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Interdental Cleaning Is Associated with Decreased Oral Disease Prevalence

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Abstract

The purpose of this study was to evaluate the associations between interdental cleaning behavior and the prevalence of caries and periodontal disease and numbers of missing teeth, with data from the National Health and Nutrition Examination Survey (2011 to 2012 and 2013 to 2014). Analysis included the following parameters: interproximal clinical attachment level (iCAL) ≥3 mm, interproximal probing depth (iPD) ≥4 mm, number of coronal and interproximal caries, number of missing teeth, ≥1 surfaces with coronal caries, and periodontal profile classes (PPCs). Chi-square was used for bivariate associations. Associations of interdental cleaning with outcomes were assessed with multiple linear regression and generalized logit regression, adjusting for age, race, sex, diabetes, smoking, education, dental visits, and sugar consumption. Nonusers had a significantly higher percentage of sites with iCAL ≥3 mm and iPD ≥4 mm as compared with individuals who used interdental cleaning devices ($P < 0.0001$). Individuals with a higher frequency of cleaning (4 to 7×/wk) had a significantly lower extent of sites with iCAL ≥3 mm as compared with lower-frequency cleaning (1 to 3×/wk; $P \leq 0.05$). Interdental cleaning users showed lower numbers of coronal caries, interproximal coronal caries, and missing teeth as compared with nonusers ($P < 0.0001$). Nonusers had 1.73-times (95% confidence interval, 1.53 to 1.94) higher odds for having ≥1 surfaces of coronal caries as compared with interdental cleaning users, regardless of the weekly frequency. Individuals were less likely to be in diseased PPCs if they were interdental cleaning users. Low-frequency cleaners (1 to 3×/wk) had significantly greater odds (1.43; 95% confidence interval, 1.08 to 1.88) to have severe disease (PPC-G) versus health (PPC-A) than were high-frequency cleaners (4 to 7×/wk). Interdental cleaning users showed lower levels of periodontal disease and caries and lower numbers of missing teeth. Higher frequency of interdental cleaning was correlated with increased periodontal health. Individuals with severe periodontal disease could show additional oral health benefits by increasing cleaning frequency. The data support the use of interdental cleaning devices as an oral hygiene behavior for promoting health.

Keywords: biofilm(s), caries, oral hygiene, periodontal disease(s)/periodontitis, preventive dentistry, dental hygiene

Introduction

Periodontal disease and dental caries are multifactorial diseases that comprise 3 main components: a susceptible host, enabling environmental factors, and the presence of oral dysbiosis (Chapple et al. 2017). Globally, severe periodontitis affects 9% to 11% of the world's adult population (Eke et al. 2012; Kassebaum et al. 2014). Untreated caries in permanent teeth was the most prevalent condition evaluated for the entire Global Burden of Diseases Study 2010 (Marcenes et al. 2013). If either disease is left untreated, tooth loss may be an undesirable outcome, which can lead to reduced quality of life (Haag et al. 2017).

A plethora of in vitro, in vivo, clinical, and epidemiologic studies since the 1960s demonstrated that microorganisms in the oral biofilm play a fundamental role in caries and periodontal disease (Loe et al. 1965; Beck and Drake 1975; Listgarten et al. 1975; Hunt et al. 1992; Guggenheim et al. 2004; Socransky and Haffajee 2005; Curtis et al. 2011; Hajishengallis et al. 2012; Jiao et al. 2013; Teles et al. 2013; Takahashi 2015; Sanz et al. 2017). Therefore, oral hygiene instructions that include removal of biofilm by the use of toothbrushing and interdental cleaning (i.e., flossing and other methods) are cited in most dental education and dental hygiene programs. These recommendations are supported by several dental professional groups, including the American Dental Association, the National Institute of Dental and Craniofacial Research, the Centers for Disease Control and Prevention (CDC), the American Academy

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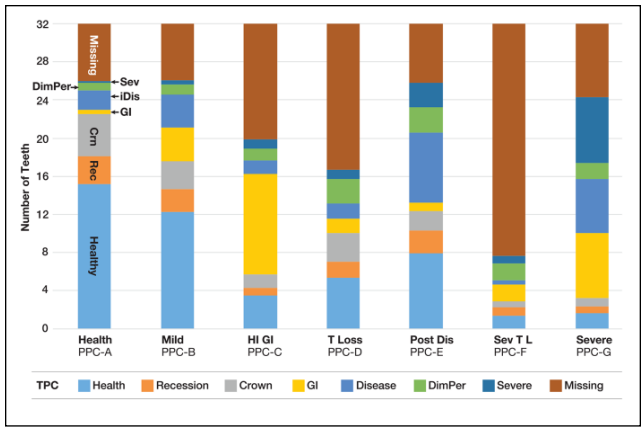

Figure 1. Distribution of tooth profile classes (TPCs) by the periodontal profile class (PPC) in the Dental ARIC Study (adapted from Morelli et al. 2007). Dim Per, diminished periodontium; Sev/Severe; severe disease; iDis, interproximal disease; GI, gingival index; Crn, crown on tooth; Rec, recession; HI GI, high gingival index; T Loss, tooth loss; Post Dis, posterior disease; Sev T L; severe tooth loss.

of Periodontology, the World Health Organization, and the European Federation of Periodontology. While abundant literature supports a role of the microbial oral biofilm in the development of caries and periodontal disease, direct evidence that flossing is associated with a lower number of caries and less periodontal disease in the adult population is still considered weak (Sambunjak et al. 2011). It is important to clarify that the weak evidence should not be interpreted as evidence of a lack of effect (as previously interpreted by some media outlets). The absence of evidence clearly differs from evidence of an absence of effect, as recently reported (Glick 2017). The categorization of the evidence as weak is mostly due to small sample sizes or study design. In fact, flossing is generally related to less caries and periodontal inflammation. In adults, flossing in addition to toothbrushing reduces gingivitis (Sambunjak et al. 2011). For children, flossing reduces interproximal caries risk by 40% (Hujoel et al. 2006). To increase the strength of data, many authors suggested the need for randomized controlled trials on interdental cleaning. However, there are a variety of issues in conducting such studies: 1) potential ethical issues in assigning people who currently perform interdental cleaning into a noncleaning regimen, 2) length of a study required for diseases to develop, and 3) difficulties in detecting early interdental caries lesions (Ismail 2004; Sambunjak et al. 2011). Until an adequate trial is done, secondary analysis and retrospective studies may produce the best available evidence.

Therefore, the purpose of this study was to estimate the prevalence of oral disease and missing teeth among interdental cleaning users and nonusers. We hypothesized that interdental cleaning users would have fewer sites with periodontal disease, lower caries levels, and diminished number of missing teeth.

Methods

Publically available data from the National Health and Nutrition Examination Survey (NHANES; 2011 to 2012 and 2013 to 2014) were used for this study. The cycles were selected per the availability of the full mouth examination and dental utilization questionnaire (used as a covariate). NHANES is a survey that has released data on a 2-y cycle since 1999 to represent the civilian, noninstitutionalized population of the United States. Data from 6,891 adults (≥30 years old) were available from the survey. Pregnant women and individuals who had partial oral examinations were excluded from the analysis. Technical details of the survey, including sampling design and data collection protocols, can be accessed at the CDC website. All NHANES protocols that generated the data used in this study were approved by the CDC's National Center for Health Statistics Ethics Review Board (Institutional Review Board equivalent). Since the current study analyzed public use data, an additional research ethics review was not necessary for our analysis. The question used for addressing interdental cleaning in both surveys was "Aside from brushing your teeth with a toothbrush, in the last 7 days, how many days did you use dental floss or any other device to clean between your teeth?" (OHQ.870). To evaluate the effect of interdental cleaning in oral disease and tooth loss, the following parameters were selected per the available clinical data: interproximal clinical attachment level (iCAL) ≥3 mm, interproximal probing depth (iPD) ≥4 mm, number of coronal and interproximal caries, number of missing teeth, ≥1 surfaces with coronal caries, and periodontal profile class (PPC; Morelli et al. 2017). Seven distinct PPCs for individuals were utilized: health (PPC-A), mild disease (PPC-B), high gingival index (PPC-C), tooth loss (PPC-D), posterior disease (PPC-E), severe tooth loss (PPC-F), and severe periodontal disease (PPC-G; Fig. 1). The PPC system differs from the traditional clinical case status indices that have been used, including the CDC–American Academy of Periodontology and European classifications. The PPCs were given monikers, or names, based on the dominant clinical feature of the teeth in that class, which uses detailed clinical measures at the tooth level, including periodontal measurements, gingival recession, crowns, and tooth loss.

Statistical Analysis

Pearson chi-square test was used to compare demographic variables between interdental cleaning users and nonusers ($P \leq 0.05$). Interdental cleaning was categorized as nonusers, low-frequency users (1 to 3×/wk), and high-frequency users (4 to 7×/wk). Multiple linear regression—adjusted for race, sex, age, diabetes, smoking education, and dental visits—compared clinical parameters based on interdental cleaning behavior. For caries and tooth loss, data were adjusted for sugar consumption. Generalized logit model (95% confidence interval [95% CI]) evaluated the odds of being in each PPC according to interdental cleaning behavior.

Results

Demographics and Clinical Characterization

NHANES is a nationally represented data set to assess the health and nutrition status of adults and children in the United

Table 1. Characteristics of the Study Population Stratified on Interdental Cleaning Behavior (*N* = 6,891).

	Interdental Cleaning, *n* (%)		
	Nonusers (0×/wk)	Users (≥1×/wk)	*P* Value
Individuals	2,141 (31)	4,750 (69)	
Age, y, mean ± SD	52.5 ± 14.7	51.8 ± 14.0	0.02
Race			
African Americans	531 (24.8)	1,002 (21.1)	
Caucasians	778 (36.3)	1,989 (41.9)	
Other	832 (38.9)	1,759 (37.0)	<0.0001
Sex			
Female	882 (41.2)	2,628 (55.3)	
Male	1,259 (58.8)	2,122 (44.7)	<0.0001
Diabetes			
Diabetic	310 (14.5)	582 (12.3)	
Nondiabetic	1,831 (85.5)	4,168 (87.8)	<0.0001
Smoker			
Current	529 (24.7)	741 (15.6)	
Former	522 (24.4)	1,188 (25.0)	
Never	1,090 (50.9)	2,816 (59.4)	<0.0001
Education			
Basic	710 (33.2)	752 (15.8)	
Intermediate	521 (24.4)	954 (20.1)	
Advance	907 (42.4)	3,043 (64.1)	<0.0001
Dental utilization			
Regular	914 (44.0)	2,975 (63.0)	
Irregular	1,164 (56.0)	1,748 (37.0)	<0.0001
Sugar consumption, g/d[a]			
≤25	126 (6.5)	201 (4.5)	
>25	1,825 (93.5)	4,230 (95.5)	0.001

[a]*n* = 6,382 (information not available for all individuals).

States. Table 1 shows the demographics and clinical condition of the individuals included in this study, as stratified by nonusers and interdental cleaning users. Sixty-nine percent of individuals reported using some type of interdental cleaning. Mean age was statistically different between groups (52.5 and 51.8 y for nonusers and interdental cleaning users, respectively). The main differences between groups were that interdental cleaning users were more likely than nonusers to be women, have higher education, be never smokers, and have regular dental utilization. Otherwise, owing to the large sample size, statistically significant while less pronounced differences were that users tended to be Caucasians (and less likely to be African Americans) and nondiabetic as compared with nonusers.

Interdental Cleaning and Oral Disease

On average, nonusers had a significantly higher percentage of sites with iCALs (≥3 mm) and iPDs (≥4 mm) as compared with interdental cleaning users ($P < 0.0001$, Table 2). Individuals who used interdental cleaning devices 4 to 7×/wk also showed a significant lower percentage of sites with iCAL ≥3 mm compared with individuals who used devices 1 to 3×/wk ($P = 0.04$; Table 2). A trend for significance was observed for 4 to 7×/wk, showing fewer sites by percentage with high iPDs (≥4 mm; $P = 0.07$). The patterns of iCAL and iPD according to frequency of interdental cleaning are shown in the Appendix Figure.

For evaluating caries and tooth loss, the data were further adjusted for the amount of sugar consumption. Interdental cleaning users showed significantly lower numbers of coronal caries and interproximal caries as compared with nonusers ($P < 0.0001$; Table 2). No significant difference in the number of coronal caries and interproximal coronal caries was found between the cleaning frequency categories. When the numbers of missing teeth were evaluated, nonusers had significantly more missing teeth than interdental cleaning users, with no difference observed between interdental cleaning frequencies.

Finally, we evaluated the effect of interdental cleaning in disease outcome by considering ≥1 caries in coronal surfaces and 7 distinct PPCs (A to G; Morelli et al. 2017). When dental caries was used as an outcome, noninterdental cleaners had 1.73 (95% CI, 1.53 to 1.94) times higher odds for having ≥1 surfaces of coronal caries as compared with interdental cleaners regardless of the weekly frequency. For periodontal conditions, our analysis of the distribution of individuals among the 7 PPCs shows that the majority of interdental cleaning users (>60%) were healthy individuals (PPC-A; Fig. 2). Interdental cleaning users had significantly lower odds to be in a disease category relative to health, regardless of whether the cleaning frequency was 1 to 3×/wk or 4 to 7×/wk; an exception was for mild disease category and flossing 1 to 3×/wk, which nonetheless showed a similar trend (Fig. 3A). Interdental cleaning users with a frequency of 1 to 3×/wk had significantly greater

Table 2. Clinical Parameters of Periodontal Disease, Caries, and Number of Missing Teeth according to Interdental Cleaning Behavior (n = 6,797).

	Parameter, Mean (SE)				
Group: Interdental Cleaning Behavior	iCAL ≥3 mm, % Sites	iPD ≥4 mm, % Sites	Coronal Caries, *n*	Interproximal Caries, *n*	Missing Teeth, *n*
A: Nonusers	30.6 (0.53)	5.77 (0.24)	1.12 (0.04)	0.62 (0.03)	9.53 (0.13)
B: Interdental cleaning users (1 to 3×/d)	22.8 (0.58)	4.37 (0.26)	0.72 (0.05)	0.37 (0.03)	7.60 (0.14)
C: Interdental cleaning users (4 to 7×/d)	21.3 (0.44)	3.77 (0.20)	0.76 (0.04)	0.43 (0.02)	7.32 (0.10)
P value					
Overall	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
A vs. B	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
A vs. C	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
B vs. C	0.04	0.07	0.59	0.14	0.11

Data adjusted for race, sex, age, diabetes, smoking, education, and dental utilization. Caries, interproximal caries, and number of missing teeth were also adjusted for sugar consumption.
iCAL, interproximal clinical attachment level; iPD, interproximal probing depth.

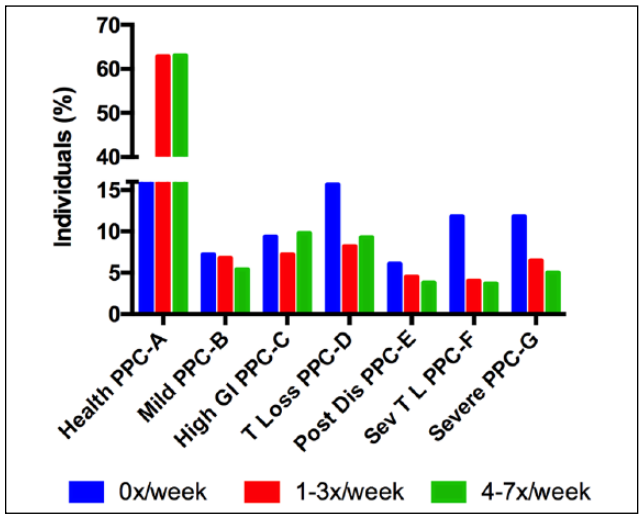

Figure 2. Distribution of individuals across periodontal profile classes (PPCs; A to G) based on interdental cleaning frequency. GI, gingival inflammation; Post Dis, posterior disease; Sev, severe disease; T L, tooth loss; T loss, tooth loss.

odds to have severe disease (PPC-G) versus health than individuals who cleaned 4 to 7×/wk (1.43; 95% CI, 1.08 to 1.88; Fig. 3B). Together, the data show that individuals who use interdental cleaning devices have a lower percentage of interproximal clinical parameters of periodontal disease, a lower number of carious lesions (teeth), and fewer missing teeth.

Discussion

In this representative cross-sectional sample of U.S. adults aged ≥30 y, interdental cleaning was significantly associated with decreased periodontal disease measurements, less caries, and increased numbers of present teeth. Extent of iCAL ≥3 mm was lower for individuals with a higher cleaning frequency (4 to 7×/wk vs. 1 to 3×/wk). Individuals were less likely to be in all periodontal disease categories of the PPC system if they were interdental cleaners than if they were noninterdental cleaners. Individuals with a low interdental cleaning frequency were more likely to have severe periodontal disease (PPC-G) versus health than individuals with a high cleaning frequency. These results further support the evidence that interdental cleaning is associated with less oral disease.

The data indicate that the benefits of a high interdental cleaning frequency may exist since individuals who reported performing interdental cleaning 4 to 7×/wk showed significantly less interproximal periodontal disease (Table 2). The conclusion of our results are different from a recent analysis of the NHANES data set by Cepeda et al. (2017), in which a higher frequency of cleaning was not associated with less disease. Note that the approach used to evaluate the data was distinct. First, we divided our cleaning frequency into 1 to 3×/wk and 4 to 7×/wk, as opposed to 0 to 1×/wk, 2 to 4×/wk, and ≥5×/wk. The outcomes utilized in the analysis were also different. Cepeda and collaborators used the CDC definition of periodontal disease (Eke et al. 2012) and included mild, moderate, and severe periodontitis into 1 category of disease. The outcomes used in the present study include iCAL ≥3 mm (percentage sites), iPD ≥4 mm (percentage sites), and the PPC system for periodontal disease classification (Morelli et al. 2017). A probing depth ≥4 mm and a clinical attachment level ≥3 mm were previously used as indicator variables for periodontal pathologic features (Moss et al. 2009; Akinkugbe et al. 2017). For the present study, we selected only the interproximal region as the outcome of interest, since the main question was addressing the effect of interproximal cleaning behavior. This approach also differs from the approach used by Cepeda et al. (2017) and could assist in explaining the different results. In addition, analysis based on a new periodontal disease classification (i.e., PPC) demonstrated that individuals with a high interdental cleaning frequency were less likely to have severe disease (PPC-G; Morelli et al. 2017) than individuals with a low interdental cleaning frequency. Therefore, the periodontal status of an individual may also influence the oral health benefit achieved by increased cleaning frequency. These individuals have not only disease but also an average of 25 teeth present in

their oral cavity. As such, they may be likely to have more teeth at risk for disease and could have a greater benefit from interdental cleaning.

The effect of flossing on interproximal caries was evaluated in a review of 6 trials with 808 children, which found a 40% risk reduction with professional flossing (Hujoel et al. 2006). In the adult population, no study evaluating the effect of flossing on caries was identified (Hujoel et al. 2006; Sambunjak et al. 2011). In accordance to Hujoel and collaborators (2006), our study shows that interdental cleaning is associated with a lower number of interproximal carious lesions. No review evaluating the effect of interdental cleaning on the number of teeth was identified.

A weakness of this study relates to the potential influence of important caries-related factors, including brushing frequency and fluoride exposure (Chapple et al. 2017; Hujoel and Lingström 2017; Jepsen et al. 2017). The NHANES data set does not include brushing information for the adult population used in the present study. Fluoride was not included in the adjustment, since the available data include only a small number of individuals (NHANES, 2011 to 2012, 2013 to 2014; $n = 27$ total). However, the study was adjusted for other important confounding factors, such as sugar consumption, diabetes, education, and dental visits, which are known to affect the development of caries (Chapple et al. 2017). Fermentable carbohydrates (which include sugars) are considered the most relevant common dietary risk factor for both diseases (Chapple et al. 2017) and, therefore, an important factor to be considered for adjustment in our analysis. We adjusted our analysis to the amount of sugar consumption based on the World Health Organization recommendation of 25 g/d. Because the high intake of sugar in the United States was well-documented in a previous analysis of the NHANES data set (Ervin and Ogden 2013; Powell et al. 2016), the expectation was that individuals who did interdental cleaning would show lower oral disease levels even after data adjustment for sugar consumption. Accordingly, the consumption of sugar did not significantly modify the results observed.

Since this is a cross-sectional study, it does not allow analysis of the direct effect of interdental cleaning in oral health outcomes but instead allows identification of associations with disease based on the selected oral health behavior. However, this study allowed analysis of a large sample that is representative of the U.S. population. Multiple factors hinder the development of a randomized controlled trial for evaluating the effect of interdental cleaning on caries and periodontal disease, including assigning individuals to a group that would not conduct interdental cleaning. The significant amount of literature supporting the importance of microorganisms in disease provides sufficient justification for not assigning individuals to a noninterdental cleaning regimen. Therefore, secondary analysis and retrospective studies of large samples may produce the best available evidence to directly support the beneficial effects of interdental cleaning.

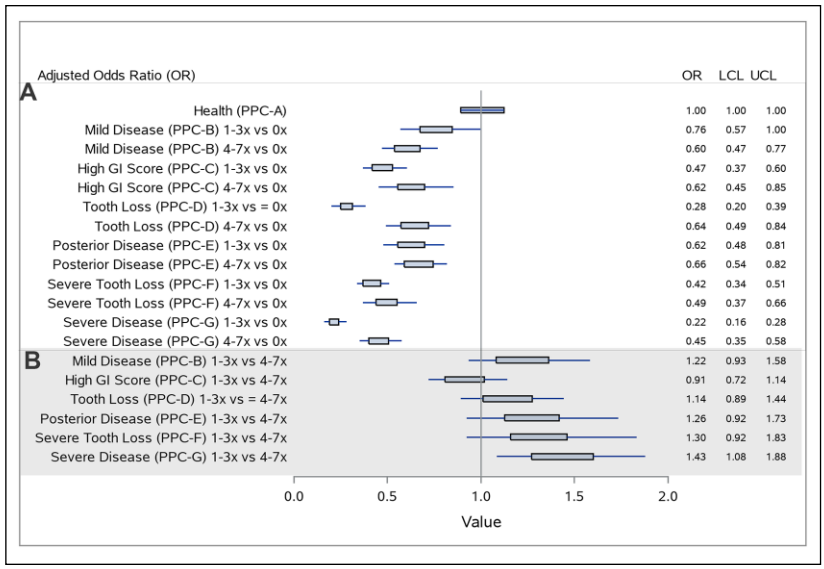

Figure 3. Odds ratios (95% confidence interval) of prevalent oral disease defined by the periodontal profile class relative to health (PPC-A) comparing (**A**) interdental cleaning users with nonusers and (**B**) individuals according to interdental cleaning frequency (1 to 3×/wk and 4 to 7×/wk vs. nonusers). GI, gingival inflammation.

In summary, our study found that interdental cleaning was associated with less periodontal disease, decreased coronal and interproximal caries, and fewer missing teeth. A higher frequency of interdental cleaning (4 to 7×/wk) was associated with less interproximal periodontal disease. Some disease categories may have improved oral health benefits from a higher frequency of interdental cleaning. Together, the data support the use of interdental cleaning devices as an oral hygiene behavior for promoting health.

Author Contributions

J.T. Marchesan, contributed to conception, design, and data analysis, drafted the manuscript; T. Morelli, contributed to conception, design, and data analysis, critically revised the manuscript; K. Moss, J.S. Preisser, A.F. Zandona, S. Offenbacher, contributed to data analysis, critically revised the manuscript; J. Beck, contributed to conception and design, critically revised the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work.

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