SCIENTIFIC ARTICLES

Oral Functional Limitation among Dentate Adults

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Abstract

Objectives: *The purpose of this study was to measure the prevalence of oral functional limitation in adults and to identify clinical and sociodemographic factors associated with that limitation.* ***Methods:*** *The Florida Dental Care Study is a longitudinal study of risk factors for changes in oral health. Subjects (n=873) with at least one tooth who were 45 years old or older participated in a baseline in-person interview and dental examination. Subjects were queried about oral functional limitations.* ***Results:*** *Twenty-three percent of subjects reported difficulty chewing one or more foods using a five-item chewing index, and 10 percent reported difficulty speaking or pronouncing words because of problems with the mouth. The covariates in a multiple logistic regression identified as being significantly associated with chewing difficulty were fewer pairs of occluding anterior teeth, fewer pairs of occluding posterior teeth, more posterior teeth that are root tips, more anterior teeth that are mobile, reporting tooth pain, reporting bad breath, having but not wearing prosthetic appliances, reporting dry mouth, and being female. Having fewer anterior teeth, reporting a sore and/or broken denture, reporting unattractive teeth, and being black were significantly associated with speaking difficulty/difficulty pronouncing words because of problems with the teeth, mouth, or dentures.* ***Conclusions:*** *The findings in this study suggest a significant prevalence of oral functional limitation in dentate adults. Certain clinical and sociodemographic factors were strongly and independently associated with its presence. [J Public Health Dent 1998;58(3):202-9]*

Key Words: functional limitation, oral, dental, chewing ability, adults, dentate, race.

Health care delivery systems in the United States and other industrialized countries have come under pressure to justify themselves and to provide health care that is effective, safe, and less costly. One of the most important reasons for the existence of dental care is to maintain or improve one's ability to use the mouth for its important daily functions, such as chewing and speaking. Therefore, it is important to identify determinants of these fundamental oral functions. The dental care delivery system can be assessed by evaluating the extent to which dental care affects these determinants directly and oral function indirectly.

Oral functional limitations, such as chewing difficulty and speaking difficulty, can be due to trauma, pathology, neurologic disturbances, psychological impairment, and anatomic anomalies, as well as acute, chronic, and episodic dental disease that causes a gradual decline in oral health and function. Various investigators have advocated the use of functional measures to quantify oral health, instead of relying only on clinical measures such as dentist-diagnosed dental caries, missing teeth, and periodontal attachment loss (1-4). One functional measure of oral health, chewing ability, has been assessed using a wide range of techniques, such as bite force, the number of chewing strokes needed before a food bolus can be swallowed, or self-assessments made by research participants themselves (5-8).

Our approach in this study was to rely on self-reported measures of oral function. Understanding is growing that subjective, self-reported data from patients can provide important information to assess the effectiveness of health care, and that this information is typically reliable and valid (9,10). Additionally, purchasers of health care, practitioners, and patients alike have all begun to take an interest in what constitutes effective care, with an interest in using outcomes of care that go beyond measurement of disease and include patient self-reports (11). Moreover, these self-reported outcomes are typically the ones that matter most to patients, whose improvement in quantity and quality of life is, after all, the reason for the existence of health care.

The overall purpose of this research project, the Florida Care Dental Study (FDCS), is to develop a risk assessment model of longitudinal oral health outcomes. The purpose of the current paper is to describe the prevalence of oral functional limitation at baseline in a diverse sample of middle-aged and older adults and to determine which subgroups are most at risk. We previously have described in detail (12) the theoretical context in which we measure the dimension of oral health called "oral functional limitation," as well as its two measures: difficulty with speaking or pronouncing words because of problems with the teeth, mouth, or dentures; and chewing difficulty.

Methods

The goal of the sampling design was to ensure that a large number of persons at a hypothesized increased risk for oral health decrements would be included—namely, blacks, residents of rural areas, persons 45 years old or older, and the poor, who were defined

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as being below the US poverty level (13). Details of sampling methodology and selection are provided in an earlier publication (14). The 873 subjects who participated at baseline from fall 1993 to spring 1994 resulted in a sample of only modest bias with respect to the population of interest (14). Also, this sample had a dental care recency similar to 1989 National Health Interview Survey (NHIS) data, and conclusions drawn from the FDCS and NHIS regarding determinants of dental care recency were the same (14). One major strength of the FDCS is that it uses a community-based sample, which offers important advantages over designs that only include those who actually seek health care (15).

Interview and Clinical Examination Methods. Subjects were asked to participate in a 30-minute, baseline in-person interview administered by trained nondentist interviewers. Forty-two of the 873 baseline subjects participated for a second, abbreviated baseline interview to estimate test-retest reliability of selected questions from the baseline interview. The mean number of days between test and retest was 4.0 (SD=3.2) days. Agreement between test and retest, expressed as percent of pairs concordant, ranged from 77 percent to 100 percent.

The interview was followed immediately by a clinical dental examination. Data were entered in the field directly into portable microcomputers. Subjects were examined for presence and location of remaining teeth, coronal and root caries, bulk restoration fractures, cusp/incisal edge fractures, root surface defects, tooth mobility, and periodontal attachment loss. All teeth were noted, including third molars. Details regarding the examination protocol, diagnostic criteria, and interexaminer agreement are described elsewhere (16-18). Specific to this report, an occluding pair of teeth was defined as having a maxillary tooth or fixed prosthetic replacement (i.e., a pontic, cantilever, or implant) that opposed a mandibular tooth or fixed prosthetic replacement.

Two self-reported measures of oral functional limitation were used. Current chewing ability was measured using with minor revision an index of chewing ability introduced by Leake (8). Subjects were asked these five questions: "Are you able to chew or bite ... [raw carrots or celery sticks]

TABLE 1
Percent of Subjects with Oral Functional Limitation by Self-reported Measures of Oral Disease and Tissue Damage and Oral Pain

Self-reported Measure of Oral Disease/Tissue Damage and Oral Pain (Weighted *n*)	Oral Functional Limitation (% Subjects)	
	With Recent* Difficulty Speaking/Pronouncing	With Current Chewing Difficulty
Has teeth that are stained/look bad		
Yes (337)	15†	31†
No (511)	6	16
Missing (21)		
Food catching problem past 6 months		
Yes (622)	10ns	24ns
No (249)	7	18
Missing (3)		
Has an abscessed tooth		
Yes (22)	26†	39ns
No (835)	9	22
Missing (16)		
Has a broken denture‡		
Yes (30)	29ns	50ns
No (180)	17	40
Missing (NA)		
Has and wears maxillary full denture¶		
Yes (80)	25ns	58†
No (9)	38	100
Missing (NA)		
Has & wears maxillary part. denture§		
Yes (99)	17ns	34ns
No (43)	23	26
Missing (NA)		
Has & wears mand. part. denture+		
Yes (119)	16ns	34ns
No (68)	10	33
Missing (NA)		
Has infected/sore gums		
Yes (102)	18†	40†
No (765)	8	20
Missing (6)		
Has bleeding gums		
Yes (117)	18*	42†
No (754)	8	20
Missing (2)		
Has bad breath		
Yes (154)	18†	40†
No (674)	8	18
Missing (45)		
Has dry mouth		
Yes (190)	13ns	37†
No (678)	9	18
Missing (5)		
Has toothache pain		
Yes (100)	16†	33†
No (772)	9	21
Missing (1)		
Has denture soreness‡		
Yes (43)	39†	61†
No (168)	13	36
Missing (NA)		

ns=not statistically signif. *Recent=within previous 6 mos. † $P<.05$. ‡Only includes persons who currently wear removable denture (n=211). ¶Only includes persons who were edentulous in maxilla (n=89). §Only includes persons who reported ever having maxillary partial denture and who had 1–15 teeth in maxillary arch (n =143). +Only includes persons who reported ever having mandibular partial denture and who had 1–15 teeth in mandibular arch (n=186). Some sample

[steak, chops, or firm meat] [a whole fresh apple without cutting it] [fresh lettuce or spinach salad] [boiled peas, carrots, or green or yellow beans] ... or something very similar to that?" Our adaptation of this chewing index was identical to that of Leake, except that the words "or something very similar to that" were included. This modification was done to decrease the likelihood that a subject would answer "have not tried" to these questions, thus resulting in missing data. Speaking difficulty was measured by asking subjects "Have you ever had difficulty speaking or pronouncing any words because you had problems with your teeth, mouth, or dentures?" Subjects who answered "yes" were asked, "How often have you had this trouble in the past six months?" and were requested to answer "very often," "fairly often," "sometimes," or "never". The actual questionnaire is available on the Internet site listed in the Acknowledgments section at the end of this paper.

Statistical Methods. Analyses were done using SAS in the microcomputer environment (SAS System for Windows 3.1®) (19). Comments about statistical significance refer to probabilities of less than .05. The chi-square and Mantel-Haenszel chi-square trend tests were used for bivariate comparisons when variables were nominal or ordinal, respectively. Fisher's exact test was used in one instance (Table 1).

Logistic regressions (LOGISTIC procedure) were used to quantify differences multivariately. Both measures of functional limitation had an ordinal metric, although both had highly skewed distributions. Although logistic regression analysis using the ordinal metric was attempted, in both cases the proportional odds assumption was violated, which is required for logistic regression analysis of ordinal data in SAS. Therefore, the logistic regressions were done using dichotomized versions of each variable. For the "current chewing ability" variable, subjects were classified as: those with none of the five chewing difficulties, or those with one or more of the five chewing difficulties. For the "speaking difficulty" variable, subjects were classified as: those who reported speaking difficulty within the previous six months as "very often," "fairly often," or "sometimes"; or those who reported no difficulty within the previous six months; as well as those who reported never having had the difficulty.

Multicollinearity was assessed using a procedure described by Belsley et al. (20). Four explanatory covariates introduced problems with multicollinearity ("sore denture," "broken denture," "toothache pain," and "abscessed tooth"). When "sore denture" and "broken denture" were combined into one variable, and when "toothache pain," "abscessed tooth," and

TABLE 2
Percent of Subjects with Oral Functional Limitation, by Clinical Measures of Oral Disease and Tissue Damage

Clinical Measure of Oral Disease/Tissue Damage (Weighted *n*)	Oral Functional Limitation (% Subjects)	
	With Recent* Difficulty Speaking/Pronouncing	With Current Chewing Difficulty
Number of remaining teeth		
25–32 (429)	3†	8†
17–24 (264)	10	20
1–16 (178)	25	62
Missing (2)		
Number of occluding pairs of teeth		
13–16 (297)	—	5†
9–12 (265)	—	12
1–8 (199)	—	40
0 (110)	—	66
Missing (2)		
Number of root fragments		
0 (779)	9†	19†
1 (42)	11	36
2 or more (47)	26	67
Missing (6)		
Number of severely mobile teeth		
0 (718)	8†	16†
1 (69)	15	49
2 or more (76)	22	60
Missing (10)		
Number of teeth with severe AL‡		
0 (500)	6†	14†
1 (95)	8	27
2 or more (176)	20	41
Missing (102)		
Number of fractured fillings		
0 (730)	11†	24ns
1 (107)	3	12
2 or more (27)	6	29
Missing (9)		
Number of fractured teeth		
0 (745)	9ns	24ns
1 (91)	11	17
2 or more (27)	13	13
Missing (10)		

ns=not statistically significant.
*Recent=within previous 6 mos.
† $P<.05$.
‡Severe attachment loss (AL) defined as 7 or more millimeters AL.
Some sample sizes do not add to 873 because of weighted rounding.

TABLE 3
Percent of Subjects with Oral Functional Limitation, by Sociodemographic Characteristics

Characteristic (Weighted *n*)	Oral Functional Limitation (% Subjects)	
	With Recent* Difficulty Speaking/Pronouncing	With Current Chewing Difficulty
Age group		
45–64 years old (513)	10ns	21ns
65+ years old (361)	9	25
Missing (0)		
Sex		
Female (491)	10ns	27†
Male (383)	9	17
Missing (0)		
Race and poverty status		
Poor black (75)	21†	43†
Poor white (57)	17	47
Nonpoor black (133)	18	26
Nonpoor white (553)	4	14
Missing (55)		
Ability to pay unexpected $500 dental bill		
Not able to pay (122)	25†	54†
Able to pay with difficulty (342)	13	24
Able to pay comfortably (406)	2	12
Missing (3)		
Area of residence		
Rural (436)	10ns	27†
Urban (437)	9	19
Missing (0)		
Highest level of formal education		
Did not graduate high school (184)	18†	41†
Graduated high school (689)	8	18
Missing (1)		

ns=not statistically significant.
*Recent=within previous 6 mos.
†$P<.05$.
Some sample sizes do not add to 873 because of weighted rounding.

"dental sensitivity to hot/cold" were combined into one variable, the problem with multicollinearity was eliminated, and these combined variables were the ones used in the regression models we describe.

We adopted a stepwise analytic technique because we had multiple measures of each of the "clinical measures of oral disease and tissue damage," "self-reported measures of oral disease and tissue damage," and "oral pain" dimensions, as well as multiple measures of sociodemographic characteristics. Consequently, we judged that a stepwise approach would be advisable for the sake of parsimony. For this stepwise modeling, we adopted a less stringent criterion for statistical significance, $P<.10$. Our approach was to test the clinical measures of oral disease and tissue damage (variables in Table 2) as the first step. We next retained the clinical measures that met the $P<.10$ criterion, and then added the self-reported measures of oral disease and tissue damage (the first 11 variables in Table 1). Next, we retained the clinical and self-reported measures that met the $P<.10$ criterion, and then added the two measures of oral pain (the last two variables in Table 1). While retaining the measures of oral disease and tissue damage and oral pain that met the $P<.10$ criterion, we then added the sociodemographic measures (variables in Table 3). The regression results appearing in Tables 4 and 5 are derived from this process, after excluding the variables in the last step that did not meet the $P<.10$ criterion.

Model fit was assessed using the "c" statistic, which is a measure of the area under the curve of the plot of the sensitivity against 1 – specificity ("Receiver Operating Characteristic"). The value of the "c" statistic for a typical test ranges from 0.50 (no better than chance) to 1.0 (perfect accuracy). Values of 0.5 to 0.7 have been classified as representing poor accuracy (or poor "fit" in the case of application to multiple logistic regressions), 0.7 to 0.9 as "useful for some purposes," and more than 0.9 as high accuracy (21).

Results were weighted using the sampling proportions to reflect the population in the counties studied. For example, although 35 percent of the sample of 873 subjects was poor, the weighted percentage was 16 percent to reflect the percent of 45-year-old or older persons in these counties who were actually poor. The demographic targets were taken from Census data detailing target populations by age, sex, race, and poverty status (US Bureau of the Census. Unpublished special tabulations for the University of Florida from the 1990 Census of Population and Housing for the United States and four counties in north Florida, 1994). The weighting approach minimized the variance inflation that resulted from sample design effects (14).

A total of 137 subjects did not provide the information necessary to determine poverty status. To facilitate regression modeling, subjects with missing data on this variable were assigned values randomly for poverty status within race, sex, and education groupings. In this manner, these subjects could be included in the regression models if they did not have missing values on any of the other variables. Although random assignment of values does create the potential for misclassification on that variable, any misclassification would lessen the apparent effect of the variable on oral functional limitation (22).

TABLE 4
Logistic Regression of Recent Difficulty Speaking/Pronouncing Words Because of Problems with Teeth, Mouth, or Dentures

Covariates	Parameter Estimates	Standard Error	*P*-value	Odds Ratio (95% CI*)
Intercept	1.96	0.71	<.01	—
Number of anterior teeth (inverted scale of 0–12)	0.22	0.04	<.01	1.25 (1.16, 1.34)
Bad denture (2=has denture that is broken and causes soreness; 1=1 of these 2 conditions; 0=neither of these conditions)	1.39	0.34	<.01	4.02 (2.05, 7.84)
Poor esthetics (1=has teeth that are stained or look bad; 0=does not)	0.91	0.29	<.01	2.48 (1.41, 4.44)
Race (0=white; 1=black)	1.81	0.30	<.01	6.08 (3.44, 11.1)

*CI=confidence interval.
The outcome of interest is whether the participant had recent difficulty with speaking/pronouncing words because or problems with teeth, mouth, or dentures (0=none, 1=had difficulty within previous 6 mos.).
n=841; pairs correct=86%; sensitivity=20%; specificity=97%; c=0.82.

TABLE 5
Logistic Regression of Current Chewing Difficulty

Covariates	Parameter Estimates	Standard Error	*P*-value	Odds Ratio (95% CI*)
Intercept	2.54	0.89	<.01	—
Number of fixed anterior pairs opposing teeth (inverted scale of 0–6)	0.56	0.08	<.01	1.83 (1.50, 2.80)
Number of fixed posterior pairs opposing teeth (inverted scale of 0–10)	0.13	0.05	<.01	1.18 (1.07, 1.33)
Number of posterior teeth that are root tips (0=none; 1=1; 2=2 or more)	0.54	0.18	<.04	1.72 (1.19, 2.46)
Number of anterior teeth that are mobile (0=none; 1=1 or more)	1.95	0.35	<.01	7.00 (3.57, 14.18)
Tooth pain (3=has a toothache, tooth abscess, and sensitive tooth; 2=has 2 of these 3 conditions; 1=has 1 of these 3; 0=has none of these 3)	0.35	0.12	<.01	1.42 (1.16, 1.82)
Bad breath (1=has bad breath problem now; 0=does not)	0.89	0.28	<.01	2.45 (1.41, 4.23)
Dry mouth (1=has dry mouth now; 0=does not)	0.66	0.26	<.01	2.44 (1.45, 4.10)
Wear maxillary full denture now (0=has and wears maxillary full denture; 1=does not)	1.02	0.46	<.03	2.77 (1.13, 6.97)
Sex (0=male; 1=female)	1.08	0.27	<.01	2.97 (1.78, 5.07)

*CI=confidence interval.
The outcome of interest is reported current chewing difficulty (0=none; 1=1 or more of 5 possible difficulties).
n=799; pairs correct=82%; sensitivity=64%; specificity=89%; c=0.88.

Results

Sample Characteristics. The mean age of subjects was 61.5 years (SD=10.4). The distributions by age group, sex, race, and poverty status, and area of residence are provided as "weighted n" values in Table 3. Twenty-two percent of subjects did not complete high school, 27 percent stated high school as their highest educational attainment, 20 percent had some college, and 32 percent had graduated college or had a higher attainment.

Forty-five percent of the subjects reported that they never go to a dentist or only go when they have a problem, compared to 55 percent who reported going regularly or occasionally whether or not they have a problem. Fifty-nine percent of subjects said their last dental visit was within the previous year, 10 percent said it was one year ago to less than two years ago, 13 percent said two years ago to less than five years ago, and 17 percent said their last dental visit was five or more years ago. The mean number of teeth per person was 22.0, meaning that the typical subject had 10 missing teeth. Although all subjects had at least one remaining natural tooth as a criterion for selection, 11 percent of subjects were edentulous in one arch. Using the modification of the chewing index, 23 percent of subjects reported chew-

ing difficulties with one or more foods. Ten percent had difficulty speaking or pronouncing words because of oral problems.

Association Between Functional Limitation and Other Variables. Oral functional limitation was significantly more prevalent among blacks, persons living below the poverty level, persons with limited ability to pay an unexpected $500 dental bill, and non-high school graduates (Table 3). Females and rural residents also were more likely to report oral functional limitation.

Table 2 summarizes the associations between oral functional limitation and the clinical measures of oral disease and tissue damage. Difficulty with speaking or pronouncing words was significantly associated with having fewer remaining teeth, more root fragments, more severely mobile teeth, more teeth with severe attachment loss, and fewer fractured fillings. Current chewing difficulty was strongly associated with the number of remaining teeth and the number of occluding pairs of teeth. Current chewing difficulty also was significantly associated with having more root fragments, more severely mobile teeth, and more teeth with severe attachment loss.

Oral functional limitation, by self-reported measures of oral disease and tissue damage and oral pain, is summarized in Table 1. Subjects with recent speaking difficulty were significantly more likely to report having teeth that are stained or look bad, having an abscessed tooth, having bleeding gums, having infected or sore gums, having bad breath, toothache pain, and having denture soreness. Subjects with current chewing difficulty were significantly more likely to have reported having teeth that are stained or look bad, not wearing their maxillary full denture, having bleeding gums, having infected or sore gums, having bad breath, dry mouth, toothache pain, and denture soreness.

Multiple Regression Analyses. A multiple logistic regression of recent difficulty with speaking or pronouncing words because of problems with the teeth, mouth, or dentures was done (Table 4). Having fewer anterior teeth, a broken and/or sore denture, reporting teeth that are stained or look bad, and race (black) were significantly associated with recent speaking difficulty. The number of remaining anterior teeth had a strong association with recent speaking difficulty. Although the point estimate of the odds ratio is only 1.25, it is interpreted as an increased probability of difficulty for each decrease in one anterior tooth. The regression results suggest, therefore, that going from 12 anterior teeth to six anterior teeth, for example, would increase the odds by 7.5 (6 times 1.25).

The logistic regression of current chewing difficulty is presented in Table 5. Having fewer anterior and posterior pairs of opposing teeth were strongly associated with chewing difficulty. Other statistically significant covariates of chewing difficulty included having more posterior teeth that are root fragments, having more anterior teeth that are severely mobile, reporting tooth pain, reporting bad breath, reporting dry mouth, not wearing one's maxillary full denture, and being female.

The fit of each of the regression models was good, correctly predicting difficulty/nondifficulty in the overwhelming majority of subjects. This finding suggests that much of the variance in oral functional limitation is explained by the variables used in the FDCS. However, the sensitivity was moderate for the current chewing difficulty model, and poor for the speaking difficulty model. Specificity for both models was very high (>90%). The regressions suggest that if a subject does not have any of the clinical conditions, then the model almost always will predict correctly that a subject does not have the difficulty (high specificity). However, for subjects who have the clinical conditions measured, the model's ability to identify all subjects with this difficulty is moderate or poor (moderate to poor sensitivity), depending upon the type of difficulty.

Discussion

Oral functional limitation was prevalent in this community-based sample of dentate adults 45 years or older. Twenty-three percent of subjects reported current chewing difficulty and 10 percent reported recent speaking/pronouncing difficulty. These findings are consistent with the results of other studies that have measured chewing ability, both from a clinical and self-assessment standpoint. Because the FDCS only included dentate persons, the prevalence of oral functional limitation presumably would have been higher had all age-eligible persons been included. Locker and Miller found a 10 percent prevalence of difficulty with pronouncing words because of dental problems in Canadians 50 years old and older (3). Twenty percent of dentate persons in a study of 414 English persons 16–60 years old reported difficulty eating (difficulty chewing, biting hard, taking a big bite, or having to change the types of food eaten) (23). Nineteen percent of 65-year-old or older residents of central Florida were usually not able to chew hard things, such as hard bread or apples (24). Atchison and Dolan (25) observed a prevalence of chewing difficulty in the previous three months of 34 percent among a sample of 65-year-old and older Californians, 11 percent of whom were edentulous. A similar range of prevalences was found when samples from North Carolina, Ontario, and South Australia were compared (26). In his study of older Canadians, Leake found that 16 percent of dentate subjects reported chewing difficulties with one or more foods (8).

Unlike the FDCS, which observed the larger odds ratio with the absence of opposing pairs of anterior natural teeth, Leake's study had the larger odds ratio with opposing pairs of posterior natural teeth (8). Chauncey and colleagues (5), using the Swallowing Threshold Test Index, related current chewing difficulty to a more impaired dentition. They found the least chewing difficulty with an intact dentition and the most with full dentures. Those subjects with a compromised dentition and one restored with removable partial dentures fell in between. Agersberg and Carlsson (27) observed no chewing difficulties in subjects with 20 or more well-distributed teeth. Conversely, people with a removable partial denture in one jaw opposing natural teeth in the other jaw had reduced function, as did denture wearers (7). A study using the Swallowing Threshold Performance Test Index ranked subjects according to their dental status and level of performance; subjects with intact, partially compromised, or compromised dentitions had the highest level of performance. Subjects with full/full dentures, full/partial, full/natural teeth had the lowest levels of performance, while

subjects with partial/partial, partial/natural, and natural/partial had intermediate levels of performance (28).

Based on the concept that having at least 20 teeth may prevent chewing difficulties, some authors have promoted the concept of shortened dental arches. Käyser (29) maintains that because biological systems can adapt to changing circumstances, a shift from coarser foods to more refined foods has possibly decreased the need for a fully functioning dentition. This position was further supported by another study that concluded there were few benefits to be gained from removable partial denture therapy for shortened dental arches (30). Other studies suggest that subjects with dentures who report no chewing difficulty are altering their food choices to a softer diet or giving overly optimistic responses (31). Therefore, common to the FDCS and the other studies is a direct relationship between self-reported chewing difficulty and having fewer teeth. However, a significant percent of subjects (11%; results not shown, but alluded to in Table 2) in the FDCS with 20 or more teeth reported chewing difficulty.

Clearly, an important influence on oral function is the number of retained teeth. Conventional removable prosthetic replacement of teeth does not always successfully restore oral function. Conventional replacement may replace lost oral structures, but as shown in this study and others, may not offer the desired effective chewing ability. Implants, although showing favorable results with regard to retention and increased chewing ability, are costly and more technically involved in their delivery (32). Both conventional prosthetics and implants require labor-intensive periodic maintenance.

Like the findings regarding the relationship between oral functional limitation and the number of remaining teeth, we also observed that limitation is related to decrement in other clinical measures—namely, having posterior teeth that are actually root tips, and having anterior teeth that are severely mobile. Presumably, these clinical factors influence the ability to generate a biting force sufficient to chew adequately. A similar circumstance likely exists to explain why three other factors (having tooth pain, having a denture that is broken and/or sore, and not wearing one's full maxillary denture) are strongly associated with oral functional limitation.

Having a dry mouth was strongly associated with chewing difficulty, as well. It is well known that mouth dryness interferes with the ability to form a food bolus and to swallow that bolus, so this is a reasonable explanation for our finding in Table 5. "Poor esthetics" and "bad breath" may act as broad indicators of a substantial decrement in oral condition not captured by the clinical measures of that condition used in the FDCS.

Oral functional limitation was especially prevalent in blacks, poor persons, and females. In previous publications from the FDCS, we have reported differences in clinical measures of disease by race, poverty status, and sex (16-18). However, with these clinical factors taken into account by the multiple regressions, sex and race were still important in explaining variation in oral functional limitation. While sex and race may not be causes of functional limitation per se, they may act as proxies for differences in symptom reporting behavior, differences that are caused by differential attention to bodily states and the importance attributed to them (33-36). An additional explanation for the findings according to race and sex is that, despite the fact that the FDCS included a broad array of clinical conditions, differences in unmeasured clinical conditions between males, females, blacks, and whites could account for our observation.

This study has documented a significant prevalence of oral functional limitation in a diverse sample of dentate adults. Based on the relationships between self-reported functional limitation and the clinical and self-reported measures of oral disease, tissue damage, and oral pain, as well as its construct validity demonstrated within the context of a multidimensional model of oral health (12), we conclude that self-reported oral functional limitation is a valid measure of an important oral health outcome. Ultimately, it may prove to be an important measure when assessing the long-term effectiveness of dental care, which clinical measures of disease alone would not detect.

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References

1. Cushing AM, Sheiham A, Maizels J. Developing socio-dental indicators: the social impact of dental disease. Community Dent Health 1986;3:3-17.
2. Locker D. Measuring oral health: a conceptual framework. Community Dent Health 1988;5:3-18.
3. Locker D, Miller Y. Evaluation of subjective oral health status indicators. J Public Health Dent 1994;54:167-76.
4. Antczak-Bouckoms A. Quality and effectiveness issues related to oral health. Med Care 1995;53(11 Suppl):NS123-42.
5. Chauncey HH, Muensch ME, Kapur KK, Waylor AH. The effect of the loss of teeth on diet and nutrition. Int Dent J 1984; 34:98-104.
6. Rosenberg D, Kaplan S, Senie R, Badner V. Relationships among dental functional status, clinical dental measures, and generic health measures. J Dent Educ 1988;52:653-7.
7. Carlsson GE. Masticatory efficiency: effect of age, the loss of teeth and prosthetic rehabilitation. Int Dent J 1984;34:93-7.
8. Leake JL. An index of chewing ability. J Public Health Dent 1990;50:262-7.
9. Patrick DL, Deyo RA. Generic and disease-specific measures in assessing health status and quality of life. Med Care 1989;27(3 Suppl):S217-32.
10. Ware JE, Jr. The status of health assessment 1994. Ann Rev Public Health 1995; 16:327-54.
11. Mitchell PH. The significance of treatment effects: significance to whom? Med Care 1995;33(4 Suppl):AS280-5.
12. Gilbert GH, Duncan RP, Heft MW, Dolan TA, Vogel WB. Multi-dimensionality of oral health in dentate adults. Med Care 1998;36:988-1001.
13. US Bureau of the Census. Census of population and housing, 1990. Public use microdata samples. Washington, DC: US Technical documentation, 1992.
14. Gilbert GH, Duncan RP, Kulley AM, Coward RT, Heft MW. Evaluation of bias and logistics in a survey of adults at increased risk for oral health decrements. J Public Health Dent 1997;57:48-58.
15. Guess HA, Jacobsen SJ, Girman CJ, et al. The role of community-based longitudinal studies in evaluating treatment ef-

fects: example: benign prostatic hyperplasia. Med Care 1995;33(4 Suppl):AS26-35.
16. Gilbert GH, Antonson DE, Mjör IA, et al. Coronal caries, root fragments, and restoration and cusp fractures in US adults. Caries Res 1996;30:101-11.
17. Dolan TA, Gilbert GH, Ringelberg ML, et al. Behavioral risk indicators of attachment loss in adult Floridians. J Clin Periodontol 1997;24:223-32.
18. Ringelberg ML, Gilbert GH, Antonson DE, et al. Root caries and root defects in urban and rural adults. J Am Dent Assoc 1996;127:885-91.
19. SAS Institute, Inc. SAS/STAT user's guide: version 6. 4th ed. Cary, NC: SAS Institute, 1989.
20. Belsley DA, Kuh E, Welsch RE. Regression diagnostics: identifying influential data and sources of collinearity. New York: Wiley, 1980.
21. Swets JA. Measuring the accuracy of diagnostic systems. Science 1988;240:1285-93.
22. Hennekens CH, Buring JE. Epidemiology in medicine. Boston, MA: Little, Brown, and Co., 1987.
23. Cushing AM, Sheiham A, Maizels J. Developing socio-dental indicators: the social impact of dental disease. Community Dent Health 1986;3:3-17.
24. Gilbert, GH, Heft MW, Duncan RP. Oral signs, symptoms, and behaviors in older Floridians. J Public Health Dent 1993;53: 151-7.
25. Atchison KA, Dolan TA. Development of the Geriatric Oral Health Assessment Index. J Dent Educ 1990;54:680-7.
26. Slade GD, Spencer AJ, Locker D, Hunt RJ, Strauss RP, Beck JD. Variations in the social impact of oral conditions among older adults in South Australia, Ontario, and North Carolina. J Dent Res 1996;75: 1439-50.
27. Agerberg G, Carlsson GE. Chewing ability in relation to dental and general health. Acta Odontol Scand 1981;39:147-53.
28. Wayler AH, Muensch ME, Kapur KK, Chauncey HH. Masticatory performance of food acceptability in persons with removable partial dentures, full dentures, and intact natural dentition. J Gerontology 1984;39:284-9.
29. Käyser AF. Shortened dental arches and oral function. J Oral Rehab 1981;8:457-62.
30. Leake JL, Hawkins R, Locker D. Social and functional impact of reduced posterior dental units in older adults. J Oral Rehab 1994;21:1-10.
31. Demers M, Bourdages J, Brodeur JM, Benigeri M. Indicators of masticatory performance among elderly complete denture wearers. J Prosth Dent 1996;75:188-93.
32. Geertman MA, Boerrigter EM, Van't Hof MA, Van Waas MAJ, van Ort RP, Boering G. Two-center trial of implant-retained mandibular overdentures versus complete dentures—chewing ability. Community Dent Oral Epidemiol 1996;24:79-84.
33. Barksy AJ, Cleary PD, Klerman GL. Determinants of perceived health status of medical outpatients. Soc Sci Med 1992;34: 1147-54.
34. Mechanic D. Social psychological factors affecting the presentation of bodily complaints. New Engl J Med 1972;286:1132-9.
35. Watson D, Pennebaker JW. Health complaints, stress, and distress: exploring the central role of negative affectivity. Psychol Rev 1989;96:234-54.
36. Gilbert GH, Duncan RP, Heft MW, Coward RT. Dental health attitudes among dentate black and white adults. Med Care 1997;35:255-71.