Side-to-side	26 (52)	16 (32)	1.75	0.53-0.75	0.368
Up-and-down	39 (78)	34 (68)	1.62	0.36-0.60	
Circles	16 (32)	20 (40)	0.93	0.25-0.76	
No set pattern	1 (2)	2 (4)	0.61	1.44-2.70	
Immediately after acidic foods					
Often	-	-	0.85	0.71-1.08	0.434
Sometimes	5 (10)	5 (10)	0.61	0.65-1.01	
Rarely	7 (14)	12 (24)	0.83	0.53-0.93	
Never	38 (76)	33 (66)	0.43	0.45-0.73	
Toothbrush type*					
Hard	5 (10)	2 (4)	1.97	0.57-1.04	0.161
Medium	30 (60)	22 (44)	2.28	0.73-1.03	
Soft	12 (24)	18 (36)	1.16	0.53-0.97	
Not sure	6 (12)	9 (18)	0.63	0.36-0.83	

*Multiple responses are available. OR=Odds ratio; CI=Confidence interval

Table 3: Percentage distribution of consumption of potentially erosive foods and drinks between meals

Dietary habits	Consumption frequency					
	Never (%)	<1/week	<1/day	1/day (%)	2-3/day (%)	>3/day (%)
Citrus fruits						
Case	20.5	6.8	20.5	20.5	9.1	
Control	28.6	14.3	19.0	11.9	4.8	
Soft drinks						
Case	36.4	47.7	4.5	6.8	4.5	-
Control	40.5	50.0	7.1	2.4	-	-
Fruit juice						
Case	72.7	22.7	-	2.2	-	-
Control	69.0	26.1	7.1	-	-	-
Sport drinks						
Case	90.9	2.3	2.3	4.5	-	-
Control	92.9	2.4	4.8	-	-	-
Citrus-flavored sweets/gums						
Case	68.2	20.5	6.8	-	4.5	-
Control	78.6	11.9	9.5	-	-	-

With the exception of one individual in the case group, a higher saliva buffer capacity was observed.

Table 4: Unstimulated and stimulated salivary parameters of case and control groups

	Mean±SD		OR	95% CI	*P*
	Case group (*n*=50)	Control group (*n*=50)			
Unstimulated saliva					
Flow rate	0.51±0.33	0.67±0.28	0.4	0.1-1.1	0.001
pH	6.7±0.5	7.04±0.4	0.9	0.5-1.5	<0.001
Stimulated saliva					
Flow rate	1.91±0.79	2.06±0.67	1.0	0.6-1.5	0.213

SD=Standard deviation; OR=Odds ratio; CI=Confidence interval

Observed tooth wear

A total of 1340 teeth and 5360 surfaces were examined. Intraexaminer reliability was 0.85 (95% confidence interval: 0.81–0.93). The most affected cervical surfaces were first premolars; the least affected were second molars [Table 5]. Figure 1 illustrates the TW on the cervical surfaces. There was a small amount of TW on buccal/labial surfaces and no wear on palatal/lingual surfaces. Wear on incisal/occlusal surfaces was primarily observed on the anterior teeth, the least on second molar teeth. Cervical and incisal/occlusal surfaces had higher scores even though there was a certain amount of wear on buccal/labial surfaces of the teeth. The incisal surfaces of anterior teeth had scores of 2, indicating that the lesions covered the dentine. Only a small number of

Table 5: Distribution of teeth according to effected surfaces

Teeth*	Tooth surfaces				
	n	Cervical, *n* (%)	Buccal/labial, *n* (%)	Palatal/lingual, *n* (%)	Incisal/occlusal, *n* (%)
Central incisors	200	67 (33.5)	18 (9.0)	-	170 (85.0)
Lateral incisors	200	59 (29.5)	10 (5.0)	-	167 (83.5)
Canines	198	106 (53.5)	5 (2.5)	-	158 (79.7)
First premolars	198	164 (82.8)	2 (1.1)	-	126 (63.6)
Second premolars	182	121 (66.4)	-	-	80 (43.9)
First molars	174	108 (62.1)	1 (0.5)	-	80 (45.9)
Second molars	188	28 (14.8)	1 (0.5)	-	43 (22.8)

*More than one surface of the teeth was affected

Table 6: Percentage distribution of tooth surfaces according to tooth wear index scores

Tooth surfaces/TWI scores	Teeth						
	Central incisors (*n*=200) (%)	Lateral incisors (*n*=200) (%)	Canines (*n*=198) (%)	First premolars (*n*=198) (%)	Second premolars (*n*=182) (%)	First molars (*n*=174) (%)	Second molars (*n*=188) (%)
Cervical							
0	65.0	70.5	46.4	17.1	33.5	36.4	85.1
1	21.0	11.5	15.6	7.5	8.3	17.7	12.9
2	9.0	9.0	24.2	36.9	35.7	27.6	1.5
3	5.0	9.0	11.3	36.4	18.6	16.5	0.5
4	-	-	2.5	2.1	3.9	1.8	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Buccal/labial							
0	91.0	93.5	97.4	98.9	100.0	98.2	99.4
1	3.5	4.5	-	-	-	1.8	0.6
2	3.5	-	2.0	-	-	-	-
3	2.0	2.0	0.6	1.1	-	-	-
4	-	-	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Incisal/occlusal							
0	15.0	16.5	20.2	36.4	56.0	54.2	77.3
1	9.5	17.0	22.3	30.7	25.8	21.2	21.2
2	74.0	66.0	56.5	30.9	15.9	22.9	1.0
3	1.5	0.5	1.0	1.5	2.3	1.7	0.5
4	-	-	-	0.5	-	-	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TWI=Tooth wear index

teeth scored 4 on the cervical surface (1.5%). Only the cervical surfaces of the premolar teeth in the mandible were scored as 2 and above [Table 6].

Discussion

In this study, we determined possible risk factors and clinical signs that may help the dentist diagnose TW. It was important to ensure that the control patients were free of TW in a matched case–control study so that diseased individuals were not included in the control group. According to our knowledge, this is the first study to investigate possible etiological factors by comparing a case group with a matched control group of adults known to have considerable TW.

Studies have shown that TW in adults is more inclined to be observed as a combination of abrasion, attrition, and erosion; erosion is the primary etiological factor of TW in a young age group.[8] Therefore, lesions were not classified as abrasion, erosion, abrasion, or abfraction, and in cases of TWI, the lesions were evaluated to determine their severity.

It has been reported that the use of a toothbrush alone does not cause enamel wear.[9] Absi *et al*. conducted a scanning electron microscopy (SEM) study and reported that the use of a toothbrush alone over time resulted in a small amount of dentine loss, which may be confined to the smear layer.[10] In our study, there were no individuals who brush their teeth more than three times a day in either group; the overuse or abuse of tooth brushing with toothpaste was not observed.

The timing of tooth brushing in relation to TW is still a matter of controversy. Hara and Zero reported that saliva is a protective feature for a tooth surface exposed to acid.[11] Attin *et al*. reported that rehardening of the erosive-damaged hard dental tissue is a process and is improved by waiting to brush until 30 min after an acidic attack.[12] In this study, the mean interval between a meal and brushing was more than 30 min in both groups. However, the absence of wear observed in individuals in the control group may be related to the waiting period after meals. More detailed studies targeting acidic diet and brushing time are needed to elucidate the reason.

Some studies have shown that nutrition is an important etiological factor in the development and progression of TW.[2,13,14] In those studies, the most important factor in the development of TW was found to be the consumption frequency of acid-containing foods. Kitasako *et al*. observed that younger subjects consumed more acidic drinks and elderly individuals consumed acid-containing fruits, suggesting that acid-containing fruits and beverages are associated with TW.[15] It has been reported that consumption of acid-containing food more than four times per day is an important factor in the development of abrasions.[16] The questionnaire used in the study asked the frequency of consumption of acidic foods among meals. No individual reported consumption of acidic food more than three times per day. Analysis of nutritional information revealed that subjects in the case group consumed more acidic foods.

Individuals in the control group reported use of straws more frequently than the case group. Drinks are known to affect the labial or palatal surfaces of teeth more than foods.[17] In our study, there was no wear on palatal/lingual surfaces. In our study, the consumption of acidic foods by individuals was evaluated by the questionnaire and nutritional analysis. As the survey questions were based on memory, answers were more subjective. Nutritional analysis was conducted by the researcher identifying nutrients with acid content among the recorded nutrients. In this way, individual eating habits have been examined in more detail.

The relationship between saliva effect and wear observed on teeth has been investigated in many studies, but different results of the possible relationship between salivary flow rate, pH, and buffering capacity values have been reported. Carvalho *et al*.[18] and Piangprach *et al*.[19] assessed resting and stimulated saliva and suggested that they are effective in tooth erosion with different properties.

Larsen and Pearce[20] and Dawes and Kubieniec[21] reported that a high salivary flow rate leads to increases in the concentrations of certain ions and proteins and to a high buffering capacity. In this study, the resting salivary flow rates of individuals in the case group were lower than the values for individuals in the control group. TW in these individuals may be related to the low basal flow rate. Järvinen *et al*.[22] suggested that individuals with a resting salivary flow rate of less than 0.1 mL/min are at an at least five times higher risk for erosion than individuals with a normal flow rate. Our study did not include any individuals with a risky resting salivary flow rate in the case or control groups.

It has been reported that saliva pH depends both on the buffer base and secreted acids, and especially on bicarbonate ion concentration.[23] It is only effective at higher salivary flow rates. In our study, the salivary pH values of individuals with TW were lower than those of individuals in the control group.

Studies have shown that low buffering capacity and/or low flow rate may be associated with erosion.[22,24] Lussi and Schaffner reported that individuals in their studies with low buffering capacity had a higher risk of cervical abrasion. In our study, there was no significant relationship between saliva buffering capacity and dental abrasion.[25] The buffering capacity was low in only one patient in the case group; it was high in all other individuals.

Goel reported that occlusal forces were most effective on cervical enamel, which is related to the contour of the cementoenamel junction and the thinner enamel in the cervical third of the buccal and lingual surfaces.[26] In this study, the maximum wear was observed on the cervical surfaces of the first premolars. This observation can also be explained by the fact that the brushing forces are most directly transmitted to these teeth.

It has been reported that abrasions on incisal/occlusal surfaces are more commonly observed in anterior teeth.[27] Panek *et al*.[28] reported that anterior guidance is the most common dynamic occlusion pattern in the natural dentition. Schierz *et al*.[29] investigated occlusal TW and suggested that more wear observations on the anterior teeth may be due to dynamic occlusal contact during function. Kitasako *et al*.[15] and Aidi *et al*.[30] conducted erosion studies and reported that severe tooth surface loss was observed on the incisal surfaces of the anterior teeth, while dentine exposure was most commonly found on the incisal surfaces of these teeth.

Our findings are in agreement with other studies. TW on the incisal and/or occlusal surfaces was primarily observed on the anterior teeth. More dentin exposure of the anterior teeth may be due to anatomic and functional factors, as these teeth may be exposed earlier and may therefore be exposed to internal and external factors for longer periods of time.

None of the methods used to determine the TW factors explains the exact causes. The large number of factors affecting the formation makes exact determination of the possible risk factors difficult; more participants and long-term follow-up studies are necessary.

Conclusion

Of the factors investigated, TW in the case group was correlated with frequency of tooth brushing, consumption of acidic foods, and lower salivary flow rate and pH. It is important for TW to be diagnosed in early stages and for the risk factors to be identified.

Acknowledgment

The authors would like to thank all individual participants who took part in this study.

Financial support and sponsorship

This study was supported by the Hacettepe University Scientific Research Project Coordination Unit (project number: 014D12201003-814).

Conflicts of interest

There are no conflicts of interest.

References

1. Taji S, Seow WK. A literature review of dental erosion in children. Aust Dent J 2010;55:358-67.
2. Lussi A, Jaeggi T, Zero D. The role of diet in the aetiology of dental erosion. Caries Res 2004;38 Suppl 1:34-44.
3. Hara AT, Lussi A, Zero DT. Biological factors. Monogr Oral Sci 2006;20:88-99.
4. Zwier N, Huysmans MC, Jager DH, Ruben J, Bronkhorst EM, Truin GJ, *et al.* Saliva parameters and erosive wear in adolescents. Caries Res 2013;47:548-52.
5. Al-Omiri MK, Lamey PJ, Clifford T. Impact of tooth wear on daily living. Int J Prosthodont 2006;19:601-5.
6. Rees JS, Thomas M, Naik P. A prospective study of the prevalence of periapical pathology in severely worn teeth. Dent Update 2011;38:24-6, 28-9.
7. Smith BG, Knight JK. An index for measuring the wear of teeth. Br Dent J 1984;156:435-8.
8. Shellis RP, Addy M. The interactions between attrition, abrasion and erosion in tooth wear. Monogr Oral Sci 2014;25:32-45.
9. Dyer D, Addy M, Newcombe RG. Studies *in vitro* of abrasion by different manual toothbrush heads and a standard toothpaste. J Clin Periodontol 2000;27:99-103.
10. Absi EG, Addy M, Adams D. Dentine hypersensitivity – The effect of toothbrushing and dietary compounds on dentine *in vitro*: An SEM study. J Oral Rehabil 1992;19:101-10.
11. Hara AT, Zero DT. The potential of saliva in protecting against dental erosion. Monogr Oral Sci 2014;25:197-205.
12. Attin T, Siegel S, Buchalla W, Lennon AM, Hannig C, Becker K, *et al.* Brushing abrasion of softened and remineralised dentin: An *in situ* study. Caries Res 2004;38:62-6.
13. Bartlett DW, Fares J, Shirodaria S, Chiu K, Ahmad N, Sherriff M, *et al.* The association of tooth wear, diet and dietary habits in adults aged 18-30 years old. J Dent 2011;39:811-6.
14. Barbour ME, Lussi A. Erosion in relation to nutrition and the environment. Monogr Oral Sci 2014;25:143-54.
15. Kitasako Y, Sasaki Y, Takagaki T, Sadr A, Tagami J. Age-specific prevalence of erosive tooth wear by acidic diet and gastroesophageal reflux in Japan. J Dent 2015;43:418-23.
16. Lussi A, Hellwig E. Risk assessment and causal preventive measures. Monogr Oral Sci 2014;25:220-9.
17. Smith BG, Knight JK. A comparison of patterns of tooth wear with aetiological factors. Br Dent J 1984;157:16-9.
18. Carvalho TS, Baumann T, Lussi A. *In vitro* salivary pellicles from adults and children have different protective effects against erosion. Clin Oral Investig 2016;20:1973-9.
19. Piangprach T, Hengtrakool C, Kukiattrakoon B, Kedjarune-Leggat U. The effect of salivary factors on dental erosion in various age groups and tooth surfaces. J Am Dent Assoc 2009;140:1137-43.
20. Larsen MJ, Pearce EI. Saturation of human saliva with respect to calcium salts. Arch Oral Biol 2003;48:317-22.
21. Dawes C, Kubieniec K. The effects of prolonged gum chewing on salivary flow rate and composition. Arch Oral Biol 2004;49:665-9.
22. Järvinen VK, Rytömaa II, Heinonen OP. Risk factors in dental erosion. J Dent Res 1991;70:942-7.
23. de Almeida Pdel V, Grégio AM, Machado MA, de Lima AA,

Azevedo LR. Saliva composition and functions: A comprehensive review. J Contemp Dent Pract 2008;9:72-80.
24. Lussi A, von Salis-Marincek M, Ganss C, Hellwig E, Cheaib Z, Jaeggi T, *et al.* Clinical study monitoring the pH on tooth surfaces in patients with and without erosion. Caries Res 2012;46:507-12.
25. Lussi A, Schaffner M. Progression of and risk factors for dental erosion and wedge-shaped defects over a 6-year period. Caries Res 2000;34:182-7.
26. McCoy G. Stresses at the dentinoenamel junction of human teeth – A finite element investigation. J Prosthet Dent 1992;68:206.
27. Pigno MA, Hatch JP, Rodrigues-Garcia RC, Sakai S, Rugh JD. Severity, distribution, and correlates of occlusal tooth wear in a sample of Mexican-American and European-American adults. Int J Prosthodont 2001;14:65-70.
28. Panek H, Matthews-Brzozowska T, Nowakowska D, Panek B, Bielicki G, Makacewicz S, *et al.* Dynamic occlusions in natural permanent dentition. Quintessence Int 2008;39:337-42.
29. Schierz O, Dommel S, Hirsch C, Reissmann DR. Occlusal tooth wear in the general population of germany: Effects of age, sex, and location of teeth. J Prosthet Dent 2014;112:465-71.
30. Aidi HE, Bronkhorst EM, Huysmans MC, Truin GJ. Factors associated with the incidence of erosive wear in upper incisors and lower first molars: A multifactorial approach. J Dent 2011;39:558-63.