Taste Threshold, Anatomical Form of Fungiform Papillae and Aging in Humans

by

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Abstract

The purpose of this study was to investigate the changes in taste sensitivity during aging using four standard taste solutions. The subjects consisted of 50 normal volunteers who were divided into two groups. The younger age group was composed of 27 individuals between the ages of 20 and 30 years. The older group consisted of 23 individuals between the ages of 50 and 77 years. In order to evaluate the anatomic form of the fungiform papillae, close-up photographs (×3) were taken on the right side of the tongue in all subjects. Then, each subject’s taste threshold was measured by placing the four taste solutions on the following structures: fungiform papillae, circumvallate papillae and soft palate.

The anatomical forms of the fungiform papillae were significantly different upon comparison of the two groups (p<0.05), and the taste sensitivity of fungiform and circumvallate papillae also showed significant differences (p<0.05).

Introduction

The average age of the population is increasing\(^1\), and the taste sensitivity of humans is known to decrease with advancing age\(^2\)–4\). Two methods are commonly used for the testing of taste sensitivity. NILSON\(^5\) discussed the use of the electrogustometer in a study of 146 subjects. However, this method does not permit measurement of the four standard taste thresholds. In many of the previous studies on taste sensitivity in aged subjects measured using taste solutions, the threshold-measuring procedure adopted was the taste sensitivity of the entire mouth, which was evaluated using a drop of taste solution\(^4\)–7\). There are three cranial nerves that control taste sensitivity\(^3\). When testing the taste sensitivity of the entire mouth, it is not possible to make individual measurements of taste sensitivity at the three types of papillae and/or taste bud which are controlled by these three cranial nerves.

With regard to taste sensitivity in humans, some studies have observed the

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anatomical form of fungiform papillae by means of close-up photography. Békésy\textsuperscript{[8]} found that there were four different forms of papillae in humans, each sensitive to one of the four standard tastes. However, Ishii\textsuperscript{[9]} found that in healthy humans, there were significant differences in papilla form according to age and sex. In this study, photographs of fungiform papillae were analyzed to determine whether their form could be related to decreases in human taste sensitivity.

The purpose of the present study was to investigate taste sensitivity in the aged using four standard taste solutions, on three kinds of papillae and/or taste buds, each of which is controlled by a different cranial nerve.

The anatomic changes occurring in fungiform papillae with advancing age were studied by comparing close-up photographs from two subject age groups.

\textbf{Materials and Methods}

The subjects of this study were 50 normal female and male volunteers who were divided into two age groups. The younger age group was composed of 27 individuals (10 females and 17 males) between the ages of 20 and 30 years (mean age=25.1±2.4 years). The older age group consisted of 23 individuals (11 females and 12 males) between the ages of 50 and 77 years (mean age=63.0±7.7 years). The younger volunteers were dental students, and the older volunteers were patients attending School of Dentistry, the University of Michigan.

All the participants were chosen from among those who did not have diabetes, were not on a salt-restricted diet, had never had any brain tumors, and were not allergic to quinine.

Magnified photographs (×3) of the fungiform papillae were taken in all of the subjects with a 35-mm camera fitted with a close-up lens (PB-6, Nikon, Tokyo, Japan). The area of the tongue photographed was approximately 2 cm from the tip, as measured along the right lateral border\textsuperscript{[9]}. Using these photographs, the anatomical and capillary vessel forms of the fungiform papillae were evaluated.

Taste threshold was measured using the method described by Okuda\textsuperscript{[6]} using four standard ready-made taste solutions, each at five concentrations (Sanwa Chemical, Nagoya, Japan) (Table 1).

In each subject, a 3-mm-diameter piece of filter paper was placed over the fungiform papillae at approximately the same location as that previously photographed. This filter paper was saturated with the lowest concentration of the sweet solution, and then the concentration was progressively increased until the taste was correctly identified.

For checking this process of taste identification, a table was used in which

<table>
<thead>
<tr>
<th>Taste</th>
<th>Concentration (%)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet (Sucrose)</td>
<td></td>
<td>0.3</td>
<td>2.5</td>
<td>10</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>Salty (Sodium chloride)</td>
<td></td>
<td>0.3</td>
<td>1.25</td>
<td>5</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Sour (Tartaric acid)</td>
<td></td>
<td>0.02</td>
<td>0.2</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Bitter (Quinine hydrochloride)</td>
<td></td>
<td>0.001</td>
<td>0.02</td>
<td>0.1</td>
<td>0.5</td>
<td>4</td>
</tr>
</tbody>
</table>
six responses were listed: four different tastes (sweet, salty, sour, bitter), no taste, and presence of taste but identification uncertain. Each subject was asked to point to one of the six responses within 30 seconds of the saturated filter paper being placed on the tongue. All subjects were then tested in a similar manner, using salty, sour and bitter solutions. When changing from one type of solution to another, the volunteer was asked to rinse the mouth thoroughly with tap water.

Using the same solutions and in a similar manner, tests were then conducted on the circumvallate papillae and on the right side of the soft palate at a spot located 2 cm oral of the uvula and 2 cm to the right of the midline.

The chi-squared test was used to compare the taste thresholds of the younger age group with those of the older age group for each of the four taste solutions at each of the three anatomic locations. The chi-squared test was also used to compare the anatomical forms of the fungiform papillae in the two groups. The fungiform papillae were classified as either ovoid or trapezoid, and the capillary vessel form of the papillae was classified as either branching or non-branching.

Results

A significant difference was found to exist for both age groups with regard to the anatomical form of the fungiform papillae and capillary vessel form (p<0.05).

<table>
<thead>
<tr>
<th></th>
<th>Fungiform Papillae</th>
<th>Circumvallate Papillae</th>
<th>Soft Palate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet</td>
<td>N.S.</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Salty</td>
<td>*</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>Sour</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Bitter</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Chi-squared analysis
* Significant difference (p<0.05)
N.S.: No significant difference (p>0.05)

Fig. 1 Fungiform Papilla Form
A: Subject from younger age group
B: Subject from older age group

Table 2 Significance of taste sensitivity by area
In the younger age group, the fungiform papillae were ovoid in form and the papilla capillary vessel form was branching or tree-like (Fig. 1A).

In the older age group, the fungiform papillae were trapezoidal in form, and the capillary vessels were almost straight with no branching (Fig. 1B).

Significant differences in taste sensitivity were noted except for sweet in conjunction with fungiform papillae and salty in conjunction with circumvallate papillae and soft palate (Table 2).

The percentage of subjects in the two groups who identified the four types of taste solutions at different concentrations are shown in Figs. 2–4. In the figures, the symbol > V is used to indicate that a correct identification could not be made even when the concentration was increased to level V (Table 1).

**Discussion**

Taste sensitivity is influenced by a number of factors besides age. For example, sex\(^{7,7}\), smoking\(^{10,10}\), olfaction\(^{11,12}\) and audition\(^{13}\) have been cited. Since taste solutions were used in this experiment, olfaction can be excluded as a factor. Subjects who smoked did not do so within one hour before the start of the experiment.
In measuring taste thresholds, measurements were done at locations controlled by the cranial nerves VII, IV and X. In the case of the tongue, measurements were taken on the fungiform papillae (VII nerve) and the circumvallate papillae (IX nerve). Among previous studies concerning the palate, particularly the hard palate, there is a report which notes that a large number of taste buds exist on the hard palate and on the free edge of the soft palate. In other studies where the hard palate has been either covered by a denture prosthesis or anesthetized, the taste sensitivity for “bitter” and “sour” has been reported to be decreased. On the other hand, there are reports stating that the insertion of a denture does not affect taste, and that taste sensitivity is higher on the soft palate posterior to the vibration line than on the hard palate. Furthermore, OKUDA found that the sensitivity was high on the soft palate near the uvula. In the present study, we chose the same area of the soft palate as that studied by OKUDA, in order to eliminate the influence of complete dentures in the older age group.

The taste sensitivity at the fungiform papillae tended to be higher in both groups for “sweet” and “salty” solutions than for the other two tastes (Fig. 3). This was previously pointed out by BEST and TAYLOR. The taste sensitivity in the younger age group was significantly different from the older age group for salty, sour and bitter, but was not significantly different for sweet (p<0.05). The factors possibly affecting such a difference in taste sensitivity in the two groups are the numbers.
of fungiform papillae and taste buds located on the anterior part of the tongue, and also the structure of the papillae themselves. However, according to previous studies on the numbers of papillae and taste buds in younger and older age groups, there was no significant difference apparent\(^{[20,21]}\). Also, Mistretta and Baum\(^{[20]}\) found that with regard to the structure of the papillae in rats, there was no difference in morphology between younger and older age groups.

In the present study, observations were made of the forms of the papillae and capillary vessels in the subjects in the younger and older age groups as they appeared in close-up photographs. Significant differences were noted between the two groups (p<0.05). Such differences could be due to the progressive degeneration caused by advancing age.

As for taste sensitivity at the circumvallate papillae, it was found to be high for “sweet” in the younger age group, as well as for “sour” and “bitter," as pointed out by Best and Taylor\(^{[19]}\). However, in the case of the older age group, the sensitivity was found to be about the same for all of the four taste solutions (Fig. 3). A comparison between the younger and older age groups with regard to taste sensitivity revealed significant differences for sweet, sour and bitter, but insignificant differences for salty (p<0.05).

As for taste sensitivity on the soft palate (Fig. 4), “sour” and “bitter” were
found to be less sensitively tasted than "sweet" and "salty" in both the younger and older age groups. A comparison between these groups with regard to taste sensitivity revealed significant differences for sweet, sour and bitter, but no significant difference for salty (p < 0.05).

The differences in taste sensitivity of circumvallate papillae and the soft palate can also be attributed to progressive degeneration with age.

These decreases in taste sensation may affect the nutritional balance of geriatric patients. A “good tasting” and nutritionally adequate diet for aged persons may differ from the needs of young adults. Other parameters for formulating a desirable diet for aged patients may include color, texture, form, arrangement, odor, temperature and cultural considerations.

Conclusions

1. The anatomical form of fungiform papillae differs significantly between younger and older individuals (p < 0.05).
2. The taste sensitivities of fungiform and circumvallate papillae are significantly different between younger and older individuals (p < 0.05).

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