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An Oral Health Study of Centenarians and Children of Centenarians

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Abstract

BACKGROUND—Poor oral health has been associated with age-related diseases such as cardiovascular disease and diabetes. Given that centenarians and their offspring significantly delay or escape age-related diseases compared to their respective birth cohorts, we hypothesized that oral health is better in these two cohorts relative to published birth-cohort matched results for centenarians and in an offspring cohort referent sample.

DESIGN—Observational cross-sectional study.

SETTING—The New England Centenarian Study (NECS).

PARTICIPANTS—Seventy-three centenarians, 467 offspring, and 251 offspring generation referent cohort subjects from the NECS.

MEASUREMENTS—A self-report questionnaire measured oral health in all three groups, with edentulous rate as the primary outcome measure. Socio-demographic and medical history were made available by the NECS. Centenarian results were compared to published birth-cohort matched results. Data from offspring and referent cohorts were analyzed to determine differences in oral health and associations between oral health measures and specific medical conditions.

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RESULTS—The edentulous rate of centenarians (36.5%) was lower than their birth cohort (46%) when they were ages 65-74 years in 1971-1974 (per National Center of Health Statistics). Adjusting for confounding factors, in comparison to the centenarian offspring, the referent cohort was more likely to be edentulous (AOR=2.78, 95%, CI=1.17-6.56), less likely to have all or more than half of their own teeth (AOR=0.48, 95%, CI=0.3-0.76), and less likely to report excellent/very good oral health (AOR=0.65, 95%, CI=0.45-0.94).

CONCLUSION—These findings support the hypothesis that centenarians and their offspring exhibit better oral health than their respective birth cohorts. Oral health may prove to be a helpful marker for systemic health and healthy aging.

Keywords

centenarian; centenarian offspring; offspring; oral health; edentulous rate; longevity

INTRODUCTION

Oral health is defined by the condition of the of the oral cavity that enables an individual to eat, speak and socialize free of pain, disease and social embarrassment.¹ Since functional oral health determines the ability to eat and communicate, it is a vital component of overall well-being.

The retention of natural teeth over a lifetime is one indicator of oral health. The last 40 years have seen a dramatic decline in the edentulous (complete tooth loss) rate of older adults aged 65-74 in the United States, from 45% in 1971-74 to 28% in 1988-1994.² The rate of edentulism is expected to continue to decline due to environmental and educational interventions and declines in smoking.

During the second half of the twentieth century dentistry evolved as a profession from solely treating dental disease, to emphasizing prevention through public health measures, increased public awareness and education. These factors allowed increasing numbers of people to retain their own teeth throughout their lives.³

The association between poor oral health and systemic diseases is well known⁴ as is the association between periodontal disease, atherosclerosis and cardiovascular disease.⁵⁻⁷ Periodontal disease, cardiovascular disease and stroke have a number of risk factors in common including older age, cigarette smoking, diabetes mellitus and poor access to health care. However because of the observational nature of much of the evidence, the American Heart Association's consensus statement notes there is no evidence to support a causal relation between periodontal disease and atherosclerotic vascular disease.⁶

The New England Centenarian Study (NECS) is a longitudinal study of centenarians, centenarian offspring, and an offspring referent cohort, and collects data on participants to assess the incidence of age-related diseases and mortality. In this study, about 45% of people surviving to approximately 100 years of age do not experience age-related diseases until after the age of 80 years and another 15% do not have age-related diseases associated with increased mortality risk until after the age of 100.⁸ With increasing age beyond 100,

morbidity generally becomes increasingly compressed towards the end of life.⁹ Therefore, we sought to investigate the associations between specific measures of oral health and exceptional survival.

Because centenarians and their offspring both demonstrate a marked delay in age related diseases,⁹⁻¹¹ relative to their birth cohorts, we hypothesized that both cohorts would demonstrate better oral health relative to their birth cohorts. The above brief historical synopsis of public oral health measures suggests that factors influencing oral health were quite different between these two generations. Thus it is important to compare centenarians and the offspring with birth cohort matched referent groups in order to assess any oral health advantage. In a prospective longitudinal study such as the NECS we can establish a birth-cohort matched referent group of the younger generation (such as spouses or the offspring of people born in the same time period as the centenarians but who died at average life expectancy), but such a prospective referent cohort for centenarians is much more difficult to come by because such subjects have already died long-ago. Thus, for this study, we rely upon historical data gathered by the US Centers for Disease Control to compare edentulous rates in centenarians to the birth cohort matched population when they were in their 60s and 70s. Additional data were not available to allow for more in-depth analyses such as accounting for potential confounders. However, in the case of the offspring and a referent group for which we had similarly collected data on potential confounders, we were able to perform a more in-depth analysis.

METHODS

Subjects

The New England Centenarian Study has been recruiting and enrolling centenarians and their family members from across the United States since 1995. As the population of centenarians has increased since then, the minimum age of enrollment in the New England Centenarian Study has increased from 95 years to 103 years (www.bumc.bu.edu/centenarian). The centenarian generation has an annual mortality rate of approximately 30%, and at any one time about 10% of the centenarian subjects in the study are alive. The annual mortality rate among the children of centenarians is currently 1.6% and for the offspring generation referent cohort it is 2.4%. All living potential subjects were contacted for participation in this cross-sectional study of oral health. The number of subjects that participated were 64 out of 73 centenarians (88%), 3 out of 3 nonagenarians (100%), 437 out of 467 (94%) offspring and 229 out of 251 (91%) offspring controls. The 9 centenarians who did not participate had died before or during the data collection effort.

The control group consisted of unrelated spouses of centenarian offspring (n=111) and unrelated individuals (n=118) whose parents were born in the same time period as the centenarians, with at least one parent who died at average life expectancy for the 1900 birth cohort which was 73 years (the methods for recruitment of this sample can be found in reference¹²). Eleven percent of the centenarian/nonagenarian sample was African-American. In the offspring and offspring control samples, the frequencies of non-Caucasians were 1.3% and 1.0%, respectively.

Data collection

Oral health variables—A self-report oral health questionnaire was developed in conjunction with faculty and researchers at the Boston University Henry M. Goldman School of Dental Medicine. Participants received the oral health questionnaire by mail, and when necessary, were assisted in answering the questions by a care-provider. The thirteen item questionnaire, administered from May to October 2011, consisted of eleven dental health questions and two general health questions. The oral health variables were self-assessed and included approximate number of remaining natural teeth, edentulous rate, oral health status and oral health habits. Oral health status was measured utilizing a Likert scale of five options, ranging from excellent to poor oral health.¹³ Participants reported the number of teeth present, with the following options: all teeth present (28-32 teeth); more than half of teeth present (16 or more); less than half teeth present (fewer than 16); or none present (edentulous).¹⁴ Subjects were asked to report the presence of any loose teeth or bleeding gums and whether or not they wear full or partial removable dentures. They were also asked about the number of visits to a dentist or dental hygienist in the past year and the number of times per day of tooth brushing and flossing.

Systemic health and other variables—Health status data are collected and updated annually for all New England Centenarian Study subjects via a validated self-report questionnaire.⁹ Health data included in these analyses were presence or past history of hypertension, diabetes, stroke, myocardial infarction, cancer (not including non-melanoma skin cancers) and osteoporosis (defined as a history of hip, vertebral or wrist fracture after the age of 50 years or physician reported diagnosis of osteoporosis). Other variables included income, categorized as greater or less than \$30,000, or 300% of the income at federal poverty level, and education, categorized as greater or less than high school graduate level.

Statistical analysis

The primary outcome of interest for the centenarian/nonagenarian, offspring and offspring controls was edentulous rate. Chi-square tests of independence were performed on the oral health outcomes as well as the systemic disease data for the comparison of the offspring and birth-cohort matched control groups (see Table 1). Such a comparison was not performed with the centenarian/nonagenarian subjects due to the lack of similar data from a birth-cohort matched sample not achieving exceptional longevity. Instead, centenarian data were qualitatively compared against edentulous rates for older adults reported in the 1970s (see discussion).

Chi-square tests of independence were also used for comparing disease prevalence rates in the combined sample of centenarian offspring and controls according to oral health measures (see Table 2). We combined the two groups for this analysis because the rates of diabetes, myocardial infarction and stroke were too small to assess associations between gradations of oral health and specific diseases.

Logistic regression was used to compare the likelihood of having excellent/very good general health; excellent/very good health of teeth and gums; and the presence of all or more

than half of the teeth between the control and offspring groups, adjusting for confounders: education, age, income, smoking, and osteoporosis (see Table 3). The statistical significance level was set at p -value 0.05. All statistical analyses were performed using SAS (Cary, NC, Version 9.3.)

RESULTS

The centenarian response rate was 87.7%, with 64 participants completing the study questionnaire (48 women, mean age 107.1 years, and 16 men, mean age 104.3 years). The response rate for the centenarian offspring was 93.6% ($n=437$, 280 women, mean age 77.8 years and 157 men, mean age 78.1 years) and for the controls the response rate was 91.2% ($n=229$, 116 women, mean age 75.9 years and 113 men, mean age 78.7 years). Table 1 displays characteristics of the three groups (centenarians, offspring and offspring controls), their oral health measures and the history or presence of specific diseases.

Among the centenarians, 34.9% had all or more than half of their teeth remaining and 36.5% reported having no natural teeth remaining (31.3% of the males and 37.5% of the females). Among the offspring, 85.1% reported all or more than half of their natural teeth remaining, and 3.4% reported having no natural teeth remaining. In comparison, 76.9% of the control group reported all or more than half of their natural teeth, and 7.0% reported no remaining natural teeth ($p=0.02$, Table 1). Excellent or very good oral health was reported by 63.2% of the offspring compared to 54.1% of the control group ($p=0.02$).

Among the centenarians, 45.9% reported hypertension, 3.3% reported diabetes, and 10.0% reported myocardial infarction. Significant differences between the offspring and controls were observed for hypertension, diabetes, myocardial infarction and stroke for men and women combined. There was no statistically significant difference for stroke between offspring and control males, and for women there were no significant differences for hypertension, myocardial infarction or stroke between the offspring and control groups.

The association between oral health measures and specific age-related diseases in offspring and controls combined is summarized in Table 2. Better oral health was associated with the absence of each of the following: hypertension, diabetes, myocardial infarction, and stroke. For example, 62.0% of those without diabetes compared to 42.7% with diabetes reported excellent or very good oral health ($p<0.01$). Diabetes was also associated with denture wearing: 24.5% of non-diabetics compared to 39.7% of diabetics reported having dentures ($p<0.01$). Significant associations with good oral health were not noted with absence of cancer or presence of osteoporosis.

We performed a logistic regression analysis to account for potential confounders that could affect the relative odds of excellent to very good physical health and different gradations of oral health for the offspring and controls. "Excellent to very good physical health" was one of five points on a Likert scale subjectively rating physical health. Age, sex, tobacco use, years of education and income were potential confounders as they are independent risk factors for tooth loss, dental caries or edentulism. We also included presence of osteoporosis since several studies, including the OSTEODENT Study, identify osteoporosis as a risk

factor for tooth loss independent of smoking and age.¹⁵ In the multivariable analyses adjusting for sex, age, education, income, smoking and osteoporosis (Table 3), the control group had only 65% the odds of the offspring in reporting excellent or very good general health, 66% odds of reporting excellent or very good oral health and 48% odds of having all or more than half of their teeth. Conversely, the control group had 278% odds of having no teeth, compared to the offspring group, and adjusting for the above factors (Table 3).

DISCUSSION

The primary outcome of interest in this study was the edentulous rate in the centenarian and the offspring cohorts. The centenarian cohorts' edentulous rate was greater than in the offspring and control groups. The higher edentulous rate amongst the centenarians was likely due to the lack of preventive oral health care during the childhood and early to mid-adult years of that generation.

In order to interpret the edentulous rate of the centenarians in the context of their birth cohort we sought results from other appropriate data sets. The National Center for Health Statistics periodically collects and maintains statistics on the edentulous rates in the United States population. In 2005-2008, the edentulous rate for those aged over 65 years was approximately 23%.¹⁶ For the period 1971-1974 (reflective of the centenarians' birth cohort who were born from 1896 to 1915), the edentulous rate was 46% for people aged 65 to 74 years.² Thus the centenarians in this study had a lower edentulous rate (36.5%) at their advanced ages than the rate reported for their birth cohort approximately forty years ago. More offspring reported all or more than half of their natural teeth remaining compared to the control group. The offspring also had significantly lower edentulous rate and lower use of dentures than the control group.

To our knowledge, this is the first published study of measures of oral health in centenarians and their offspring. The finding of better oral health among the offspring compared to the control group corresponds with previously reported reduced rates of age-related diseases in the offspring compared to the average rates for their birth cohort.¹⁰ It will be important to follow the study participants' oral health in conjunction with their systemic health longitudinally, to see if these associations continue over time.

We also found that among the combined sample of offspring and the birth-cohort matched controls (Table 2), there was a significant association between measures of relatively better oral health (lower edentulous rate, less tooth loss and higher rate of self-reported excellent/good oral health) and lower rates of hypertension, diabetes, myocardial infarction and stroke. The association was independent of typical confounders such as smoking, income and education. Such an association was not noted for cancer and osteoporosis.

Other studies (though not inclusive of centenarians) have also found associations between oral health and age-related diseases^{4-6, 15, 17}. For example, Stewart et al recently analyzed Health, Aging and Body Composition Study (Health ABC) data for associations between measures of oral health and cognitive decline.¹⁷ Gingivitis was independently associated with cognitive impairment and decline. An important question emanating from this and our

work is whether interventions to improve oral health can enhance life expectancy and aging-related conditions such as cognitive function. A popular hypothesis is that gingivitis is a source of chronic inflammation and that markers accompanying inflammation such as cytokines and interleukins potentiate atherosclerosis. However as of yet, a direct causal relation between poor oral health and atherosclerosis has not been demonstrated.⁶ As people who have benefitted from fluoridated water¹⁸ and preventive dental care when they were young (from the 1950s onward) achieve older age, we are likely to see many more centenarians maintaining all or most of their natural dentition throughout their lives.

Given previously noted associations between gum disease and cardio- and cerebro-vascular disease⁴⁻⁶ having most or all of one's teeth at very old age could be a marker for good systemic health. However, inferring a direct causative link between good oral health and healthy aging remains unproven and more investigation in this area is warranted. Furthermore, whether interventions to improve oral health can enhance life expectancy and ameliorate aging-related conditions such as cognitive function,¹⁷ atherosclerosis,⁶ and diabetes has yet to be demonstrated.

A limitation of this study is that a healthy volunteer effect could have biased the results towards a decreased edentulous rate among the centenarian subjects relative to the general population of centenarians. Thus more specifically, our findings pertain to centenarians who are relatively healthy, and in these individuals we observed a lower edentulous rate compared to substantially younger people from the same birth cohort. Another concern is that the oral health data were self-reported and it is possible that the subjects either underestimated or over-estimated their degrees of tooth loss. Tempering this concern, however, are studies¹³ (though not involving extremely old subjects) that demonstrate validity for this approach. Furthermore, it seems unlikely that comparison groups would consistently differ in over- versus under-estimation.

Low rates of diabetes, myocardial infarction and stroke in the offspring of centenarians, precluded the separate analysis of the association between these diseases and oral health measures in the offspring compared to the controls. Our primary goal, however, was to test the hypothesis that measures of oral health are associated with the presence or absence of these diseases and therefore, in order to reduce our false negative rate, we combined the offspring and control samples to test this hypothesis. It is possible that the degrees of association between particular measures of oral health and specific diseases are different between the offspring and controls, but given the small sample sizes and ages of these samples, we were not able to assess such differences.

In this study, the associations between oral disease and systemic disease were found to be independent of established risk factors including education, smoking and poverty level. However, other potential confounders related to healthy aging remain, such as exercise, diet, and access to health and dental care and should be accounted for in future studies.

We found that centenarians had a lower rate of edentulism in comparison to younger members of their birth cohort. Similarly, compared to birth cohort matched controls, centenarian offspring had less edentulism, less tooth loss and better subjectively assessed

oral health. Higher rates of good oral health are consistent with the compression of morbidity towards the end of life in many centenarians and the delay of age-related diseases in offspring of centenarians. Though our findings suggest an association between oral health and a number of age-related diseases, we are not able to assert a cause and effect relationship in this study.

Future studies that collect more comprehensive and longitudinal data from dental records and clinical examinations are needed to further understand the relationship between oral health and survival to extreme old ages. Longitudinal study of the offspring of centenarians and their birth cohort matched controls would also facilitate the collection of data at older ages when a greater divergence in age-related disease incidence and prevalence will likely be observed.

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Table 1

Oral Health and Systemic Conditions in Centenarians, Offspring and Controls

Characteristics	Centenarians (n=64)	Offspring (n=437)	Offspring Controls (n=229)	<i>p</i> ^a
Mean age, years (SD)	106.4 (3.9)	77.9 (7.1)	77.3 (7.1)	0.25
All or more than half teeth present, %	34.9	85.1	76.9	0.02 ^b
Less than half teeth present, %	28.6	11.4	16.2	<i>b</i>
Edentulous, %	36.5	3.4	7.0	<i>b</i>
Uses dentures, %	66.7	23.2	31.4	0.02
"Excellent/very good" health of teeth and gums, %	28.6	63.2	54.1	0.02
Hypertension, %	45.9	50.3	62	<0.01
Diabetes, %	3.3	6.9	16.6	<0.01
Myocardial Infarction, %	10.0	5.5	10.0	0.03
Stroke, %	6.6	3.9	7.9	0.03
Cancer, %	14.8	25.6	31.9	0.09
Osteoporosis, %	35.0	27.7	23.1	0.20

^a statistical test result for comparison of offspring with offspring controls^b statistical test applied for the comparison of the distribution of number of teeth between the groups.

Table 2

Frequencies of Age Related Diseases According to Oral Health Measures in Combined Offspring and Birth Cohort Matched Controls

	Self-reported Oral Health "excellent/very good" (%)	Complete/partial dentures (%)	Number of teeth present ^a		
			All or more than half (%)	Less than half (%)	None (%)
Hypertension (HTN) (n=362)	54.7	30.1	78.2	15.5	6.4
No HTN (n=304)	66.5	21.1	87.2	10.2	2.6
p-value	<0.01	<0.01			<0.01
Diabetes (n=68)	42.7	39.7	64.7	23.5	11.8
No diabetes (n=598)	62.0	24.5	84.3	11.9	3.9
p-value	<0.01	<0.01			<0.01
Myocardial infarction (MI) (n=47)	40.4	44.7	70.21	17.0	12.8
No MI (n=619)	61.6	24.6	83.2	12.7	4.0
p-value	<0.01	<0.01			0.01
Stroke (n=35)	40	42.9	68.6	17.1	14.3
No stroke (n=631)	61.2	25.1	83.0	12.8	4.1
p-value	0.01	0.02			0.01
Cancer (n=185)	60.5	24.9	83.2	11.4	5.4
No cancer (n=481)	59.9	26.5	81.9	13.7	4.4
p-value	0.88	0.68			0.63
Osteoporosis (n=174)	58.1	23.6	86.8	9.2	4.0
No osteoporosis (n=492)	60.8	26.9	80.7	14.4	4.9
p-value	0.53	0.39			0.18

^a statistical test applied for the comparison of the distribution of number of teeth between the groups

Table 3
Multivariable Model Comparing Offspring to Controls: General Health and Dental Health Outcomes

	General health ('excellent/very good')		Health of teeth and gums ('excellent/very good')		Number of teeth ('all or more than half')		Number of teeth ('none')	
	Odds Ratio (95% CI)	p-value	Odds Ratio (95% CI)	p-value	Odds Ratio (95% CI)	p-value	Odds Ratio (95% CI)	p-value
Risk group ^a	0.65 (0.45, 0.94)	0.02	0.66 (0.46, 0.94)	0.02	0.48 (0.3, 0.76)	<0.01	2.78 (1.17, 6.56)	0.02
Sex ^b	1.58 (1.06, 2.33)	0.02	1.18 (0.81, 1.71)	0.39	0.82 (0.5, 1.33)	0.42	0.66 (0.27, 1.62)	0.36
Age	0.96 (0.93, 0.99)	<0.01	0.98 (0.96, 1.01)	0.15	0.94 (0.9, 0.97)	<0.01	1.09 (1.02, 1.18)	0.01
Education ^c	2.63 (0.46, 15.08)	0.28	5.78 (0.65, 51.13)	0.11	2.59 (0.47, 14.29)	0.27	0.06 (0.01, 0.35)	<0.01
Income ^d	1.95 (1.29, 2.95)	<0.01	1.94 (1.3, 2.9)	<0.01	2.32 (1.4, 3.86)	<0.01	0.54 (0.22, 1.33)	0.18
Smoking ^e	0.69 (0.47, 1.00)	0.05	0.77 (0.54, 1.1)	0.15	0.3 (0.18, 0.51)	<0.01	4.3 (1.4, 13.21)	0.01
Osteoporosis ^f	1.73 (1.16, 2.58)	<0.01	1.22 (0.83, 1.8)	0.30	0.6 (0.35, 1.02)	0.06	0.88 (0.35, 2.22)	0.79

^a referent cohort vs. offspring

^b female vs. male

^c high school graduate or more vs. less than high school; education was not included in the models for males as there was not enough variability to estimate its coefficient accurately

^d above poverty level vs. below poverty level (>\$30,000 vs. <\$30,000)

^e ever smoked vs. never smoked

^f no vs. yes