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The association between tooth loss and the self-reported intake of selected CVD-related nutrients and foods among US women

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Abstract – *Objectives:* Many studies have reported associations between oral health and cardiovascular diseases; poor nutritional status due to impaired dentition status has been suggested as a mediator. Our objective is to evaluate the associations between tooth loss and the self-reported consumption of fruits and vegetables and selected CVD-related nutrients. *Methods:* A total of 83,104 US women who completed a food frequency questionnaire (FFQ) in 1990 and 1994 and reported number of natural teeth in 1992, were included in a cross-sectional analysis relating dietary intake to number of natural teeth. A longitudinal analysis was also conducted to evaluate whether tooth loss in 1990–1992 was associated with change in diet between 1990 and 1994. *Results:* After adjusting for age, total calorie intake, smoking and physical activity, edentulous women appeared to have dietary intake associated with increased risk for CVD, including significantly higher intake of saturated fat, trans fat, cholesterol and vitamin B_{12}, and lower intake of polyunsaturated fat, fiber, carotene, vitamin C, vitamin E, vitamin B_6, folate, potassium, vegetables, fruits, and fruits excluding juices compared with women with 25–32 teeth. In the longitudinal analyses, women who lost more teeth were more likely to change their diet in ways that would potentially increase risk for development of CVD. They also tended to avoid hard foods, such as raw carrot, fresh apple or pear. *Conclusions:* Women with fewer teeth have unhealthier diets such as decreased intake of fruits and vegetables, which could increase CVD risk. Diet may partially explain associations between oral health and cardiovascular disease.

Key words: cardiovascular disease; diet; edentulousness; nutrients; tooth loss

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Many studies have reported associations between oral health and cardiovascular diseases (1–9), and poor nutritional status due to impaired dentition status has been suggested as a mediator (9–12).

Tooth loss is associated with decreased masticatory performance, perceived ease of chewing and acceptability of some specific foods (13, 14). Several studies reported an inverse association between progressively impaired dentition and intake of several nutrients, as well as certain foods, such as fruits and vegetables (10, 15–19). Considering the high prevalence of tooth loss among older adults, even a small excess risk of systemic diseases due to dietary changes stemming from tooth loss would still have a substantial impact (20–22). However, most of these studies have been cross-sectional, based on short-term dietary intake, or were not adjusted for total calorie intake and other potential confounders. Also, most were conducted among men (10).

In a cohort of 49,501 men, Joshipura et al. observed that edentulous participants had a significantly higher intake of calories, saturated fat and cholesterol, and a lower intake of fiber, carotene and vegetables than those with 25 or more teeth (10). The differences were independent of age, smoking, profession, and physical activity. These results were further confirmed by the longitudinal analysis on incident tooth loss and in change of dietary intake over 8 years (23). However, this cohort consisted of all males. To evaluate whether tooth loss and dietary change is similar among females, in the present report, we evaluated the associations between tooth loss and the consumption of fruits and vegetables and selected nutrients reported to be associated with cardiovascular diseases in a female cohort (24). The dietary variables evaluated ncluded vitamins B_6, B_{12}, C, D and E, carotene and beta-carotene, folic acid, fiber, potassium, total flavonoids, cholesterol, and fats, based on their reported associations with cardiovascular disease (24–26).

Methods

Nurses' health study

In 1976, 121,700 female registered nurses between the ages of 30 and 55 residing in 11 US states completed a mailed questionnaire, which inquired about lifestyle practices, potential risk factors for cardiovascular diseases and cancers, and medical history. Follow-up questionnaires have been completed every 2 years to update the information. In 1980, a 61-item food frequency questionnaire (FFQ) was included to assess dietary intake, and the questionnaire was expanded to include 116 items in 1984. Similar dietary questionnaires were used in 1986, 1990 and 1994 to update the dietary information. The questions regarding the number of remaining teeth and teeth lost in the past 2 years were added in 1992. On average, the response rates for each biennial questionnaire were over 90% and about 80% for dietary questionnaires (27). This study has been approved by the Human Subjects' Committee at Brigham and Women's Hospital, Boston, MA. The return of the questionnaire(s) constituted informed consent.

Data collection

In 1992, the participants reported the number of natural teeth present in one of five categories (none, 1–10, 11–16, 17–24 and 25–32) and the number of teeth lost in the previous 2 years in the following categories: 0, 1, 2, 3, 4, 5–9, 10+. Validity of self-reported incident tooth loss has not been evaluated but Douglass et al. have shown that self-reported number of remaining teeth is reliable and highly correlated with the actual number of teeth upon clinical examination of the general population ($r = 0.97$) (28).

Data on dietary intake in 1990 and 1994 was collected by semi-quantitative FFQ. Participants reported the frequencies of consuming specific foods in nine different categories over the past year. Frequency of consumption ranged from less than once a month to six or more times per day in a commonly used unit or portion for all items of food (such as 1 tomato, 1 glass or 1/2 cup). Nutrient intake was computed by multiplying the consumption frequency of each food by the nutrient content (29) of the specified portion without supplements, as supplement use is unlikely to be directly associated with remaining teeth number, and adjusted for total calorie intake by the residual method (24).

The daily intakes of all fruits (with and without juice) and of all vegetables for each respondent were calculated. The proportions of women consuming banana, cantaloupe, fresh apple or pear and cooked or raw carrots (fruits assessed in our FFQ which represent different hardness), at least one time per week, were evaluated across number of natural teeth to evaluate the impact of tooth loss on foods of different hardness. The questionnaire assessed intake of fresh apples or pears which presumably consist of raw apples or pears, as additional items had included apple sauce and apple juice. The validity and reproducibility of this FFQ have been published in previous studies (30–32).

Data analysis

In cross-sectional analysis of dietary intake and number of remaining teeth in 1992, only participants who answered the dental questions in 1992 and completed at least one of the dietary questionnaires in 1990 or 1994 were included. Participants who left 70 or more items blank in dietary questionnaires or who reported extreme total energy intake (<2761 kJ/day or >14,644 kJ/day) were excluded. There were 83,104 eligible women for this analysis.

The average dietary intake of these CVD-related nutrients and fruits and vegetables from the FFQs in 1990 and 1994 was computed using the available measurement for those who returned only one dietary questionnaire. To control the confounding effect and compare consumption across groups

with different numbers of teeth, analysis of covariance was used to compute the least square means for each category of number of teeth while adjusting for potential confounders.

Because oral health and diet are both associated with health consciousness, the impact of several potential confounders was assessed, including smoking status, body mass index, physical activity, diabetes, hypertension, hypercholesterolemia, alcohol drinking, and vitamin use. Some confounders did not affect the association between the number of teeth and dietary intake appreciably. Hence only age (5-year categories), physical activity (overall weekly activities summed and categorized in quintiles) (33), and smoking status (never, past and current smoker) were included in the final model. Because the dietary intake data showed some departures from normality, tests for trend using rank-transformed dietary intake values were conducted. As the results were similar for the parametric and nonparametric rank-transformed analyses, only the parametric analyses were shown. The percentage of women consuming banana, cantaloupe, fresh apple or pear and cooked or raw carrot at least once per week was compared across categories of number of teeth adjusted for age, smoking status and physical activity.

In the longitudinal analysis, only 59,467 participants with 11 or more remaining teeth in 1992, who had also completed both dietary questionnaires were included. The mean changes of dietary intake between 1990 and 1994 (intake in 1994 minus intake in 1990) among women who lost 0, 1–4 and 5 or more teeth after controlling baseline dietary intake, age, smoking, and physical activity were compared. In addition, the percentages of women consuming specific fruits and vegetables in 1994 among participants consuming the specified food at least one time per week in 1990 between women with 0, 1–4 and 5 or more teeth lost in 1990–1992 were also compared, after adjusting for confounders to test whether tooth loss would change intake of foods characterized by hardness.

Results

Table 1 shows the distributions of age and the least-square means and tests for trend across five categories of different number of teeth adjusted

Table 1. Multivariate-adjusted means (±SD) for daily intake of total energy and energy-adjusted nutrients (excluding supplements), and fruit and vegetables by number of teeth[a]

	0 Teeth	1–10	11–16	17–24	25–32	Percentage of difference[b]	*P*-value for trend[c]
No. (%)	4395 (5.6)	5068 (6.5)	4170 (5.4)	16014 (20.6)	48261 (61.9)		
Age	62.8 ± 5.9	62.1 ± 6.2	61.4 ± 6.4	60.1 ± 6.9	57.3 ± 7.1		
Total energy (kcal)	1745 ± 7	1739 ± 7	1736 ± 8	1748 ± 4*	1739 ± 3	0.4	0.05
Saturated fat (g)	18.6 ± 0.1*	18.4 ± 0.1*	18.3 ± 0.1*	18.2 ± 0.03*	18.0 ± 0.03	3.5	<0.001
Trans fat (g)	2.63 ± 0.01*	2.58 ± 0.01*	2.54 ± 0.01*	2.53 ± 0.01*	2.45 ± 0.01	7.5	<0.001
Monounsaturated fat (g)	20.7 ± 0.1*	20.7 ± 0.1*	20.8 ± 0.1	20.8 ± 0.04	20.9 ± 0.03	−0.9	0.002
Polyunsaturated fat (g)	9.48 ± 0.04*	9.63 ± 0.03*	9.70 ± 0.04*	9.72 ± 0.02*	9.82 ± 0.01	−3.5	<0.001
Cholesterol (mg)	217 ± 1*	218 ± 1*	217 ± 1*	216 ± 1*	214 ± 0.4	1.4	<0.001
Dietary fiber (g)	17.6 ± 0.1*	17.9 ± 0.1*	18.2 ± 0.1*	18.2 ± 0.04*	18.7 ± 0.03	−5.7	<0.001
Carotene (IU)	8784 ± 87*	9173 ± 81*	9434 ± 89*	9579 ± 48*	10095 ± 34	−13.0	<0.001
Beta-carotene (IU)	4204 ± 37*	4337 ± 34*	4464 ± 38*	4486 ± 20*	4671 ± 14	−10.0	<0.001
Vitamin C (mg)	142 ± 1*	141 ± 1*	143 ± 1*	143 ± 0.5*	146 ± 0.3	−3.4	<0.001
Vitamin E (mg)	6.28 ± 0.06*	6.34 ± 0.06*	6.45 ± 0.06*	6.63 ± 0.03*	6.79 ± 0.02	−7.5	<0.001
Vitamin B_6 (mg)	1.92 ± 0.01*	1.92 ± 0.01*	1.92 ± 0.01*	1.94 ± 0.004*	1.96 ± 0.003	−1.8	<0.001
Vitamin B_{12} (mcg)	6.83 ± 0.06*	6.85 ± 0.05*	6.77 ± 0.06*	6.57 ± 0.03*	6.40 ± 0.02	6.7	<0.001
Folate (mcg)	295 ± 1*	297 ± 1*	299 ± 1*	303 ± 1*	311 ± 0.5	−5.1	<0.001
Potassium (mg)	2931 ± 8*	2940 ± 7*	2955 ± 8*	2970 ± 4*	3016 ± 3	−2.8	<0.001
Total flavonoids (mg)	21.6 ± 0.2	22.0 ± 0.2	22.0 ± 0.2	22.1 ± 0.1	22.1 ± 0.1	−2.2	0.07
Fruits (servings)	2.31 ± 0.02*	2.30 ± 0.02*	2.35 ± 0.02*	2.33 ± 0.01*	2.39 ± 0.01	−3.7	<0.001
Fruits excluding juices and sauces (servings)	1.54 ± 0.01*	1.55 ± 0.01*	1.60 ± 0.01*	1.58 ± 0.01*	1.63 ± 0.01	−6.0	<0.001
Vegetables (servings)	3.50 ± 0.03*	3.61 ± 0.03*	3.67 ± 0.03*	3.75 ± 0.01*	3.92 ± 0.01	−10.7	<0.001

*$P < 0.05$ for testing the difference in the mean intake of the specified group from the reference group with 25–32 teeth.
[a]Means are adjusted for total energy intake, age, physical activity, BMI and smoking.
[b]Percentage difference between women with 25–32 teeth and no teeth [(intake of edentulous group − intake of group with 25–32 teeth)/intake of group with 25–32 teeth] × 100.
[c]Test for linear trend across groups with 0, 1–10, 11–16, 27–42 and 25–32 teeth.

Table 2. Percentage of women consuming selected fruit and vegetable items one or more times per week in 1990 or 1994 by number of remaining teeth (crude analysis)

Number of remaining teeth	0 Teeth	1–10	11–16	17–24	25–32
No. (%)	4724 (5.7)	5467 (6.6)	4501 (5.4)	17,202 (20.7)	51,365 (61.7)
% Consuming banana in 1990 or 1994	56	56	57	56*	56
% Consuming cantaloupe in 1990 or 1994*	49*	51	50	51	50
% Consuming apples or pears in 1990 or 1994	64*	68*	70*	73*	77
% Consuming raw carrot in 1990 or 1994**	45*	54*	59*	65*	73
% Consuming cooked carrot in 1990 or 1994	84*	84	84	85*	83

*P-value <0.05 for testing differences between each category of tooth loss compared with women with 25–32 teeth as referent group, adjusted for total energy intake, age, physical activity, BMI and smoking.
**P-value <0.05 for the test for linear trend across these five categories of number of teeth.

for age, smoking, physical activity and total calorie intake. Among 83,104 participants, there were 4395 (5.6%) edentulous women, 5068 (6.5%) women with 1–10 teeth, 4170 (5.4%) women with 11–16 teeth, 16,014 (20.6%) women with 17–24 and 48,261 (61.9%) women with 25–32 teeth. Women with fewer teeth were older. The mean age for edentulous women was 62.8 years, and 57.3 years for women with 25–32 teeth. Compared to women with 25–32 teeth, edentulous participants had significantly higher intake of saturated fat, *trans* fat, cholesterol and vitamin B_{12}, and lower intake of polyunsaturated fat, fiber, carotene, beta-carotene, vitamin C, E and B_6, folate, potassium, vegetables, fruits and fruits excluding juices. The trends were significant for all items other than total flavonoids.

As shown in Table 2, women with more teeth were more likely to eat fresh apples or pears and raw carrots at least one time per week. Among women with 25–32 teeth, 77% consumed fresh apples or pears and 73% consumed raw carrot while only 64% and 45% of edentulous women consumed these items, respectively. Banana, cantaloupe, and cooked carrot intake did not vary much by number of teeth.

Table 3 shows the dietary changes between 1994 and 1990 for women with 0, 1–4 and 5 or more teeth lost in 1990–1992, separately. The tests for trend across these three categories of tooth loss were significant for changes of intake in saturated, *trans*, and monounsaturated fats, cholesterol, fiber, carotene, vitamin C and B_{12}, and folate. Women who lost teeth between 1990 and 1992 seemed to have detrimental changes in CVD-related nutrients. Compared with participants without any tooth loss, women who lost five or more teeth had significantly smaller reduction in consumption of monounsaturated fat, and cholesterol and women with one to four teeth lost had significantly smaller reductions in saturated, and *trans* fats, and cholesterol, smaller increases in fiber, carotene, vitamin C, and potassium, and greater reduction in folate.

In Table 4, each analysis was limited only to those consuming the specific food item in 1990. Women who lost 0, 1–4 and 5 or more teeth in 1990–1992 appeared to have different patterns of change in consumption of specific fruits and vegetables. Women who lost more teeth were more likely to reduce intake of fresh apples or pears and raw carrot, but they were likely to maintain their consumption of cooked carrot. In 1994, the percentage of women who maintained weekly consumption of fresh apples or pears was 78% for women without tooth loss and 67% for women who lost five or more teeth. For raw carrots, 79% of women without tooth loss and 67% of women who lost five or more teeth maintained weekly consumption, while 68% of women without tooth loss and 72% of women who lost five or more teeth consumed cooked carrots.

Discussion

In this study, women with fewer teeth were more likely to have an unhealthy dietary pattern for risk of cardiovascular diseases, which was consistent with previous results in a male cohort (10). Women with fewer teeth tended to have greater intake in the nutrients positively associated with risk of cardiovascular disease, such as saturated fat, *trans* fatty acids, and cholesterol and smaller intake in most of the beneficial nutrients except vitamin B_{12} compared with women with more teeth. The findings were further confirmed in the prospective analyses of incident tooth loss and dietary changes.

The absolute differences in our study were relatively small compared with total consumption although the trends were significant, given the large sample size. For example, each increment of

Table 3. Means of baseline intake and adjusted means of change (1994–1990) in daily intake of total energy and energy-adjusted nutrients (excluding supplements), fruits and vegetables among women with 11 or more teeth in 1992 by number of teeth lost between 1990 and 1992[a]

No. of teeth lost		0		1–4	≥5
No. of participants		50,686		8526	255
Mean age		58.2		59.5	60.2
	Dietary intakes in 1990	Least square means of change in dietary intakes			Difference in dietary change[b]	*P*-value for trend[c]
Total energy (kcal)	1748	−7.5	−2.7	3.2	10.7	0.3
Saturated fat (g)	18.77	−1.63	−1.50**	−1.16*	0.47	0.001
Trans fat (g)	2.63	−0.31	−0.29*	−0.30	−0.1	0.06
Monounsaturated fat (g)	21.34	−1.11	−1.03	−0.42**	0.69	0.04
Polyunsaturated fat (g)	10.54	−1.40	−1.43	−1.04**	0.36	0.9
Cholesterol (mg)	222.3	−16.9	−15.1**	−7.5**	9.4	0.002
Dietary fiber (g)	18.26	0.85	0.66**	0.59	−0.26	<0.001
Carotene (IU)	9163	1334	1165**	891	−443	0.01
Beta-carotene (IU)	4300	517	482	433	−84	0.2
Vitamin C (mg)	141.6	6.94	5.86*	1.67	−5.27	0.03
Vitamin E (mg)	6.96	−0.41	−0.43	−0.42	−0.01	0.8
Vitamin B_6 (mg)	1.91	0.09	0.09	0.11	0.02	0.8
Vitamin B_{12} (mcg)	6.57	−0.49	−0.38**	−0.01*	0.48	0.005
Folate (mcg)	312.6	−5.56	−8.37**	−11.13	−5.57	0.007
Potassium (mg)	2875	219	208*	204	−15	0.06
Total flavonoids (mg)	21.34	1.39	1.48	1.07	−0.32	0.7
Fruits (servings)	2.35	0.07	0.07	0.01	−0.06	0.9
Fruits excluding juices and sauces (servings)	1.60	0.07	0.08	0.04	−0.03	>0.9
Vegetables (servings)	3.68	0.29	0.25	0.32	0.03	0.2

*$P < 0.1$ and **$P < 0.05$ for dietary change among women with 1–4 and ≥5 teeth compared with women losing no teeth.
[a]Adjusted for total energy intake, age, physical activity, BMI and smoking.
[b]Difference in dietary change between women who lost no teeth and five or more teeth (dietary change of women with five or more lost teeth − dietary change of women with zero teeth lost).
[c]Linear trend across women with 0, 1–4 and 5 or more lost teeth in 1990–1992.

5% of energy from saturated fat and 2% of energy from *trans* unsaturated fat may increase risk of coronary heart disease by 17% and 93%, respectively, and each 10 g increment in total fiber may reduce risk of coronary heart disease by 20% (27, 34). In this study, the absolute differences in individual nutrients would be too small to be clinically significant. The differences between women with 25–32 teeth and zero teeth were 0.6 g in saturated fat (approximately 5.4 cal and 0.3% of total-energy intake), 0.18 g in *trans* fat (approximately 1.6 cal and 0.1% of total-energy intake) and 1 g in dietary fiber. These differences are associated with reduction of coronary heart disease risk by 3%, 1% and 2%, respectively. However, the combined effect of these detrimental changes in multiple nutrients could play an appreciable role in developing cardiovascular diseases and other chronic diseases. Hence, although the strength of effect of dietary changes resulting from tooth loss needs to be further evaluated, dental professionals should consider assessing the dietary changes related to dental health in clinical practice, and recommend healthier diets to patients with compromised diets.

Table 4. Percentage of women consuming selected fruit and vegetable items one or more times per week in 1994 among women who consumed the same food one or more times per week in 1990

		Percent consuming the food in 1994		
		Teeth lost		
Food	Number consuming the food in 1990	0	1–4	≥5
Banana	37,754	86	86	91
Cantaloupe	22,360	61	60	58
Apple or pear[a]	38,984	78	76[b]	67[b]
Raw carrot[a]	34,278	79	75[b]	67[b]
Cooked carrot	24,619	68	70	72

[a]*P*-value <0.05 for linear trend across these three groups.
[b]*P*-value <0.05 comparing consumption of specific food items between women who lost teeth and women who did not lose teeth after adjusting for total energy intake, age, physical activity, BMI and smoking.

Tooth loss decreases chewing ability, which in turn can alter the choice of foods. Wayler et al. found that subjects with complete dentures and compromised dentition demonstrated decreased masticatory performance, lower perceived ease of chewing, and preference for softer, easier-to-chew foods (13, 14). In our study, total calorie intake was not associated with dentition, suggesting that women maintain the same total calorie intake regardless of their dental status. However, consumption of different foods was associated with number of remaining teeth, and limited chewing ability might partially account for the diet choices among women with fewer teeth.

In this cohort, women with more teeth were more likely to eat raw carrot than women with fewer teeth (73% vs. 46%) but they had a similar consumption pattern for cooked carrot (85% vs. 84%), which was considered softer after processing. In the prospective analyses, women losing five or more teeth were even more likely to maintain their consumption for cooked carrot than women without any tooth loss in 1994 (72% vs. 68%). In additional analysis among women who consumed raw carrot once or more per week in 1990, 17% of women with five or more teeth lost decreased consumption of raw carrots and increased intake of cooked carrots, while only 10% of women without tooth loss showed the same pattern. These findings suggest that some participants might try to maintain their 'healthy diet' by modifying the hardness of foods.

Measurement error is inherent in the assessments of dietary information. In this study, the misclassifications of dietary intake were more likely to be nondifferential and would dilute the observed associations as the participants did not know the purpose of this study at the time of collecting data and reported similar total calorie intake across groups with different levels of tooth loss. The results were not likely to be caused by confounders as potential confounders were adjusted in the analyses, and the homogeneity in socioeconomic status, education, and health awareness of this population would further reduce an unmeasured confounding effect. Due to their relatively high socioeconomic status, this population may be more likely to have better prosthetic treatment to restore their chewing ability and a better motivation toward maintaining their healthy diet in spite of the effect of losing teeth. Hence, the impact of tooth loss on diet is expected to be larger in the general population.

However, in general, the differences in average change in nutrient consumption for women losing five or more teeth were more substantially different from women without teeth lost than women losing one to four teeth, but the significant differences were fewer for the former due to smaller sample size. The significant linear trends across different levels of lost teeth suggest that women with more teeth lost would have greater change in their dietary patterns.

The dietary changes between 1990 and 1994 were evaluated, but data on the number of teeth lost was only available for 1990–1992. This study was unable to capture those losing teeth from 1992 to 1994 and assumed no tooth loss during this period. This is unlikely to bias the results much, as only a few women (<15%) had experienced tooth loss in a 2-year period. The information on number of remaining teeth in 1990 was not available. To reduce the effect of number of teeth at baseline, the analyses were restricted to women with at least 11 remaining teeth in 1992. The analyses also controlled for baseline intake, which may help in controlling for some other unmeasured confounders.

In conclusion, our study suggests that women with fewer teeth are more likely to have detrimental changes in dietary intake in CVD-related nutrients and foods. The temporal association between tooth loss and dietary changes was further supported by longitudinal analyses. The combined effect of these dietary changes could contribute to risk of cardiovascular and other systemic diseases.

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