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Effects of age and removable artificial dentition on taste

Alan H. Wayler, Lawrence C. Perlmuter,
Armand V. Cardello, Judith A. Jones, and
Howard H. Chauncey.

U.S. Army Natick RD&E Center
Soldier Science Directorate
Kansas Street
Natick, MA 01760-5000

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Sodium chloride and sucrose gustatory recognition thresholds, suprathreshold taste intensity function, and sucrose suprathreshold taste preference in healthy adult males with removable artificial dentition were compared with persons having natural dentition. In addition, several inorganic salivary constituents were evaluated for their possible relationship with these modalities. The 75 participants studied were divided into two age and two dentition groups: less than 65 years versus 65 years and older; and natural dentition only versus either removable partial dentures or complete artificial dentition. Recognition threshold and suprathreshold psychophysical functions were assessed using aqueous solutions of sodium chloride and sucrose. Suprathreshold hedonic judgments were also determined for sucrose. Samples of stimulated parotid saliva were analyzed for sodium, potassium, and bicarbonate. As age increased, a statistically significant decrease was noted in the exponent of the psychophysical function for sodium chloride.

TASTE DENTISTRY DENTURES
TEETH ORAL INTAKE MOUTH

Alan H. Wayler, PhD; Lawrence C. Perlmuter, PhD;
Armand V. Cardello, PhD; Judith A. Jones, DDS, MPH; and
Howard H. Chauncey, PhD, DMD

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As age increased, a statistically significant decrease was noted in the exponent of the psychophysical function for sodium chloride. A similar, but nonsignificant, trend was observed for sucrose, which was complicated by an interaction between age and dentition status. For sodium chloride, recognition thresholds tended to be higher for older persons with removable partial and complete dentures. However, no statistically significant effect was observed on the sucrose threshold or hedonic response as a result of dentition status. Analysis of several parotid saliva constituents showed no statistically significant effect caused by age or dentition status and correlations noted among the psychophysical measures appeared to be fortuitous.

Hypogeusia and ageusia in older persons[1] can contribute to loss of appetite and a deficient nutritional state.[2] In addition, the sequelae of altered food selection patterns frequently exhibited by elderly individuals, especially edentulous persons, may be related, at least in part, to this altered nutritional intake,[3] and is a factor which has aroused public concern.[4] Furthermore, several Federal agencies as well as medical and dental societies have strongly supported restricting salt and sugar intake by the elderly.[5] Thus, the relationship between age, dentition status, and taste perception, as well as the impact of these variables on the ingestion of various nutrients, and the use of salt and sugar is of critical importance in understanding factors that may influence the health status of this segment of the population.

As individuals age,[6,7] a number of changes that may affect gustatory sensitivity occur within the oral milieu. Although it has been conjectured that the number of taste buds decreases with age, the high degree of individual variability precludes any conclusion from being drawn from cross-sectional studies of the relationship between age and taste bud density.[8] With advancing age, morphological changes occur in the salivary glands as well as in the oral mucosa.[9] Some studies have found that in older persons the sodium and chloride levels of stimulated parotid saliva are reduced, while the potassium level increases.[10-16] Other studies have reported only increased salivary sodium levels with advancing age.[15,17,18] Baum and others[19] reported that stimulated parotid saliva potassium values remained invariant with age in contrast to the sodium concentration that was lower in middle aged and older persons than in young individuals.

Other studies have examined the role of saliva in taste sensitivity.[20,21] Bartoshuk[22,23] as well as Mandel and Wotman[24] and Pfaffmann[25] have shown that sodium chloride recognition sensitivity, at threshold levels, is inversely related to the salivary sodium concentration. Furthermore, in a small sample of older women with no salivary gland activity, sensitivity to weak gustatory stimuli was impaired, as measured by cross modal matching. However, with strong stimuli there was no evidence of an altered scaling of taste intensity in this salivary-impaired group.[26]

The relationship of salivary flow rate to taste sensitivity has also been examined. Reduced salivary flow rates, induced by various pharmacological agents had little effect on taste threshold, at least in 18 to 35-year-old nonsmokers.[27] In young individuals with high salivary flow rates, taste sensitivity to acid was reduced, but large volumes of acid were easily perceived.[28] No differences in flow rate have been found between young and old healthy subjects.[29]

Although the specific relationship between advancing age and changes in salivary composition still remains controversial, various studies have indicated that as age increases the sodium chloride taste threshold is raised.[15,16,30] An age-related decline in gustatory sensitivity for sweet and salt solutions was noted by Hinchcliffe,[31] with the detection threshold increasing exponentially between the ages of 20 and 70 years, while Richter and Campbell[32] observed a three-fold age-related increase in the sucrose detection and recognition thresholds of elderly subjects. In addition, others have documented age-related decreases in human gustation.[33-37]

The most dramatic changes in the detection and recognition thresholds for sodium chloride and sucrose appear to occur after age 60.[38] Barlough and Lelkes,[39] also observed a sensitivity decline at approximately 60 years of age. Reports by Leshkinova and Budylina[40] and Megighian[41] suggest that these sensory losses occur only at an advanced age, but other studies[30,33,42,43] have indicated that the decline may be continuous throughout life.

Pfaffmann,[44] on reviewing numerous recognition threshold studies, observed that detection thresholds varied widely and that the sodium chloride recognition threshold was reported to range from 0.003 to 0.985 mol/L, while the recognition threshold for sucrose varied from 0.012 to 0.037 mol/L. Byrd and Gertman[45] using a forced-choice identification procedure with suprathreshold solutions of sodium chloride and sucrose, found that in persons between 18 to 90 years of age, taste identification tended to decline with age. Similarly, Cohen and Gitman[1] using single supraliminal concentrations of sucrose and sodium chloride, observed no significant age-related change in sensitivity to suprathreshold stimuli. Because the concentrations tested were 10 to 300 times greater than typical threshold values, they may have been too high to detect small perceptual losses.

Because of the different methodological procedures, disagreement still exists regarding the exact nature and degree of taste acuity loss with increasing age. Whether the changes observed in the specific gustatory modalities represent a general decline in the neurogustatory reflex or are caused by receptor alteration still remains unknown.[46]

Research in altered sensory function in people who wear dentures has been limited. After inserting a complete maxillary denture, the patient frequently experiences a reduction in taste acuity.[48] This appears to be the result of covering the palate, which has been shown to inhibit olfaction.[50-52] Qualitative support for this thesis has recently been presented.[35] While Laird[53] and Strain[49] did not find any significant alteration in taste acuity or oral sensation in individuals having artificial dentition, Giddon and co-workers,[54] using traditional taste threshold techniques, found that persons with complete dentures were less able to perceive subtle differences in sweetness when compared with persons having natural dentition. Kapur[55] reported that the presence of complete artificial dentition appeared to improve taste discrimination and recognition for sweet and sour solutions. Although these findings are contrary to the results reported in other investigations, support for this enhancement has recently been reported.[56] In another study, elderly participants with complete maxillary and mandibular dentures had slightly lower gustatory thresholds than persons with some natural dentition.[57] To account for those apparently contradictory effects, it has been suggested that the loss of natural dentition may be associated with disguesia, rather than artificial dentition promoting increased gustatory sensitivity.

Currently, most studies[55,23,25,57] about the effects of age and complete artificial dentition on human gustatory perception have been conducted using only threshold-testing techniques, procedures which examine only the lower limits of the taste intensity spectrum and provide little information regarding the dynamic range of sensory function encountered during food consumption. This investigation studied the effect of age and dentition status on suprathreshold psychophysical function as well as recognition thresholds for sucrose and sodium chloride, and hedonic judgments for sucrose. Stimulated parotid saliva levels for sodium, potassium, and bicarbonate were measured and evaluated for a possible correlation with age, dentition status, and the psychophysical measures.

Methods

Subjects

A cohort of 75 men from the VA Normative Aging Study (NAS),[58] who were also participants in the VA Dental Longitudinal Study (DLS)[59] were used in the present investigation. Initiated at the VA Outpatient Clinic, Boston, in 1969, the DLS was designed to assess the oral health and aging patterns of 1,221 healthy men, aged 25 to 75 years.[58]

The DLS population is a cohort derived from the NAS, an interdisciplinary and longitudinal investigation of 2,280 healthy males, initiated in 1963.[59] Carefully screened from more than 6,000 volunteers, the final selection of NAS participants was based on their ability to meet specific health criteria. A comprehensive physical examination that included an electrocardiogram, chest radiographs, as well as an extensive battery of clinical laboratory tests was also conducted. This detailed series of comprehensive medical examinations and laboratory tests is repeated at 5-year intervals for participants younger than 55 years of age and at 3-year intervals for participants 55 years or older.

Only individuals who were determined by medical and clinical chemistry examination to be in good physical health were requested to participate in the DLS. Selection criteria that precluded participation were: prescription medication usage, excessive alcohol consumption, a restricted dietary regimen, or a history of either taste complaints or other oral aberrations. Approximately 400 men are recalled each year.

The DLS collects pertinent data relating to the incidence, distribution, changes, and interrelationships of specific variables used to assess oral health and disease status. Periodic examinations, performed at 3-year intervals, include: a dental health history; a comprehensive orofacial examination (evaluations of the periodontium, caries, and prostheses); masticatory function tests and a survey of dietary habits (preferences for taste, texture, chewing ease, and ingestion frequency); analysis of stimulated whole and parotid saliva; and various general procedures including intraoral and panoramic radiographs, lateral and frontal cephalometric radiographs, diagnostic casts, and oral cytological smears.

Forty-one subjects with intact natural dentition (28-32 teeth) formed one group, while 34 persons with either a removable partial denture or complete maxillary and mandibular dentures comprised the second group. For the primary analyses, these individuals were segregated into two age cohorts: <65 years of age ($n=38$) and > 65 years of age ($n=37$). Subjects ranged in age from 55 to 78 years.

Stimuli

Aqueous solutions of sucrose and sodium chloride were prepared from reagent grade chemicals and deionized distilled water. All solutions used for testing were prepared by mixing premeasured amounts of sucrose or sodium chloride with appropriate volumes of distilled water until the desired molarity was obtained. Concentrations used to determine recognition thresholds for sucrose were .0012, .0018, .0024, .0036, .0048, .0072, .0096, .014, .019, .029, and .038 mol/L; while the sodium chloride concentrations were .003, .0045, .006, .009, .012, .018, .024, .036, .048, .072, and .096 mol/L. Solutions used for suprathreshold testing were .0625, .125, .25, .50, 1.0, and 2.0 mol/L sucrose, and .05, .1, .2, .4, .8, and 1.6 mol/L sodium chloride.

Procedures

During the first session, taste recognition thresholds, suprathreshold taste intensity function and suprathreshold taste preferences (hedonics) for sucrose were determined. In another test session, conducted on a different day, recognition thresholds and suprathreshold taste intensity function for sodium chloride were determined. The order of testing for the different taste indexes was randomized. Subjects were randomly assigned to the morning or afternoon testing periods. Parotid saliva was collected on a separate day, subsequent to the final experimental taste session,[14] with half of the subjects evaluated before noon and the remainder in the early-mid afternoon. Persons with artificial dentition were always tested with their prosthetic appliance in place.

Recognition thresholds

Recognition thresholds for sucrose and sodium chloride were determined by the "Staircase" method,[60,61] which incorporated a forced-choice paradigm to eliminate subject response bias.[23,62,63] For each trial, the subjects were presented with two plastic cups, one containing 10 mL of a specific concentration of tastant solution, the other cup containing 10 mL of distilled water. Distilled water was also used for rinsing between the test solutions. If a difference in the taste quality of the first pair of test solutions was correctly recognized, a lower stimulus concentration was presented on the next trial. If the subject again correctly recognized the cup containing the tastant, a still lower concentration was presented. This procedure continued until a "no taste" description for both the tastant and distilled water cups was elicited. This transition point was noted as a "reversal." Then, starting at a tastant concentration just below that which the subject had been unable to recognize, a series of increasing concentrations were presented in combination with distilled water, until the subject correctly recognized the taste quality. Once more, starting at a concentration just above that at which the recognition was made, decreasing solution concentrations were provided until another endpoint was reached. The mean recognition threshold was then determined by averaging the six concentrations where the reversals occurred.

An incorrect recognition response, for example, "it tastes bitter" to a sweet solution was considered as a nonrecognition response. The testing took approximately 45 minutes per subject per tastant.

Suprathreshold psychophysical functions

Measurement of suprathreshold taste intensity was determined by the method of modulus-free magnitude estimation.[64] All solutions were presented in randomized order. Subjects were instructed to assign an arbitrary number to represent the perceived magnitude of the first stimulus. Subsequent judgments were made in relation to the first stimulus so that the ratio of the magnitude of each stimulus to the first was the same as the ratio of the numbers assigned to each. Thus, if the first stimulus was assigned a taste magnitude of 10.0 and the second stimulus was twice as sweet (salty) it would be assigned the number 20.0. If the second stimulus was one-third as sweet as the first, it would be assigned the number 3.33, and so on. An interstimulus interval of 90 seconds was maintained throughout the test series. Each randomized concentration series was presented twice to each subject.

Hedonic judgments

The same set of instructions, procedures, and tastant concentrations used for suprathreshold intensity scaling were also used for the magnitude estimation scaling of suprathreshold taste preference (hedonics).[65] The subjects were instructed to rate the pleasantness or unpleasantness of each solution by using positive integers. The larger the integer, the greater the degree of pleasantness. In addition, the subject assigned a code (P = pleasantness, UP = unpleasantness) to each magnitude estimate.

Salivary measures

Stimulated parotid saliva collections were made in the morning or afternoon, at least 1.5 hours postprandial. A vacuum-maintained metal collection device[50] was positioned over the orifice of Stenson's duct. The gustatory stimulus used was a sour lemon-flavored lozenge. A 1-minute "acquaintance" interval was used to allow the capped salivary gland to adjust to the stimulus. Subsequently, the plastic collection tu-

Table 1. Sodium chloride recognition thresholds (molar concentration).

	Dentition status								
	Natural dentition			Removable partial and complete dentures			Total group		
Age group	N	Mean	SD	N	Mean	SD	N	Mean	SD
<65 years	25	0.036	.025	12	0.044	.023	37	0.039	.024
≥65 years	16	0.035	.037	18	0.071	.079	34	0.054	.064
All ages	41	0.036	.030	30	0.060	.063	71	0.046	.048

bule was transferred to a graduated tube and 10.0 mL of parotid fluid collected. The lozenge was renewed every 5 minutes to maintain a constant level of stimulation. Parotid saliva flow rates (mL/min) were calculated by recording the time necessary to collect the standard volume.[13] Immediately after collection, the saliva bicarbonate level was measured.[67] The other variables determined were sodium and potassium (IL Digital Flame Photometer).

Data analysis

Because the magnitude estimates provided by the subjects were free to vary, an equalization procedure was required to standardize the modulus for the group.[68] This procedure consisted of multiplying each subject's judgment for the six standard tastant solutions (sucrose and sodium chloride) by a fixed factor that made the geometric mean of the ratings for each subject equal to the geometric mean of the group.[69] Using this procedure, the ratios among the estimates for a given subject remained unchanged and the hedonic responses were equalized. The geometric mean of the equalized magnitude estimates was calculated across subjects because magnitude estimates have been shown to have a log-normal distribution.[70] The geometric means were then plotted as a function of solution concentration in log-log coordinates. For each stimulus series, the slopes of the psychophysical functions were calculated for age groupings and dentition categories by linear regression analysis applied to the logarithms of the data. Analysis of variance (ANOVA) was used to determine the significance of the differences among the slopes for each taste compound for the different age groups and the different dentition categories.

A hedonic breakpoint, defined as the solution concentration that was assigned the largest hedonic magnitude estimate, was calculated for the sucrose data. Analysis of variance (ANOVA) was performed on the breakpoint concentrations for age and dentition status. Slight variations in sample sizes for the various indexes are attributable to missing data.

Results

Sodium chloride

Threshold. Table 1 indicates the mean recognition thresholds (RL) for sodium chloride by age and dentition group. While RLS were not significantly different in the two age groups ($P > .15$), subjects with partial and complete dentures tended to show a higher RL ($F = 3.64$, $P = .06$). Although the highest RL was observed for older subjects with partial and complete dentures, the possible interaction of Age X Dentition Status was not significant ($P > .20$).

Suprathreshold function. As displayed in Table 2, the mean magnitude estimations (slopes) as a function of molar concentrations were significantly lower for the older persons ($F = 8.85$, $P < .01$). However, neither dentition status nor the possible Age X Dentition Status interaction was significant ($F < 1.0$). Analyses of the intercepts of these functions resulted in F values uniformly less than 1.0.

Correlations among salivary and psychophysical parameters. Pearson product-moment correlations were calculated for salivary sodium, potassium, and bicarbonate thresholds, slopes, and intercepts. Few of these correlations were significant. However, as the threshold increased, the intercept decreased ($r = -.33$, $P < .01$). In addition, as salivary potassium levels increased, the slope of the psychophysical function decreased ($r = -.28$, $P = .02$).

Sucrose

Thresholds. An examination (Table 3) of the mean sucrose thresholds (RL) for age and dentition groups showed no significant effects or interaction.

Suprathreshold functions. While the slopes obtained from plotting the magnitude estimates as a function of molar concentrations were somewhat greater for younger subjects, and for persons with removable partial or complete dentures, neither age ($F[1, 71] = 3.43$, $P = .07$) nor dentition status ($F[1, 71] = 2.82$, $P < .10$) reached statistically significant levels (Table 4). The possible interaction of Age X Dentition Status was nonsignificant ($F < 1.0$). Analysis of the intercepts of the sucrose functions revealed no significant effect of age, dentition status, or Age X Dentition Status.

The sucrose breakpoint ANOVA revealed that the point of maximal liking was lower for younger persons ($F[1, 71] = 7.21$, $P < .01$), but neither dentition status nor its possible interaction with age was significant (Table 5). Apparently, older persons require higher concentrations of sucrose in solution before the perceived sweetness intensity becomes objectionable.

Correlations of psychophysical parameters with salivary components. Pearson product-moment correlation coefficients were calculated between the psychophysical parameters of threshold, slope, intercept, hedonic breakpoint, as well as salivary sodium, potassium, and bicarbonate levels. There was a positive relationship between the intercept and slope ($r = .94$, $P < .001$). In addition, there was a negative correlation between the salivary potassium level and the sucrose threshold ($r = -.25$, $P < .05$) and between the salivary sodium level and the hedonic breakpoint ($r = -.25$, $P < .05$). There was no association with age or dentition status and the salivary components.

Table 2. Mean sodium chloride slopes and standard deviations (molar concentration).

	Dentition status								
	Natural dentition			Removable partial and complete dentures			Total group		
Age group	N	Mean	SD	N	Mean	SD	N	Mean	SD
<65 years	25	0.85	.26	13	0.81	.31	38	0.83	.27
≥65 years	16	0.62	.19	21	0.68	.29	37	0.65	.25
All ages	41	0.76	.26	34	0.73	.30	75	0.74	.28

Table 3. Sucrose recognition thresholds and standard deviations (molar concentration).

	Dentition status								
		Natural dentition			Removable partial and complete dentures			Total group	
Age group	N	Mean	SD	N	Mean	SD	N	Mean	SD
< 65 years	25	0.034	.015	12	0.030	.010	37	0.033	.014
≥ 65 years	15	0.027	.012	21	0.028	.017	36	0.028	.015
All ages	40	0.032	.015	33	0.029	.015	73	0.030	.015

Discussion

Threshold observations. In the present study, the mean recognition thresholds obtained for sodium chloride (0.046 mol/L) and sucrose (0.03 mol/L) were similar to the range of threshold values noted by previous investigators.[44] However, neither the sodium chloride nor sucrose thresholds showed a statistically significant association with age. While the failure to find a significant age-related effect for sucrose is consistent with most previous studies, the absence of a significant age effect for sodium chloride is surprising in light of prior studies,[36,57] that have demonstrated advanced age is associated with increased sodium chloride taste thresholds. There was a tendency toward lower sodium thresholds in individuals with natural dentition. The present findings on the effect of artificial dentition on the sodium chloride threshold do not support the findings of Kapur[55] or Langan and Yearick.[34]

Suprathreshold observations. The suprathreshold data indicated that as age increased, the sodium chloride exponent decreased. This would appear to reflect a reduction in sensitivity within the dynamic range for taste of sodium chloride for older individuals. That is, to induce a unit change in the salt sensation of the older group, a larger change in the sodium chloride concentration was needed.

Although the sucrose data also showed a lower slope (exponent) for older persons, the main effect of age was only marginally significant. It thus appeared that only a slight decline in taste responsiveness to sucrose occurred with age.

Examination of the correlations among the psychophysical parameters showed an inverse relationship ($r = -.33$, $P < .01$) between the threshold and intercept for sodium chloride. The intercept is the theoretical taste intensity of a compound at zero concentration, the higher this value, the greater the sensitivity at the lowest concentrations.

Table 4. Mean sucrose slopes and standard deviations (molar concentration).

	Dentition status								
		Natural dentition			Removable partial and complete dentures			Total group	
Age group	N	Mean	SD	N	Mean	SD	N	Mean	SD
< 65 years	25	0.79	.41	13	1.00	.39	38	0.86	.41
≥ 65 years	16	0.68	.26	21	0.74	.28	37	0.72	.27
All ages	41	0.75	.36	34	0.84	.35	75	0.79	.35

Since the threshold is that concentration at which the taste is perceptible 50% of the time, the lower this value, the greater the sensitivity. Thus, thresholds and intercepts should be negatively correlated. However, a significant threshold-intercept relationship was not found for sucrose; the positive relationship between the sucrose intercept and the slope suggests that throughout the dynamic range of the stimuli, including thresholds, higher slopes values were associated with increased sensitivity at the theoretically zero value of the stimulus. Hence, to the extent that age or dentition status alter taste sensitivity, the effect was evident throughout the dynamic range of the stimulus values.

Salivary measures and taste. Although certain of the salivary measures were significantly correlated with the psychophysical measures, none varied systematically with age or dentition status. Although the salivary sodium level affects the sodium chloride threshold and suprathreshold judgments, only the salivary potassium concentration appeared to be significantly related to sodium chloride taste (negative correlation with the slope). In addition, neither the negative relationship of salivary potassium to the sucrose threshold nor the positive relationship of salivary sodium level to the sucrose hedonic breakpoint was consistent with any expected physico-chemical interaction among these factors.

Table 5. Sucrose breakpoints and standard deviations (molar solution).

	Dentition status								
		Natural dentition			Removable partial and complete dentures			Total group	
Age group	N	Mean	SD	N	Mean	SD	N	Mean	SD
< 65 years	23	0 67	0.67	12	0.66	0.68	35	0.67	0.66
≥ 65 years	15	0.96	0.61	21	1.21	0.75	36	1.10	0.70
All ages	38	0.78	0.66	33	1.01	0.76	71	0.89	0.71

Conclusion

The lack of consistent findings by various investigators regarding the extent and nature of taste sensitivity changes associated with aging or artificial dentition may be due, at least in part, to the utilization of nonstandardized testing techniques. Differences in the procedures used for the delivery of the stimulus, the amount given, application to a particular area of the tongue, flow rate of the stimulus, solution temperature, and the influence of water rinses all may produce measurement variations. Furthermore, many studies have not defined either the general health or oral health status of the participants. In certain disease states[71] and with many of the medications commonly used for elderly persons, alterations in taste sensitivity, saliva flow rate, and saliva composition can occur. These factors have the potential to affect gustatory psychophysical responses.

The current investigation indicated that changes in suprathreshold taste function do take place between the ages of 55 and 78. Specifically, with advancing age, declines in the exponents (slopes) of the psychophysical functions for sodium chloride occurred. However, these perceptual losses were not reflected by the taste threshold measure, neither could they be attributed to age-related changes in the oral milieu as indicated by parotid saliva sodium, potassium, and bicarbonate levels, nor by the presence of artificial dentition, the latter having only a minor interactive effect with age. Rather, it appears that the functional decline in gustatory perception was more likely related to a physiological degradation in the taste receptors or the peripheral transduction processes. Future analyses of changes in sensory function associated with aging should include an evaluation of the bitter and sour qualities, as well as the olfactory sense, to assist in distinguishing between a generalized degradation in the central processes and modality-specific declines.

Dr. Wayler is DVA research scientist; Dr. Perlmuter is director, Learning and Memory Clinic, DVA, Outpatient Clinic; and Dr. Chauncey is associate chief of staff for research and development, DVA Outpatient Clinic, Boston, and Tufts University School of Dental Medicine, Boston; Dr. Cardello is Chief, Sensory Analysis Section, Behavioral Sciences Division, Science and Advanced Technology Laboratory, U.S. Army Natick Research, Development, and Engineering Center, Natick, MA; and Dr. Jones is director, Geriatric Dental Program, Edith Nourse Rogers Memorial Department of Veterans Affairs Medical Center, Bedford, MA. Address requests for reprints to Dr. Chauncey, Veterans Administration Outpatient Clinic (151), 251 Causeway, Boston 02114.

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