Original Article

Assessment of oral stereognostic ability of healthy adults

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Abstract

Purpose: *A novel method for assessing oral stereognostic ability (OSA) in the older people was developed. The association between OSA and age, oral functions as masticatory performance and subjective chewing experience, were investigated.*

Materials and methods: *Testing objects fabricated by self-cured resin were designed in different thickness and diameter to assess the OSA, five discs were used for assessment, two trials were performed, accuracy and reaction time were recorded. Color-changeable chewing gum was adopted to quantify masticatory performance. Subjective experience of chewing was assessed by questionnaire translated into Chinese. Statistical correlation and comparison were performed in each variable.*

Results: *Twenty-four subjects completed OSA (11 males and 13 females, mean age: 34.5 years-old) were recruited. The correlation in accuracy between the first and the second tests did not reach a statistical significance (Spearman's rho = 0.051, p = 0.482). Between the two tests, the accuracy did not differ significantly (two-tailed Wilcoxon signed-rank test, p = 0.061).*

The correlation in reaction time between the first and the second tests reached a statistical significance (Spearman's rho = 0.786, p < 0.001). Between the two tests, the reaction time showed a significantly difference (two-tailed Wilcoxon signed-rank test, p = P = 0.028). The correlation between OSA accuracy and masticatory performance was not statistically significant (the first test: Spearman's rho = 0.301, p = 0.275; the second test: Spearman's rho = 0.114 p = 0.685).

Conclusion: *The current study reported a novel assessment of evaluating OSA, which revealed a high consistence in between-test reaction time, as an index of OSA performance.*

Key words: Color-changeable chewing gum, experience of chewing, masticatory performance, oral stereognostic ability

Introduction

When age increases, the human teeth reduce its number due to decay, periodontal disease[1]. The increased number of missing teeth would substantially influence individual ability in mastication, e.g., a decrease in masticatory performance[2, 3]. Critically, not only the oromotor ability but also the sensory ability can be compromised due to aging[4-6]. It's critical to discriminate the size and location of bolus, which means oral perception, and to coordinate with the muscular system in the masticatory process. If the perceptive or coordination ability decreases, it will disturb denture adaptation and may lead to mistrust to the clinicians. The ability of sensing the size and form of intraoral objects, namely, the oral stereognosis[7], has relatively been ignored in the literature. The association between oral stereognosis, masticatory performance, aging, and experience of feeding, has not been fully studies.

The "stereognosis" is to discriminate the shape, size or texture of an object by contact. The oral stereognosis is to achieve this process in the oral cavity[8]. Previous studies suggested that the oral stereognostic ability decreases with age[5, 6, 9, 10], but worse oral stereognostic ability does not correlate to worse masticatory performance[11]. In addition, the study with palatal coverage did not reveal the correlation between oral stereognosis with masticatory performance [12, 13]. All these studies suggest complicated relationship between oral stereognosis, chewing function and age.

Until now, several methods have been proposed to assess the oral stereognostic ability (OSA). In general, a test object is put into the subject's mouth, and the subject needs to sense the shape of the object and makes a correct judgment on its size or form. The accuracy of the judgment and/or the reaction time to make a correct judgment was quantified, as the index of OSA[5, 13, 14]. These oral stereognostic assessment can be further Classified into two categories: (a) the assessment of the form of the objects, which may differ in their geometric form (e.g. triangle or square)[5, 12, 13], and (b) the assessment of the size of the objects, which may vary from small to large[15]. Until now, there has not been a standardized method for assessing OSA.

Based on the previous research, in the current study, a novel method for assessing OSA in the older people was reported. The method adopted an older people-friendly object, which was designed similarly to a drug pill. OSA was indexed as the accuracy and reaction time to make a correct judgment on the size of the pill. The association between OSA and age, oral functions as masticatory performance and subjective chewing experience, were investigated as the following objectives:

1. It was hypothesized that the novel method showed a good reliability between two tests. Specifically, across the subjects, the accuracy and reaction time (i.e., the OSA performance) between the first and second test would be significantly correlated.
2. The association between the OSA performance and age, masticatory performance, and the experience of chewing were investigated.

Materials and methods

Study sample

The current study is designed as a cross-sectioned observational research based on healthy adults, who were physically and mentally healthy, between 20 to 85 years-old and were able to understand and cooperate with the experiments. The study was examined and reviewed by the internal review board of National Yang-Ming University (YM104028E). Written informed consent was received from all the subjects before the study began.

Assessment of oral stereognostic ability (OSA)

The design of the testing objects was modified according to the method from a previous study[15]. The testing objects were fabricated by instilling self-cured resin (ALIKE™ Temporary Crown & Bridge Resin, GC America) into customized molds (Fig.1). The molds were specifically designed as a disc-like shape, with 8, 10, 12 mm in diameter and 2, 3, 4 mm in thickness. In total, nine different resin-based discs were fabricated for each subject. Each disc was attached with a piece of dental floss so that the subject may not swallow the disc accidentally[5].

After the test object was put into mouth, the subject was instructed to estimate size of the testing object and give an answer by matching the testing object visualized on an 'answer board' (Fig.2). Notably, the subjects were not allowed to see the testing objects nor could they touch the objects. Five

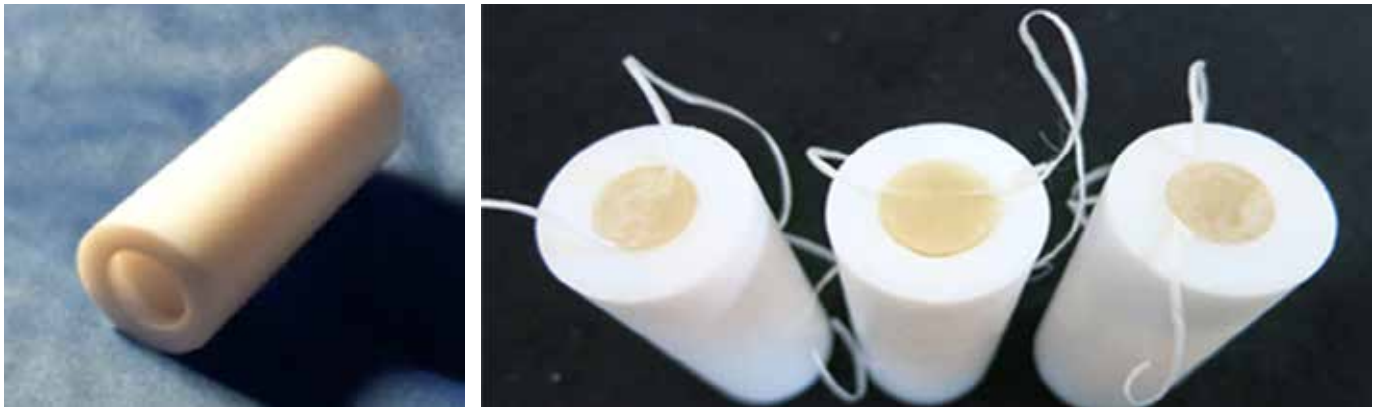

Figure 1. The Teflon mold and fabrication of testing discs.

of the testing discs (No.1, 3, 4, 8, 9 in Fig.2) were used for the assessment. Two trials were performed for each subject. The OSA performance was quantified as (a) the accuracy that the subject correctly answered the size (i.e., the proportion of the correct answer to the total number of testing) and (b) the response time of giving the answer (i.e., the time-delay between putting the object into mouth and giving the answer).

Masticatory performance

Masticatory performance was assessed based on the method using a color-changeable chewing gum[16], a widely used method for assessing the oral mixing ability[16]. In general, the subjects were asked to chew the gum (XYLITOL, Lotte Co., Ltd., Tokyo, Japan) for three minutes. The chewed gum was then digitalized by a scanner and its colorimetric properties (i.e., the L*, a* and b* value from the CIELAB color space) were assessed digitally[17]. Masticatory performance was quantified as the change in the color space (ΔE) between the chewed gum and un-chewed gum[18].

Experience of chewing

The subject's experience of chewing was assessed using the self-rating questionnaire, which composed of the questions modified from a previous study[19]. The questions are '*Is there any food which you have difficulty to chew and therefore avoid to eat?*', '*Do you feel dryness in your mouth?*', '*Do you get food stuck in the throat?*', '*Does it take longer time for you to finish a meal than for other people?*'. All the questions were answer by 'yes' or 'no'.

Statistical methods

The normality test revealed a non-normal distribution of the research variables (Table 1). Therefore, non-parametric methods were adopted for statistical analyses. Wilcoxon signed-rank test was conducted for a within-subject comparison between two tests. Mann-Whitney U test was conducted for between-group comparison. Spearman's rho coefficient was calculated for quantifying the association between variables.

Figure 2. Answer board for the OSA test.

Results

Descriptive statistics

Twenty-four subjects completed oral stereognosis assessment (11 males and 13 females, mean age: 34.5 years-old) were recruited. Among the subjects, 15 subjects completed all the tests (4 males and 11 females, mean age: 39.1 years-old). The results of the descriptive analyses were summarized in Table 1.

The accuracy of oral stereognosis assessment

The correlation in accuracy between the first and the second tests did not reach a statistical significance (Spearman's rho = 0.051, p = 0.482). Between the two tests, the accuracy did not differ significantly (two-tailed Wilcoxon signed-rank test, p = 0.061) (Fig.3).

The response time of oral stereognosis assessment

The correlation in reaction time between the first and the second tests reached a statistical significance (Spearman's rho = 0.786, p < 0.001). Between the two tests, the reaction time showed

Table 1. Results of descriptive analyses.

	Max.	Min.	Median	Mean	S.D.	Normality[1]
Accuracy (%) (n=24)						
1st test	100	20	40	50	22.4	0.008
2nd test	100	20	60	64	25.8	0.034
Reaction time (seconds) (n=24)						
1st test	33.2	2.8	10.9	12.4	7.7	0.031
2nd test	20.0	3.0	7.3	9.6	5.0	0.023
	Max.	Min.	Median	Mean	S.D.	Normality[1]
Masticatory performance (ΔE) (n=15)						
	XX	XX	XX	XX	XX	XX

[1]Shapiro-Wilk test was performed for normality test. The P value < 0.05 indicates that the data were distributed non-normally.
OAcc: Accuracy of OSA, Rt: reaction time.

a significantly difference (two-tailed Wilcoxon signed-rank test, p = P = 0.028) (Fig.4).

Association with masticatory performance:

The correlation between OSA accuracy and masticatory performance was not statistically significant (the first test: Spearman's rho = 0.301, p = 0.275; the second test: Spearman's rho = 0.114 p = 0.685).

Subjective chewing experience:

All the subjects completed both the OSA and the questionnaire. As shown in Table 2, for each question, the accuracy and reaction time of the OSA test did not significantly differ between the subjects who answered 'yes' and those who answered 'no' (two-tailed Mann-Whitney U test p > 0.05).

Discussion

Major findings of the current study

The current study reported a novel assessment of evaluating OSA. The results indicated partly confirming the hypothesis that the reaction time showed a consistency between the first and the second tests (Fig.4); while the accuracy did not show such a good consistency (Fig.3). Both the accuracy and reaction time did not differ between the two tests, suggesting a consistency between tests.

The OSA performance, however, were not significantly associated with the objective assessment (masticatory performance) and the subjective assessment (self-reporting questionnaire) of chewing (Table 2). The results were discussed as follows.

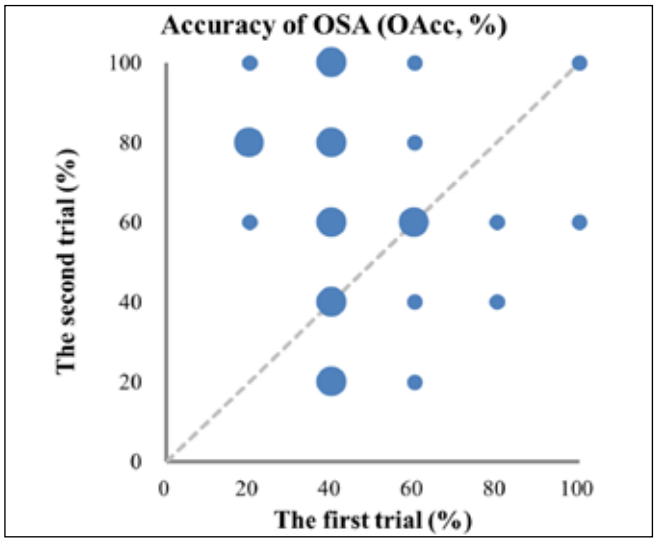

Figure 3. Correlation and comparison of two trials of OSA accuracy. Wilcoxon signed-rank test: P = 0.061, Spearman's rho = 0.051, P = 0.482.

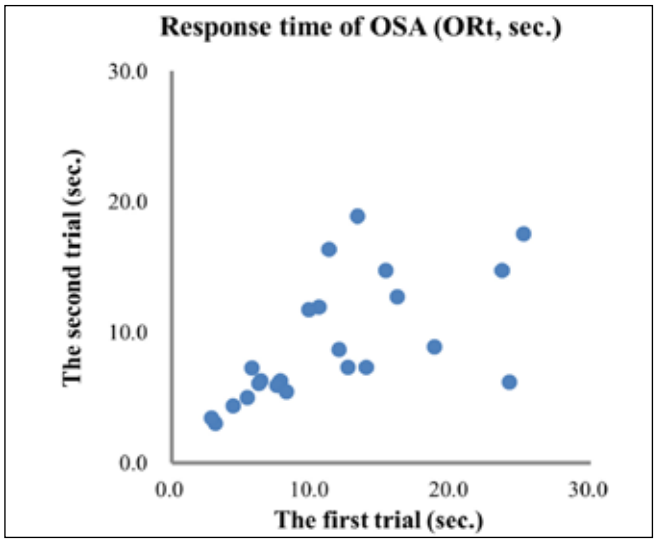

Figure 4. Correlation and comparison of two trials of OSA response time. Wilcoxon signed-rank test: P = 0.028, Spearman's rho = 0.786, P = 0.000.

Table 2. Subjective chewing experience and OSA accuracy and response time. Mann-Whitney U test was performed for analysis.

	Accuracy (%)		Reaction time (sec)	
Questions	1st test	2nd test	1st test	12nd test
Is there any food which you have difficulty to chew and therefore avoid to eat?				
No (n=13)	40	60	11.2	11.8
Yes (n=11)	4	8	8.2	6.
	p=0.865	p=0.252	p=0.820	p=0.228
Do you feel dryness in your mouth?				
No (n=11)	40	60	8.2	7.3
Yes (n=13)	40	60	11.2	8.7
	p=0.303	p=0.424	p=0.303	p=0.361
Do you get food stuck in the throat?				
No (n=10)	50	60	7.2	6.8
Yes (n=14)	40	70	11.6	8.0
	p=1.000	p=0.709	p=0.472	p=0.403
Does it take longer time for you to finish a meal than for other people?				
No (n=8)	50	60	12.2	14.8
Yes (n=16)	40	70	10.1	6.8
	p=0.569	p=0.742	p=0.742	p=0.093

Oral stereognosis: an issue remained unclear

A critical step in human feeding behavior is to discriminate the size and location of bolus, which means oral perception, and to coordinate with the muscular system in the masticatory process[20]. If the perceptive or coordination ability decreases, it may disturb denture adaptation and may lead to mistrust to the clinicians. One of the key oral perceptive abilities is the oral stereognosis. The "stereognosis" is to discriminate the shape, size or texture of an object by contact. The oral stereognosis is to achieve this process in the oral cavity[8].

Previous studies suggested that the oral stereognostic ability decreases with age[5, 6, 9, 10], but worse oral stereognostic ability does not correlate to worse masticatory performance[11]. In addition, the study with palatal coverage did not reveal the correlation between oral stereognosis with masticatory performance[12, 13]. The accuracy of OSA improved statistically with palatal coverage[21], it was inferred that the tongue perceived the spheres more precisely than palate, the tongue rolling the objects on a solid surface may be crucial to oral stereognosis[21]. But other researchers did not report the consistent findings[12, 13]. Improved OSA was also observed in the elder participants after wearing complete dentures[5]. Finally, most literature showed that older subjects have worse OSA[4, 5, 9.] All these studies suggest complicated relationship between oral stereognosis, chewing function and age.

How to quantify OSA performance: by accuracy or by reaction time?

The results revealed high between-test correlation in response time but not in the accuracy. The findings suggested that reaction time, which is associated with one's processing of perception and decision-making, could be a better index for OSA performance. In contrast, the accuracy may be more vulnerable to the learning effect, i.e., an improvement in giving correct answer in the second test, compared to the first test. As shown in our results, comparing the first and the second trial, the accuracy increased (median accuracy from 40% to 60%) and the response time decreased (reaction time from 10.9 sec to 7.3 sec), which implied that the subjects become more familiar to the experiment and had better performance in the second test.

Interestingly, even with the potential learning effect, the subjects showed between-test consistency in reaction time. The findings suggested that reaction time, as an index for OSA performance, may be dominated by the psychological factors other than perception per se. For example, a scrutinous subject may perceive each testing object very carefully when giving an answer; in contrast, an impatient subject may give the answer quickly based on his or her instinct. The association between these psychological factors (e.g., personal traits) and the OSA performance would require more investigation in the future.

Association between OSA and chewing ability

No significant correlation between the OSA score and the results from assessment of mastication were revealed. In terms of the masticatory performance, the lack of a significant correlation may be accounted by the distribution of the scores: in the results, the variation of masticatory performance was small, and therefore the association between masticatory performance and the OSA performance was less pronounced. Another important reason is the method for testing masticatory performance. In the previous study that reported a high correlation[22], the masticatory performance was quantified by assessing the ability to cutting/crushing the standardized food[8, 14]. This ability of cutting/crushing food is different from the oral mixing ability, as assessed using color-changeable chewing gum[23]. The difference between these two abilities may lead inconsistent results in different studies.

In terms of the subjective experience of chewing, the results can be biased by the fact that most of the subjects were younger adults, who would find fewer difficulties during chewing. It should be noted that even in older subjects, there could still be an inconsistence between the subjective rating of chewing and the score from objective assessment, since the subjective experience is shaped by long-term experience of feeding, and the subjects may already adapt to their oral conditions.

Limitations and clinical implications

The current study introduced a novel method for assessing OSA. Still, the results should be carefully interpreted. First, the insignificant findings may be associated with the existence of Type II error, which was further associated with the number of sample size. Secondly, the results revealed that reaction time, a widely used index for evaluating performance, may be associated with individual personal traits. The psychological factors underlying OSA performance would require future investigation. One of the commonest ways to restore is wearing removable dentures, but the clinicians still have to deal with several challenges: some patients to the intraoral fixed prosthesis, or some patients could not adapt to well-designed removable dentures. First, the chewing ability may decrease due to degenerated muscular activity and strength with age[3, 24, 25]. Second, the denture adjustment should accord to the subjective wearing feedback from the patient, the clinicians could not adjust the denture efficiently if the patients could not express themselves explicitly. Finally, according to the up-date neuroscientific evidence, mastication is not only a pure muscular exercise, but a complicated coordination between movement and sensation, to achieve better chewing efficiency[26, 27].

Conclusion

The current study reported a novel assessment of evaluating OSA, which revealed a high consistence in between-test reaction time, as an index of OSA performance. The accuracy of the OSA test was not significantly associated with the objective assessment (masticatory performance) and the subjective assessment (self-reporting questionnaire) of chewing.

Conflict of interest

The authors declared no conflict of interest.

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