Validation of Chemical Gustatory Function Tests in the Elderly

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Validation of Chemical Gustatory Function Tests in the Elderly

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저자 이혜진 드림

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Validation of Chemical Gustatory Function Tests in the Elderly

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Purpose: Taste is a predictor of the overall health of the elderly. Diagnosis of altered taste sensations in the elderly involves objective measurement of taste function. However, objective evaluation of taste sensation is challenging compared to other senses. Moreover, there is no unified gustatory function test, with several methods used. Therefore, this study aimed to confirm whether two chemical gustatory function tests commonly used in clinical practice could effectively measure the taste function of the elderly. Furthermore, the elderly have decreased saliva secretion, swallowing function, cognitive function and the number of remaining teeth, which may affect gustatory function tests more than in the young. Therefore, this study aimed to analyze these factors affecting taste function tests.

Methods: The study enrolled 100 subjects aged 65 years or older (males: 27, females: 73) and assessed them using the questionnaire for a subjective loss of taste. An oral examination revealed the number of remaining teeth and denture wearing. Two gustatory function tests using taste solutions (whole-mouth method), and taste strips were performed for each subject. Unstimulated whole saliva (UWS) flow rates were measured to evaluate saliva secretion function. Swallowing function was measured using repetitive saliva swallowing test (RSST), and the Mini-Mental State Examination (MMSE) assessed cognitive function. The collected data were statistically analyzed.

Results: Taste scores were lower in the subjective hypogeusia group for both gustatory function tests. The gustatory function test using taste solutions had lower taste scores in the hyposalivation group, and the taste strip test had lower taste scores in the group with decreased swallowing function. For both tests, the number of remaining teeth and denture wearing did not affect the taste scores, and taste scores were lower in the cognitive impairment group than in the normal cognitive group.

Conclusions: Gustatory function tests using taste solutions and taste strips can objectively evaluate the subjective taste change of the elderly. However, a decline in oral functions, such as salivary secretion and swallowing function, may produce lower taste sensitivity depending on the factors affecting each test. Taste sensitivity may be measured low by the taste solution method in subjects with decreased swallowing function. Taste sensitivity may be measured low by the taste strip method in hyposalivation. Moreover, both tests showed lower taste sensitivity in subjects with cognitive impairment. Therefore, additional tests for cognitive impairment may be required in hypogeusia. The objectivity of the gustatory function test for the elderly can be increased, by examining saliva secretion, swallowing function, and cognitive function. Although the two gustatory function tests have these disadvantages, they are considered valid in evaluating taste changes in the elderly if tests on factors affecting the test results are performed together.

Keywords: elderly, subjective hypogeusia, taste solution, taste strip, gustatory function test, salivary flow rate, swallowing function, cognitive function

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I. Introduction

The five senses of humans are known to decrease gradually with age (da Silva et al., 2014; Heft & Robinson, 2010), and taste is also known to decline due to aging (Alia et al., 2021; da Silva et al., 2014; Kennedy et al., 2010; Schiffman, 1993; Syed et al., 2016; Yoshinaka et al., 2007). Poor physical nutrition in the elderly affects prevention, treatment, and recovery from disease. Malnutrition reduces immunity to infectious diseases, deteriorating health conditions, and resulting in poor quality of life. The main cause of nutritional deficiency in the elderly is loss of appetite, and impaired taste sensation contributes to loss of appetite (Raynaud-Simon & Lesourd, 2000; Schiffman,

1993) and weight loss in the elderly (Woschnagg et al., 2002). Therefore, proper gustatory function in the elderly is important for the quality of life and enjoyment of food (Solemdal et al., 2014).

However, taste perception is affected not only by the stimulation of taste buds but also by the sense of smell, mechanical receptors in the mouth, the sensation of pain associated with nerve fibers, stress, or psychological conditions. Therefore, objective testing for taste sensation is more challenging than other senses (Tole et al., 2019; Ye, 2007). Moreover, it is often impossible to recognize taste changes until the symptoms worsen (Ye, 2007). Most studies on taste changes according to age showed that taste sensitivity decreased in the elderly (Barragan et al., 2018; Fukunaga et al., 2005; Kennedy et al., 2010; Lee et al., 2014; Mojet et al., 2001; Solemdal et al., 2014; Stevens et al., 1995; Yoshinaka et al., 2007). However, previous studies have shown conflicting results depending on the study method (Mojet et al., 2001). Lee et al. reported that taste sensitivity decreased in all four basic tastes (Lee et al., 2014). Barragan et al. reported that taste sensitivity decreased with age for five tastes, including umami (Barragan et al., 2018). Other studies have reported that some taste sensitivities decrease in the elderly (Kennedy et al., 2010; Solemdal et al., 2014; Yoshinaka et al., 2007). A gustatory function test that can objectively measure taste function is necessary to diagnose taste changes in the elderly and determine the cause of taste disorders. Compared with olfactory function tests, standardization of gustatory function tests is insufficient. There is no unified gustatory function test with various methods used. (Kang et al., 2020; Ye, 2007).

Gustatory function tests include chemical gustatory tests and an electrogustometry (EGM), depending on the methods of applying stimuli. The EGM is a taste detection threshold test that quantitatively measure and records the change in potential by electrical stimulation of the nerve fibers in the taste buds (Ellegard, Hay, et al., 2007; Stillman et al., 2003; Tomita & Ikeda, 2002). The disadvantage is that qualitative evaluation is impossible, and it is difficult to measure the overall taste of the oral cavity (Stillman et al., 2003; Tomita & Ikeda, 2002). The chemical gustatory test uses chemical stimulants, such as taste solutions and taste strips. These methods have the advantage of providing quantitative and qualitative measurements, hence, they are common in clinical practice.

Previous studies that analyzing the correlation between gustatory function tests reported varying results. A significant correlation was present between the EGM thresholds and the salty taste recognition threshold of the taste solution method (Ellegard, Goldsmith, et al., 2007; Tomita & Ikeda, 2002). However, Kang et al. reported that the EGM thresholds showed no significant correlations with total scores and any of the four taste scores of the taste solution and the taste strip method (Kang et al., 2020). Few studies have compared chemical gustatory test methods in the elderly.

This study aimed to confirm whether the two chemical gustatory function tests commonly used in clinical practice can effectively measure the taste function of the elderly. Furthermore, the elderly have decreased saliva secretion, swallowing function, cognitive function, and masticatory function with fewer teeth and denture wearing. Therefore, our study analyzed whether these factors affect taste function tests.

II. Materials and Methods

1. Participants

This study was approved by the Institutional Review Board (2-2018-0032) of Yonsei University Dental Hospital, Seoul, Korea. Participants were recruited from welfare facilities for the elderly in Seoul and Gyeong-gi province. The participants were elderly 65 years or older with no specific systemic disease, who could move without assistance and volunteered to participate. The study excluded subjects with severe dental disease and pain, patients receiving dental treatment, and persons with communication difficulties to reduce the data disturbance factors. A total of 100 subjects were recruited for this study.

2. Questionnaire

The study assessed the socio-demographic characteristics of the participants and obtained information on smoking status, alcohol and drug use, past medical history, and subjective decline in taste. A subjective decline in taste was answered "Yes" or "No".

3. Oral Examination

The number of remaining teeth was recorded by counting natural and restored teeth, except for pontics, third molars, and residual roots. Denture-wearing was investigated.

4. Measurement of Salivary Flow Rate

Unstimulated whole saliva (UWS) flow rates were measured after verifying that the participants consumed no food other than water for at least 1 h prior before the test. UWS was collected for 5 min by the spitting method. This method allowed the participants to spit saliva into a prescribed container once a minute for 5 minutes while sitting comfortably without external stimuli. The collected saliva was calculated as the salivary flow rate per minute (mL/min). We used a cutoff value of < 0.2 mL/min considering salivary gland hypofunction (Flink et al., 2005; Manthorpe & Axell, 1990).

5. Assessment of Swallowing Function (Repetitive Saliva Swallowing Test)

Swallowing function was evaluated with the repetitive saliva swallowing test (RSST), which assesses the potential to swallow saliva. Participants swallowed saliva repeatedly as much as possible for 30 seconds while sitting comfortably. A trained researcher recorded the number of movements of the laryngeal prominence and the elevation of the hyoid bone for 30 seconds. According to previous studies, swallowing function was decreased when the number of swallowable times was less than three (Sugiyama et al., 2013).

6. Assessment of Cognitive Function

The Mini-Mental State Examination (MMSE) was used to assess the cognitive function of each participant. The MMSE score is generally classified into three levels: 24–30, no cognitive impairment; 18–23, mild cognitive impairment; <17, severe cognitive impairment (Bassuk et al., 2000; Tombaugh & McIntyre, 1992).

7. Gustatory Function Test

Two gustatory function tests were performed using taste solutions (whole-mouth method), and taste strips for each participant, and the taste score was measured. The gustatory function was measured using a test score; higher taste scores indicated higher taste sensitivity. Gustatory function tests were based on the procedure used in previous studies (Hwang et al., 2018; Landis et al., 2009; Mueller et al., 2003).

7.1. Taste solution method (whole-mouth method)

For the assessment of gustatory function, liquid solutions were used. The test consisted of 30 taste solutions [six concentrations of five tastants; sweet (sucrose), bitter (quinine hydrochloride), salty (sodium chloride), sour (citric acid), and umami (monosodium glutamate)]. The solution with the highest concentration of each tastant received a score of 1, and the solution with the lowest concentration of each tastant received a score of 6 (Table 1). If subjects did not perceive concentration in step 1, they received a score of 0. Distilled water was used as the solvent. The concentration of the solution used for the present study was based on information from a previous report (Hwang et al., 2018).

Table 1. The concentrations of the taste solutions

Taste modality	Taste score					
	6	**5**	**4**	**3**	**2**	**1**
Sweet (sucrose, g/mL)	0.0048	0.0097	0.0195	0.039	0.0781	0.1563
Bitter (quinine, g/mL)	0.00005	0.0001	0.0002	0.0004	0.0008	0.0016
Salty (sodium chloride, g/mL)	0.0006	0.0012	0.0024	0.0048	0.0096	0.0192
Sour (citric acid, g/mL)	0.0002425	0.000485	0.00097	0.00195	0.00391	0.00781
Umami (monosodium glutamate, g/mL)	0.002	0.004	0.008	0.016	0.032	0.064

Solvent : Distilled Water

1- the highest concentration; 6- the lowest concentration.

7.2. Taste strip method

Following the manufacturer's instructions, this study used the Burghart test strip (Burghart Messtechnik GmbH, Holm, Germany), a simple and appropriate tool to measure taste sensitivity. The Burghart taste strips are a validated examination procedure to investigate gustatory function. The taste strip is divided into four levels of concentration of five flavors (sweet, bitter, salty, sour, and umami) and includes two tasteless strips, consisting of a total of 22 types of strips. The concentration of the taste strip is shown in Table 2.

The taste strips were placed on the middle part of the anterior third of the protruded tongue. The participant was instructed to close the mouth, move the tongue slowly, and let saliva dissolve the tastants in the strips. Before each new test, the participant was asked to rinse the mouth with distilled water. If the taste was matched, the participant received a score of 1. The number of correctly identified tastes was summed to a "taste score" for each taste quality and a "total (taste) score"(sum of five taste scores) for each individual (Landis et al., 2009; Mueller et al., 2003). The score for each taste ranged from 0 to 4, and the total score ranged from 0 to 20. Higher taste scores indicated better taste sensitivity.

Table 2.The concentrations of the taste strips

Taste modality	Concentration level			
Sweet (sucrose, g/mL)	0.05	0.1	0.2	0.4
Bitter (quinine-hydrochloride, g/mL)	0.0004	0.0009	0.0024	0.006
Salty (sodium chloride, g/mL)	0.016	0.04	0.1	0.25
Sour (citric acid, g/mL)	0.05	0.09	0.165	0.3
Umami (monosodium glutamate, g/mL)	0.016	0.04	0.1	0.25

8. Statistical Analysis

The data collected in this study were analyzed using IBM SPSS Statistics 25.0 (IBM Co., Armonk, NY, USA), with the statistical significance level set to $P<0.05$. The characteristics of participants according to gender were compared using the Mann-Whitney U test and the Chi-square test. The difference in taste scores according to subjective taste sensitivity was compared using the Mann-Whitney U test. The difference in taste scores according to oral functions was analyzed using the Mann-Whitney U test. The difference in taste scores according to cognitive function was analyzed using the Kruskal-Wallis test and Mann-Whitney U test. The Spearman's rank correlation coefficient analyzed the correlation between two gustatory function tests.

III. Results

1. Subjects' Characteristics According to Sex

The study included 100 participants aged 65 years or older (75.88±6.37 years). Table 3 shows the results of the data analysis; 27 men and 73 women were recruited (Male 76.56±6.22 years, female 75.63±6.44 years). There was no significant difference between the mean age of men and women. Twenty-seven people answered that they felt a decrease in taste sensitivity, and 73 people did not feel a decline in taste sensitivity.

The saliva secretion significantly decreased in men compared to women, but the average salivary flow rate in men was 0.23±0.12 (ml/min), which was more than 0.2 (mL/min), the standard for hyposalivation. There was no significant difference between men and women in swallowing function and cognitive function. There was a significant difference between men and women only in umami taste in both gustatory function tests.

Table 3. Subjects' characteristics according to sex

Variable	Total (N=100)	Male (N=27)	Female (N=73)	*P*-value
Age	75.88±6.37	76.56±6.22	75.63±6.44	0.343[b]
Subjective hypogeusia				
Yes	27(27.0)	9(33.3)	18(24.7)	0.386[a]
No	73(73.0)	18(66.7)	55(75.3)	
Salivation (ml/min)	0.27±0.17	**0.23±0.12**	**0.36±0.23**	**0.018[b]**
RSST	2.86±0.89	2.59±0.50	2.96±0.98	0.101[b]
MMSE	26.3±3.01	26.67±2.47	26.15±3.19	0.684[b]
Taste score using solutions				
Sweet	4.35±0.98	4.15±1.38	4.42±0.78	0.460[b]
Sour	3.88±2.13	3.81±2.43	3.90±2.03	0.827[b]
Salty	2.47±1.43	2.07±1.64	2.62±1.33	0.129[b]
Bitter	5.61±0.92	5.52±1.22	5.64±0.79	0.878[b]
Umami	**3.85±2.3**	**2.81±2.56**	**4.23±2.11**	**0.020[b]**
Total score	20.16±5.18	18.37±5.88	20.82±4.76	0.061[b]
Taste score using strips				
Sweet	3.00±1.01	2.85±1.03	3.05±0.10	0.310[b]
Sour	1.33±1.04	1.30±0.91	1.34±1.08	0.958[b]
Salty	1.79±1.22	1.74±1.43	1.81±1.14	0.820[b]
Bitter	2.10±1.43	2.04±1.37	2.12±1.46	0.778[b]
Umami	**1.30±1.28**	**0.89±1.22**	**1.45±1.27**	**0.027[b]**
Total score	9.50±3.59	8.81±3.56	9.75±3.59	0.212[b]

Values are presented as n(%) or mean±standard deviation.

[a]Chi-square test, [b]Mann-Whitney U test.

2. Taste Score Using Taste Solution According to the Characteristics of the Elderly

In the gustatory function test using a taste solution, taste scores were significantly lower in salty, bitter, and umami tastes in the group with subjective hypogeusia. There was no significant difference between salivary secretion decrease and taste scores, and the taste sensitivity for umami was lower in the group with fewer than 20 teeth and mandibular (Mn.) denture wearing. There was no correlation between maxillary (Mx.) denture wearing and taste scores. In the swallowing functional degradation group, salty, umami, and total taste score were lower. The cognitive function was divided into normal and cognitive impairment below 24 according to the MMSE score, and the normal cognitive group was divided into high normal for 28-30 and low normal for 24-27. The MMSE score for the cognitive impairment group was 17-23. In the group with reduced cognitive function, taste scores for sweet, umami, and total score were significantly lower.

Table 4. Taste scores using solutions according to the characteristics of the elderly

Variable	N	Sweet Mean±SD	Sour Mean±SD	Salty Mean±SD	Bitter Mean±SD	Umami Mean±SD	Total score Mean±SD
Subjective hypogeusia							
No	73	4.38±0.94	4.15±1.20	2.67±1.31	5.82±0.39	4.27±2.10	21.30±4.43
Yes	27	4.26±1.10	3.15±2.35	1.93±1.62	5.04±1.53	2.70±2.52	17.07±5.83
p value		0.592	0.054	**0.015**	**0.002**	**0.006**	**0.001**
The number of remaining teeth							
≥20	74	4.35±0.88	3.82±2.14	2.61±1.30	5.61±0.99	4.14±2.24	20.53±5.15
<20	26	4.35±1.23	4.04±2.14	2.08±1.72	5.62±0.70	3.04±2.38	19.12±5.21
p value		0.495	0.635	0.190	0.716	**0.021**	0.231
Upper denture							
No	78	4.31±0.90	3.81±2.14	2.53±1.37	5.55±1.00	3.99±2.27	20.18±5.20
Yes	22	4.50±1.23	4.14±2.15	2.27±1.63	5.82±0.50	3.36±2.46	20.09±5.20
p value		0.113	0.589	0.529	0.173	0.270	0.990
Lower denture							
No	72	4.32±0.90	3.90±2.16	2.47±1.39	5.64±0.86	4.24±2.17	20.57±5.07
Yes	28	4.43±1.17	3.82±2.11	2.46±1.55	5.54±1.07	2.86±2.42	19.11±5.39
p value		0.339	0.753	0.832	0.895	**0.004**	0.239
Salivation							
Normal	59	4.37±1.08	3.97±2.10	2.61±1.45	5.64±0.83	3.64±2.39	20.39±5.57
Hyposalivation	41	4.32±0.82	3.76±2.20	2.37±1.43	5.56±1.05	4.15±2.20	20.00±4.93
p value		0.781	0.631	0.419	0.659	0.288	0.713
RSST							
≥3	66	4.45±0.90	4.06±2.02	2.80±1.36	5.64±0.87	4.30±1.99	21.26±4.73
<3	34	4.15±1.11	3.53±2.33	1.82±1.36	5.56±1.02	2.97±2.66	18.03±5.40

p value		0.137	0.240	**0.001**	0.692	**0.006**	**0.003**
MMSE score							
28-30 (high normal)	35	**4.40±0.88[a]**	3.60±2.20	2.26±1.34	5.63±1.09	**4.03±2.32[a]**	**19.91±5.69[a]**
24-27 (low normal)	53	**4.45±1.03[a]**	4.32±1.90	2.60±1.49	5.74±0.52	**4.09±2.18[a]**	**21.21±4.56[a]**
17-23 (cognitive impairment)	12	**3.75±0.87[b]**	2.75±2.49	2.50±1.51	5.00±1.48	**2.25±2.45[b]**	**16.25±4.53[b]**
p value		**0.037**	0.078	0.517	0.064	**0.038**	**0.009**

Values are presented as mean±standard deviation.

By the Mann-Whitney U test and the Kruskal-Wallis test

[a,b] The same superscript characters are not significant by Mann-Whitney *U* test

3. Taste Score Using Taste Strips According to the Characteristics of the Elderly

In the gustatory function test using a taste strip, the taste score was significantly lower for sour, bitter, and umami tastes in the group with subjective hypogeusia. There was no significant difference between the normal and hyposalivation groups for each taste, however, in the total score, the taste score was significantly lower in the hyposalivation group. The taste strip method was not affected by the swallowing function, the number of remaining teeth, and denture wearing. In the group with reduced cognition, there was a significant difference in total score.

Table 5. Taste scores using strips according to the characteristics of the elderly

Variable	N	Sweet Mean±SD	Sour Mean±SD	Salty Mean±SD	Bitter Mean±SD	Umami Mean±SD	Total score Mean±SD
Subjective hypogeusia							
No	73	3.04±0.94	1.52±1.04	1.86±1.17	2.30±1.37	1.44±1.23	10.14±3.43
Yes	27	2.89±1.19	0.81±0.83	1.59±1.34	1.56±1.48	0.93±1.36	7.78±3.50
p value		0.798	**0.002**	0.344	**0.021**	**0.023**	**0.003**
The number of remaining teeth							
≥20	74	3.01±0.99	1.39±1.06	1.78±1.19	2.16±1.43	1.35±1.27	9.68±3.48
<20	26	2.96±1.08	1.15±0.97	1.81±1.33	1.92±1.47	1.15±1.32	9.00±3.90
p value		0.907	0.351	0.894	0.465	0.406	0.307
Upper denture							
No	78	3.01±0.97	1.36±1.04	1.77±1.21	2.04±1.46	1.28±1.29	9.44±3.58
Yes	22	2.95±1.13	1.23±1.02	1.86±1.28	2.32±1.32	1.36±1.33	9.73±3.68
p value		0.993	0.674	0.755	0.432	0.809	0.917
Lower denture							
No	72	2.97±0.99	1.35±1.04	1.79±1.20	2.13±1.40	1.36±1.29	9.57±3.52
Yes	28	3.07±1.05	1.29±1.05	1.79±1.29	2.04±1.53	1.14±1.27	9.32±3.83
p value		0.530	0.707	0.994	0.805	0.403	0.579
Salivation							
Normal	59	3.12±0.79	1.46±0.97	1.98±1.32	2.25±1.45	1.32±1.40	10.14±3.42
Hyposalivation	41	2.83±1.24	1.15±1.11	1.51±1.00	1.88±1.40	1.27±1.10	8.59±3.37
p value		0.158	0.140	0.057	0.198	0.837	**0.033**
RSST							
≥ 3	66	3.00±1.04	1.41±1.05	1.92±1.23	2.12±1.40	1.30±1.24	9.93±3.63
< 3	34	3.00±0.94	1.18±0.99	1.53±1.16	2.06±1.52	1.29±1.36	9.06±3.52
p value		1.000	0.289	0.125	0.838	0.974	0.380

MMSE score							
28-30 (high normal)	35	2.94±1.14	1.51±1.10	1.83±1.25	2.23±1.44	1.51±1.25	**9.97±3.91**[a]
24-27 (low normal)	53	3.13±0.86	1.32±1.02	1.75±1.21	2.21±1.41	1.32±1.33	**9.74±3.23**[a]
17-23 (cognitive impairment)	12	2.58±1.17	0.83±0.84	1.83±1.27	1.25±1.36	0.58±0.90	**7.08±3.45**[b]
p value		0.300	0.150	0.961	0.092	0.064	**0.042**

Values are presented as mean±standard deviation.

By the Mann-Whitney U test and the Kruskal-Wallis test

[a,b] The same superscript characters are not significant by Mann-Whitney *U* test

4. The Rate of Failure to Recognize Each Taste

Table 6 shows data on the rate of failure to recognize each taste. Results showed that the highest concentration of each taste in the taste solution method was not recognized, and none of the four strips of each taste was matched in the taste strip method. In both the normal cognitive group and the cognitive impairment group, the taste strip method had a higher rate of 0 taste score than the taste solution method. The sour, salty, and umami flavors of taste solutions had a higher percentage of 0 taste scores than the normal cognitive group. The sour, bitter, and umami flavors of taste strips had a higher percentage of 0 taste scores than the normal cognitive group.

Table 6. The rate of failure to recognize each taste

	Normal cognitive (N=88)		Cognitive impairment (N=12)	
	N	%	N	%
Taste solutions				
Sweet	1	1.1	0	0
Sour	13	14.7	3	25
Salty	9	10.2	2	16.6
Bitter	1	1.1	0	0
Umami	16	18.1	6	50
Taste strips				
Sweet	1	1.1	1	1.1
Sour	21	23.8	5	41.6
Salty	17	19.3	2	16.6
Bitter	13	14.7	5	41.6
Umami	28	31.8	7	58.3

5. Correlation of the Taste Score Between the Two Tests

There was a moderate correlation between the two gustatory function tests for sour, bitter, umami, and total score. There was weak correlation for sweet and salty tastes. The correlation between the two tests was analyzed for subjects without oral functional degradation affecting gustatory function tests. However, the correlation between the two tests was also not high in the group without functional degradation.

Table 7. Correlation of the taste scores between taste solution and taste strip

			Solutions					
			Sweet	Sour	Salty	Bitter	Umami	Total score
total (n=100)	Strips	Sweet	0.164*					
		Sour		0.393**				
		Salty			0.289*			
		Bitter				0.383**		
		Umami					0.549**	
		Total score						0.493**
Excluding the hyposalivation group and swallowing function decline group (n=36)	Strips	Sweet	0.141*					
		Sour		0.185*				
		Salty			0.281*			
		Bitter				0.415**		
		Umami					0.653**	
		Total score						0.456**

By Spearman’s rank correlation coefficient

IV. Discussion

The taste sensitivity of the elderly decreases with age (Alia et al., 2021; Barragan et al., 2018; Fukunaga et al., 2005; Hwang et al., 2018; Kennedy et al., 2010; Schiffman, 1993; Solemdal et al., 2014; Stevens et al., 1995; Syed et al., 2016; Yoshinaka et al., 2007) due to various factors, such as a reduction in the number of taste buds, decreased saliva secretion, hormonal changes, drug side effects, chronic diseases, malnutrition, poor prosthetics, and psychological problems (Fernandes et al., 2021; Henkin, 1994; Kuga et al., 1999; Mojet et al., 2001; Tanaka, 2002; Walliczek-Dworschak et al., 2017). Taste change in the elderly can lead to a decrease in appetite or a preference for strong stimuli for a specific taste, which can cause problems, such as nutritional deficiencies (Ahmed & Haboubi, 2010; Raynaud-Simon & Lesourd, 2000; Wilson & Morley, 2003; Wysokinski et al., 2015), diabetes, and hypertension (Gondivkar et al., 2009; Perros et al., 1996; Schiffman, 1997; Zervakis et al., 2000). However, since taste loss often fails to recognize itself before it becomes very severe, a gustatory function test that can objectively evaluate taste function is needed to diagnose taste problems before symptoms worsen.

The validity of the test means that the purpose to be measured is reflected in the test result and the measurement purpose can be achieved. The gustatory function test has validity if it can determine whether taste function is impaired or normal. Several studies have validated gustatory function tests using taste solutions and taste strips (Doty et al., 2021; Huang et al., 2021; Mueller et al., 2003; Ribeiro et al., 2016; Wolf et al., 2016). In this study, taste sensitivity was lower in the subjective hypogeusia group in both gustatory function tests, implying that both tests could reflect actual taste sensitivity changes in the elderly and be clinically applied to evaluate the taste function of the elderly. However, the correlation between the two test results was not high. Previous studies also reported little correlation between chemical gustatory function tests (Jiang et al., 2022; Kang et al., 2020), probably due to different factors affecting each test.

Salivary secretion decreases in proportion to age (Flink et al., 2005; Manthorpe & Axell, 1990), which could be a side effect of medications rather than the effect of aging. Taste molecules must be dissolved in a liquid for recognition of tastants. The saliva secreted by the salivary glands acts as a solvent for taste substances. Therefore, taste perception is closely related to salivation (Huang et al., 2022). The taste solution method showed no significant difference in taste scores between the hyposalivation group and the normal group. However, the taste strip method exhibited a significant difference in total score between the two groups. Previous studies have shown that taste strip method are affected by dry mouth (Al-Ezzi et al., 2020; Sasano et al., 2014). Satoh-Kuriwada et al. reported that taste strips could lead to inaccurate taste assessment because patients with dry mouth may have difficulty dissolving the taste substances in saliva required for stimulating taste receptors (Satoh-Kuriwada et al., 2014). This study also showed that the taste strip method was affected by hyposalivation. Hence, gustatory function test for the elderly with hyposalivation can be evaluated more objectively by taste solution method than the taste strip method.

Age-related changes negatively impact functional swallowing ability. Reductions in muscle mass and connective tissue elasticity result in loss of strength and range of motion (Sura et al., 2012). In this study, a decrease in the swallowing function did not affect the taste strip method, but affected the taste solution method. Results confirmed that the degradation of the swallowing function of the elderly influenced the taste solution method, probably because the taste solution method is a whole mouth test, and motor changes in the palate can affect taste recognition. Taste strips are applied to the anterior part of the tongue, and the taste strip method may not reflect problems in the posterior part of the tongue or other parts of the oral cavity. However, taste solution method can reflect the taste of the entire oral cavity. This finding suggests that the taste strip method is advantageous for the gustatory function test of the elderly with dysphagia. The taste strips can be applied separately on the left and right sides in patients with hemiplegia (partial paralysis) and enable a detailed evaluation of the cause of the taste disorder. Taste sensations on the anterior and posterior parts of the tongue and soft palate can be measured with the localized use of taste strips.

In the group with cognitive function decline, both tests showed decreased taste function compared to the normal cognitive group, consistent with previous studies on the relationship between cognitive function and taste function. Ogawa et al. reported taste disorders in patients with Alzheimer's disease, and Steinbach et al. found a decrease in taste function in patients with mild cognitive impairment (Ogawa et al., 2017; Steinbach et al., 2010). However, since this study recruited healthy elderly subjects, only 12 people scored less than 24 points in MMSE. It was impossible to compare the gustatory function test results by classifying mild cognitive impairment, moderate cognitive impairment, and normal group. The normal cognitive group was divided into high normal for 28-30 MMSE scores and low normal for 24-27 MMSE scores. The MMSE scores for the cognitive impairment group were 17-23. There was no difference between high normal and low normal in both tests, but taste scores were lower in the cognitive impairment group than in the normal cognitive group. The taste strip method showed statistical significance only in total score, and the taste solution method showed statistical significance for sweet, umami, and total score. Since these two tests showed consistent results, cognitive impairment could be a factor that reduces taste function. However, the normal aging process is associated with declines in cognitive abilities, such as processing speed (Harada et al., 2013). Many cognitive changes in healthy older adults are due to slowed processing speed. Thus, this “slowing” can affect gustatory function tests in the elderly. The method of guessing the taste used in this study may produce low taste scores in the gustatory function test even though the actual taste sensitivity has not decreased, probably because the effect of the error in the gustatory function test is reflected in the test results. The taste solution test is more intuitive than taste strip test because taste solutions used in the whole-mouth method spread and almost immediately become diluted throughout the mouth, while taste strips recognize taste by dissolving tastants in saliva. The taste strip method may seem relatively more difficult even for the elderly without cognitive impairment. Even the elderly with normal cognition often could not recognize some flavors. The taste strip method showed a higher rate of unrecognizable responses even in the elderly with normal cognitive than the taste solution method, probably because the taste solution method uses sequential concentrations from low to high, and the taste strip method involves random use of all taste strips. Of the 88 elderly with normal cognition, 25 participants in the taste solution method and 53 participants in the taste strip method had a taste score of 0 for more than one taste. Therefore, gustatory function tests of the elderly are more suitable for taste solutions than taste strips. Both tests showed lower taste scores for the group with cognitive impairment; however, there was a large difference in the number of samples between the cognitive impairment and the normal group. Therefore, follow-up studies are needed to match the sample size. Moreover, it is necessary to investigate whether there is a difference in taste scores between severe and mild cognitive impairment.

Since dentures cover palatal and gingival tissues (unlike fixed prostheses), they can impair taste and smell. Specifically, the upper denture covering the palate can interfere with the natural airflow between the oral cavity and the nasal cavity. However, Ghaffari et al. reported that complete dentures did not affect taste perception and taste and flavor sensations (Ghaffari et al., 2009). In the group with less than 20 remaining teeth, the taste solution method showed a significantly lower taste score for the umami taste. In the lower denture wearing group, the taste solution method exhibited a significantly lower taste score for the umami taste. However, the total score did not show a significant difference. The taste strip method was not affected by the number of remaining teeth and denture wearing and was more objective than the taste solution method. Taste is affected by the stimulation of mechanical and pain receptors in the oral cavity and psychological factors. Denture wearing for the first time can alter taste sensation due to changes in touch and pain stimuli; however, these factors do not seem to affect gustatory function tests.

The study analyzed the correlation between the two tests for groups without functional degradation that affected each test to confirm whether the low correlation was attributable to the differences in factors affecting each test. Results showed that the correlation between the two tests was not high, probably due to differences in factors affecting each test and varied methods of measuring taste scores.

Both methods are valid for evaluating taste sensitivity in the elderly, and both tests have strengths and weaknesses. Taste solutions can enable a more physiological taste test by better representing real edible stimuli. Since test substances are immediately diluted in saliva, values acquired with this method might represent overall sensations of the oral cavity (Hwang et al., 2018). However, the taste strip test may not reflect actual taste changes compared to the taste solution method. Taste sensitivity varies depending on the measurement area, and localized taste function measurements may not reflect actual taste changes. However, if a taste disorder occurs due to a problem in a specific part of the oral cavity, taste strips may help diagnose taste problems. This feature can also be a key to diagnosing taste disorders because it allows separate examination of the left and right sides and each area, such as the anterior and, posterior portion of the tongue and soft palate.

Taste is not a simple sensory function limited to taste buds in the mouth and involves various physical and mental factors that work in combination. Furthermore, since the elderly have compromised oral functions, such as hyposalivation and dysphagia, with decreased cognitive ability, it can be more challenging to measure taste function objectively in the elderly than in the young. The two gustatory function tests have these disadvantages, but considering that they can reflect actual taste changes, they are considered effective in evaluating the taste function of the elderly. Based on our findings, taste functions may show different results depending on the test method. One gustatory function test cannot comprehensively evaluate the taste function of the elderly, and it is necessary to identify various physical and mental factors affecting taste function tests for objective evaluation of results.

This study has the following limitations. Since the study subjects were healthy elderly, there was a difference in the number of samples between the normal group and the functional decline group. MMSE is affected by educational levels, however, educational levels of subjects were not considered in MMSE scores.

V. Conclusion

1. Gustatory function tests using taste solutions and taste strips are valid methods that can objectively evaluate the subjective taste change of the elderly.
2. The taste solution method needs to consider swallowing function, and the taste strip method needs to consider hyposalivation.
3. Regarding cognition, the taste solution method is more objective for the elderly. The elderly with cognitive impairment show a decline in taste function.
4. The number of remaining teeth and denture wearing did not affect both methods.
5. Due to differences in factors affecting each test are different, the taste functions of the elderly can produce variable results depending on the methods. Therefore, to compensate for these problems, it is necessary to identify various physical and mental factors affecting gustatory function tests.
6. The correlation between the two tests was not high, probably due to the differences in factors affecting each test and the method for measuring taste scores.

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Abstract (in Korean)

노인에서 화학적 미각검사의 유효성 검증과 영향요인 분석

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연구목적: 미각은 노인의 건강한 삶을 위해 중요한 감각이다. 노인의 미각문제를 진단하기 위해서는 객관적으로 미각기능을 측정할 수 있어야 한다. 하지만 미각은 다른 감각에 비해 객관적인 검사가 쉽지 않고, 하나의 표준화된 방법이 아닌, 여러 방법이 혼재되어 사용되고 있다. 이에 본 연구는 임상에서 많이 사용되고 있는 미각용액과 미각스트립을 이용한 화학적 미각기능검사가 노인의 미각기능을 측정하기 위해 유효성이 있는 검사인지 확인하고자 한다. 또한 노인은 구강기능 및 인지기능이 저하되는데, 이러한 요인들이 미각기능검사에 어떤 영향을 주는지 고찰하고자 한다.

연구대상 및 방법: 65세 이상 노인을 대상자로 모집하였으며, 총 100명(남성:

27명, 여성: 73명)의 데이터를 분석하였다. 설문지를 통해 주관적으로 미각저하를 느끼는지를 조사하였고, 구강검사를 통해 잔존 치아 수와 의치 사용 유무를 확인하였다. 각 피험자에게 미각용액과 미각스트립을 이용하여 미각기능검사를 시행하였으며, 타액분비기능을 확인하기 위해 비자극성 타액분비량을 측정하였다. 연하기능은 반복타액연하테스트(RSST)로 측정하였으며 인지기능 평가를 위해 간이정신상태검사(MMSE)를 이용하였다. 수집된 데이터를 통계 분석 하였다.

연구결과: 미각용액과 미각스트립을 이용한 미각기능검사에서 주관적 미각민감도 저하가 있는 그룹에서 두 검사 방법 모두 미각점수가 낮았다. 미각용액을 이용한 미각기능검사는 타액분비저하가 있는 경우 미각점수가 낮았고, 미각스트립을 이용한 검사는 연하기능저하가 있는 경우 미각점수가 낮았다. 잔존치아 수와 의치 사용 유무는 두 검사 모두 미각 점수와 상관성을 보이지 않았다. 두 검사 모두 인지기능이 정상인 그룹보다 인지기능장애가 있는 그룹에서 미각 점수가 낮았다.

결론: 미각용액과 미각스트립을 이용한 미각기능검사는 노인의 주관적인 미각저하를 객관적으로 평가할 수 있는 방법이다. 하지만 구강기능 및 인지기능이 저하된 경우 각 검사에 영향을 주는 요인에 따라 미각민감도가 낮게 측정될 수 있다는 문제점이 있다. 미각용액 검사법은 연하기능에 문제가 있는 경우 미각 민감도가 낮게 측정 될 수 있고, 미각스트립 검사법은 타액분비

저하가 있는 경우 미각 민감도가 낮게 측정 될 수 있다. 또한 두 방법 모두 인지기능이 저하된 경우 미각 민감도가 낮게 측정될 수 있으며, 심한 미각 저하의 경우 인지장애에 대한 추가 검사가 필요할 수 있다. 노인의 미각기능검사의 객관성을 높이기 위해서는 타액분비량, 연하기능, 인지기능에 대한 확인이 필요하다. 두 미각기능검사는 이러한 단점이 있지만 검사결과에 영향을 줄 수 있는 요인에 대한 검사가 함께 시행된다면 노인의 미각변화를 평가하는데 유효성이 있는 검사라 할 수 있다.

핵심어 : 노인, 주관적 미각감소, 미각용액, 미각스트립, 미각기능검사, 타액분비율, 잔존 치아 수, 연하기능, 인지기능