Research

Association Between Dental Hygiene, Cardiovascular Disease Risk Factors and Systemic Inflammation in Rural Adults

Stephanie J. Frisbee, MSc; Christopher B. Chambers, BS; Jefferson C. Frisbee, PhD; Adam G. Goodwill, BS; Richard J. Crout, DMD, PhD

Abstract

Purpose: A growing body of epidemiologic evidence links oral health, periodontal disease and cardiovascular health. While underlying pathophysiologic mechanisms are unclear, several studies have suggested a sub-acute inflammatory state, also implicated in the etiology of cardiovascular disease. The objective of the current study was to investigate associations between self-reported dental hygiene (brushing, flossing, preventive care and overall dental health), cardiovascular disease risk factors and systemic inflammation.

Methods: 128 adults from 5 different rural counties in West Virginia participated in a comprehensive, community-based health screening that included anthropometric assessments, collection of a blood specimen and completion of a questionnaire about dental hygiene practices and oral health.

Results: Univariate analysis demonstrated multiple statistically significant associations between self-reported dental hygiene and cardiovascular disease risk factors and markers of systemic inflammation. In regression analysis, after controlling for demographic and cardiovascular disease risk factor covariates, self-reported dental hygiene demonstrated statistically significant and independent associations with adiponectin, fibrinogen, C-reactive protein (CRP) and cellular adhesion molecule-1 (sICAM-1).

Conclusion: This study demonstrated associations between dental hygiene and systemic inflammation, independent from BMI and blood cholesterol. Future studies should investigate whether periodontal-related systemic inflammation begins before the onset of clinical disease. Results from this and other studies highlight the importance of dental hygiene in overall systemic health, and are beginning to collectively suggest that regular dental hygiene care is an integral part of comprehensive health care.

Keywords: Oral health, dental hygiene, cardiovascular disease risk factors, systemic inflammation, rural health

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Introduction

In 2000, the landmark United States Surgeon General's report on "Oral Health in America" defined oral health broadly, emphasizing that oral health is "integral to general health."[1] Despite important links between oral health and general health, oral diseases are common in the population, and public health and prevention efforts aimed at improving population dental health have lagged prevention efforts for other common, chronic health conditions. In adults, periodontal disease increases throughout adulthood from an estimated prevalence of approximately 40% for those aged 18 to 24 to more than 90% for those above the age of 75, with men and individuals with lower socio-economic status having higher prevalence.[1] Geographic disparities in oral health are particularly seen in areas of Appalachia, with West Virginia, Kentucky, Louisiana and Arkansas cited as having the highest percentage of adults older than 65 years of age without any natural teeth remaining.[1] Based on results from the Center for Disease Control's 2004 Behavioral Risk Factor Surveillance System, 42.9% of adults older than 65 years of age in West Virginia reported having had all natural teeth removed, and 37.5% reported having not been to a dentist or dental clinic in the past year, both the highest in the nation.[2]

Given known associations between oral and systemic health, persistent disparities in dental hygiene and oral health are of public health concern, especially given the implication for health outcomes related to other systemic chronic disease conditions. In particular, recent epidemiologic studies have reported relationships between cardiovascular health and oral health. Mattila et al were among the first to report a link between dental health and acute myocardial infarction, dental infections and coronary atheroscle-

rosis and dental infections and acute myocardial infarctions.[3-5] These early reports were supported with similar findings from other investigators.[6-11] In attempting to identify an underlying mechanism for this association, studies have reported a relationship between the cumulative burden of periodontal pathogenic burden and coronary heart disease.[12] There have also been established links between periodontitis and elevated levels of systemic c-reactive protein (CRP) and IL-6,[13] and more recent studies have suggested that localized immune response to periodontal infection leads to elevated systemic inflammatory markers.[14,15]

While causative pathways between periodontal and cardiovascular disease have yet to be definitively established, there are important public and preventive health implications for the links between oral health and systemic inflammation. The understanding of the role of inflammation in cardiovascular disease has expanded rapidly in recent years.[16] If both systemic inflammation and vascular function can be improved with improved periodontal health, then by extension, prevention of poor periodontal health through dental hygiene and preventive dental care should lead to lower systemic inflammation and, ultimately, lower risk for poor cardiovascular health.

The purpose of this study was to investigate associations between self-reported dental hygiene practices, cardiovascular disease risk factors and systemic inflammation in adults living in rural communities. The hypothesis was that better dental hygiene practices and more frequent preventive dental care would be associated with more favorable levels of systemic inflammation.

Methodology

Participants

Participants were selected from 5 different counties in West Virginia. Counties ranged in rurality from 3 to 9 on the United States Department of Agriculture Economic Research Service 2003 Rural-Urban Continuum Codes (9 being the most rural). Multiple avenues of recruitment were used to invite participation in a comprehensive health screening taking place in their community during the spring to fall months of 2006. Results reported here are from adult participants (older than 18 years of age at the time of their enrollment), thus representing a cross-sectional, convenience sample of adults from rural Appalachian communities. All methods and protocols were approved by the West Virginia University Institutional Review Board.

Data Collection

Mobile data collection teams were stationed in community-based facilities for health screenings from 7 am to 11 am. Participants, having completed a fast of at least 8 hours, underwent standard anthropometric assessment that included height, weight, hip and waist circumference, estimated body fat using a hand-held body impedance meter (Omron HBF 300) and blood pressure (Omron HEM-711AC). All anthropometric measures were taken in duplicate and results were averaged for analysis. Participants provided a blood sample for determination of a fasting lipid profile and systemic inflammation, and blood glucose levels were determined immediately (FreeStyle Flash Blood Glucose Monitoring System). All participants also completed questions about health and lifestyle habits, and a structured questionnaire (14 questions) about their dental hygiene practices, preventive dental care and dental health. Many of these elements were also used as part of a multi-site study of dental health in Appalachia.[17,18] Of the 128 total participating adults, 115 (89.8%) completed the dental health survey.

Biochemical Analysis

All physiologic samples were processed at the time of screening, with plasma fractions snap-frozen on dry ice. Plasma samples were analyzed in a nearby hospital laboratory to obtain a fasting lipid profile. Endocrine, cytokine and other inflammatory markers were obtained from frozen plasma using the Luminex200 system (Luminex Corporation, Austin, TX) with the appropriate Lincoplex® multiplex assay kits and protocols from LincoResearch (Millipore Corporation, Billerica MA). Concentrations for all markers determined via the Luminex system were obtained in duplicate. Only concentrations with a coefficient of variation ≤0.5 were included. Blood samples were available from 120 of 128 participating adults. In considering blood sample availability, blood analysis data quality control procedures and survey response rate, 73 to 110 participants had complete data for inclusion in the analyses reported below.

Statistical Analysis

For statistical analysis, questionnaire responses were evaluated and used to create a series of dichotomous categorical variables hereafter collectively referred to as "self-reported dental hygiene." Self-reported dental hygiene included measures of dental hygiene practices, attitudes, preventive care and overall dental health, all of which were self-reported by participants. Dental hygiene practices included the frequency of brushing (at least daily or less than daily) and frequency of flossing (2 to 6 times per week or less than weekly). Attitudes included the importance of dental health (very important, somewhat important or less) and dental fear (not at all afraid of the dentist, somewhat afraid or very afraid of the dentist). Preventive care included presence of a dental care home (dental health care home for regular dental care, or no dental health care home for regular dental care) and the frequency of preventive dental care (every 6 months, or less than annually). Finally, dental health included self-rated overall dental health (very good or better, or good or less than good).

Univariate analysis using Pearson's chi-square statistic was performed to identify statistically significant differences in self-reported dental hygiene based on participant demographic groups (gender, dental insurance, education and smoking). Univariate ANOVA analysis was performed to identify statistically significant (unadjusted) differences in cardiovascular disease risk factors and markers of systemic inflammation based on self-reported dental hygiene. All analyses reported focused on 3 cardiovascular disease risk factors: BMI (kg/m2), mean arterial pres-

sure ([two-thirds diastolic pressure + one-third systolic pressure] and total cholesterol (mg/dL)) and 6 markers of systemic inflammation (adiponectin (pg/mL), c-reactive protein (CRP, mg/dL), fibrinogen (ng/mL), interleukin-1β (IL-1β, pg/mL), soluble cell adhesion molecule-1 (s-ICAM-1, pg/mL) and tissue plasminogen activator inhibitor-1 (tPAI-1, pg/mL)).

To assess the robustness of associations between self-reported dental hygiene and systemic inflammation, multiple linear ordinary least squares (OLS) regression was performed. Regression permits the assessment of both the statistical significance and direction of the association between the dependent and predictor variable of interest after adjustment for, and so independent of, the effects of confounding (covariate) variables. In each OLS regression model reported, a marker of systemic inflammation was predicted (the dependent variable) by a self-reported dental hygiene variable, key demographic variables and a cardiovascular disease risk factor. For simplicity, all models included the same demographic variables (age, gender, smoking and dental insurance). All regression models (except for those models predicting CRP) also included a variable to adjust for indication of an acute infection (CRP≥10 mg/dL, coded as a dummy variable). For regression models predicting CRP, only participants with CRP<10 mg/dL were included in the model. CRP≥10 mg/dL is considered a marker of acute infection.[19] In total, regression models included 6 or 7 independent variables: 4 demographic variables, 1 cardiovascular disease risk factor and 1 self-reported dental hygiene variable. All models, except those predicting CRP, included a variable indicating presence of an acute infection. For all models, dependent variables were natural-log transformed to adjust for the effects of skewed distributions common to most biologic variables. Thus, the β-coefficient for the self-reported dental hygiene variable can be interpreted as the increase in systemic inflammation with every 1 unit increase in the self-reported dental hygiene variable after the effects of all other variables in the model have been accounted for (that is, the "ceteris paribus" effect of self-reported dental hygiene on systemic inflammation).

Finally, as the vast majority of participants in the current study were genetically unrelated, statistical models did not require adjustment for potential sample autocorrelation or bias. There was no meaningful heteroscedasticity in any of the regression models. All statistical analyses were performed with SPSS (SPSS Inc., Chicago, IL).

Results

The average age of the 128 participating adults was 41.5 ±9.3 (standard deviation) years. Sixty-two and a half percent of participants were women and 22.8% were smokers (a proportion similar to the West Virginia population).[2] Further, 52.5% of participants had more than a high school education and 70.2% reported having dental care covered as part of an insurance plan. Neither education nor dental insurance was different between men and women (p>0.05).

Table I summarizes general characteristics of respondents with regard to self-reported dental hygiene. While the vast majority of respondents reported brushing daily (89.6%), a smaller proportion reported flossing at least multiple times weekly (55%) or receiving biannual preventive dental care (46.8%). Women had higher ratings for both fear of dental care and the importance of dental care (p<0.05), with 27% reporting at least some fear of dental care and 58.3% reporting that preventive dental care was very important. Women reported flossing more frequently than men, but self-reported dental health was similar between men and women, with 43.8% reporting excellent or very good dental health.

While there was no relationship between education and dental insurance (p>0.10), there was a univariate relationship between these variables and several measures of self-reported dental hygiene (Table I). As anticipated, having a dental care home and seeking biannual dental preventive care was related to having dental insurance, and biannual dental preventive care was related to education. Further, more frequent brushing (but not flossing), less fear and higher rating of overall dental health was also related to higher levels of education. Smoking was related to the frequency of preventive dental care and self-reported overall rating of dental health. Smokers were less likely to seek biannual preventive dental care and more likely to rate their dental health as poor to good compared to non-smokers.

In Table II, univariate, unadjusted relationships (ANOVA analysis) between self-reported dental hygiene and cardiovascular disease risk factors and markers of systemic inflammation are summarized. Less frequent brushing was associated with elevated total cholesterol and less frequent flossing was associated with elevated mean arterial pressure. There was a trend toward an association between less frequent preventive dental care and higher mean arterial pressure, though this association did not achieve statistical significance (p=0.06).

Also reported in Table II, self-reported dental hygiene was found to be statistically significantly related to multiple markers of systemic inflammation. In particular, less frequent brushing was associated with higher levels of IL-1β and a trend toward an associated higher level of tPAI-1 (brushing, p=0.093). More frequent brushing and flossing were both associated with higher levels of adiponectin and higher levels of fibrinogen. Additionally, less frequent preventive care was associated with higher levels of sICAM-1 and a trend toward higher tPAI-1. Finally, better self reported, overall dental health was associated with lower levels of CRP and a trend toward lower sICAM-1 (p=0.055), but higher adiponectin (p=0.091).

Results from 15 separate regression models are shown in Table III. Specifically, the β-coefficients assessing the independent association between self-reported dental hygiene and a marker of systemic inflammation are reported. In 3 separate regression models (models 1 to 3), more frequent brushing was associated with statistically significantly increased levels of adiponectin independent of the effects of the demographic

variables and also after controlling for the effects of BMI, total cholesterol or mean arterial pressure.

Increased frequency of flossing was also associated with increased adiponectin (model 5), independent of the effects of the demographic variables and after controlling for total cholesterol. Further, in separate models (models 7 to 9), increased frequency of flossing was associated with increased levels of fibrinogen independent of the effects of the demographic variables and after controlling for BMI, total cholesterol or mean arterial pressure.

In unique regression models (models 10 to 12), increased frequency of preventive care was associated with lower levels of sICAM-1 independent of the effects of the demographic variables and after controlling for BMI, total cholesterol or mean arterial pressure.

Finally, in independent models, better overall dental health was associated with lower levels of CRP (models 13 to 15), unrelated to the effects of the demographic variables and after controlling for BMI, total cholesterol or mean arterial pressure. However, it was associated with a trend toward higher levels of adiponectin (models 16 to 18), independent of the effects of the demographic variables and after controlling for BMI or total cholesterol.

Several univariate associations between self-reported dental hygiene and systemic inflammation persisted after controlling for multiple covariates, including cardiovascular disease risk factors. Specifically, associations between increased frequency of brushing and flossing and increased adiponectin persisted after multiple adjustments in OLS regression analysis, as did associations between increased frequency of flossing and increased fibrinogen. Additionally, associations between increased frequency of preventive care and lower sICAM-1 and better overall dental health and lower CRP persisted after multiple adjustments in OLS regression analysis. Univariate associations between self-reported dental hygiene and IL-1β and tPAI-1 did not persist after multiple adjustments in OLS regression analysis.

Discussion

This study investigated associations between self-reported dental hygiene, cardiovascular disease risk factors and systemic inflammation in adults living in rural communities. In both unadjusted (univariate) and adjusted (regression) analyses, this study demonstrated statistically significant and independent associations between self-reported dental hygiene and systemic inflammation.

The findings that frequent brushing (but not flossing), along with less fear and higher rating of overall dental health, were related to higher levels of education have been noted in previous studies.[20] The findings that women reported flossing more frequently than men are also consistent with previously reported findings.[21]

The results that indicate better overall dental health was associated with lower levels of CRP are consistent with multiple, previous studies. Earlier investigations have consistently reported that CRP, an acute phase protein, is associated with both aggressive and localized periodontitis, periodontal attachment loss and other metrics of periodontal health.[13] While in this cross-sectional study, the temporality of association cannot be established. Future studies should investigate whether elevations in CRP begin with poorer dental hygiene, with or without related periodontitis.

The observation that increased frequency of preventive care was associated with lower levels of sICAM-1 is consistent with recent studies reporting association between serum levels of cellular adhesion molecules[26] and sICAM-1, specifically in gingival crevicular fluid in patients with chronic periodontitis.[27] This observation is also consistent with our hypothesis that better dental hygiene practices would be associated with more favorable levels of systemic inflammation.

Results of this study illustrate that better self-reported dental hygiene was associated with higher levels of adiponectin. This is also consistent with previous studies that have reported higher levels of adiponectin in those with lower BMI.[30,31] While some studies have suggested a minimal role for adiponectin in periodontal related cardio-

Table I. Differences in Self-Rep Status (n (%))

Dental Hygiene Practices	Frequency of Brushing	At Least Dai
		< Daily
	Frequency of Flossing	2-6 Times/W
		Weekly or Le
Attitudes	Dental Health	Very Importa
		Somewhat o Less
	Fear of Dentist	Not At All
		Some – Muc
Preventive Care	Health Care Home	Has Dental Home
		No Dental Home
	Frequency of Preventive Care	Every 6 Mont
		Annually or Less
Dental Health	Self-Rated Overall Health	Very Good o Better
		Poor – Good

*p value for Pearson's Chi-Square. †HS=High Sc

Table II. Univariate (ANOVA) Re Inflammation

		Frequen
		At Least Daily
CVD Risk Factors	BMI (kg/m2)	
	Total Cholesterol (mg/dL)	182.9 ±34.2
	Mean Arterial Pressure	
Marker of Systemic Inflammation	Adiponectin (pg/mL)	1.3E4 ±4.6E3
	CRP (mg/dL) ζ	
	Fibrinogen (ng/mL)	
	IL-1B (pg/mL)	1.5±1.6
	sICAM-1 (pg/mL)	
	tPAI-1 (pg/mL)	1.8E4 ±9.6E3

ζAnalysis included only for those participants with C
*p value for ANOVA F-statistic

oorted Dental Hygiene Based on Gender, Dental Insurance, Education and Smoking

	Gender			Dental Insurance			Education			Current Smoker		
	Male	Female	p*	No	Yes	p*	≤HS†	>HS†	p*	No	Yes	p*
y	37 (86%)	66 (92%)	0.34	28 (85%)	71 (91%)	0.34	44 (83%)	59 (95%)	0.03	79 (92%)	20 (80%)	0.09
	6 (14%)	6 (8%)		5 (15%)	7 (9%)		9 (17%)	3 (5%)		7 (8%)	5 (20%)	
k	16 (40%)	44 (64%)	0.02	16 (53%)	42 (56%)	0.80	24 (48%)	36 (68%)	0.17	46 (55%)	12 (55%)	0.94
ss	24 (60%)	25 (36%)		14 (47%)	33 (44%)		26 (52%)	23 (43%)		37 (45%)	10 (45%)	
nt	18 (42%)	49 (68%)	0.01	18 (54%)	47 (60%)	0.58	28 (53%)	39 (63%)	0.28	54 (63%)	11 (44%)	0.09
r	25 (58%)	23 (32%)		15 (46%)	31 (40%)		25 (47%)	23 (37%)		32 (37%)	14 (56%)	
	37 (86%)	47 (65%)	0.02	23 (70%)	57 (73%)	0.72	32 (60%)	52 (84%)	0.005	61 (71%)	19 (76%)	0.62
h	6 (14%)	25 (35%)		10 (30%)	21 (37%)		21 (40%)	10 (16%)		25 (29%)	6 (24%)	
	34 (77%)	58 (80%)	0.67	22 (67%)	68 (86%)	0.02	42 (78%)	50 (81%)	0.70	72 (83%)	18 (72%)	0.23
	10 (23%)	14 (20%)		11 (33%)	11 (14%)		12 (22%)	12 (19%)		15 (17%)	7 (28%)	
hs	17 (39%)	35 (52%)	0.16	9 (29%)	41 (54%)	0.02	17 (34%)	35 (57%)	0.01	45 (55%)	5 (50%)	0.002
	27 (61%)	32 (48%)		22 (71%)	35 (46%)		33 (66%)	26 (43%)		37 (45%)	5 (50%)	
r	16 (37%)	33 (48%)	0.27	13 (39%)	34 (45%)	0.57	16 (30%)	33 (56%)	0.006	43 (50%)	4 (17%)	0.004
l	27 (63%)	36 (52%)		20 (61%)	41 (55%)		37 (70%)	26 (44%)		42 (50%)	19 (83%)	

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lationships Between Self-Reported Dental Hygiene and CVD Risk Factors and Systemic

cy of Brushing		Frequency of Flossing			Frequency of Preventive Care			Self-Rated Overall Dental Health		
<Daily	p*	2-6 Times/ Wk	Weekly or Less	p*	Every 6 Months	Annually or Less	p*	Excellent or Very Good	Poor-Good	p*
	p>0.10			>0.10			>0.10			>0.10
203.2 ±26.9	0.049			>0.10			>0.10			>0.10
	>0.10	96.3 ±9.3	102.4 ±11.8	0.003	96.9 ±11.2	101.3 ±12.7	0.06			>0.10
8.9E3 ±2.8E3	0.013	1.3E4 ±4.2E3	1.1E4 ±4.9E3	0.033			>0.10	1.3E4 ±4.5E3	1.2E4 ±4.6E3	0.097
	>0.10			>0.10			>0.10	2.7±2.2	4.1±2.7	0.017
	>0.10	4.2E6 ±1.3E6	3.4E6 ±1.2E6	0.004			>0.10			>0.10
2.8±3.1	0.029			>0.10			>0.10			>0.10
	>0.10			>0.10	201.1 ±68.8	268.2 ±110.4	<0.0001	216.7 ±90.1	253.6 ±101.5	0.055
2.4E4 ±1.8E4	0.093			>0.10	1.6E4 ±9.9E3	2.0E4 ±1.1E4	0.091			>0.10

RP<10 mg/dL

Table III. Multiple Regression Analysis Demonstrating Independent Associations Between Self-Reported Dental Hygiene and Systemic Inflammation

Model	Dependent Variable	Cardiovascular Disease Risk Factor Adjustment (Dependent) Variable	Self-Reported Dental Hygiene (Dependent) Variable	n / β±SE; p
1†	Adioponectin	BMI	Frequency of Brushing‡	84 / 0.3±0.1; p=0.025
2†	Adioponectin	Total Cholesterol	Frequency of Brushing‡	82 / 0.3±0.1; p=0.019
3†	Adioponectin	Mean Arterial Pressure	Frequency of Brushing‡	82 / 0.3±0.1; p=0.022
4†	Adioponectin	BMI	Frequency of Flossing¥	p>0.1
5†	Adioponectin	Total Cholesterol	Frequency of Flossing¥	78 / 0.2±0.1; p=0.054
6†	Adioponectin	Mean Arterial Pressure	Frequency of Flossing¥	p>0.1
7†	Fibrinogen	BMI	Frequency of Flossing¥	90 / 0.2±0.1; p=0.008
8†	Fibrinogen	Total Cholesterol	Frequency of Flossing¥	88 / 0.1±0.1; p=0.028
9†	Fibrinogen	Mean Arterial Pressure	Frequency of Flossing¥	88 / 0.1±0.1; p=0.02
10†	sICAM-1	BMI	Frequency of Preventive Careψ	92 / -0.2±0.1; p=0.003
11†	sICAM-1	Total Cholesterol	Frequency of Preventive Careψ	90 / -0.2±0.1; p=0.01
12†	sICAM-1	Mean Arterial Pressure	Frequency of Preventive Careψ	90 / -0.2±0.087; p=0.005
13ζ	CRP	BMI	Self-Rated Overall Dental Healthξ	74 / -0.6±0.2; p=0.004
14ζ	CRP	Total Cholesterol	Self-Rated Overall Dental Healthξ	73 / -0.6±0.2; p=0.002
15ζ	CRP	Mean Arterial Pressure	Self-Rated Overall Dental Healthξ	73 / -0.6±0.2; p=0.002
16†	Adioponectin	BMI	Self-Rated Overall Dental Healthξ	82 / 0.2±0.1; p=0.062
17†	Adioponectin	Total Cholesterol	Self-Rated Overall Dental Healthξ	80 / 0.1±0.1; p=0.096
18†	Adioponectin	Mean Arterial Pressure	Self-Rated Overall Dental Healthξ	p>0.1

†Model also adjusted for age, gender, smoking, dental insurance, and acute immune response (CRP≥10)

ζModel adusted for age, gender, smoking, and dental insurances; model included only participants with CRP<10 mg/dL

‡Coded as 0=Less Than Daily; 1=At Least Daily

¥Coded as 0=Less Than 2-6 Times Weekly; 1=At Least 2-6 Times Weekly

ψCoded as 0=Preventive Dental Care Annually or Less Frequently; 1=Preventive Dental Care Every 6 Months

ξCoded as 0= Overall Rating <Very Good (Poor-Good); 1= Overall Rating Excellent or Very Good

vascular disease,[32] current findings indicated that adiponectin increased with more frequent brushing and flossing. To the extent that elevated adiponectin can be considered cardioprotective (i.e., positively associated with good cardiovascular outcomes),[33] it may be that adiponectin functions as a correlate of positive health behaviors, such as those associated with lower BMI. It would be logically consistent to consider brushing and flossing as a positive health behavior and thus be associated with elevated levels of adiponectin. This observation is also consistent with our hypothesis that better dental hygiene practices would be associated with more favorable levels of systemic inflammation.

Results that show self-reported dental hygiene was associated with higher levels of fibrinogen suggest more complex relationships, and is the only observation that is not consistent with our hypothesis that better dental hygiene practices would be associated with more favorable levels of systemic inflammation. Although fibrinogen levels have been positively correlated to age, smoking[28] and periodontal disease,[29] it is more difficult to explain the positive association in the increase in flossing. These findings warrant further study to determine if this finding is more generalizable or unique to the characteristics of this study, such as the sample or size.

Conclusion

After controlling for variables with known, previous association with systemic inflammation, self-reported dental hygiene was significantly associated with more favorable levels of systemic inflammation, and thus suggests that dental hygiene may be independently contributing to systemic inflammation. While previous studies have linked periodontal infection with systemic inflammation, and the link between dental hygiene and oral health is well established, from our literature search this is the first known study demonstrating an association between dental hygiene and systemic inflammation. Further, while previous studies have demonstrated that periodontal therapy and improved periodontal health can reduce markers of systemic inflammation in clinical populations,[22-24] results from the current study suggest similar associations in non-clinical populations. This study also extends previous observations of associations between self-reported oral hygiene behaviors in a clinical population of coronary heart disease patients.[25] Results from this study suggest that periodontal-related systemic inflammation may begin before the onset of clinical disease with poorer dental hygiene.

Future longitudinal studies should further investigate these findings.

Limitations of the Current Study

This study has several limitations, and so requires cautious interpretation of results. As this is a cross-sectional study, results must be interpreted as associations, not causal relationships. The conservative criteria for inclusion of inflammatory markers in the final analysis limited the sample size, resulting in underpowered analyses, though all regression models were within the rule of thumb of 10 observations for each independent variable. It should also be noted that reduced sample size, combined with multicollinearity in regression models, work to bias toward accepting the null hypothesis of no effect, and so observed associations between dental hygiene and systemic inflammation are less likely to be attributable to type 1 error (false positive).

While participants in this study were generally healthy (i.e., a non-clinical population), they were voluntary participants in a health screening and are at least somewhat health conscious. They were resident in rural communities in a geographic area renowned for its poor health, dental and otherwise. While 70.2% of participants reported having dental insurance and 79.3% reported having a dental home, only 46.8% reported preventive dental care at least annually, a proportion lower than reported in the NHANES 1999-2004 study (59.9% for adults 20 to 64).[34] It is not well understood how issues related to access to care, socioeconomic concerns and cultural influences affect dental health care seeking in the rural communities in this study, and if these influences and effects are generalizable to other populations. It is also unclear how issues such as lower rates of water fluoridation in rural communities may have affected the results reported here. Although 80% of publicly provided water sources in West Virginia are fluoridated,[35] it does not necessarily follow that 80% of the population in rural communities receive or ingest fluoridated water.

Finally, periodontal health was not directly evaluated, and measures of dental hygiene were self-reported. While a periodontal exam by a dental professional is clearly ideal, the challenges of such exams in epidemiologic and community-based studies, such as that reported, have been noted.[36-38] Recent studies have reported a reasonable clinical validity and reliability of self-reported measures for surveillance studies.[37-38]

Implications of the Current Study

Results reported here will clearly benefit from additional studies in larger and more diverse populations. However, these initial results clearly highlight the importance of dental hygiene in overall, systemic health. Results reported here suggest that the effects of poorer dental hygiene may extend beyond poorer dental health to poorer systemic health, with the associations between dental hygiene and systemic inflammation of particular concern, given the known relationship between systemic inflammation and cardiovascular disease. The health policy implications from these results are also potentially compelling, including the importance of the dentist and dental hygienist as an integral part of the health care team. Results from the 2005 BRFSS survey reported that 85.5% of Americans had some form of health insurance, but only 61.2% of Americans were estimated to have at least some dental insurance coverage (modular supplement to the 2001 BRFSS survey).[2] If results from future studies continue to suggest, as this and previous studies have, that dental hygiene and health is a key component to systemic health, our understanding of comprehensive health insurance may need to be revised to include mandatory coverage for dental care.

Stephanie J. Frisbee, MSc, MA, PhD (Cand) is a Clinical Assistant Professor in the West Virginia University School of Dentistry Department for Rural Health and Practice, and a Research Instructor in the West Virginia University School of Medicine Department of Community Medicine. Christopher B. Chambers, BS, DDS, is a graduate of the West Virginia University School of Dentistry. Jefferson C. Frisbee, PhD, is an Associate Professor in the West Virginia University School of Medicine Department of Physiology and Pharmacology. Adam G. Goodwill, BS, PhD (Cand.) is a doctoral candidate in the West Virginia University School of Medicine Cellular and Integrative Physiology graduate program. Richard J. Crout, DDS, MS, PhD, is the Associate Dean for Research and Professor of Periodontics in the West Virginia University School of Dentistry.

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