The Effect of Functional Dentition on Healthy Eating Index Scores and Nutrient Intakes in a Nationally Representative Sample of Older Adults

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Abstract

Objective: *The objectives of this study were to examine the associations between functional dentition and the Healthy Eating Index (HEI) scores and nutrient intakes among older adults in the United States.* ***Methods:*** *The sample consisted of 2,560 adults, 60 years and over from the National Health and Nutrition Examination Survey 1999-2002. We used multivariate linear regression to examine associations between functional dentition and HEI scores or nutrient intakes controlling for the potential confounding effects of age, race/ethnicity, education, smoking status, body mass index (BMI), self-reported health, and caloric intake. Dentate status was classified as: edentulous (no natural permanent teeth or implants), 1-20 teeth, or ≥21 teeth. A functional dentition was defined as having 21 or more teeth present. HEI scores and nutrient intakes were based on one 24-hour dietary recall.* ***Results:*** *Males with a functional dentition consumed slightly more fruit and had higher alpha- and beta-carotene intakes than edentulous males. Females with any natural teeth had higher vitamin C intakes than edentulous females. There were no significant associations between dentate status and any of the remaining HEI scores or nutrient intakes for either sex.* ***Conclusions:*** *Having a functional dentition did not contribute substantially to higher HEI scores or nutrient intakes in this nationally representative sample of older adults. However, older men and women with no teeth or those who wear dentures consumed fewer servings of fruits and vegetables, especially those rich in carotenes and vitamin C, than those with teeth.*

Key Words: NHANES, Healthy Eating Index (HEI), nutrients, dentate status, carotenes, elderly

Introduction

Dentate status is an important factor affecting dietary intake and nutritional status. Older adults who are either edentulous, have fewer natural teeth, or fewer pairs of posterior teeth are less likely to eat fruits and vegetables like fresh apples, oranges, pears, carrots, tomatoes, and dark yellow and green leafy vegetables including salads, nuts, cooked meats, and well-done steaks (1-6). They have lower intakes of energy, protein, carotenes, vitamins A and C, B vitamins, calcium, non-heme iron, zinc, and dietary fiber (1-3,6-7), and higher intakes of total fat, saturated fat, and cholesterol (2,4). Yet, the studies that only examine the effect of dentate status on the intake of a few specific foods or nutrients fail to consider the impact a compromised dentition may have on the total diet. A few studies have examined the impact of various dentition characteristics on dietary variety or overall diet quality (1,2,7,8). In general, these researchers found that diet quality declines as oral problems increase or number of teeth decrease.

Another way to examine the effect of dentate status on food and nutrient intake is from the perspective of a "functional dentition." A "functional dentition" is based on the concept that a person requires a minimum number of natural teeth to have adequate dental function, without the aid of prosthetic replacements (9,10). When the number of teeth falls below this threshold, it can result in eating problems and selective food avoidance which may lead to compromised nutrient intakes (11). Generally, this threshold is set around 21 teeth (9-11).

Most of the studies that have examined the effect of compromised dentition on diet and nutritional status have not looked at men and women separately. It is well known that women often have lower energy and nutrient intakes than men and often prefer different foods than men (12-14). Compared with men, women tend to eat more fruits and vegetables, follow lower-fat dietary practices regarding meat and chicken, and substitute lower-fat alternatives for higher-fat counterparts for luncheon meats, dairy desserts, and salad dressings (15-18). Furthermore, women are more knowledgeable about food and nutrition than men, and are more likely to adopt dietary guidance designed to promote health and reduce the risk of chronic diseases (15,16,18,19). Because females tend to be more knowledgeable about food, nutrition, and diet–health relationships, they may be more likely than males to make modifications in

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their diet that compensate for a compromised dentition.

The objectives of this study were to use multivariate linear regression to examine the associations between functional dentition and (1) the Healthy Eating Index (HEI) scores and (2) nutrient intakes among adults, 60 years and over in the National Health and Nutrition Examination Survey (NHANES), 1999-2002. The HEI is a tool developed by the US Department of Agriculture's (USDA) Center for Nutrition Policy and Promotion, to assess and monitor the dietary status of Americans (20). We hypothesize that there will be significant associations between functional dentition and HEI scores and nutrient intakes with those with 21 or more teeth having higher scores and intakes than edentulous adults or those with less than 21 teeth. Furthermore, we hypothesize that males, more often than females, will have significant associations between functional dentition and the measures of food and nutrient intake.

Methods

NHANES is a cross-sectional, nationally representative health and nutrition examination survey conducted by the National Center for Health Statistics, Centers for Disease Control and Prevention. The survey design is a complex, stratified, multistage probability sample of the civilian, noninstitutionalized US population. In 1999-2002, adults 60 years of age and over were oversampled to improve the precision of the estimates for this age group.

The survey includes an interview administered in the home and a subsequent health examination performed at a mobile examination center (MEC). Trained interviewers conducted the interviews. Trained dentists performed the oral health examinations at the MEC, and the overall quality of the dentate status data was considered to be excellent (21). Additional details about these surveys can be found at http://www.cdc.gov/nchs/about/major/nhanes/datalink.htm.

Sample Population. A total of 4,976 adults, 60 years of age and over, were eligible to participate in NHANES 1999-2002. Of the eligible sample, 3,706 adults 60 years of age and over, or 74 percent, participated in the household interview. Approximately 87 percent (3,234) of the household interview sample also participated in the MEC exam. Only those adults who participated in both the household interview and the MEC exam were included in the analytic sample ($n = 3,234$).

Participants were excluded from this sample if their dietary recall was not reliable and complete (173), their race and ethnic group was "Other" (182), they had missing information on education (9), smoking status (3), self-reported health status (3), body mass index (BMI; 146), or dentate status (158). The final analytic sample size was 2,560 older adults.

Predictor and Confounding Variables. A person's dentate status was assigned to one of three categories based on a count of the number of permanent teeth present, regardless of the position of the teeth. The 12 anterior and 16 posterior teeth, excluding third molars were used for this count. Dental implants were considered to be the equivalent to natural teeth in this study and were counted as if the replaced permanent tooth was present. Participants who had no remaining natural permanent teeth or implants were defined as edentulous. Edentulous participants may have used removable dental prostheses (dentures), but we did not assess the impact of denture use. The remaining two dentate status categories were "1-20 natural teeth" and "21 or more natural teeth."

We used 21 or more natural teeth to define a "functional dentition" based on criteria described by Nuttall *et al.* (9). Using functional occlusal pairs in this analysis would have been the more preferred approach, but this information was not collected during NHANES 1999-2002. We could have derived summary measures of posterior units aggregating the number of occluding pairs, but they would be more representative of a static relationship between maxillary and mandibular teeth instead of a functional relationship.

Earlier bivariate analyses revealed that age, race/ethnicity, education, smoking status, self-reported health, and BMI were often significantly associated with the HEI scores (22). In the multivariate linear regression models examining the association between dentate status and HEI scores or nutrient intakes, these variables were treated as potential confounders and were defined in the following manner. We categorized age into three groups: 60-69 years old, 70-79 years old, and 80 years of age or over. Race/ethnicity consisted of non-Hispanic Whites, non-Hispanic Blacks, or Mexican Americans. We categorized education into three groups: less than high school (HS), high school diploma including a General Education Development high school equivalency degree (GED), or more than high school. We based the smoking status variable on cigarette smoking only. Participants who never smoked or smoked less than 100 cigarettes in their lifetime were labeled as "never smokers"; participants who smoked at least 100 cigarettes in their lifetime, but were not currently smoking were labeled "former smokers"; and participants who had smoked at least 100 cigarettes in their lifetime and currently smoked some days or everyday were labeled "current smokers."

BMI measures relative weight for height and is calculated by dividing weight in kilograms by the square of height in meters (kg/m^2). For these analyses, we created three categories for BMI using the National Heart, Lung, and Blood Institute definitions (23). We combined underweight and normal weight into one group labeled "BMI less than 25," and we combined obese and extremely obese into another group labeled "BMI greater than 29.9." The middle group consisted of overweight people (BMI: 25.0-29.9).

Response Variables. Trained interviewers conducted dietary recall interviews using an automated data

TABLE 1
Components of the Healthy Eating Index Scoring System for Adults 51 Years of Age and Over*†

Healthy Eating Index components	Criteria for minimum score of zero	Criteria for maximum score of 10 for males	Criteria for maximum score of 10 for females
Food group			
Meat	0 servings	2.5 servings‡§	2.2 servings‡§
Dairy	0 servings	2 servings	2 servings
Fruits	0 servings	3.2 servings	2.5 servings
Vegetables	0 servings	4.2 servings	3.5 servings
Grains	0 servings	9.1 servings	7.4 servings
Nutrient			
Total fat	≥45% of energy	≤30% of energy	≤30% of energy
Saturated fat	≥15% of energy	<10% of energy	<10% of energy
Cholesterol	≥450 mg	≤300 mg	≤300 mg
Sodium	≥4,800 mg	≤2,400 mg	≤2,400 mg
Dietary variety	≤3 different foods in a day	≥8 different foods in a day	≥8 different foods in a day

* Adapted from tables found in Basiotis *et al.* (20).
† The scoring range for each of the ten components is 0 to 10.
‡ The number of servings per day for meat, dairy, fruits, vegetables, and grains depend on the recommended energy allowance specified in the Food Guide Pyramid (26). The recommended energy allowance for males, 51 years of age and older, is 2,300 kcal and the recommended energy allowance for females is 1,900 kcal (27).
§ One serving of meat equals 2.5 ounces of lean meat.

collection system during the MEC examination. Detailed descriptions of the 1999-2000 and 2001-2002 dietary interview and data processing procedures can be found under the dietary interview components at http://www.cdc.gov/nchs/about/major/nhanes/exam99_00.htm and http://www.cdc.gov/nchs/about/major/nhanes/exam01_02.htm, respectively.

One 24-hour dietary recall was used to estimate intakes from foods and beverages. USDA calculated HEI component and overall scores for individuals with complete food recalls. Prior research has indicated that food intake data based on 1-day dietary recalls are reliable measures of usual intakes of population groups (24). USDA has followed this same approach in their examination of HEI scores in the Continuing Survey of Food Intakes by Individuals (CSFII) 1994-1996 and NHANES 1999-2000 (20,25). Because this report covers the survey years 1999-2002, we downloaded data files for HEI 1999-2000 and 2001-2002 from the USDA Center for Nutrition Policy and Promotion website (http://www.cnpp.usda.gov/HealthyEatingIndex.htm) and used them in these analyses. (Please note that at the time we began this project, the 1999-2002 dietary data had not been recalculated using The Healthy Eating Index 2005 scoring systems.)

HEI measures how well the diet of Americans conforms to the recommendations of the Dietary Guidelines for Americans and the Food Guide Pyramid (25,26). It is a summary measure of the overall quality of an individual's diet (broadly defined in terms of adequacy, moderation, and variety). The HEI consists of 10 components, each representing different aspects of a healthful diet (20).

Table 1 presents the HEI components and scoring system for adults 51 years of age and over. Components 1-5 measure the degree to which a person's diet conforms to the recommended number of servings for the five major food groups of the USDA Food Guide Pyramid (26): meat, dairy, fruits, vegetables, and grains. The recommended number of Pyramid servings for the five food groups depends on a person's caloric requirement (20). USDA estimated the recommended number of servings for the five food groups for males and females, 51 years of age and over, based on their recommended energy allowance. The recommended energy allowance for males, 51 years of age and over, is 2,300 kcal, and the recommended energy allowance for females is 1,900 kcal (20,27). If a person's diet met or exceeded the recommended number of servings for a food group, that person was awarded a score of 10 points. If a person did not eat any item from the food group, a score of zero was assigned. Intermediate scores were calculated proportionately to the number of servings or partial servings that a person consumed. For example, if eight servings are recommended for a food group and a person only consumed four servings, then the component score would be 5 points (20).

Components 6 and 7 measure total and saturated fat consumption, respectively, as a percentage of total food energy (calorie) intake. Component 8 measures total cholesterol intake, component 9 measures total sodium intake, and component 10 examines variety in a person's diet. The maximum score for each of these components is 10 and the minimum score is zero. High component scores indicate intakes close to the recommended ranges or amounts; low component scores indicate less compliance with the recommended ranges or amounts (20).

The overall or total HEI score is a summary measure of the overall quality of a person's diet. It is calculated by summing each of the 10

TABLE 2
Distribution of Characteristics among Survey Participants by Sex, NHANES 1999-2002

Characteristics	Males ($n = 1,277$) % (SE)	Females ($n = 1,283$) % (SE)
Age		
60-69 years	52.5 (1.8)	45.5 (2.3)
70-79 years	34.4 (1.6)	36.4 (1.8)
80 years and older	13.1 (1.1)	18.1 (1.2)
Race and ethnicity		
Non-Hispanic White	89.1 (1.1)	87.6 (1.4)
Non-Hispanic Black	7.6 (1.1)	9.3 (1.4)
Mexican American	3.3 (0.6)	3.0 (0.7)
Education		
Less than high school	28.3 (2.1)	29.0 (1.6)
High school or GED*	25.2 (2.1)	33.7 (1.4)
Greater than high school	46.5 (2.8)	37.3 (1.8)
Smoking status		
Never	30.7 (1.8)	59.8 (2.3)
Former	56.4 (1.8)	29.6 (2.2)
Current	12.9 (1.2)	10.6 (1.1)
Self-reported health		
Excellent or very good	44.9 (1.3)	40.9 (2.1)
Good	31.5 (1.4)	35.1 (2.1)
Fair or poor	23.5 (1.8)	24.0 (1.5)
Body Mass Index (BMI)†		
Less than 25.0	25.5 (1.4)	31.7 (1.8)
25.0-29.9	43.2 (1.6)	34.3 (1.7)
30.0 or more	31.2 (1.3)	34.0 (1.4)
Tooth retention		
Edentulous	20.6 (1.9)	24.6 (1.8)
1-20 teeth	32.3 (1.8)	33.8 (1.6)
21 or more teeth	47.0 (2.6)	41.6 (1.6)

* GED is a General Education Development high school equivalency degree.
† Underweight or normal weight (BMI < 25.0); overweight (BMI: 25.0-29.9); obese or extremely obese (BMI ≥ 30.0).
SE, standard error.

component scores. The maximum overall HEI score is 100. A HEI score over 80 implies a "good" diet, a HEI score between 51 and 80 implies a diet that "needs improvement," and a HEI score less than 51 implies a "poor" diet (20). Basiotis *et al.* provides a more detailed description about the HEI structure and coding system (20).

Nutrient intakes were calculated from the 24-hour dietary recalls. The nutrients examined in this report included: kilocalories, protein, carbohydrate, total and saturated fats, cholesterol, dietary fiber, vitamins A, C, E, B-6, and B-12, alpha- and beta-carotenes, beta-cryptoxanthin, lycopene, lutein, and zeaxanthin, thiamin, riboflavin, niacin, total folate, calcium, iron, magnesium, phosphorus, potassium, and zinc. We did not include nutrient intakes from dietary supplements in these analyses.

Statistical Tests. We analyzed data using SAS for Windows (release 9.1; SAS Institute Inc., Cary, NC) and SUDAAN (release 9.0; Research Triangle Institute Inc., Research Triangle Park, NC). We used sample weights that incorporated the differential probabilities of selection and included adjustments for oversampling of certain populations and nonresponse to the household interview and MEC examination. We report percentage distributions and standard errors for the confounding and predictor variables by sex.

To examine the association between dentate status and HEI component scores or nutrient intakes, we ran multivariate linear regression models controlling for the potential confounders age, race/ethnicity, education, smoking status, BMI, and self-reported health. We also controlled for the confounding effect of caloric intake on HEI scores and nutrient intakes. We ran separate multivariate linear regressions for each sex. Log_{10} transformations were performed for those nutrients that deviated substantially from normality. Because zero cannot be log-transformed, when a nutrient intake was zero, this value was recoded to a value greater than zero, but less than the lowest intake reported for that nutrient.

We assessed the significance of the effect of dentate status in the model using a Satterthwaite-adjusted F statistic with statistical significance set at $P < 0.05$. We compared the Least Square Means (LSM) for HEI scores and nutrient intakes among the three dentate status categories using the Satterthwaite-adjusted F statistic, and we used the Bonferroni method of adjusting the critical value of 0.5 for the family of pair-wise comparisons. For nutrients that were transformed, the significance tests were based on the log-transformed values.

Results

Sample. Table 2 presents the weighted distribution for the confounding and predictor variables among the analytic sample. The sample size for males was 1,277 and the sample size for females was 1,283. Slightly more males than females were in the 60- to 69-year-old age group, but the opposite pattern was true for participants who were 80 years of age and over. The samples were primarily non-Hispanic White (89 percent for males and 88 percent for females) and more than two-thirds of them had a high school degree or a more advanced education (approximately 71 percent for each sex). More males than females were current or former smokers (69 percent males versus 40 percent females), and about three out of four respondents from both sexes rated their health as good or better. BMIs for females were fairly evenly

distributed among the three BMI categories (32 percent, 34 percent, and 34 percent). Fewer males than females were in the underweight and normal weight BMI category (26 percent), but more males than females were in the overweight category (43 percent). The distribution of males and females across the dentate status categories were fairly similar, although slightly more females than males were edentulous (21 percent males versus 25 percent females) and slightly more males than females had 21 or more teeth (47 percent males versus 42 percent females).

HEI Scores. After controlling for caloric intake and the other potential confounders, we observed a statistically significant association between dentate status and the fruit scores for males ($P < 0.05$) (Table 3). Males with 21 or more teeth had a significantly higher fruit score than edentulous males (LSM: 5.0 versus 4.0; $P < 0.017$), but there was no significant difference between those with 21 or more teeth and those with 1-20 teeth. There was a significant association between dentate status and the overall HEI score for females ($P < 0.05$), but no significant differences in the overall HEI scores among the three levels of dentate status (Table 3). The models for the fruit and vegetable components for females were close to the critical value but did not reach statistical significance. After controlling for caloric intake and the other potential confounders, there were no statistically significant associations between dentate status and any of the other HEI component scores or the overall HEI score for either sex.

When the fruit and vegetable component scores are viewed in terms of the recommendations from the Food Guide Pyramid (Table 1), males with a functional dentition (21 or more teeth) consumed half the recommended number of servings of fruit and females with a functional dentition consumed a little less than two-thirds of the recommended number of servings of fruit. Those with no natural teeth or less than 21 teeth consumed even fewer servings of fruit per day than those with a functional dentition. In contrast, males and females with 1-20 teeth consumed a little more than two-thirds of the recommended number of servings of vegetables, while edentulous males and females and those with a functional dentition consumed even fewer servings of vegetables per day than those with 1-20 teeth. The overall HEI score, which is a summary measure of the overall quality of a person's diet, indicates that regardless of dentate status, the diets of both sexes "need improvement."

Nutrient Intakes. We examined the associations between dentate status and caloric intakes controlling for the potential confounders in the models. We also controlled for caloric intake in the models examining the associations between dentate status and the macronutrients, vitamins, and minerals. Table 4 and the appendix list LSMs and standard errors for nutrients. We report the antilogs of the LSMs and standard errors for nutrients that were log-transformed prior to analysis.

Dentate status was significantly associated with alpha- and beta-carotene intakes for males ($P < 0.05$ for each nutrient), and vitamin C intakes for females ($P < 0.001$) (Table 4). Specifically, males with 21 or more teeth had significantly higher alpha- and beta-carotene intakes than edentulous males. The LSMs were 58.3 μg versus 20.0 μg, respectively ($P < 0.017$), for alpha-carotene and 1,059 μg versus 723 μg, respectively ($P < 0.017$), for beta-carotene. There were no significant differences between those with 21 or more teeth and those with 1-20 teeth for either nutrient. Females with any natural teeth had significantly higher vitamin C intakes than edentulous females (LSM: 69.2 mg for 1-20 teeth, 64.6 mg for 21 or more teeth, and 50.1 mg for edentulous females; $P < 0.017$ for each comparison). There was also a significant association between dentate status and riboflavin intakes for males ($P < 0.05$), but no significant differences in the intake levels among the three dentate status categories (see the appendix). Dentate status was not significantly associated with kilocalories, protein, carbohydrate, total and saturated fats, cholesterol, dietary fiber, vitamins A, B-6 and B-12, beta-cryptoxanthin, lycopene, lutein and zeaxanthin, thiamin, niacin, total folate, calcium, iron, magnesium, phosphorus, potassium, and zinc for either sex.

Discussion

The purpose of this study was to examine the associations between a functional dentition, defined as 21 or more teeth, and HEI scores and nutrient intakes among older adults. The results indicate that having a functional dentition did not contribute substantially to higher HEI scores or nutrient intakes in this nationally representative study of adults 60 years of age and over. Males having 21 or more teeth consumed slightly more fruit and had higher alpha- and beta-carotene intakes than edentulous males, but their intakes were not significantly higher than males with 1-20 teeth. Females with any natural teeth had higher vitamin C intakes than edentulous females. In general, these results seem to indicate that older men and women with no teeth or those who wear dentures consumed fewer servings of fruits and vegetables, especially those rich in carotenes and vitamin C, than those with teeth. These results may reflect differences in food choices between men and women. They may also indicate that women may be better able to modify their diets when faced with limited dentition because they tend to have more knowledge about food and nutrition than men.

Although we did not examine the specific foods that these older adults ate, the main food sources of carotenoids and vitamin C are fruits and vegetables (28). According to CSFII 1989-1991 and 1994-1996, the major sources of carotenes in the diets of US adults were carrots, tomatoes and tomato juices, spinach and other greens, sweet potatoes, cantaloupe, broccoli, and peppers, and the major sources of vitamin C were citrus

TABLE 3
Associations Between Tooth Retention and Healthy Eating Index (HEI) Component and Overall Scores for Adults 60 Years of Age and Older, Controlling for Kilocalories, Socio-Demographic and Health Characteristics: United States, 1999-2002*

	Males			Females		
HEI component	R^2 for model†	*P*-value‡	LSM (SE)§	R^2 for model†	*P*-value‡	LSM (SE)§
Meats	14.5%	0.758		17.7%	0.232	
Edentulous			7.1 (0.2)¶			5.9 (0.3)¶
1-20 teeth			7.3 (0.2)			5.9 (0.2)
21 or more teeth			7.1 (0.1)			6.4 (0.2)
Dairy	14.8%	0.327		17.2%	0.385	
Edentulous			6.1 (0.3)			5.0 (0.3)
1-20 teeth			5.9 (0.2)			5.4 (0.2)
21 or more teeth			5.6 (0.1)			5.3 (0.2)
Fruits	14.4%	0.013		10.7%	0.051	
Edentulous			4.0 (0.3)a,**			5.3 (0.2)
1-20 teeth			4.6 (0.2)a,b			5.7 (0.2)
21 or more teeth			5.0 (0.2)b			6.1 (0.2)
Vegetables	10.6%	0.152		9.4%	0.053	
Edentulous			6.3 (0.3)			6.1 (0.3)
1-20 teeth			6.8 (0.1)			6.8 (0.2)
21 or more teeth			6.4 (0.2)			6.6 (0.2)
Grains	27.3%	0.847		32.5%	0.407	
Edentulous			6.6 (0.2)			6.6 (0.2)
1-20 teeth			6.5 (0.2)			6.5 (0.1)
21 or more teeth			6.5 (0.1)			6.3 (0.2)
Total fat	4.0%	0.928		6.2%	0.743	
Edentulous			6.5 (0.3)			6.4 (0.2)
1-20 teeth			6.4 (0.2)			6.6 (0.2)
21 or more teeth			6.3 (0.2)			6.6 (0.2)
Saturated fat	4.8%	0.334		5.4%	0.410	
Edentulous			6.9 (0.4)			7.0 (0.3)
1-20 teeth			6.4 (0.2)			7.4 (0.2)
21 or more teeth			7.0 (0.2)			7.1 (0.2)
Cholesterol	14.2%	0.368		8.7%	0.868	
Edentulous			7.3 (0.3)			8.3 (0.2)
1-20 teeth			7.2 (0.3)			8.4 (0.2)
21 or more teeth			7.7 (0.2)			8.5 (0.2)
Sodium	37.0%	0.484		38.0%	0.654	
Edentulous			5.7 (0.3)			7.8 (0.2)
1-20 teeth			6.1 (0.2)			8.0 (0.2)
21 or more teeth			6.0 (0.1)			8.1 (0.1)
Dietary variety	26.0%	0.059		22.9%	0.642	
Edentulous			7.8 (0.2)			7.6 (0.2)
1-20 teeth			8.4 (0.1)			7.8 (0.2)
21 or more teeth			8.3 (0.1)			7.9 (0.2)
Overall HEI	14.9%	0.432		13.1%	0.046	
Edentulous			64.3 (0.9)			66.1 (0.9)
1-20 teeth			65.5 (0.7)			68.4 (0.8)
21 or more teeth			66.0 (0.8)			68.8 (0.7)

* The independent variables in the regression model include the potential confounders and tooth retention. The confounders were age, race and ethnicity, education, smoking status, self-reported health, BMI, and caloric intake.
† This statistic is a model-based R^2, not a design-based R^2.
‡ Based on Satterthwaite-adjusted *F* statistic testing the relationship between tooth retention and HEI scores.
§ LSM, Least square means; SE, standard error.
¶ LSMs for tooth retention were compared using the Bonferroni method of adjusting the critical value of 0.5 for the family of pair-wise comparisons. LSMs with different letters are significantly different from each other. No letters are shown if there are no significant differences among the LSMs.
** $p < 0.017$.

TABLE 4
Associations Between Tooth Retention and Selected Nutrient Intakes for Adults 60 Years of Age and Older, Controlling for Kilocalories, Socio-demographic and Health Characteristics: United States, 1999-2002.*

	Males			Females		
Nutrient	R^2 for model† (%)	*P*-value‡	LSM (SE)§	R^2 for model† (%)	*P*-value‡	LSM (SE)§
Kilocalories	6.2%	0.110		4.8%	0.856	
Edentulous			1948 (58)¶			1548 (57)¶
1-20 teeth			2079 (39)			1556 (37)
21 or more teeth			2136 (60)			1573 (38)
Protein (gm)	61.1%	0.487		56.5%	0.308	
Edentulous			81 (2)			60 (1)
1-20 teeth			83 (2)			59 (1)
21 or more teeth			81 (1)			61 (1)
Carbohydrate (gm)	74.1%	0.287		73.7%	0.171	
Edentulous			260 (4)			201 (3)
1-20 teeth			253 (4)			204 (3)
21 or more teeth			250 (4)			196 (3)
Total fat (gm)	78.6%	0.395		72.9%	0.545	
Edentulous			77 (2)			60 (1)
1-20 teeth			80 (1)			59 (1)
21 or more teeth			81 (1)			60 (1)
Alpha-carotene (µg)**	9.9%	0.009		5.9%	0.358	
Edentulous			20.0 (1.3)a,††,‡‡			46.8 (1.2)††
1-20 teeth			38.2 (1.2)a,b			60.3 (1.1)
21 or more teeth			58.3 (1.1)b			55.0 (1.1)
Beta-carotene (µg)**	11.1%	0.026		9.0%	0.248	
Edentulous			723 (1.1)a,††,‡‡			871 (1.1)††
1-20 teeth			889 (1.1)a,b			1023 (1.1)
21 or more teeth			1059 (1.1)b			1047 (1.1)
Vitamin C (mg)**	17.3%	0.060		16.5%	<0.001	
Edentulous			49.5 (1.1)††			50.1 (1.1)a,††,‡‡
1-20 teeth			64.3 (1.1)			69.2 (1.0)b
21 or more teeth			66.2 (1.0)			64.6 (1.1)b
Vitamin E as alpha-tocopherol (mg)**	38.4%	0.114		40.9%	0.232	
Edentulous			5.6 (1.0)††			4.5 (1.0)††
1-20 teeth			5.5 (1.0)			4.9 (1.0)
21 or more teeth			6.1 (1.0)			4.8 (1.0)
Folate (µg)**	37.9%	0.661		36.9%	0.699	
Edentulous			350 (1.0)††			285 (1.0)††
1-20 teeth			356 (1.0)			295 (1.0)
21 or more teeth			344 (1.0)			291 (1.0)

* Independent variables in the regression model include the potential confounders and tooth retention. The confounders were age, race and ethnicity, education, smoking status, self-reported health, BMI, and caloric intake.
† This statistic is a model-based R^2, not a design-based R^2.
‡ Based on Satterthwaite-adjusted *F* statistic testing the relationship between tooth retention and nutrient intakes.
§ LSM, Least Squares Means; SE, standard error.
¶ LSMs for tooth retention were compared using the Bonferroni method of adjusting the critical value of 0.5 for the family of pair-wise comparisons. LSMs with different letters are significantly different from each other. No letters are shown if there are no significant differences among the LSMs.
** Nutrient values were transformed using a Log_{10} transformation prior to regression analyses.
†† Antilog of the Log_{10} values for least squares means and standard errors from the linear regression.
‡‡ $p < 0.017$.

juices, fruit drinks, tomatoes, peppers, white potatoes, broccoli, and oranges/tangerines (29).

Older adults in the NHANES survey consumed between 40 and 61 percent of the recommended number of servings of fruit from the Food Guide Pyramid and consumed between 61 and 68 percent of the recommended number of servings of vegetables. The overall HEI score, which is a summary measure of the overall quality of a person's diet, indicates that the diets of both sexes "need improvement" regardless of dental status.

It is not unusual for older adults to have low fruit and vegetable intakes. Sahyoun *et al.* (2) reported the mean HEI fruit component scores for males and females 50 years and

over in NHANES III were 4.4 and 5.4, respectively, and mean vegetable component scores were 6.6 for each sex, after controlling for caloric intake and other potential confounders. Basiotis *et al.* (20) reported the mean fruit component scores for males and females 51 years and over in NHANES 1999-2000 were 4.5 and 5.3, respectively, and the mean vegetable component scores were 6.7 and 6.4, respectively.

When food and nutrient intakes have been examined in connection with dentate status, other researchers (1-7) have reported that older adults who were edentulous, had a limited number of teeth, had fewer occluding pairs of teeth or complained of persistent oral health problems had lower fruit and vegetable intakes, less variety in their diets, and a lower overall quality to their diets. They also had lower intakes of energy, protein, fat, fiber, vitamins A, C, and E, carotenes, and most other nutrients. It is not clear why we did not observe many of the differences in nutrient intakes that other studies reported. One possible reason may be because we used too few dentate status categories with each of our categories consisting of more teeth. Other researchers have examined food and nutrient intakes based on the number of posterior occluding pairs of teeth, or treated the total tooth count as a continuous variable or created more dentate status categories with each category containing a smaller number of teeth. Nonetheless, these studies consistently demonstrate that there is a positive association between the presence and number of teeth and fruit and vegetable intakes as well as intakes of many of the leading nutrients found in these foods.

It is unfortunate if older adults are restricting fruit and vegetable intakes because of limited dentition. Increased intakes of fruits and vegetables may reduce the risk of some chronic diseases. Fruits and vegetables are rich sources of carotenoids, including those with provitamin A activity, vitamin C, folate, potassium, fiber, and other substances associated with good health. Carotenoid-rich diets have been associated with reduced risk of many types of cancer and cardiovascular disease. Vitamin C is an antioxidant. Although evidence is limited at present, some studies suggest a protective effect of vitamin C against cardiovascular disease and some types of cancers (28). Finally, fiber has been shown to attenuate blood glucose responses, normalize blood lipid concentrations, and improve laxation (30).

There are limitations to this study. Estimates were based on one 24-hour recall per respondent. However, 1-day dietary recalls can be used to provide reliable estimates of usual intakes of population groups (24). These data were cross-sectional in nature and, therefore, causal associations can not be established based on these results. It would have been helpful to have serum carotenoid and vitamin C levels available to compare with the dietary intakes, but these nutritional biochemistries were not available for the full 4 years used in these analyses. However, other researchers have shown that edentulous adults or those with fewer teeth or fewer posterior pairs of occluding teeth had significantly lower blood levels of vitamin C and beta-carotene (2,3,5,6). Finally, our models generally only explained a small amount of the variation in the food and nutrient intakes. Other factors not present in these models, such as diet and health knowledge, food preferences, and income, might have explained more of the variation.

In conclusion, having a functional dentition did not contribute substantially to higher HEI component scores, the overall quality of the diet, or nutrient intakes in this nationally representative sample of older adults. If anything, older men and women with no teeth or those who wear dentures consumed fewer servings of fruits and vegetables, especially those rich in carotenes and vitamin C, than those with teeth. Males with 21 or more teeth had higher fruit intakes and alpha- and beta-carotene intakes than edentulous males, but their intakes were not significantly different from those of males with 1-20 teeth. Females with any natural teeth had higher vitamin C intakes than edentulous females. More importantly, older adults did not meet the recommended intakes for fruits and vegetables, and their overall dietary quality "needs improvement," regardless of their dentition status. Adults in this age group need to be encouraged to eat more fruits and vegetables, especially foods rich in vitamin C and, for males, foods rich in alpha- and beta-carotenes.

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APPENDIX

Associations Between Tooth Retention and Selected Nutrient Intakes for Adults 60 Years of Age and Older, Controlling for Kilocalories, Socio-demographic and Health Characteristics: United States, 1999-2002*

	Males			Females		
Nutrient	R^2 for model†	*P*-value‡	LSM (SE)§	R^2 for model†	*P*-value‡	LSM (SE)§
Saturated fat (gm)	68.1%	0.574		60.9%	0.492	
Edentulous			25 (1)¶			19 (<1)¶
1-20 teeth			26 (<1)			18 (<1)
21 or more teeth			25 (1)			18 (<1)
Cholesterol (mg)	25.3%	0.584		16.0%	0.461	
Edentulous			296 (25)			227 (16)
1-20 teeth			296 (13)			207 (10)
21 or more teeth			278 (10)			216 (7)
Dietary fiber (gm)	33.7%	0.910		32.3%	0.106	
Edentulous			18 (0.6)			13 (0.6)
1-20 teeth			18 (0.7)			14 (0.5)
21 or more teeth			18 (0.4)			15 (0.4)
Vitamin A, RAE (μg)**	22.3%	0.248		24.1%	0.647	
Edentulous			557 (1.0)††			479 (1.1)††
1-20 teeth			508 (1.0)			468 (1.0)
21 or more teeth			509 (1.0)			447 (1.0)
Beta-cryptoxanthin (μg)**	9.6%	0.153		7.3%	0.864	
Edentulous			22.4 (1.3)††			33.9 (1.2)††
1-20 teeth			34.4 (1.1)			37.2 (1.1)
21 or more teeth			38.5 (1.2)			37.2 (1.2)
Lycopene (μg)**	6.4%	0.231		5.2%	0.206	
Edentulous			32.4 (1.5)††			49.0 (1.4)††
1-20 teeth			84.5 (1.3)			74.1 (1.5)
21 or more teeth			65.8 (1.3)			35.5 (1.3)

Appendix
Continued

Nutrient	Males			Females		
	R^2 for model†	*P*-value‡	LSM (SE)§	R^2 for model†	*P*-value‡	LSM (SE)§
Lutein & Zeaxanthin (μg)**	12.7%	0.300		7.8%	0.268	
Edentulous			740 (1.1)††			759 (1.1)††
1-20 teeth			849 (1.1)			871 (1.0)
21 or more teeth			838 (1.1)			871 (1.1)
Thiamin (mg)	41.6%	0.187		39.0%	0.219	
Edentulous			1.8 (0.1)			1.3 (<0.1)
1-20 teeth			1.7 (<0.1)			1.4 (<0.1)
21 or more teeth			1.7 (<0.1)			1.3 (<0.1)
Riboflavin (mg)	42.9%	0.046		39.2%	0.532	
Edentulous			2.4 (0.1)			1.8 (0.1)
1-20 teeth			2.2 (0.1)			1.8 (<0.1)
21 or more teeth			2.1 (<0.1)			1.7 (<0.1)
Niacin (mg)	42.0%	0.309		36.8%	0.773	
Edentulous			24.4 (0.9)			17.5 (0.4)
1-20 teeth			23.8 (0.6)			17.8 (0.5)
21 or more teeth			22.9 (0.4)			17.5 (0.3)
Vitamin B–6 (mg)**	34.2%	0.205		34.2%	0.582	
Edentulous			1.8 (1.0)††			1.3 (1.0)††
1-20 teeth			1.7 (1.0)			1.3 (1.0)
21 or more teeth			1.7 (1.0)			1.3 (1.0)
Vitamin B-12 (μg)**	18.7%	0.116		21.9%	0.513	
Edentulous			4.0 (1.1)††			2.9 (1.1)††
1-20 teeth			4.2 (1.0)			2.9 (1.0)
21 or more teeth			3.7 (1.0)			2.7 (1.0)
Calcium (mg)	39.1%	0.510		29.8%	0.358	
Edentulous			849 (38.7)			652 (25.4)
1-20 teeth			843 (19.6)			695 (21.2)
21 or more teeth			809 (21.5)			668 (16.8)
Iron (mg)	29.8%	0.403		31.6%	0.481	
Edentulous			17.5 (0.8)			13.0 (0.5)
1-20 teeth			17.4 (0.5)			13.3 (0.4)
21 or more teeth			16.4 (0.4)			12.7 (0.3)
Magnesium (mg)	51.7%	0.778		47.6%	0.070	
Edentulous			307 (10.8)			220 (6.2)
1-20 teeth			310 (8.3)			234 (5.9)
21 or more teeth			303 (5.9)			242 (4.8)
Phosphorus (mg)	68.9%	0.215		59.6%	0.431	
Edentulous			1,355 (30.9)			978 (21.1)
1-20 teeth			1,347 (23.9)			999 (15.8)
21 or more teeth			1,299 (19.3)			1,016 (16.5)
Potassium (mg)	52.8%	0.664		45.3%	0.084	
Edentulous			3,056 (74.5)			2,255 (65.0)
1-20 teeth			3,038 (57.6)			2,384 (43.2)
21 or more teeth			2,981 (49.9)			2,434 (45.0)
Zinc (mg)**	38.4%	0.630		39.5%	0.531	
Edentulous			10.7 (1.0)††			7.3 (1.0)††
1-20 teeth			10.7 (1.0)			7.7 (1.0)
21 or more teeth			10.3 (1.0)			7.7 (1.0)

* Independent variables in the regression model include the potential confounders and tooth retention. The confounders were: age, race and ethnicity, education, smoking status, self-reported health, BMI, and caloric intake.

† This statistic is a model-based R^2, not a design-based R^2.

‡ Based on Satterthwaite-adjusted *F* statistic testing the relationship between tooth retention and nutrient intakes.

§ LSM, Least Squares Means; SE, Standard error.

¶ LSMs for tooth retention were compared using the Bonferroni method of adjusting the critical value of 0.5 for the family of pairwise comparisons. LSMs with different letters are significantly different from each other. No letters are shown if there are no significant differences among the LSMs.

** Nutrient values were transformed using a Log_{10} transformation prior to regression analyses.

†† Antilog of the Log_{10} values for least squares means and standard errors from the linear regression.