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Tooth wear and the role of salivary measures in general practice patients

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Abstract

Objectives—The goal of this study was to investigate the association between tooth wear and salivary measures in a random sample of patients from practices of dentist members of a practice-based research network.

Materials and methods—Patients completed a questionnaire on oral self-care, health, dietary habits, medications, and socio-demographic variables. Six salivary characteristics (consistency, resting salivary flow, resting salivary pH, stimulated salivary flow, stimulated salivary pH, and buffering capacity) were measured, and a dental examination included categorizing patients according to the dentist's judgment of the degree of tooth wear (i.e., none/minimal, some, or severe/extreme). Bivariate and multinomial logistic regression models were used to relate salivary characteristics and other factors to the outcome of tooth wear.

Results—Data are reported from 1,323 patients (age range 16–97 years) from 61 practices. Patient age, gender, number of teeth, and perception of dry mouth were associated with tooth wear, but salivary and dietary factors were either weakly or not related.

Conclusions—The findings of this cross-sectional assessment suggest that using these salivary tests and dietary assessments in real-life clinical settings is unlikely to be useful in assessing tooth wear risk. Suggestions are offered about risk assessment for tooth wear.

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Clinical relevance—Assessing a dental patient's risk of tooth wear using salivary measures and dietary assessments as described is not recommended for general dental practice until stronger evidence exists indicating its utility.

Keywords

Tooth wear; Diet; Saliva; Dietary habits; Erosion; Salivary buffering capacity

Introduction

There is growing clinical and scientific interest in tooth wear as indicated by a 50 % increase in the number of published articles on tooth wear in the past decade compared to the previous decade [1]. Tooth wear is commonly described as resulting from any or all of three primary types of mechanisms: erosion, abrasion, and attrition. Erosion is the process whereby the enamel and dentin are partially demineralized and consequently lost because of exposure to intrinsic or extrinsic acids, but it excludes hard tissue loss caused by bacterial acids. Abrasion occurs when the tooth structure is lost due to abrasive material wearing against the teeth, and attrition refers to tooth wear caused by functional, as well as parafunctional (e.g., bruxism), tooth-to-tooth contacts. Tooth wear usually results from a combination of these mechanisms, although erosion is being increasingly suggested as a key contributor to severe wear [2]. The term "erosive tooth wear" describes the accelerated loss of tooth structure due to the combined effect of erosion and mechanical wear resulting from abrasion and attrition [3]. Because the causal factors for tooth wear usually coexist and interact dynamically in the oral environment, tooth wear reflects the combined results of these causal factors with usually no causative-specific clinical appearance or distribution [4]. Since erosion, attrition, and abrasion can occur simultaneously, albeit in different proportions for different individuals, it can be difficult to distinguish the process(es) responsible for the observed wear [4–6].

Numerous risk factors have been suggested to influence tooth wear severity, and the relationship among these putative risk factors and tooth wear is typically complex and difficult to interpret. For example, diet provides an extrinsic source of acid such that the consumption of acidic foods and beverages has been suggested as a likely risk factor for erosive tooth wear [7–9]. While the results of national surveys suggest weak or no association between dietary factors and tooth erosion [10, 11], Johansson and colleagues [2] assert that soft drink consumption in children and adolescents is a dominant causative factor for erosion. The point is that the relationship between dietary exposures and tooth wear severity is not straightforward, in large part because it is influenced by numerous other variables. Factors such as the amount of acid, duration of exposure, frequency of exposure, as well as the behavioral style of beverage consumption (e.g., sipping, gulping, swishing, holding in the mouth before swallowing, use of straw) can alter the magnitude of an erosive challenge [2, 12–15]. Toothbrushing may have a variable effect on tooth wear depending on bristle stiffness [8] and whether it occurs in temporal association with an erosive challenge that makes hard tissues more susceptible to loss from abrasion [2, 16]. Ganss and colleagues [17] hypothesize that individual differences in salivary factors and/or the composition of the enamel and dentin may also modify the relationship between diet and tooth wear.

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Saliva is generally viewed as one, if not the most important, physiological defense mechanism that protects against erosive tooth wear [2, 18, 19]. Both quantity and quality of saliva (e.g., lubrication and buffering) are thought to play a role in the tooth wear process [20, 21]. Dawes [22] reviewed possible reasons why saliva may have limited capacity to protect teeth against erosion, yet salivary characteristics are commonly considered possible risk factors for tooth wear. These include stimulated and unstimulated salivary flow rates, clearance via swallowing, neutralization of acidic challenges via salivary buffering capacity, salivary pellicle, ion content of saliva that can influence the balance of demineralization and remineralization processes, salivary pH, and salivary viscosity [2, 6, 12, 20, 22–28]. This has clinical implications as Lussi and colleagues [6] have suggested that clinical testing of "stimulated and unstimulated flow rates as well as of the buffering capacity of saliva may provide some information about the susceptibility of an individual to dental erosion" (p. 5).

Northwest Practice-based REsearch Collaborative in Evidence-based DENTistry (PRECEDENT), one of the three dental practice-based research networks (PBRNs) funded and established by the National Institute of Dental and Craniofacial Research in 2005, conducted a study investigating salivary characteristics in relation to the assessment of the risk of caries, and the primary results pertaining to caries were recently published [29]. As reviewed above, many of the putative risk factors for tooth wear are also considered risk factors for caries, including diet and salivary factors. A tooth wear assessment was therefore included in the clinical exam phase of the project to assess whether associations exist among salivary, dietary, or other measured behavioral or socio-demographic factors and tooth wear. A requirement for all PRECEDENT investigations was that the research methods employed must be practical and compatible with being conducted in a dental practice setting. Consequently, the results of these studies are intended to be highly generalizable to dental practice.

Materials and methods

Faculty and staff from the University of Washington (UW) and Oregon Health & Science University (OHSU) developed the study protocol and had management responsibility for the PRECEDENT network. The UW Institutional Review Board reviewed and approved the study. The data presented in this analysis were collected in the offices of 61 dentist members in the five-state region of Washington, Oregon, Idaho, Montana, and Utah. A clinical exam was performed on the permanent teeth, and data were collected on historical, environmental, and behavioral factors, in addition to salivary characteristics at the baseline visit.

Study materials, including a detailed Manual of Procedures, data collection forms with line-by-line instructions for performing the salivary tests and dental examination, and salivary test kits assembled by PRECEDENT staff, were sent to offices for review prior to their telephone training session. Dentists and office staff received study-specific training from their assigned regional coordinator during a telephone conference call followed by a monitoring visit conducted early in the patient enrollment period. Dentists were free to use their own preferred clinical exam methods (e.g., lighting, chair position, whether to dry the teeth) as they do in private practice. Most in-person monitoring visits took place between the enrollment into the study of the second and fifth patients.

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Participating practices randomly selected patients for study enrollment until their target goal of 30 patient participants was met. The selection process was designed to sample approximately one patient per day to allow offices to incorporate the data collection procedures smoothly into their daily patient flow. Each practice was randomly assigned a specific weekday to begin patient selection and a unique interval for randomly sampling from the daily appointment schedule based on the average number of patients seen per day. Patients eligible for participation in the caries risk assessment study were 9 years of age or older, had at least four permanent teeth, were able to understand English, and could provide consent (or parental consent) for participation. The overall enrollment objective was approximately equal numbers of patients in three age groups: 9–17, 18–64, and 65 and older. As the sample size for 18–64-year-olds was reached first, practices joining the study later or wishing to enroll beyond 30 patients (up to 50) targeted patients in the 9–17 and 65 and older age groups by enrolling the first patient of the day in either of those two age groups. For the purpose of tooth wear sub-analyses, only patients age 16 years and older at the baseline visit were included to limit the presence of primary teeth which often have considerable wear and could unduly influence the dentist's assessment of wear on the permanent teeth. In addition, patients with Sjögren's syndrome or a history of radiation to the head and neck were excluded from the tooth wear analysis.

Selected patients (or the parents of minor patients) were informed about the study at their appointment confirmation call, and those volunteering to participate signed a written consent when they presented to the office. Baseline data collection included a patient questionnaire, six salivary tests, a dental exam, and chart review. The questionnaire gathered information on self-reported oral hygiene habits, smoking and alcohol use, snacking and beverage consumption, health and medications, history of experiencing dry mouth or low salivary flow, education level, and other socio-demographic variables. The salivary tests assessed resting salivary consistency, flow from labial salivary glands and pH, as well as stimulated salivary flow rate, pH, and buffering capacity. The testing materials and procedures, including the pH strips (Advantec MFS, Inc., Tokyo, Japan) and the colorimetric paper strip test (Saliva Check Buffer test, GC Co., Tokyo, Japan) for measuring buffering capacity, are described elsewhere and were considered to have acceptable inter-rater reliability [29, 30]. The participating dentist, blind to the results of salivary tests and the patient questionnaire, performed a dental examination and recorded the decayed, missing, and filled teeth (DMFT) index for all permanent teeth. The exam recorded measures pertinent to the primary goal of caries risk (e.g., whether or not readily visible heavy plaque was evident, the presence of any exposed roots, deep pits and fissures, developmental defects, dental fluorosis, visible cavitation, white spots), and an assessment was made of the severity of occlusal and incisal wear to investigate a secondary objective of determining whether there is an association between salivary measures and tooth wear. A chart review captured caries diagnosed and treated in the previous 24 months if the patient had been in the practice for that minimum period of time. Trained office staff entered the data from the patient questionnaire, salivary tests, chairside exam, and chart review into an online data capture system.

Dentists conducting the clinical exam assessed the permanent teeth for incisal anterior tooth wear and occlusal posterior tooth wear. Although scoring systems exist for assessing tooth wear severity, these indices were not deemed practical for use in a practice-based clinical

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study that was primarily focused on caries risk assessment, and the newer more recently proposed indices were not available at the start of this study [2, 31–34]. Therefore, the dentist was asked to classify the overall amount of anterior incisal tooth wear and posterior occlusal tooth wear for each patient into one of three categories: no or very little visible tooth wear (in the lowest, 5 % of individuals you have seen at this age), some tooth wear (in the middle, 90 % of individuals at this age), or extreme tooth wear (in the top, 5 % of individuals you have seen at this age). This approach was believed to be clinically meaningful because practitioners are expected to make these clinical diagnostic assessments in the management and treatment of excessive tooth wear.

Statistical analyses

A new tooth wear variable was created that combined anterior incisal and posterior occlusal tooth wear measures. A participant was categorized as having extreme tooth wear if either the anterior incisal or the posterior occlusal teeth were adjudged to have extreme tooth wear (i.e., in the top, 5 % of same-age patients). A participant was categorized as having some tooth wear if one of the anterior incisal or posterior occlusal measures reported some tooth wear and neither reported extreme tooth wear. A participant was categorized as having none or minimal tooth wear if both anterior incisal and posterior occlusal measures reported none/minimal tooth wear (i.e., in the lowest, 5 % of same-age patients).

Descriptive statistics (counts and percentages) were calculated for all variables of interest: salivary characteristics, age, gender, milk consumption, coffee consumption, acidic beverage consumption, alcohol use, chewing tobacco use, toothbrushing frequency, taking medications affecting saliva, incidence of dry mouth, and number of teeth present (the levels of each variable used in the statistical analysis are provided in Table 1). The salivary measures, except consistency (watery and clear vs. thick, sticky, or frothy), were categorized into three levels based on the 90th and 75th percentiles of each measure: resting salivary flow rate (≤60, >60–<90, and ≥90 s), stimulated salivary flow rate (≤0.6, >0.6–<1, and ≥1 ml/min), resting salivary pH (5–≤6.0, >6.0–<6.4, and ≥6.4–7.8) and stimulated salivary pH (5–≤7.0, >7.0–<7.6, and ≥7.6–7.8), and salivary buffering capacity [low (0–3 points), moderate (4–5 points), and high (6–12 points)].

Unadjusted and adjusted multinomial logistic regression models were used for the analysis of tooth wear since the assumption of parallel regression was not believed to be true. Clustering for dental practice and robust standard errors were used to account for within-practice correlation. Analyses were performed using STATA 12.1 (StataCorp LP, College Station, TX, USA).

Results

Subjects (a total of 1,763 patients) were enrolled from May 2008 through February 2011 for the caries risk assessment study. To investigate risk factors for tooth wear, we excluded from this analysis 418 participants who were less than 16 years old, 7 patients with Sjögren’s syndrome, 12 with a history of radiation to the head and neck, and 3 with unreported tooth wear data. Thus, this report includes data from a clinical evaluation of permanent teeth of 1,323 patients (age range 16–97 years). Fifty-eight percent of the

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participants were females, 23 % were 16–35 years old, 31 % were 36–55 years old, and 46 % were 56 years of age or older.

Among all participants, 21.6 % had none or minimal tooth wear, 68.8 % had some tooth wear, and 9.6 % had extreme tooth wear; 13.9 % of males had extreme tooth wear and 6.5 % of females had extreme tooth wear. Extreme tooth wear prevalence increased with age: 5.8 % for 16–35 years old, 8.8 % for 36–55 years old, and 12 % for 56 years of age or older (Table 1). Table 1 provides participant descriptive statistics, stratified by tooth wear categories, for the demographic, salivary, dietary, and other selected variables.

Some and extreme tooth wear levels were compared to none/minimal tooth wear, and results from the unadjusted and adjusted multinomial logistic regression models are provided in Table 2. Tooth wear was significantly associated with both gender and age. The odds of having extreme tooth wear were 174 % higher for males than for females (odds ratio (OR)=2.74, 95 % confidence interval (CI)=1.54, 4.86) in all age groups. After adjustment for other covariates, the odds of extreme tooth wear were still 167 % higher for males than for females (OR=2.67, 95 % CI=1.49, 4.79). Interestingly, the odds of having some tooth wear were not significantly different between males and females. Compared to participants between the ages of 16 and 35 (reference group), the odds of having extreme tooth wear were 185 % higher for people between the ages of 36 and 55 (OR=2.85, 95 % CI=1.42, 5.74) and the odds increased further to 445 % for those 56 years of age or older (OR=5.45, 95 % CI=2.64, 11.25). After adjustment for other covariates, and relative to the reference group, the odds of having extreme tooth wear were as follows: 195 % higher for people between the ages of 36 and 55 (OR=2.95, 95 % CI=1.44, 6.04) and 395 % higher for those 56 years of age or older (OR=4.95, 95 % CI=2.30, 10.66). As was found for extreme wear, the odds of having some tooth wear also increases with age (Table 2).

Assessments of salivary consistency indicated that individuals with thick, sticky, or frothy saliva (rather than watery and clear saliva) had a 180 % increased risk of extreme tooth wear (OR=2.80, 95 % CI=1.05, 7.50). However, after adjustment for other covariates, the odds of having extreme tooth wear were no longer significantly related to salivary consistency (OR=2.63, 95 % CI=0.91, 7.58). Further, there was no association between salivary consistency and the odds of having some tooth wear.

When compared to individuals with stimulated salivary flow rates ≥1.0 ml/min, participants with low stimulated salivary flow rates (≤0.6 ml/min) were 41 % less likely to have some tooth wear (OR=0.59, 95 % CI=0.35, 1.00), and this protective effect against having some tooth wear was maintained after adjusting for other covariates (OR=0.55, 95 % CI=0.35, 0.86). However, no association was found between stimulated salivary flow rates and the odds of having extreme tooth wear.

Compared to the reference group with the least acidic resting saliva (pH≥6.4), participants with intermediate pH values for resting saliva (>6.0–<6.4) had higher odds for having some tooth wear, but this association was not present when the resting saliva became more acidic (pH≤6.0). Furthermore, after adjusting for other covariates, there was no longer a statistically significant association between intermediate pH values and having some tooth wear (OR=1.36, 95 % CI=0.84, 2.22). There was no association between resting salivary pH and extreme tooth wear. The analogous situation occurred for salivary buffering capacity. Compared to the reference group with the greatest salivary buffering capacity values (6–12), participants with intermediate buffering values (4–5) had a 35 % reduced chance for some tooth wear (OR=0.65, 95 % CI= 0.45, 0.94), but this protective association against having some tooth wear was not present when salivary buffering capacity was lower (0–3). After adjusting for other covariates, the observed protective association between intermediate buffering values and some tooth wear was no longer present (OR=0.79, 95 % CI=0.52, 1.22). There was no association between salivary buffering capacity and extreme tooth wear.

Two other factors were statistically associated with tooth wear, a history of having a dry mouth, and the number of teeth present. Participants who reported having had a perception of dry mouth had increased odds for having some tooth wear which was still present after adjusting for other covariates(OR=1.40, 95 % CI=1.03, 1.92), although this factor was not related to having extreme tooth wear (Table 2). Participants with fewer teeth had a higher chance of having more wear. For example, compared to individuals with ≥24 teeth, those with 13–23 teeth had increased odds of having some tooth wear, and this association remained statistically significant after adjusting for other covariates (OR=1.93, 95 % CI=1.05, 3.56; Table 2).

Other covariates included in the models (e.g., dietary factors such as acidic beverage consumption, toothbrushing frequency, taking medications that affect saliva; see Table 1) were not statistically significant in the crude or adjusted models (Table 2). Three statistical models using age, age and gender, and all covariates together appear to have little predictive power for tooth wear in this sample (pseudo R^2=0.031, 0.040, and 0.077, respectively).

Discussion

Increasing age is one of the most consistently identified factors associated with increasing tooth wear [e.g., [8, 35–45]]. As evident in the current study, the proportion of individuals with both some and extreme tooth wear increases with age. Tooth wear is a progressive condition that increases over a lifetime, although the rate of wear differs greatly between individuals, emphasizing the importance of identifying risk factors that account for this difference in the rate of wear. Gender is another commonly reported factor that is related to tooth wear, with males being more likely to exhibit greater tooth wear than females [e.g., [4, 35–40, 45–47]]. In the current study, this gender difference was present for those with extreme wear but not for individuals with some wear.

The findings of this study did not suggest a compelling relationship between tooth wear and salivary measures. The only salivary measure that remained statistically significant after adjusting for covariates was low stimulated flow rates, which had a protective effect of a 41 % reduction in the odds of having some tooth wear. However, a protective effect of reduced salivary flow rate was not present for individuals with extreme wear. Furthermore, studies that report a relationship between salivary flow rates and tooth wear typically find that reduced flow rates increase the risk of wear rather than reduce it [7, 24, 46] while other

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studies find no association [13, 15, 27, 48–51]. Holbrook and colleagues [42] did find a protective effect of reduced flow rates but questioned its clinical relevance.

The association between salivary buffering capacity and tooth wear was similarly unconvincing. Relative to individuals with high salivary buffering, intermediate buffering values reduced the chance of having some tooth wear, although this effect was no longer statistically significant after adjusting for covariates. In addition, there was no association between buffering and extreme tooth wear. When associations between salivary buffering capacity and tooth wear are reported in the literature, they indicate that lower buffering capacity is related to increased tooth wear [e.g., [8, 15, 37, 42, 46, 49, 51]], and there are studies that report no association [7, 13, 27, 48, 50].

After adjustment for covariates, having a reduced number of teeth and self-reported history of having experienced a dry mouth were both related to an increased risk of some tooth wear. These associations have been reported previously for the perception of dry mouth [7] and for a reduced number of teeth [37, 40, 44].

Dietary factors are thought to play a role in erosive wear, and a detailed dietary assessment is therefore recommended over less formal chairside interviews as part of a clinical strategy to manage tooth wear [52]. In the current study, although patients completed a survey that included questions to assess dietary habits that might contribute to erosive wear, none of the dietary measures assessed were associated with wear. For example, one of the most frequently cited risk factors for tooth wear is consumption of carbonated or acidic drinks. Research findings are not consistent on this question, with some studies finding an association [4, 7–9], and others not [10, 26, 50, 53].

Two limitations of the present practice-based research study merit discussion. The first relates to measuring the primary outcome variable, tooth wear. Despite the recognized need for clinical measures that can assess wear in general dental practice [33], the development of a simple index for clinical settings has been challenging [32]. Methods for measuring tooth wear that are feasible for research purposes are too time consuming for clinical use by patient and dentist [2], and so those methods are not suitable in a practice-based research setting. The Basic Erosive Wear Examination is a scoring method that has the potential to improve clinical assessments [31], and the evaluation of recent clinical scoring methods is underway [34, 54]. The approach used in the present study was selected because of its face validity for clinical practice. Dentists were asked to use their own clinical experience to assess whether each patient had the least wear (lowest, 5 % with no or very little visible tooth wear), some tooth wear (middle, 90 % with some tooth wear), or most severe wear (top, 5 % with extreme tooth wear) of patients they had seen of a similar age. Clinicians are routinely expected to make diagnostic distinctions between none, some, and extreme wear if suitable treatment strategies are to be based on a diagnostic assessment. Because measuring reliability and calibrating dentists to use a common scale were not considered feasible given the large number of practices and their broad geographic distribution, this intra-practitioner scaling approach for assessing tooth wear was selected. While it is reassuring that this scoring system found commonly reported associations with tooth wear (e.g., age, gender), it is important to understand that the present scoring method is unique and not validated.

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A second limitation pertains to this study's salivary measurements. A battery of salivary assessments is not typically done in general practice and can be time consuming. Nevertheless, salivary measurements were necessary to address the questions of interest and were within the scope of what could be conducted in private practice. Thus, offices were given salivary test kits with instructional materials and telephone training and support, and an early monitoring visit occurred to assist in making these measurements. Although lab-based methods exist to measure salivary buffering (e.g., Ericsson's test), these are not practical for in-office testing, and thus, a commercially available diagnostic test was selected that is appropriate for use at chairside [28, 55, 56]. The use of more sensitive research methods for salivary assessments may have produced different results for some measures. In addition, there is within-subject variation of salivary viscosity [57]. Circadian variation in salivary measures has led to the recommendation that salivary assessments be done at a consistent time of day [6, 52], but this was not attempted in this study. Due to these multiple sources of within-subject variability, concern has been expressed that attempts to classify individuals based on a single salivary measure are suspect [58]. These are legitimate concerns that temper the interpretation of the salivary results reported in this study. Nevertheless, the approaches that were selected were intended to reflect the way these assessments would be done in a practice-based setting, which means these results are relevant to whether these methods would be useful in clinical practice.

It is important to consider the overarching question of risk assessment for tooth wear and future research directions. Using methods appropriate for clinical practice, the current study supported the commonly reported associations relating tooth wear to age and gender but was unable to find meaningful associations with salivary and dietary factors. Those studies that do find these suspected associations often report that they account for only a small amount of the variation in tooth wear. For example, Holbrook and colleagues [42] emphasize that significant factors of gender, age, diet, diagnosed reflux disease (an intrinsic source of acid), salivary flow, and salivary buffer capacity were able to account for only 15.1 % of the differences in tooth wear. Age typically accounts for a major part of the observed variation. In a study of selected high-wear individuals, 57 % of the variation in tooth wear was explained by three variables (age, bite force, and buffer capacity) with age being the primary explanatory variable accounting for 45 %, while bite force and buffer capacity respectively explained only 8 and 5 % of the variation [46]. Similarly, the importance of age was emphasized by Bernhardt and colleagues [40] who found that 32 % of the variance in tooth wear was explained by age, gender, several occlusal factors, bruxism, and unemployment. However, when age was removed from the model, the other remaining factors were only able to explain 12 % of the variance.

Two studies have accounted for a larger proportion of the variance in tooth wear than is typically reported [37, 59]. Ekfeldt and colleagues [37] found significant associations for age, gender, number of teeth, history of bruxism, snuff/smokeless tobacco use, and low salivary buffer capacity that together explained 41 % of the variation in tooth wear. Almond and colleagues [59] accounted for 42 % of the variation in adult tooth wear based on data from childhood, i.e., age, gender, wear of mandibular primary canines and molars, two cephalometric variables (ANB angle, posterior ramal height), and selected interactions of these variables.

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To the best of our knowledge, all of the studies that have investigated the relationship between the wear on primary teeth and subsequent wear on an individual's permanent teeth have found a significant association [17, 38, 47, 48, 59]. The suggestion has been made that wear in the primary dentition may be a useful predictor of wear on permanent teeth [17, 38, 47]. Apparently, there are reliable individual differences that are present during the primary/mixed dentition that persist into adulthood. It is unknown what individual difference variables are responsible for this association, but they could include salivary factors, learned dietary habits/preferences, or factors that could influence tooth loss due to attrition (e.g., bite force, bruxism). Bruxism has been suggested to be a persistent individual trait [60, 61] that is associated with tooth wear [37, 40, 41, 62]. Thus, we suggest that just as an individual's caries level during childhood is a good predictor of adult caries level [63, 64], early evidence of tooth wear in the primary dentition may be one of the most informative single predictors of an individual's future degree of wear.

Tooth wear is a complex clinical phenomenon with a multifactorial etiology. When addressing the surprisingly low explanatory value of the measured risk factors to account for tooth wear, Holbrook and colleagues [42] suggested that as-yet unidentified important etiological or pathogenic factors of tooth erosion remain to be determined. Numerous associations have been reported with tooth wear, and only a subset is typically included in any given investigation. In terms of risk assessment, some factors are easier to measure in the clinical dental setting than others, and thus, those factors may have greater potential practical utility. The results of the present study do not support the value of administering these specific salivary tests and dietary surveys to assess tooth wear risk. Although risk assessment for tooth wear does not currently have sufficient predictive value to be of clinical benefit in daily clinical practice, the practitioner still needs to care for patients with varying degrees of tooth wear. Clinical advice is available for the prevention and management of tooth wear [52].

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Table 1

Characteristics of participants by tooth wear

	Tooth wear			
	None or minimal (*N*=286) ***N* (%)**	**Some (*N*=910)** ***N* (%)**	**Extreme (*N*=127)** ***N* (%)**	**Total (*N*=1,323)** ***N* (%)**
Gender				
Male	103 (18.5 %)	376 (67.6 %)	77 (13.8 %)	556 (100 %)
Female	183 (23.9 %)	534 (69.6 %)	50 (6.5 %)	767 (100 %)
Age				
16–35 years	117 (37.7 %)	175 (56.5 %)	18 (5.8 %)	310 (100 %)
36–55 years	82 (20.1 %)	289 (71.0 %)	36 (8.8 %)	407 (100 %)
56+ years	87 (14.4 %)	446 (73.6 %)	73 (12.0 %)	606 (100 %)
Salivary consistency				
Watery and clear	272 (22.3 %)	837 (68.6 %)	111 (9.1 %)	1,220 (100 %)
Thick, sticky, or frothy	14 (13.6 %)	73 (70.9 %)	16 (15.5 %)	103 (100 %)
Resting salivary flow				
≤60 s	215 (21.9 %)	673 (68.5 %)	94 (9.6 %)	982 (100 %)
>60–<90 s	25 (28.1 %)	57 (64.0 %)	7 (7.9 %)	89 (100 %)
≥90 s	46 (18.3 %)	180 (71.4 %)	26 (10.3 %)	252 (100 %)
Stimulated salivary flow				
≤0.6 ml/min	37 (28.9 %)	76 (59.4 %)	15 (11.7 %)	128 (100 %)
>0.6–<1.0 ml/min	48 (21.9 %)	142 (64.9 %)	29 (13.2 %)	219 (100 %)
≥1.0 ml/min	200 (20.5 %)	692 (71.0 %)	83 (8.5 %)	975 (100 %)
Unreported	1 (100 %)	0	0	1 (100 %)
Resting salivary pH				
≤6.0	22 (16.1 %)	99 (72.2 %)	16 (11.7 %)	137 (100 %)
>6.0–<6.4	30 (17.1 %)	135 (77.2 %)	10 (5.7 %)	175 (100 %)
≥6.4	233 (23.1 %)	675 (66.9 %)	101 (10.0 %)	1,009 (100 %)
Unreported	1 (50.0 %)	1 (50.0 %)	0	2 (100 %)
Stimulated salivary pH				
≤7.0	37 (23.4 %)	104 (65.8 %)	17 (10.8 %)	158 (100 %)
>7.0–<7.6	67 (24.8 %)	176 (65.2 %)	27 (10.0 %)	270 (100 %)
≥7.6	182 (20.4 %)	629 (70.3 %)	83 (9.3 %)	894 (100 %)
Unreported	0	1 (100 %)	0	1 (100 %)
Salivary buffering capacity				
0–3	27 (22.9 %)	83 (70.3 %)	8 (6.8 %)	118 (100 %)
4–5	51 (26.3 %)	113 (58.2 %)	30 (15.5 %)	194 (100 %)
6–12	208 (20.6 %)	713 (70.6 %)	89 (8.8 %)	1,010 (100 %)
Unreported	0	1 (100 %)	0	1 (100 %)
Milk consumption				
≤1.0 per week	103 (22.0 %)	321 (68.4 %)	45 (9.6 %)	469 (100 %)
1.1–5.5 per week	74 (21.0 %)	243 (69.0 %)	35 (10.0 %)	352 (100 %)
5.6–8.0 per week	64 (23.2 %)	189 (68.5 %)	23 (8.3 %)	276 (100 %)

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	Tooth wear			
	None or minimal (*N*=286) ***N* (%)**	**Some (*N*=910)** ***N* (%)**	**Extreme (*N*=127)** ***N* (%)**	**Total (*N*=1,323)** ***N* (%)**
8.1+ per week	43 (19.3 %)	156 (69.9 %)	24 (10.8 %)	223 (100 %)
Unreported	2 (66.7 %)	1 (33.3 %)	0	3 (100 %)
Coffee consumption				
0 per week	146 (23.2 %)	428 (68.0 %)	55 (8.7 %)	629 (100 %)
0.1–6.5 per week	63 (23.5 %)	176 (65.7 %)	29 (10.8 %)	268 (100 %)
6.6+ per week	75 (17.7 %)	305 (72.1 %)	43 (10.2 %)	423 (100 %)
Unreported	2 (66.7 %)	1 (33.3 %)	0	3 (100 %)
Acidic beverage consumption				
≤2.0 per week	74 (20.7 %)	247 (69.2 %)	36 (10.1 %)	357 (100 %)
2.1–6.0 per week	73 (20.2 %)	259 (71.5 %)	30 (8.3 %)	362 (100 %)
6.1–9.5 per week	65 (23.0 %)	188 (66.7 %)	29 (10.3 %)	282 (100 %)
9.6+ per week	72 (22.6 %)	215 (67.4 %)	32 (10.0 %)	319 (100 %)
Unreported	2 (66.7 %)	1 (33.3 %)	0	3 (100 %)
Alcohol consumption				
No	99 (21.0 %)	325 (68.9 %)	48 (10.2 %)	472 (100 %)
Yes	187 (22.0 %)	585 (68.7 %)	79 (9.3 %)	851 (100 %)
Chew tobacco use				
No	280 (22.1 %)	873 (68.7 %)	117 (9.2 %)	1,270 (100 %)
Yes	6 (11.5 %)	36 (69.3 %)	10 (19.2 %)	52 (100 %)
Unreported	0	1 (100 %)	0	1 (100 %)
Toothbrushing frequency				
<1 time per day	20 (23.0 %)	52 (59.8 %)	15 (17.2 %)	87 (100 %)
1 time per day	55 (17.4 %)	228 (72.4 %)	32 (10.2 %)	315 (100 %)
2+ times per day	211 (22.9 %)	630 (68.4 %)	80 (8.7 %)	921 (100 %)
Number of medications affecting saliva				
0–2	263 (22.3 %)	807 (68.3 %)	111 (9.4 %)	1,181 (100 %)
3+	23 (16.2 %)	103 (72.5 %)	16 (11.3 %)	142 (100 %)
Ever have dry mouth				
No	203 (23.6 %)	577 (67.0 %)	81 (9.4 %)	861 (100 %)
Yes	83 (18.0 %)	331 (72.0 %)	46 (10.0 %)	460 (100 %)
Unreported	0	2 (100 %)	0	2 (100 %)
Number of teeth present				
≤12	7 (21.2 %)	18 (54.6 %)	8 (24.2 %)	33 (100 %)
13–23	16 (10.3 %)	117 (75.0 %)	23 (14.7 %)	156 (100 %)
24+	263 (23.2 %)	775 (68.3 %)	96 (8.5 %)	1,134 (100 %)

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Table 2

Associations between tooth wear and patient characteristics: crude and adjusted ORs from multinomial logistic regression

	Crude OR (95 % CI)		Adjusted OR (95 % CI)[a]	
	Tooth wear (ref. none or minimal)		Tooth wear (ref. none or minimal)	
	Some	Extreme	Some	Extreme
Gender (ref. female)				
Male	1.25 (0.87, 1.79)	2.74** (1.54, 4.86)	1.15 (0.79, 1.67)	2.67** (1.49, 4.79)
Age (ref. 16–35 years)				
36–55	2.36*** (1.56, 3.57)	2.85** (1.42, 5.74)	2.29*** (1.49, 3.51)	2.95** (1.44, 6.04)
56+	3.43*** (2.10, 5.59)	5.45*** (2.64, 11.25)	3.13*** (1.84, 5.35)	4.95*** (2.30, 10.66)
Salivary consistency (ref. watery and clear)				
Thick, sticky, or frothy	1.69 (0.80, 3.60)	2.80* (1.05, 7.50)	1.68 (0.73, 3.86)	2.63 (0.91, 7.58)
Resting salivary flow (ref. ≤60 s)				
>60–<90 s	0.73 (0.42, 1.27)	0.64 (0.23, 1.77)	0.56 (0.31, 1.02)	0.47 (0.19, 1.15)
≥90 s	1.25 (0.79, 1.97)	1.29 (0.61, 2.74)	0.93 (0.57, 1.52)	0.83 (0.38, 1.80)
Stimulated salivary flow (ref. ≥1.0 ml/min)				
≤0.6 ml/min	0.59* (0.35, 1.00)	0.98 (0.50, 1.90)	0.55** (0.35, 0.86)	0.99 (0.52, 1.88)
>0.6–<1.0 ml/min	0.86 (0.59, 1.23)	1.46 (0.84, 2.51)	0.90 (0.61, 1.34)	1.79 (0.94, 3.38)
Resting salivary pH (ref. ≥6.4)				
≤6.0	1.55 (0.98, 2.47)	1.68 (0.84, 3.34)	1.44 (0.81, 2.56)	1.35 (0.54, 3.41)
>6.0–<6.4	1.55* (1.02, 2.36)	0.77 (0.35, 1.69)	1.36 (0.84, 2.22)	0.53 (0.21, 1.32)
Stimulated salivary pH (ref. ≥7.6)				
≤7.0	0.81 (0.54, 1.22)	1.01 (0.58, 1.74)	0.80 (0.45, 1.43)	0.78 (0.36, 1.68)
>7.0–<7.6	0.76 (0.54, 1.08)	0.88 (0.52, 1.50)	0.89 (0.62, 1.27)	0.84 (0.48, 1.47)
Salivary buffering capacity (ref. 6–12)				
0–3	0.90 (0.58, 1.39)	0.69 (0.32, 1.52)	0.98 (0.59, 1.62)	0.76 (0.26, 2.26)
4–5	0.65* (0.45, 0.94)	1.37 (0.78, 2.41)	0.79 (0.52, 1.22)	1.77 (0.88, 3.55)
Acidic beverage consumption (ref. ≤2.0 per week)				
2.1–6.0 per week	1.06 (0.75, 1.51)	0.84 (0.44, 1.63)	1.13 (0.79, 1.62)	0.89 (0.46, 1.75)
6.1–9.5 per week	0.87 (0.59, 1.27)	0.92 (0.52, 1.63)	0.90 (0.62, 1.31)	0.90 (0.47, 1.73)
9.6+ per week	0.89 (0.62, 1.29)	0.91 (0.53, 1.58)	1.03 (0.70, 1.51)	0.95 (0.54, 1.65)
Toothbrushing frequency (ref. <1 time per day)				
1 time per day	1.59 (0.96, 2.65)	0.78 (0.31, 1.92)	1.57 (0.90, 2.75)	0.71 (0.27, 1.90)
2+ times per day	1.15 (0.69, 1.91)	0.51 (0.22, 1.15)	1.12 (0.65, 1.94)	0.54 (0.22, 1.37)
Number of medications affecting saliva (ref. 0–2)				
3+	1.46 (0.85, 2.51)	1.65 (0.78, 3.47)	1.00 (0.57, 1.76)	1.31 (0.58, 2.92)
Ever have dry mouth (ref. no)				
Yes	1.40* (1.01, 1.94)	1.39 (0.93, 2.08)	1.40* (1.03, 1.92)	1.32 (0.86, 2.01)
Number of teeth present (ref. 24+)				

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	Crude OR (95 % CI)		Adjusted OR (95 % CI)[a]	
	Tooth wear (ref. none or minimal)		Tooth wear (ref. none or minimal)	
	Some	Extreme	Some	Extreme
≤12	0.87 (0.36, 2.13)	3.13* (1.11, 8.84)	0.53 (0.23, 1.22)	1.79 (0.59, 5.42)
13–23	2.48** (1.44, 4.28)	3.94** (1.65, 9.40)	1.93* (1.05, 3.56)	2.74 (0.97, 7.71)

OR odds ratio, *CI* confidence interval, *ref.* reference category for statistical comparisons (e.g., some and extreme tooth wear categories were compared with the reference category of none/minimal tooth wear)

* $p<0.05$;

** $p<0.01$;

*** $p<0.001$

[a] Adjusted for all saliva variables, age, gender, acidic beverage consumption, tooth brushing frequency, taking medications affecting saliva, ever had dry mouth, and number of teeth present