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The association of periodontal disease parameters with systemic medical conditions and tobacco use

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Abstract

Objectives: The objective of this study was to determine if an association existed between periodontal disease and various systemic medical conditions and tobacco use.

Material and Methods: The study design was a case-controlled, retrospective chart review. Patient charts ($n = 2006$) were selected from more than 13,000 active patients attending the University of Minnesota dental clinics. These charts were examined to determine patient's self-reported systemic condition and smoking history. In addition, the number of missing teeth and bone loss were recorded. Two examiners collected the data. One examiner abstracted patient's medical history from the standard clinic medical questionnaire. The second examiner assessed the radiographs and dental charts to determine bone loss and number of missing teeth. Each examiner was blind to the findings of the other.

Results: After adjusting for age, sex, diabetes and smoking (yes/no) status, seven conditions were significantly ($p = 0.0003$–0.04) related to bone loss or number of missing teeth (vascular disease, heart surgery, vascular surgery, heart attack, thyroid problems, arthritis, stomach ulcers). From these conditions, thyroid problems and arthritis had a negative association with bone loss.

Conclusions: These findings support the results from previous investigators that a number of systemic conditions and smoking are closely associated with missing teeth or bone loss.

Key words: bone loss; missing teeth; periodontal disease; risk factors; systemic conditions

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In the last 20–25 years, researchers and clinicians have provided a very different view of periodontal disease and a new paradigm has been put forward regarding the nature of periodontal disease susceptibility, its etiology and pathogenesis (Page & Kornman 1997). The three main tenets of this new model are that: (1) specific bacterial types cause periodontitis; (2) the host immunoinflammatory response, although protective, is also in part responsible for periodontal tissue destruction; and (3) much diversity exists among individuals with regard to susceptibility to periodontitis, with specific innate and acquired risk factors contributing to susceptibility. As more is learned about the human body, a relationship between diseases of the oral cavity (specifically periodontal infections) and a number of systemic conditions is emerging.

A growing body of scientific evidence suggests an association between oral infections and some systemic diseases (Arbes et al. 1999, Buhlin et al. 2002). Transmissible and opportunistic microorganisms are responsible for periodontal disease (Loe et al. 1986). These bacteria themselves present a substantial infectious burden to the entire body, but in addition specific microorganisms associated with periodontal disease can release products that invoke an inflammatory response (Socransky & Haffajee 1991). Bacteria, bacterial toxins, localized tissue response cytokines and other inflammatory mediators enter the circulation where they have the potential to activate a systemic response (Page 1998). Therefore, this systemic response may be

associated with periodontal disease. The main systemic conditions that have been associated with periodontal disease to date are cardiovascular disease (Beck et al. 1996, Beck & Offenbacher 1998, Haraszthy et al. 2000), diabetes (Emrich et al. 1991, Loe 1993, Oliver & Tervonen 1994, Tervonen & Karjalainen 1997), preterm low birth weight babies (Offenbacher et al. 1996, 1998, Dasanayake 1998) and respiratory diseases (Scannapieco et al. 1998). It appears that not only are the teeth at stake in maintaining good oral health, but good oral health is an important component of general health; individuals with periodontitis may be at a higher risk for many other systemic conditions. As a result dental professionals may need to assume a larger responsibility for the overall health of patients.

The evidence that smoking has a deleterious effect on periodontal health is convincing. Numerous investigations into this relationship have been carried out in recent years (Bergström et al. 1991, Hyman et al. 2002). Both cross-sectional and longitudinal studies provide strong epidemiological evidence that smoking confers considerable risk for periodontal disease. Grossi et al. (1996), in a study of more than 1400 people aged 25–74 years, demonstrated that light smokers had twice the risk of developing periodontitis compared with non-smokers and that heavy smokers had a risk up to five times higher, using clinical attachment loss as a criterion. These studies were adjusted for age, gender, socioeconomic status, plaque and calculus. Smoking has been directly related to the severity of periodontal disease, to the number of teeth lost and to an increased incidence of recurrent and refractory periodontal disease (Haber 1994). Smokers have also been shown to have a poorer response to periodontal treatment (Magnusson & Walker 1996). Furthermore, Jette et al. (1993) demonstrated that in 1156 community dwelling New England elders, the number of years of exposure to tobacco products was a significant risk factor for periodontal disease regardless of other social and behavioral factors.

The record department at the University of Minnesota School of Dentistry provided the opportunity to examine a large number of charts from patients with completed medical health questionnaires. This allowed us to further investigate the link between periodontal disease and the four main systemic conditions reported in the literature (cardiovascular disease, diabetes, preterm low birth weight babies and respiratory diseases), and also to consider many other systemic conditions included in the medical questionnaire to determine if any associations existed. This study's purpose was then to determine if an association existed between periodontal disease and the various systemic medical conditions recorded in the patient's medical health questionnaire. To investigate this, patient's periodontal health was characterized by determining the number of missing teeth and the percentage of bone loss from the patient's radiographic records. An additional aim of this study was to further investigate the relationship of tobacco use with bone loss and missing teeth.

Material and Methods

Target population

This study was a retrospective chart review and was approved by the University of Minnesota Institutional Review Board. The standard procedure when obtaining a medical history at the University of Minnesota School of Dentistry is to orally follow-up every written questionnaire completed by a patient. Dental charts were randomly selected from among patients who had attended the University of Minnesota Dental Clinics for treatment. A total of 2006 dental charts were evaluated. These charts along with full-mouth radiographs were examined to determine for each patient the percentage bone loss and the number of missing teeth.

Patients included were all 50 years of age or older (range 50–92 years), had six or more remaining teeth, a full set of periapical radiographs and had fully completed the dental school medical questionnaire, Fig. 1. From a total of approximately 13,000 active charts on file, the 2006 charts evaluated for this study were randomly selected by a computer program. A randomly selected sample of patients referred to the periodontics clinic for root planing and/or periodontal surgery therapy ($n = 1039$) and also a randomly selected group of patients presenting to the School of Dentistry for general dental treatment but not referred to the periodontics clinic for periodontal therapy ($n = 967$) were included in the data analyses.

Chart evaluation

Two examiners collected data. Each examiner was blind to the findings of the other. Examiner #1 (A.L.G.) collected the data from the medical questionnaire, along with the patient's chart number, sex, age and date. For these data, 10 randomly selected charts out of every hundred were reviewed by a separate examiner to check for recording errors. Examiner #2 (J.M.) evaluated the full set of periapical radiographs from every patient on a radiographic viewing screen. The patient's chart number, the percentage bone loss and number of missing teeth were recorded. A patient's bone loss was rated as either mild (0–25%), moderate (26–50%) or severe (greater than 50%). In measuring bone loss, an estimation of the distance from the alveolar crest to the cemento-enamel junction (CEJ) was determined for the entire dentition, with greater emphasis being placed on the molar and premolar teeth. Any patient with greater than 50% bone loss involving four or more premolar or molar teeth was automatically placed in the severe bone loss category. A bone loss reliability test was carried out to determine the accuracy with which the examiner assessed the percentage of bone loss. Specifically, 6 months after the first rating, 100 charts were selected at random and a second radiographic assessment was carried out. The two readings of percentage bone loss disagreed in five of 100 cases, giving a κ of 0.82, which can be considered excellent agreement. The number of missing teeth was determined by subtracting the total number of teeth present on the radiographs from 32. Ten randomly selected radiographs out of every hundred were re-assessed to monitor consistency in recording missing teeth. Data from the chart regarding smoking were recorded as a yes/no response. The data needed to compute pack years were often absent and not reliable; therefore, pack years were not considered here.

Statistical analysis

Univariate analyses (Fisher's exact test) and adjusted analyses (logistic regression) were used to test for an association between the systemic medical conditions and the percentage bone loss groups (mild, moderate and severe). Where the univariate tests showed a

Chart No:

Sex: **Age:** **Date of Questionnaire:** **Month** **Year**

Date of Radiographs: **Month** **Year**

% Bone Loss: **Missing Teeth:**

Medical Questionnaire:

O Yes	O No	Cardiovascular Conditions	Other Conditions		
O Yes	O No	Rheumatic fever, Rheumatic heart disease	O Yes	O No	Liver disease, jaundice
O Yes	O No	Heart murmur	O Yes	O No	Hepatitis
O Yes	O No	Congenital heart defect	O Yes	O No	Liver Transplant
O Yes	O No	Vascular disease	O Yes	O No	Diabetes mellitus
O Yes	O No	Heart surgery/angioplasty	O Yes	O No	Kidney trouble, dialysis, transplant
O Yes	O No	Vascular surgery	O Yes	O No	Thyroid problems
O Yes	O No	Infective endocarditis	O Yes	O No	Allergies
O Yes	O No	Mitral valve prolapse	O Yes	O No	Asthma
O Yes	O No	Pacemaker	O Yes	O No	Hay fever
O Yes	O No	Prosthetic heart valve	O Yes	O No	Hives or skin rash
O Yes	O No	High blood pressure	O Yes	O No	Arthritis, Rheumatism
O Yes	O No	Stroke	O Yes	O No	Joint Replacement
O Yes	O No	Heart attack (heart trouble)	O Yes	O No	Anemia
O Yes	O No	Angina	O Yes	O No	Leukemia
O Yes	O No	Heart transplant	O Yes	O No	Hemophilia, other bleeding disorders
O Yes	O No	Other cardiovascular problems	O Yes	O No	Tuberculosis
O Yes	O No	Describe other cardiovascular disease:	O Yes	O No	HIV - infection
			O Yes	O No	Stomach ulcers
		Do you have or have you had:			**Have you taken any of the following:**
O Yes	O No	Chest pain upon exertion?	O Yes	O No	Antibiotics, Sulfa drugs?
O Yes	O No	Shortness of breath after exercise?	O Yes	O No	Antihistamines?
O Yes	O No	Ankle swelling?	O Yes	O No	Corticosteroids?
O Yes	O No	Fainting spells or seizures?	O Yes	O No	Dilantin?
O Yes	O No	Shortness of breath when lying down?	O Yes	O No	Insulin?
O Yes	O No	Require extra pillows when sleeping?	O Yes	O No	Anticoagulants (blood thinners)?
O Yes	O No	Urinate > 6 times a day?	O Yes	O No	Digitalis or drugs for heart trouble?
O Yes	O No	Thirsty much of the time?	O Yes	O No	Nitroglycerine?
O Yes	O No	Dry mouth much of the time?	O Yes	O No	Tranquilizers?
O Yes	O No	White lesions in the mouth?	Number of medications patient is taking:		
O Yes	O No	Lumps or tumors in mouth or neck?			**Women:**
O Yes	O No	Unusual weight loss?	O Yes	O No	Are you taking contraceptives?
O Yes	O No	Do you use tobacco?	O Yes	O No	Have you had a miscarriage or stillbirth?
		How much Cigarettes/day	O Yes	O No	Birth weight > 10 pounds or low weight?
		How long Years			**Periodontal History:**
			O Yes	O No	Have you had gum treatment?
			O Yes	O No	Has anyone in your family had gum treatment?

Fig. 1. University of Minnesota Dental School Medical Questionnaire.

significant ($p<0.05$) association, an adjusted analysis, adjusting for age, sex, diabetes and smoking, was done to determine if the association remained. To analyze the association of systemic medical conditions with the number of missing teeth, logistic regression was used with the number of missing teeth treated as a continuous variable. For systemic conditions that were significantly related to the number of missing teeth, prevalence of the condition was computed for nine categories of patients defined by the number of missing teeth (0–3, 4, 5, 6, 7, 8, 9–10, 11–13 and >13 missing teeth), where the categories were defined to contain roughly similar numbers of patients. This allowed a simple display of how the percent of patients with a particular systemic condition changed as the number of missing teeth increased. Also, for conditions that were significantly associated with missing teeth, an adjusted analysis (logistic regression), adjusting for age, sex, diabetes and smoking was done to determine if the association remained.

Results

The systemic conditions investigated in this study included a history of rheumatic fever and rheumatic heart disease, heart murmur, congenital heart defect, vascular disease, heart surgery, vascular surgery, infective endocarditis, mitral valve prolapse, pacemaker, prosthetic heart valve, high blood pressure, stroke, heart attack, angina, heart transplant, other cardiovascular problems, liver disease/jaundice, hepatitis, liver transplant, diabetes mellitus, kidney disease/transplant, kidney trouble, thyroid problems, allergies, asthma, hay fever, hives or skin rash, arthritis/rheumatism, joint replacement, anemia, leukemia, hemophilia or other bleeding disorders, tuberculosis, HIV infection and stomach ulcers (Fig. 1). Heart transplant, liver transplant and leukemia were not reported by any patient in our sample and will not be discussed further. An

Table 1. Patient characteristics compared between the radiographic bone loss groups

	Bone loss groups		
	none to mild (0–25%) ($n = 1530$)	moderate (26–50%) ($n = 411$)	severe (>50%) ($n = 65$)
missing teeth mean (±SD)	7.6 (4.5)	9.9 (4.7)	13.3 (5.4)*
% female	51.4	44.5	36.9*
age mean (±SD)	64.9 (9.7)	65.7 (9.3)	63.1 (10)
% using tobacco	10.5	29.7	47.7*

SD, standard deviation.
*Significant difference between the severe bone loss group and the none to mild or moderate bone loss groups ($p \leqslant 0.05$).

Table 2. Prevalence of systemic conditions and tobacco use stratified separately for females and males

Condition	Prevalence (%)		*p*-Value*
	females	males	
rheumatic fever	3.4	2.7	0.36
heart murmur	10.3	6.8	**0.007**
congenital heart defect	0.7	1.1	0.48
vascular disease	2.4	4.8	**0.004**
heart surgery	2.8	9.4	**<0.0001**
infective endocarditis	0.20	0.20	1.00
vascular surgery	1.4	3.4	**0.005**
mitral valve prolapse	2.3	0.9	**0.012**
pacemaker	0.6	0.9	0.61
prosthetic heart valve	0.4	0.2	0.45
high blood pressure	26.9	28.4	0.45
stroke	3.2	3.2	1.00
heart attack	3.8	10.1	**<0.0001**
angina	3.5	6.7	**0.001**
other cardiovascular problems	3.2	4.6	0.13
liver disease/jaundice	2.5	2.1	0.55
hepatitis	3.1	3.7	0.54
diabetes	6.4	8.7	0.063
kidney trouble	2.1	2.9	0.32
thyroid problems	13.4	3.0	**<0.0001**
allergies	34.0	22.7	**<0.0001**
asthma	8.2	5.7	**0.035**
hay fever	13.9	9.5	**0.002**
hives/skin rash	14.9	6.3	**<0.0001**
arthritis/rheumatism	32.7	20.5	**<0.0001**
joint replacement	3.3	3.8	0.63
hemophilia/bleeding disorder	0.80	0.40	0.26
anemia	4.7	1.0	**<0.0001**
HIV	0.0	0.2	0.50
tuberculosis	0.50	0.40	0.28
stomach ulcers	7.6	7.4	0.93
low birth weight	6.1	–	–
miscarriage	15.7	–	–
tobacco use	13.2	18.1	**0.003**

*p-Value $\leqslant 0.05$ represents a significant difference in prevalence between females and males.

additional non-systemic condition, the patients' smoking history, was also recorded. In addition, for the females in this study, any history of oral contraceptive use, miscarriage or low birth weight was recorded.

Patient characteristics compared between the radiographic bone loss groups are shown in Table 1. These characteristics included missing teeth, percent of females, age and percent using tobacco. Patients with more severe bone loss, when compared with the mild and moderate bone loss groups, had significantly ($p < 0.05$) more missing teeth and included significantly fewer females. Also, patients in the severe bone loss group, when compared with the mild or moderate bone loss groups, were significantly ($p < 0.05$) more likely to smoke.

Prevalence of systemic conditions and tobacco use

Prevalence of systemic conditions and tobacco use are presented separately for females and males in Table 2. Systemic conditions found to be significantly ($p < 0.05$) more prevalent in females included heart murmur, mitral valve prolapse, thyroid problems, allergies, asthma, hay fever, hives/skin rash, arthritis/rheumatism and anemia. On the other hand, vascular disease, heart surgery, vascular surgery, heart attack, angina and tobacco use were significantly ($p < 0.05$) more prevalent in males. Low birth weight and miscarriage, unique to females, had a prevalence of 6.1% and 15.7%, respectively.

Systemic medical conditions and tobacco use associated with percentage bone loss and missing teeth

p-Values testing the association between the percentage bone loss and missing teeth on the one hand, and systemic medical conditions and tobacco use, on the other hand, are shown in Table 3. In the unadjusted univariate analysis, six medical conditions of 33 showed a significant ($p < 0.05$) association with percentage bone loss. These conditions included a history of vascular disease ($p = 0.05$), heart attack ($p = 0.02$), thyroid problems ($p = 0.02$), allergies ($p = 0.02$), arthritis ($p = 0.01$) and stomach ulcers ($p = 0.04$). Tobacco use was also significantly ($p < 0.001$) associated with percentage bone loss. Analyses adjusting for age, sex, diabetes and smoking were done for conditions that were significant in the (unadjusted) univariate analysis. *p*-Values for the adjusted analyses associating the percentage bone loss with systemic medical conditions are also shown in Table 3. Three of the six systemic conditions remained significant ($p < 0.05$) in the adjusted analysis. These included thyroid problems ($p = 0.04$), arthritis ($p = 0.02$) and stomach ulcers ($p = 0.04$).

Also shown in Table 3 are *p*-values testing the association between the number of missing teeth and the systemic medical conditions and tobacco use. In the unadjusted analysis, 12 systemic medical conditions and tobacco use showed a significant association

Table 3. *p*-Values testing for the unadjusted univariate and adjusted analysis in determining the association between percentage bone loss and missing teeth with systemic medical conditions and tobacco use

Condition	Bone loss		Missing teeth	
	unadjusted *p*-values*	adjusted *p*-values*	unadjusted *p*-values*	adjusted *p*-values*
rheumatic fever/heart disease	0.66		0.60	
heart murmur	0.75		0.50	
congenital heart defect	0.09		0.15	
vascular disease	**0.05**	0.14	**<0.001**	**0.014**
heart surgery	0.27		**<0.001**	**0.007**
infective endocarditis	0.09		0.37	
vascular surgery	0.13		**<0.001**	**0.001**
mitral valve prolapse	0.21		0.96	
pacemaker	0.30		<0.11	
prosthetic heart valve	0.20		0.77	
high blood pressure	0.08		**<0.001**	0.07
stroke	0.25		**<0.005**	0.15
heart attack	**0.02**	0.07	**<0.001**	**0.001**
angina	0.63		**0.02**	0.42
other cardiovascular problems	0.35		0.51	
liver disease/jaundice	0.90		0.30	
hepatitis	0.23		0.86	
diabetes	0.19		**<0.005**	0.09†
kidney trouble	0.29		0.57	
thyroid problems	**0.02**	**0.04**	0.58	
allergies	**0.02**	0.07	0.86	
asthma	0.58		0.94	
hay fever	0.23		**0.04**	0.13
hives/skin rash	0.09		0.67	
arthritis/rheumatism	**0.01**	**0.02**	**0.005**	0.56
joint replacement	0.47		**0.005**	0.16
hemophilia/bleeding disorder	0.82		0.10	
anemia	0.30		0.08	
HIV	0.42		0.93	
tuberculosis	1.00		0.80	
stomach ulcers	**0.04**	**0.04**	**<0.001**	**0.0003**
low birth weight	0.22		0.21	
miscarriage	0.97		0.15	
tobacco use	**<0.001**		**<0.001**	

*Results in bold indicate statistical significance ($p \leqslant 0.05$).
†Statistical analysis performed adjusting for age, sex and smoking.

with number of missing teeth: vascular disease ($p<0.001$), heart surgery ($p<0.001$), vascular surgery ($p<0.001$), high blood pressure ($p<0.001$), stroke ($p=0.005$), heart attack ($p<0.001$), angina ($p=0.02$), diabetes ($p=0.005$), hay fever ($p=0.04$), arthritis ($p=0.005$), joint replacement ($p=0.005$) and stomach ulcers ($p<0.001$). Tobacco use was also significantly associated with missing teeth ($p<0.001$). In the unadjusted analysis, systemic conditions that were significantly associated with both percent bone loss and the number of missing teeth included vascular disease, heart attack, arthritis/rheumatism and stomach ulcers ($p<0.05$). Tobacco use was also significantly associated with both percent bone loss and the number of missing teeth ($p<0.001$). Analyses adjusting for age, sex, diabetes and smoking were done for systemic medical conditions that were significant in the unadjusted univariate analyses. *p*-Values for the adjusted analysis associating the number of missing teeth with the systemic medical conditions are also shown in Table 3. Five of the 12 systemic medical conditions remained significant ($p<0.05$) in the adjusted analysis. These included vascular disease ($p=0.014$), heart surgery ($p=0.007$), vascular surgery ($p=0.001$), heart attack ($p=0.001$) and stomach ulcers ($p=0.0003$).

Prevalence of the systemic medical conditions and tobacco use in the three bone loss groups is shown in Table 4. Vascular disease, heart attack, stomach ulcers and tobacco use were significantly ($p<0.05$) more prevalent in patients with more severe bone loss compared with those patients with mild bone loss. Thyroid problems, allergies and arthritis were more prevalent in patients with mild bone loss compared with patients with severe bone loss.

Prevalence of systemic conditions that were significantly associated with the number of missing teeth is shown in Table 5. For data shown in Table 5, patients were divided into nine categories, each representing a number of missing teeth and containing roughly equal numbers of patients. This allowed us to see, for those systemic conditions that were significantly related to the number of missing teeth in the unadjusted analyses, how the percentage of patients with a specific systemic condition changed as the number of missing teeth increased. All the systemic medical conditions except hay fever were significantly ($p<0.05$) more prevalent as the number of missing teeth increased.

Discussion

This study was a chart review involving 2006 patients to determine if an association existed between periodontal disease and various systemic medical conditions and smoking status. The aim of this study was to develop the hypothesis that periodontal disease is associated with certain systemic medical conditions, although, of course, simply finding a relationship is not sufficient to label periodontal diseases as a true risk factor for the systemic condition. Our study design would, however, allow us to label periodontal disease as a possible ''risk indicator'' for the systemic conditions where a significant association was found. Larger and more detailed studies (Beck 1994) would then be justified to determine the extent of the association and whether periodontal disease truly is a risk factor for the conditions. By selecting subjects 50 years of age and older, we believed there was a greater likelihood of finding an association between specific systemic disease conditions (such as heart disease, stroke, diabetes) and periodontal disease, if one existed, in this population group.

Information regarding the prevalence of systemic medical conditions in this study was based on data obtained from a self-reported questionnaire. Although information from health questionnaires is less reliable than information obtained by laboratory and clinical inves-

Table 4. Prevalence of the systemic medical conditions and tobacco use in the three bone loss groups

Condition	Bone loss groups		
	none to mild (0–25%) ($n = 1530$)	moderate (26–50%) ($n = 411$)	severe (>50%) ($n = 65$)
vascular disease	3.4	3.7	9.2*
heart attack	6.4	7.8	15.4*
thyroid problems	8.9†	6.8	0
allergies	29.5†	25.8	15.4
arthritis	27.3†	26	10.8
stomach ulcers	7.7	5.6	13.9*
tobacco use	10.5	29.7	47.7*

*Vascular disease, heart attack, stomach ulcers and tobacco use were significantly ($p \leqslant 0.05$) more prevalent in patients with more severe bone loss compared with patients with mild bone loss in the unadjusted analyses.

†Thyroid problems, allergies and arthritis were significantly ($p \leqslant 0.05$) more prevalent in patients with mild bone loss compared with patients with severe bone loss in the unadjusted analyses.

Table 5. Prevalence of systemic medical conditions that were significantly associated with the number of missing teeth

Condition*	# missing teeth								
	0–3	4	5	6	7	8	9–10	11–13	>13
vascular heart disease	1.8	2.1	2.4	2.4	3.3	3.1	4.7	5.5	6.3
heart surgery	2.3	4.5	6.1	4.7	6.6	8.1	4.3	6.6	10.8
vascular surgery	0.6	0.7	1.4	2.4	1.6	1.8	2.1	3.5	5.9
high blood pressure	21.6	25.0	25.8	27.8	29.3	26.9	23.5	28.5	36.9
stroke	1.8	1.7	4.7	2.4	1.1	3.8	2.1	4.3	5.9
heart attack	3.5	5.8	6.1	4.3	5.0	5.6	6.4	10.1	12.5
angina	2.3	3.4	5.1	4.2	5.0	8.1	4.3	7.0	6.6
diabetes	4.7	5.5	5.6	9.0	7.2	9.4	7.7	8.2	10.5
hay fever	9.4	17.1	10.8	12.7	14.4	5.0	15.0	8.6	9.4
arthritis	20.5	21.2	22.0	31.1	29.9	25.7	26.0	30.5	30.7
joint replacement	2.9	1.7	1.4	4.7	3.9	0.6	5.1	5.5	4.8
stomach ulcers	2.3	6.2	4.7	7.1	8.8	6.3	6.4	10.6	12.2

*All systemic medical conditions (except hay fever) were significantly ($p \leqslant 0.05$) more prevalent as the number of missing teeth increased in the unadjusted analyses.

tigations, this method has been shown to be cost effective and reliable, and medical questionnaires are used routinely in epidemiological and clinical studies (Nery et al. 1987). Brady & Martinoff (1980) and Scully & Boyle (1983) advocated a written medical questionnaire with appropriate oral follow-up to accurately assess the patients' medical history for broad systemic disease categories. Also, a recent study by Ho et al. (1997) showed that there was high agreement ($\kappa = 0.79$–0.90) between self-reported health conditions and the actual presence of the systemic condition. The standard procedure when obtaining a medical history at the University of Minnesota Dental School is to orally follow-up every medical questionnaire completed by each patient. In the present study, we assumed this in fact did take place; however, since this was a retrospective chart review, we were unable to determine how thoroughly this was carried out for each patient.

Certainly, radiographs have an important role in the diagnosis of periodontal disease. Recommendations for periodontal assessment vary from full-mouth intra-oral radiography, including bitewings, to panoramic radiographs supplemented by the appropriate periapical or bitewing views (Barrington & Nevins 1990). In our radiographic assessment, a full-mouth periapical set, including molar and pre-molar bitewings, was used in determining each patient's bone loss group. Swan & Lewis (1993) found that a full-mouth radiograph survey complied with the recommendations of the Center for Devices and Radiological Health and was the most frequently used radiographic survey for periodontal disease assessment. Also, Pepelassi et al. (2000) concluded that periapical radiography was almost three times as successful at detecting periodontal osseous defects compared with panoramic radiographs. In our radiographic assessment, we paid particular attention to bone loss in the molar and premolar area because Shrout et al. (1990) showed that recording bone loss around mandibular molars and one other posterior tooth provided an accurate representation of full-mouth bone loss measurements.

When relating systemic medical conditions to percentage bone loss, six conditions were significantly ($p < 0.05$) associated with bone loss in the univariate analyses. Vascular disease, heart attack and stomach ulcers were more prevalent in patients with more severe bone loss compared with patients with mild bone loss. On the other hand, thyroid problems, allergies and arthritis were more prevalent in the mild bone loss group. The increased incidence of vascular disease and heart attack in those patients with more severe bone loss (in our univariate analyses) agrees with studies by DeStefano et al. (1993), Mattila et al. (2000), Mattila et al. (1989) and Offenbacher et al. (1998). However, Hujoel et al. (2000) did not find a significant association between periodontal disease and these conditions when he reanalyzed the data from the same population as DeStefano et al. (1993) 5 years later.

Studies by Goodson et al. (1984) and Reedy (1992) highlighted that radiographs do not show minor destructive changes in bone and tend to underestimate bone loss in mild and moderate periodontitis patients. Up to 30–50% of bone mineral content must be lost before bone changes can be detected on intra-oral radiographs. In our study, a full set of periapical and bitewing radiographs was assessed on a view box and patients were assigned to a bone loss group based on observation of the overall bone loss. The distance from the CEJ to the alveolar crest for individual teeth was not measured. This, in all likelihood, led to an increased error (and probable further underestimation) in our assessment of the radiographic bone loss, which would be determined in a clinical setting.

Since periodontal disease is a major determinant of tooth loss (Loe et al. 1986), it could be argued that the relationship between tooth loss and the systemic medical conditions investi-

gated in our study reflects the relationship of periodontal disease with these systemic conditions. Studies by DeStefano et al. (1993), Mattila et al. (1989) and Joshipura et al. (1996) reported an association between tooth loss and cardiovascular disease and stroke. Grossi & Genco (1998) also demonstrated an association between periodontal disease and diabetes. Our findings agreed with these investigators when relating tooth loss to systemic medical conditions. Of 33 systemic medical conditions considered, a significant association was found for 12 (vascular disease, heart surgery, vascular surgery, high blood pressure, stroke, heart attack, angina, diabetes, hay fever, arthritis, joint replacement and stomach ulcers). All of these conditions became more prevalent as the number of missing teeth increased except hay fever, which was more prevalent in patients with more teeth present. The association of periodontal disease with hay fever, arthritis, joint replacement and stomach ulcers has not been reported previously in the literature and may warrant further consideration. After adjusting for available confounders (age, sex, diabetes and smoking), five systemic conditions (vascular disease, heart surgery, vascular surgery, heart attack and stomach ulcers) remained significantly ($p<0.05$) more prevalent as the number of missing teeth increased.

It is important to remember that periodontal disease is only one of a number of conditions that contribute to tooth loss. Other confounders need to be considered to understand the correct relationship between periodontal disease and systemic medical conditions. Generally, teeth are extracted because of caries or periodontal disease and in our chart review we were unable to distinguish between these two causes. Also, people who lack either access to oral health care or a belief that oral health is of little value to themselves are not likely to foster health-promoting activities. These characteristics would act as confounders and possibly increase patients' likelihood of systemic diseases such as cardiovascular diseases, diabetes and possibly stomach ulcers. The patient's life style should also be taken into consideration: diet and physical activity along with smoking have a considerable impact on general health (Joshipura et al. 1996). Our findings strongly support the results of previous investigations (Jette et al. 1993, Haber 1994, Grossi et al. 1996, Magnusson & Walker 1996) that smoking is closely associated with severity of periodontal disease. In this study, smoking was recorded as a yes/no response by the patient to the question: ''Do you use tobacco?'' However, patients were not consistent in recording how much they smoked, how long they smoked, the number of cigarettes smoked each day and years smoked; therefore, pack years could not be reliably used in this statistical model. If tooth loss is related to the various systemic medical conditions as reported in the literature and in our study, the implications for millions of people would be substantial. Further studies are therefore needed to rule out confounding factors as possible explanations for the association found between periodontal disease and the various systemic medical conditions examined in this study.

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