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Original Paper

Comparison of three representative subjective evaluations of chewing function

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Abstract

In 2018, oral hypofunction was registered officially as a disease in Japan. It is important to detect oral hypofunction symptoms early in patients, before frank oral dysfunction symptoms occur. Subjective evaluations of chewing function, which help to identify foods that cannot be chewed, might be useful in diagnosing oral hypofunction. Previous evaluations used to identify patients with oral hypofunction used varying standards, making it impossible to compare and integrate them without first developing a unified screening method. This study aimed to compare and integrate known evaluation methods that are useful for diagnosing oral hypofunction. A total of 76 elderly participants (aged >65 years) were enrolled after providing consent to participate in this study. The established subjective evaluation methods of chewing function investigated for this study included the Yamamoto denture performance judgment table, the Sato table for evaluation of chewing function in complete denture wearers, and the Hirai evaluation method for the masticatory function in complete denture wearers. As the Yamamoto method lacks scoring, the total number of circles was used as the score. A time study was performed on the time taken for the description, entry, and analysis of these tables. There was a strong correlation between the Sato and Hirai methods ($r = 0.71$) and between the Sato and Yamamoto ($r = 0.68$) and Hirai and Yamamoto ($r = 0.60$) methods. During the time study, the description time was the shortest with the Yamamoto method, and the entry and analysis times were the shortest with the Sato method. The total time was significantly shorter with the Sato method than with the Yamamoto method. Three evaluation methods showed correlation, but the examination times varied. In future studies, we plan to clarify the selection criteria, including the relevance of objective evaluation and usability.

Key words: subjective evaluations of the chewing function, time study, correlation, questionnaire, comparison

Introduction

In 2014, the concept of oral frailty was introduced in Japan, showing that maintenance of oral function is important to prevent overall physical frailty[1]. In 2016, the Japanese Society of Gerodontology published a position paper on oral hypofunction[2], and in 2018, oral hypofunction was registered officially as a disease in Japan[3]. Methods for measuring chewing function/ability include assessment of food digestion, breakdown of foods, occlusal contact areas, and electromyography[4–16]. One of the symptoms of oral frailty is the loss of chewing ability for an increasing number of food types[2]. Therefore, subjective evaluations of chewing function that are based on the total number of tolerated food types are useful. Various evaluation approaches, including the Yamamoto, Sato, and Hirai methods, have been used for subjective evaluation of chewing function. These three established subjective evaluations of chewing function were initially developed to measure the masticatory ability of complete dentures.

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However, subsequent studies have shown that these evaluations also correlate with nutritional status, objective masticatory function tests, and bite strength tests, and these correlations are seen not only in complete denture wearers but also in partial denture wearers and non-denture wearers[17–22]. Previous studies intended to compare these evaluation methods employed varying assessment standards, making it impossible to effectively compare and integrate these studies' assessment methods. The Department of Geriatric Dentistry at Showa University Dental Hospital receives a wide variety of patients at its outpatient clinic, including patients with complete dentures, patients with partial dentures, and patients without dentures. The purpose of this study was not to compare the individual scores of each patient but rather to compare the three subjective evaluation methods applied to the same patient; thus, the study required participants with varied patient characteristics.

This study aimed to compare and integrate existing evaluation methods that are useful for diagnosing oral hypofunction.

Subjects and methods

1. Participants

The sample was comprised of new and returning patient participants who were examined at the Department of Geriatric Dentistry at Showa University Dental Hospital between January and October 2019. All participants were treated for acute symptoms and consented to participate in the study. The inclusion criteria were as follows: participants aged 65 years or older, first-time participants who had completed acute symptom management, and newly diagnosed participants. The exclusion criteria were as follows: participants younger than 65 years, participants with acute symptoms, and participants with missing data. This study was approved by the hospital's internal ethics committee (Institutional Review Board of Showa University Dental Hospital [approval no. DH2018-032]), and it conformed to the Declaration of Helsinki on human research ethics.

2. Evaluation Methods

1) Denture performance judgment table (Yamamoto method)[23] (Figure 1)

The Yamamoto method is a visual evaluation method in which foods tolerated by the patient are circled from among the 35 food types shown in the figure. As the Yamamoto method does not include any scoring, the total number of circles was used as the score. One point was assigned to each circle, for the total score of up to 35 points.

2) Table for evaluation of chewing function in complete denture wearers (Sato method)[24] (Figure 2)

The Sato method is an inspection method that evaluates 20 foods from a table by marking "○" for foods that are "easy to chew," "△" for foods that are "difficult to chew," and "×" for foods that are "impossible to chew." Five points are allotted for each "○" and 0 points are allotted for "△" and "×," for a maximum total score of 100 points.

3) Evaluation method for the masticatory function in complete denture wearers (Hirai method)[25] (Figure 3)

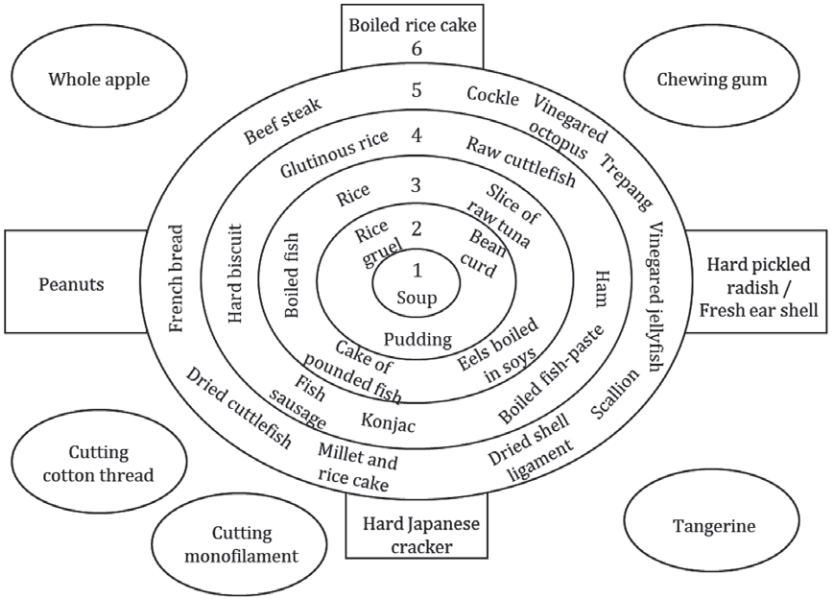

Fig. 1. Denture performance judgment table

1	Whole apple Chewing gum Dried shell ligament Dried cutlefish	
2	Fresh ear shell Hard pickled radish Hard cracker Hard biscuit	
3	Pickled Radish Peanuts Beaf steak Rice-cake cubes	
4	Burdock Potato chips Boiled fish-paste(kamaboko) Artificially-grown soybean	
5	Boiled carrot Boiled potato Boiled eggplant Bean curd(toufu)	

Check as follows ;

○ : Easy to chew
△ : Difficult to chew
× : Impossible to chew

PATIENT No._____

NAME_____

AGE _____

SEX F・M

DATE_____.____.____

STAGE OF PROSTHESIS

_____

CHEWING FUNCTION SCORE
(Number of ○／20×100)

_____

NAME OF DENTIST_____

Fig. 2. Table for evaluation of chewing function in complete denture wearers

Questionnaire on Masticatory Function

Please fill in the blanks as follows

{2} ... can be eaten easily
{1} ... can be eaten with difficulty
{0} ... cannot be eaten
{△} ... I do not eat it because I dislike it
{□} ... I have never eaten it since wearing of dentures

1	{ } fried rice cracker	2	{ } rice cake
3	{ } raw abalone	4	{ } sliced raw cuttlefish
5	{ } starawberries	6	{ } boiled fish paste patty
7	{ } raw cabbage	8	{ } boiled beef
9	{ } boiled cabbage	10	{ } raw cucumbers
11	{ } jellyfish	12	{ } konnyaku
13	{ } boiled taro	14	{ } dried cuttlefish
15	{ } vinegaerd octopus	16	{ } pickled radish
17	{ } boiled onions	18	{ } takuwan (pickled radish)
19	{ } boiled kombu (tukudani kombu)	20	{ } fried chicken
21	{ } boiked chicken	22	{ } roast chicken
23	{ } pickled eggplant	24	{ } raw trepang
25	{ } raw carrots	26	{ } boiled carrots
27	{ } banana	28	{ } ham
29	{ } peanuts	30	{ } roast pork
31	{ } pork cutlets	32	{ } pudding
33	{ } sliced raw tuna	34	{ } pickled scallion
35	{ } apples		

Thank you very much for your cooperation.

Fig. 3. Evaluation method for the masticatory function in complete denture wearers

The Hirai method evaluates 35 food types by scoring foods that "can be eaten easily" as "2," foods that "can be eaten with difficulty" as "1," foods that "cannot be eaten" as "0," foods that "I do not eat because I dislike it" as "△," and foods that "I have never eaten since I began wearing dentures" as "□."

A total of 35 foods were divided into groups I–V, according to the difficulty of consumption. Each difficulty rate was 1 for I, 1.14 for II, 1.30 for III, 1.52 for IV and 3.00 for V. The total scores of the first, second, third, fourth, and fifth food groups were labeled as a, b, c, d, and e, respectively. A chewing score of 100 points was obtained by multiplying each weighted factor as a multiplier. Spreadsheet software (Excel, Microsoft Corporation, Redmond, WA, USA) was used to create a table that illustrated:

rate of food intake ability = (a + 1.14b + 1.30c + 1.52d + 3.00e)×100/111.4)

The calculation of the mastication score was as previously described[25].

Correlations between the scores obtained using the Yamamoto, Sato, and Hirai methods were compared across data for the same patient participant.

4) Time study between the three established subjective evaluations of chewing function

To compare the Yamamoto, Sato, and Hirai time studies, ten participants were randomly selected and each of the three methods were administered by one evaluator to measure and compare the description, entry, and analysis times. The intended purpose of the time study was to identify the easiest test to perform out of the three evaluation methods.

Description time: For the Yamamoto method, we instructed participants to circle foods on the evaluation form that they could eat. For the Sato method, we instructed participants to mark foods with "○" if they were easy to chew, "△" if they were difficult to chew, and "×" if they were impossible to chew. For the Hirai method, we instructed participants to mark foods with "2" if it could be eaten easily, "1" if it could be eaten with difficulty, "0" if it could not be eaten, "△" if they did not eat it because they disliked it, and "I have never eaten it" if they had never eaten it since they began wearing dentures. The time spent answering questions was included in the measurement.

Entry times were recorded at the time the entry form was given to the participants, the time when they began to fill it out, and the time that they finished.

The analysis time was calculated by counting the total number of points from the form. While the total scores from the Yamamoto and Sato methods can be calculated manually, the Hirai method requires complex calculations; therefore, we entered Hirai scores into a predetermined mathematical formula within our spreadsheet software and measured the time it took to obtain the result.

3. Statistical analysis

1) Correlation (r) between the three representative

subjective evaluations of chewing function

Correlations between the Yamamoto, Sato, and Hirai methods were assessed using Spearman's rank correlation coefficient. The significance level was set at $p < 0.05$.

2) Time study between the three representative subjective evaluations of chewing function

The Wilcoxon signed-rank test was used to compare the differences in total time between the three subjective evaluations of chewing function. The significance level was set at $p < 0.05$.

We set the significance level at $p < 0.05/3$ after the Bonferroni correction.

All statistical analyses were performed using IBM SPSS Statistics (version 25.0; IBM, Armonk, NY, USA).

Results

The sample included 30 men (mean age, 77 years; median age, 77 years) and 46 women (mean age, 78 years; median age, 77 years) with an age range of 65–95 years.

1. Correlation (r) between the three representative subjective evaluations of chewing function

There was a strong correlation between the Sato and Hirai methods ($r = 0.71$) (Figure 4) and moderate correlation between the Sato and Yamamoto methods ($r = 0.68$) (Figure 5) and the Hirai and Yamamoto methods ($r = 0.60$) (Figure 6).

2. Time study between the three representative subjective evaluations of chewing function (Figure 7)

In the time study, the description time was the shortest in the Yamamoto method, while the entry and analysis times were shortest in the Sato method. We set the significance level at $p < 0.05$. The Friedman test was used to compare the difference in total time between the three subjective evaluation methods.

The results of the Wilcoxon signed-rank test revealed no significant difference ($p \geq 0.05$) between the test times of the Yamamoto and Sato methods and the Yamamoto and Hirai methods. There was a significant difference ($p < 0.05/3$ after Bonferroni correction) between the test times of the Sato and Hirai methods.

Discussion

1. Denture performance judgment table (Yamamoto method)[23] (Figure 1)

The Yamamoto method was first published to evaluate the ability level of denture wearers, mainly regarding masticatory function, including psychological aspects from foods that can be ingested, and it has become the basis of many subsequent studies[23-27]. In the Yamamoto method, hard pickled radish, boiled rice cakes, peanuts, and hard Japanese crackers are shown in the four corners of the form as representative foods that are difficult to eat for patients with edentulous jaws. Soup, which can be ingested readily, is shown in the center of the form. Bean curd, pudding, and rice gruel, which can be eaten without chewing, are also placed at the center, while foods that are soft but need to be chewed are placed around them in order of hardness. The total number of foods included is 35, 5 of which are functional and included non-food items. The difficulty rank was a 6 + function (including non-food items). This was based on a long period of clinical experience and has no particular scientific basis. The Yamamoto method has a long history of clinical use and is easy to explain visually to patients in order to compare chewing ability before and after denture installation, but it is difficult to evaluate the method objectively within set standardized scores.

2. Table for evaluation of chewing function in complete denture wearers (Sato method)[24] (Figure 2)

The Sato method was the first attempt to score the food sequence criteria of Yamamoto's denture performance judgment table within a scientific framework. A chewing index of 100 foods was created by scoring the difficulty level of chewing each of those 100 foods. The difficulty level scores were obtained via questionnaire method, excluding those with little difference in results, and referring to the 35 foods listed in the Yamamoto method. The data for this study was collected from 300 patients with various complete dentures. The score can be easily calculated.

3. Evaluation method for the masticatory function in complete denture wearers (Hirai method)[25] (Figure 3)

The Hirai method used an original evaluation chart based on measurements of the physical properties of various foods, which have been verified to correlate with objective testing methods[19]. A total of 35 foods were carefully selected from 170 options based on hardness level as measured by a texturometer. Data was collected from 39 patients with complete dentures. Scores were weighted into five ranks, which is difficult to calculate by rote methods and requires spreadsheet software. The Hirai method is characterized by the inclusion of a wide variety of foods, and it can be scored precisely, although the

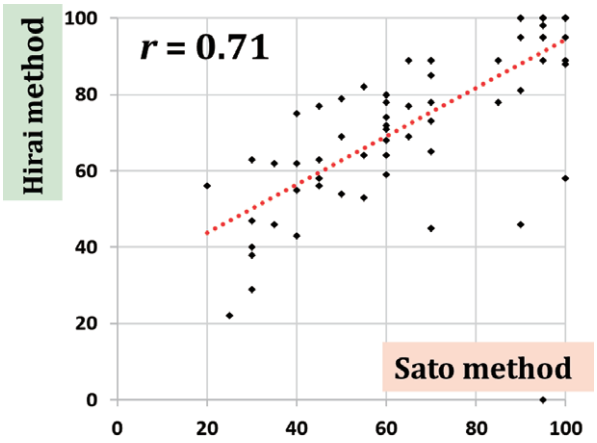

Fig. 4. Correlation between the Hirai and Sato methods

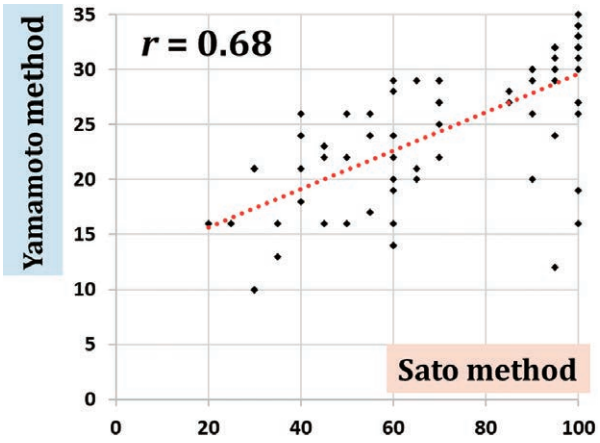

Fig. 5. Correlation between the Yamamoto and Sato methods

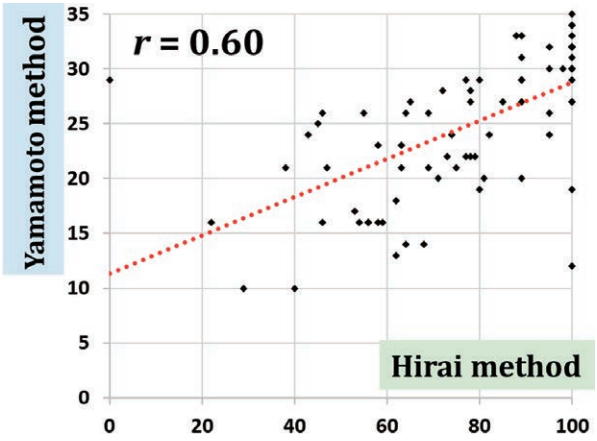

Fig. 6. Correlation between the Yamamoto and Hirai methods

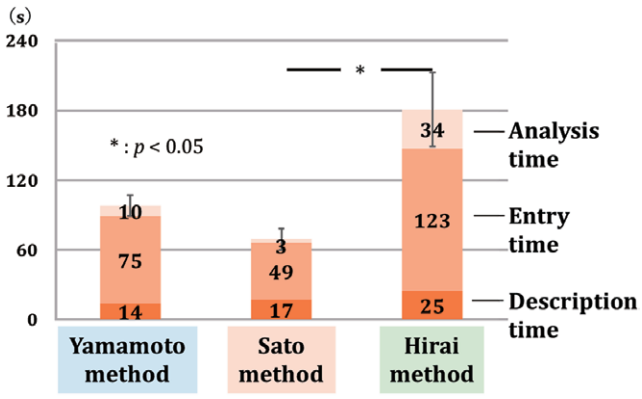

Fig. 7. Time study of the Yamamoto, Sato, and Hirai methods

calculation is time-consuming.

4. Correlation (r) between the three representative subjective evaluation methods of chewing function

The Sato method is also based on the Yamamoto method. The Hirai method was recently developed based on food hardness obtained using a texturometer[17, 18].

There was a strong correlation between the Sato and Hirai methods ($r = 0.71$) (Figure 4), which are both derived from the Yamamoto method.

This may be because the Sato and Hirai methods are based on data from participants and a texturometer, respectively. Consequently, these three subjective evaluation methods are expected to produce similar results as they correlate with each other, although the specific contents of the methods are different.

There was a moderate correlation between the Yamamoto and Sato methods ($r = 0.68$) (Figure 5). Since the selection of foods was based on the Yamamoto method, it can be assumed that there was a correlation.

There was a moderate correlation between the Yamamoto and Hirai methods ($r = 0.60$) (Figure 6). Among all pairs examined, this correlation was the lowest. The Yamamoto and Sato methods are comprised of items that can be eaten or not eaten, and regardless of patient preference, a score is given if the item can be eaten. In contrast, in the Hirai method, some items that can be eaten are not eaten because they are disliked by the patient; therefore, these items are not scored. In the Hirai method, this is reflected by the item, "I do not eat it because I dislike it." The Hirai method has a moderate correlation, but this correlation was low among the participants. The Hirai method is subjective and may be influenced by patient preferences, such as food likes and dislikes, in addition to the Yes/No questions regarding whether the food is edible or not.

5. Time study between the three representative

subjective evaluations of chewing function (Figure 7)

1) Description time

The Yamamoto method includes only one item (○), while the Sato method includes three items (○, △, ×) and an explanation for each item. Finally, the Hirai method consists of five options (2, 1, 0, △, □) and an explanation for each item.

2) Entry time

The number of food items in both the Yamamoto and Hirai methods was 35, while the Sato method included 20 food items. The Yamamoto method uses a diagram form, while the Sato and Hirai methods use a table form. There is a difference in the entry time between the Yamamoto and Hirai methods, although the number of food items is the same. This difference may be attributed to the use of a diagram in the Yamamoto method and a table in the Hirai method. The diagram form is easier to comprehend visually than the tables are, but the order in which the items are filled is difficult to understand and requires more time to complete. These factors might have resulted in the Sato method having the shortest time to record results.

3) Analysis time

In the Yamamoto method, the counting order is difficult to understand because it is in diagram format, and it takes additional time to complete because there are 35 foods.

Even if the scores from the Hirai method are analyzed using Excel, analysis can still be time-consuming because it requires the input of 2 items (2 and 1) and 35 foods related to the score. Therefore, the Sato method is considered the quickest to execute.

Regarding examination time, the Sato method was significantly shorter than the Hirai method. There was no significant examination time difference between the Yamamoto and Sato methods or between the Yamamoto and Hirai methods.

The Yamamoto method was the first subjective evaluation method established, and it has no scientific basis because it is purely based on clinical experience in selecting foods, but the Sato and Hirai methods do have scientific bases, with the Sato method data demonstrating the shortest administering time[23–25]. Thus, the Sato method is suggested to be useful.

This study was limited by its single-center design and the demographic and geographic limitations of the recruited patient participants. The age restrictions of our recruitment also limited the generalizability of the study results.

In conclusion, the Sato method strongly correlated with the Hirai and Yamamoto methods, and the timed study results showed that the Sato method had the shortest administering time. In future studies, we plan to clarify the selection criteria, including the relevance of objective evaluation and usability.

Acknowledgments

Author contributions

Conceptualization, YS, TS, and YU; data curation, YU, YS, TS, TO, IA, MT, and YH; formal analysis, YU, YS, TS, and JF; supervision, YS, TS, and MT. Writing—original draft, YU and JF; writing—review and editing, YU, SY, NK, TS, TO, AI, MT, YH, and JF.

All authors have read and agreed to the published version of the manuscript. All authors read and approved the final manuscript.

Conflict of interest

The authors declare no conflicts of interest regarding this study.

Disclosure

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