Intraoral Tactile Sensitivity in Adults With Diabetes

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OBJECTIVE — The intraoral tactile sensitivity (ITS) of diabetic and nondiabetic subjects was compared. The effects of age, ethnicity, sex, and intraoral site were considered.

RESEARCH DESIGN AND METHODS — The sample comprised 589 participants of the Oral Health: San Antonio Longitudinal Study of Aging. A total of 107 subjects (61.8 ± 10.0 years; 48 women, 59 men) met American Diabetes Association diagnostic criteria for diabetes and 482 subjects (58.8 ± 11.1 years; 274 women, 208 men) did not. ITS was assessed with an oral microaesthesiometer with a cross-modality matching procedure. The dependent variable was the slope of the psychophysical function relating physical stimulus intensity (air pressure) and subjects' judgments of stimulus intensity. Data were analyzed using ANOVA for repeated measures with between-subject factors of age, sex, ethnicity, and diabetes and the within-subject factor of intraoral site.

RESULTS — Diabetic and nondiabetic subjects showed no significant differences in ITS at any of the three test sites. European Americans demonstrated greater soft-palate sensitivity (mean ± SD 0.26 ± 0.15) compared with Mexican Americans (0.24 ± 0.16; $P = 0.046$). The three intraoral test sites differed in tactile sensitivity ($P < 0.001$); posterior tongue (0.33 ± 0.22) was most sensitive, followed by the soft palate (0.25 ± 0.15) and the anterior tongue (0.23 ± 0.13). Potentially confounding factors were not associated with ITS.

CONCLUSIONS — Our results suggest that diabetes per se may not influence ITS.

Diabetes Care 27:869–873, 2004

Long-term complications of diabetes include microvascular impairment and clinical neuropathies. Diabetic peripheral neuropathies affect motor, sensory, and autonomic nerves through several different mechanisms and are associated with increased morbidity and mortality in patients with diabetes (1).

It is widely assumed that diabetic neuropathy and microcirculatory disturbances also lead to alterations in the oral cavity. Periodontal disease is considered a complication of diabetes (2), and there is evidence that treatment of periodontal infection contributes to better metabolic control (3,4). Patients with diabetes often complain of reduced salivary flow and/or xerostomia, altered saliva composition, inflammation, loss of sensation, changes in taste perception, numbness, burning mouth syndrome, and lesions of oral mucosa and tongue (5–7). Peripheral and autonomic neuropathies also constitute independent risk factors for tooth loss and temporomandibular disorders in elderly patients with type 2 diabetes (8). Histopathologic and histochemical changes also occur in the denture base–bearing mucosa that supports masticatory pressure (9,10).

Alteration of oral sensation, such as reduced intraoral tactile sensitivity (ITS), also may be expected from diabetes complications. However, to date, knowledge of the relationship between diabetes status and ITS remains inconclusive. Lack of such knowledge is an important problem because impaired sensitivity may predispose diabetic patients to clinical challenges such as denture adaptation problems and lack of awareness of developing ulcers.

The purpose of this study was to evaluate ITS in diabetic and nondiabetic adults from a large community-based sample. The a priori hypothesis was that subjects with diabetes would have impaired ITS compared with subjects without the disease.

RESEARCH DESIGN AND METHODS

— The study sample consisted of participants of the Oral Health: San Antonio Longitudinal Study of Aging, conducted in San Antonio, Texas, from July 1994 to May 1998. These subjects comprise a stratified random sample of younger individuals (aged 34–64 years) drawn from the San Antonio Heart Study and older individuals (aged ≥65 years) drawn from the San Antonio Longitudinal Study of Aging. Subjects were recruited from households randomly selected from three socioeconomically distinct neighborhoods in San Antonio, Texas: *1*) a low-income, almost exclusively Mexican-American "barrio" neighborhood; *2*) a mixed Mexican-American/European-American, middle-income, "transitional" neighborhood; and *3*) an upper-income, "suburban" neighborhood containing ~10% Mexican Americans and 90% European Americans. Stratified random sampling was conducted in the transitional and suburban neighborhoods to obtain approximately equal numbers of Mexican-American and European-American subjects, but only Mexican-American subjects were recruited from the barrio neighborhood due to the small

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Received for publication 17 September 2003 and accepted in revised form 20 December 2003.

Abbreviations: ICC, intraclass correlation coefficient; ITS, intraoral tactile sensitivity; OMA, oral microaesthesiometer.

Table 1—*Oral, medical, and sociodemographic characteristics of sample subjects*

Variable	Diabetic subjects	Nondiabetic subjects	*P*
n	107	482	
Duration of diabetes (years)	8.5 ± 8.7	NA	
Weight (kg)	84.3 ± 16.8	78.1 ± 17.4	<0.001
Height (cm)	166.4 ± 10.9	166.7 ± 9.6	0.769
BMI (kg/m^2)	31.0 ± 5.4	28.6 ± 5.7	<0.001
HbA_{1c} (%)	8.6 ± 2.2	5.6 ± 0.8	<0.001
Age (years)	61.8 ± 10.0	58.8 ± 11.1	0.010
Alcohol consumption (g/week)	35.2 ± 93.3	39.5 ± 94.2	0.671
Neighborhood			
Barrio	37 (34.6)	76 (15.8)	<0.001
Transitional	40 (37.4)	188 (39.0)	
Suburban	30 (28.0)	218 (45.2)	
Hypertensive	53 (50.0)	165 (34.2)	0.003
Education (years)			
<12	34 (31.8)	89 (18.5)	0.003
12	32 (29.9)	127 (26.3)	
13–15	26 (24.3)	139 (28.8)	
16+	15 (14.0)	127 (26.3)	
Income (U.S. $/month)			
0–999	27 (25.2)	58 (12.0)	<0.001
1,000–1,999	35 (32.7)	112 (23.2)	
2,000–2,999	13 (12.1)	95 (19.7)	
3,000+	32 (29.9)	217 (45.0)	
Ethnic group			
Mexican American	75 (70.1)	255 (52.9)	0.001
European American	32 (29.9)	227 (47.1)	
Sex (women)	48 (44.9)	274 (56.8)	0.032
Currently uses alcohol	37 (34.6)	247 (51.5)	0.002
Ever used tobacco	58 (54.2)	233 (48.4)	0.287
Currently uses tobacco	15 (14.0)	70 (14.5)	1.000

Continuous variables are shown as mean ± SD; categorical variables are shown as frequency (percent). Statistical testing used Pearson's χ^2 test, Fisher's exact test, and Student's *t* test for independent groups.

numbers of European Americans living there. Subjects were excluded if they were pregnant or if their ethnicity could not be identified as either European American or Mexican American according to an algorithm (11). Subjects were selected without regard to dental treatment status.

For the present analysis, subjects were excluded if they were not assessed for diabetes using American Diabetes Association diagnostic criteria (n = 36); if they reported current use of digluconate mouthwash or any other medication with the potential to cause oral stinging, tingling, numbness, burning, or trismus (n = 31); if their ITS data were missing (n = 13); or if their ITS data were judged to be invalid by virtue of having a psychophysical slope function (see below) that did not follow a monotonic positive trend (n = 135). The remaining subjects included 107 who met American Diabetes Association diagnostic criteria for type 2 diabetes and 482 who did not meet those criteria. Some oral, medical, and sociodemographic characteristics of the sample are shown in Table 1.

Data were collected during three assessment sessions held on different days. One session was held at the subject's home, one at a medicine clinic, and one at a dental clinic. Data collection procedures included interviews, questionnaires, and laboratory tests as well as physical, psychological, and performance-based examinations. All subjects gave written informed consent for their participation, and the University of Texas Health Science Center at San Antonio Institutional Review Board approved the research protocol.

Diabetes

Classification of subjects as diabetic or nondiabetic was according to the American Diabetes Association criteria (2). Control status of diabetes was assessed through measurements of plasma concentration of HbA_{1c}. Subjects were further classified into three groups based on their HbA_{1c} level using criteria specified for the Diabetes Control and Complications Trial (12). Subjects with HbA_{1c} levels ≥9.49% were classified as in poor control; those with levels from 6.88 to 9.49% were classified as in medium control; and those with levels ≤6.87% were classified as in good control.

ITS

ITS was measured using a cross-modality matching technique (13) at three sites: the anterior tongue, the posterior tongue, and the soft palate. The length of the tongue was measured, and test sites were marked with blue denture marker 3 mm to the right of the midline at the anterior and posterior one-third points. The soft palate site was marked 8 mm above the base of the uvula. Small calibrated puffs of air were directed at the test sites with an oral microaesthesiometer (OMA; Neurocommunication Research Laboratories, Danbury, CT) using a handheld nozzle at a distance of 2 mm from the oral mucosal membrane. The reliability and validity of the OMA to measure the sensitivity of the mucous membranes of the oral cavity were documented by Weinstein (14).

Stimulus intensities of 0, 0.0022, 0.028, and 0.140 g were presented twice at each site in random order, after demonstration and a few practice trials. The OMA was calibrated monthly. Intensity judgments of the air pressure perceived at each oral cavity site were obtained with a direct scaling procedure (13). Subjects registered their responses by extending a retractable tape measure to a distance proportional to the perceived stimulus intensity. Response magnitude was read in millimeters from the reverse side of the tape, which was not visible to the subject. Participants were instructed to respond to the initial stimulus with a distance that seemed appropriate to them, rather than by comparison with a standard reference stimulus.

ITS was characterized by the slope of the psychophysical function relating physical stimulus intensity to tape measure distance. Responses to two presentations of each stimulus intensity were averaged for each intraoral site. The common logarithm of the mean response

Table 2—*ITS of diabetic and nondiabetic subjects by intraoral site*

Intraoral site	Diabetic subjects	Nondiabetic subjects	*P*
n	107	482	
Anterior tongue	0.23 ± 0.12	0.23 ± 0.13	0.868
Posterior tongue	0.34 ± 0.24	0.32 ± 0.22	0.384
Soft palate	0.26 ± 0.16	0.25 ± 0.15	0.446

Data are means ± SD.

magnitude (in millimeters) was regressed onto the logarithm of delivered stimulus intensity (in grams) using the least-squares method, and the slope of the resulting regression line was taken as the measure of ITS. A nonparametric test for monotonic trend was performed, and subjects failing to show a significant monotonic trend in their responses as a function of increasing physical stimulus intensity were excluded. Failure of subjects' responses to follow a monotonic trend suggests failure to comprehend the task or some other technical problem. The intraclass correlation coefficient (ICC) was calculated for each test site in each subject to assess consistency in responding across repeated trials.

Data analysis

Differences in ITS (slopes) were analyzed using ANOVA for repeated measures with diabetes status (diabetic subjects versus nondiabetic subjects), age-group (<65 vs. ≥65 years), sex (men versus women), and ethnic group (Mexican American versus European American) as between-subject factors and intraoral test site (anterior tongue versus posterior tongue versus soft palate) as a within-subject factor. Residuals following application of this model to all available data showed positive kurtosis. Residuals approached normality after a 1% trim of the data and square root transformation. Greenhouse-Geisser–adjusted *P* values were used for testing within-subject effects ($\varepsilon = 0.94$). Significant interactions were explored by performing pairwise comparisons of groups comprising the interaction. Exploratory analyses to test the effects of potentially confounding variables (e.g., level of diabetes control, duration of diabetes, concurrent hypertension, tobacco and alcohol use, and use of medications) were performed using Student's *t* tests for independent groups, reduced ANOVA models, and correlational methods. Differences between groups on socioeconomic, demographic, and health variables were tested using independent groups using Student's *t* tests in the case of continuous variables and Pearson's χ^2 or Fisher's exact test in the case of categorical variables. A two-sided α level of 0.05 was adopted for all statistical testing. The Bonferroni adjustment was applied within families of multiple comparisons, and adjusted *P* values are reported. All data are presented as untransformed mean ± SD.

RESULTS — Contrary to our predictions, the diabetic subjects showed slightly superior ITS compared with the nondiabetic subjects at the posterior tongue and soft palate sites (see Table 2), but these differences did not approach statistical significance. The diabetes status by ethnic group interaction was statistically significant [$F(1,573) = 4.91$; $P = 0.027$], with the diabetic European Americans demonstrating slightly greater ITS at all three sites compared with both nondiabetic groups and the diabetic Mexican Americans (see Table 3). These differences were not statistically significant after adjusting for multiple comparisons. The main effect of ethnic group [$F(1,573) = 3.92$; $P = 0.048$] was statistically significant. At the soft palate site only, European Americans demonstrated greater ITS (0.26 ± 0.15) compared with Mexican Americans (0.24 ± 0.16; $P = 0.46$).

The three-way interaction of diabetes status by age-group by intraoral site also achieved statistical significance [$F(2,1146) = 6.42$; $P = 0.002$]. Again, however, the direction of this effect was contrary to our prediction, with older and diabetic subjects tending to have slightly greater ITS compared with the younger and nondiabetic subjects at posterior tongue and soft palate sites. These pairwise differences were not statistically significant after controlling for multiple comparisons.

ITS at the three sites was different [$F(2,1146) = 1.44$; $P < 0.001$]; the posterior tongue (0.33 ± 0.22) was significantly more sensitive than the anterior tongue (0.23 ± 0.13) and the soft palate (0.25 ± 0.15). The sensitivity of the anterior tongue and soft palate were not significantly different.

The Z-transformed ICCs were analyzed to assess whether the reliability of subjects' responding was associated with the study variables. Responding was significantly more reliable at the anterior tongue (1.31 ± 0.65) compared with the posterior tongue (1.03 ± 0.66) and soft palate (1.21 ± 0.65) [$F(2,1138) = 12.61$; $P < 0.001$]. Diabetes status showed no significant association to reliability of responding.

The following supportive analyses were undertaken in an effort to disclose possible influences on ITS of potentially confounding variables that could not be studied within the general analysis model.

Tobacco use

Subjects were classified based on their verbal report according to whether they currently used any tobacco products or had a lifetime history of using any tobacco

Table 3—*ITS as a function of diabetes status and ethnic group*

	Diabetic		Nondiabetic		
Intraoral site	European Americans	Mexican Americans	European Americans	Mexican Americans	*P*
n	32	75	227	255	
Anterior tongue	0.26 ± 0.13	0.22 ± 0.12	0.22 ± 0.12	0.24 ± 0.14	0.090
Posterior tongue	0.40 ± 0.25	0.32 ± 0.23	0.32 ± 0.19	0.33 ± 0.24	0.077
Soft palate	0.29 ± 0.18	0.24 ± 0.16	0.25 ± 0.14	0.24 ± 0.16	0.228

Data are means ± SD. The *P* value shown is for the diabetes by ethnic group interaction at each intraoral site (df = 1,573). This interaction is statistically significant taken over all three intraoral sites ($P = 0.027$).

products. Neither current nor lifetime tobacco use was significantly associated with ITS.

Alcohol use
Subjects were classified according to their verbal report as either current users or not current users of alcohol in any amount. Typical alcohol consumption also was estimated from verbal report and expressed as g/week. Neither current use status nor typical alcohol consumption was associated with ITS. This was true for all subjects and for current alcohol users.

Hypertension
Subjects were classified as hypertensive if the diastolic pressure was higher than 95 mmHg or they were currently taking antihypertensive medications (6). Hypertension was not significantly associated with ITS.

Diabetes control
ANOVA using only diabetic subjects showed no statistically significant association between diabetes control (good, medium, poor) and ITS. Correlations between the ITS at each site and HbA_{1c} levels were nonsignificant.

Duration of diabetes
Duration of diabetes was available for 97 of the diabetic subjects. This was estimated by asking subjects the question: "When did a doctor first tell you that you had diabetes?" Duration was calculated by subtracting the reported date from the interview date and rounded to the nearest year. The correlations between duration of diabetes and ITS at each site were not significant.

BMI
Correlation analysis was used to assess the association between BMI and the measures of ITS. None of the correlations approached statistical significance, suggesting that BMI and hyperphagia probably do not affect ITS.

Reliability of subject responding
If some subjects were unable to reliably perform the cross-modality matching task for reasons unrelated to ITS (e.g., misunderstanding of instructions, poor motivation), this could adversely impact the validity of results. Therefore, analyses were conducted using only subjects meeting certain standards for consistency in their responses. Three analyses were completed, one each including only subjects with ICC ≥0.6 (n = 70 diabetic subjects; n = 327 nondiabetic subjects), ICC ≥0.7 (n = 59 diabetic subjects; n = 285 nondiabetic subjects), and ICC ≥0.8 (n = 44 diabetic subjects; n = 200 nondiabetic subjects). These analyses demonstrated no statistically significant differences in ITS between diabetic and nondiabetic subjects at any site.

Potential oral adverse effects of medications
All medications subjects reported taking during a home-based and/or a dental clinic–based assessment were recorded. Three standard drug references (15–17) were consulted to identify all listed adverse effects potentially affecting the oral cavity. Subjects were classified according to whether they were potentially at risk for the following oral adverse effects from medications they were taking: dry mouth, altered taste perception, glossitis, stomatitis, gingival bleeding, gingival hypertrophy, lichenoid reactions, excessive salivation, angioedema, candidiasis, burning sensation, salivary gland pain, perioral dermatitis, hypersensitive gag reflex, stinging sensation, and tardive dyskinesia. No significant differences in ITS were found between subjects who were and those who were not taking medications with the potential to cause these oral adverse effects.

A total of 16 (15%) of the diabetic subjects were taking insulin, 55 (51%) were taking oral medication for diabetes, and 36 (34%) were controlling their diabetes through diet and exercise only. ITS was not significantly associated with diabetes treatment at any site [$F(2,104)$ = 0.78; P = 0.46]. Five diabetic subjects were taking the oral antidiabetic drug metformin, which is reported to cause an unpleasant metallic taste. Although this group of subjects had the poorest ITS at the posterior tongue and soft palate sites, the mean ITS was not significantly different from that of the diabetic subjects who were not taking metformin or the healthy control subjects [$F(2,586)$ = 0.11; P = 0.89].

CONCLUSIONS — Diabetic peripheral neuropathy is reported to cause oral pain, hyperesthesia, dysesthesia, and loss of sensation, whereas autonomic neuropathy may impair salivary flow rate (5,7); however, the dental literature shows inconsistencies regarding the association between diabetic condition and oral complications. For instance, diabetic subjects may be more prone to oral dryness and infections than nondiabetic subjects (6), but the various forms of diabetic neuropathy are not associated with the occurrence of oral mucosal lesions (8). We predicted that diabetic subjects would have lower ITS compared with nondiabetic subjects. Our data, however, suggest that diabetes per se may not directly influence ITS as assessed by OMA. Confounding factors and potential modifiers of diabetes status (e.g., level of diabetes control, duration of diabetes, hypertension, tobacco and alcohol use, and medications having oral adverse effects) also were not associated with ITS. Therefore, it is unlikely that these potentially confounding variables masked the effects of diabetes on ITS. However, our inability to control these variables experimentally is a limitation of the present study. In relation to medications, drugs commonly used to treat diabetes or hypertension do not present any significant potential oral adverse effects concerning ITS. Metformin and tolbutamide may affect taste and some antihypertensive drugs cause dry mouth, but there is no report of potential ITS alteration (15).

The three sites tested had different levels of ITS, although the differences were slight. The highest ITS was found for the posterior tongue, followed by the soft palate and the anterior tongue. Differences in innervation may explain these findings, which are consistent with other studies on oral mucosal sensory testing (18).

Ethnicity also influenced ITS; European Americans had greater soft palate ITS than Mexican Americans. These results suggest some cultural influence on the perception of the presented stimuli or the performance of the task.

No significant differences in ITS were found between younger and older subjects, which is contradictory to previous findings that perception of localized pressure on the anterior dorsal tongue and accuracy of intensity judgments decline with age in healthy individuals (13). Inclusion of subjects from different ethnic groups and altered health conditions may be responsible for these results.

Further studies should analyze ITS in diabetic patients with peripheral neurop-

athy as well as other types of diabetic sensory impairment to further elucidate the influence of the disease on oral perception.

Acknowledgments— The oral microaesthesiometer was a donation of the NeuroCommunication Research Laboratories (Danbury, CT), under the auspices of a Small Business Innovative Research Grant from the National Institute of Deafness and Communications Disorders, National Institutes of Health. This study was supported by National Institutes of Health/National Institute of Deafness and Communications Disorders Grant P50-DE-10756 and by CAPES/Brazil BEX 0807/99-0.

We thank Dr. Helen P. Hazuda, Department of Medicine, University of Texas Health Science Center at San Antonio, for her assistance in the data management.

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