Reproducibility and Accuracy in Measuring Masticatory Performance Using Test Gummy Jelly

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Clinical significance
A reliable assessment of masticatory performance would be a valuable contribution to the practice of evidence-based dentistry. A method of measuring masticatory performance using the glucose concentration from test gummy jelly simplified the procedure, reduced the time involved, and provided accurate and reproducible feedback for assessing masticatory ability.

ABSTRACT

Purpose: To establish a simpler and more accurate method of measuring masticatory ability in routine dental practice compared to current methods.

Materials and Methods: To find the most suitable conditions for assessing masticatory performance using the test gummy jelly, variable factors were investigated, such as temperature and length of rinse time in water, temperature of distilled water, and dissolution time of glucose. The accuracy of this test was confirmed by correlating the surface area of the jelly and the glucose concentration. A student's t-test or ANOVA was used for statistical analysis at the 5% level of significance. The Bonferroni method was used for multiple comparisons.

Results: The glucose concentration decreased gradually (p<0.05) as the rinsing time increased but tended to remain unchanged at 30 seconds or more. As the temperature of the distilled water for dissolving the glucose or the dissolution time increased, the glucose concentration constantly increased (p<0.05). A linear regression analysis showed that the concentration of glucose had a significantly high correlation to the surface area (mm²) of the comminuted jelly (r=0.993, p<0.01).

Conclusion: The concentration of glucose dissolved from the comminuted particles of the test gummy jelly indicated high reproducibility and accuracy when the rinsing time, temperature of the distilled water, and dissolution time of the glucose were strictly prescribed.

Key words
masticatory performance, test gummy jelly, glucose, reproducibility, accuracy
INTRODUCTION

The primary purpose of prosthodontic treatment is not only to restore dental and periodontal structures, but also to achieve acceptable masticatory function. Accordingly, establishment of an objective evaluation of masticatory ability is indispensable for pre- and post-prosthetic treatment.

The aim of mastication is to comminute food and to increase the surface area of the food to promote proper digestion and absorption of nutrients. There are several objective measures of masticatory function, such as masticatory performance, masticatory efficiency, swallowing threshold and occlusal force. The most common technique for qualifying chewed food has been to measure particle size distribution with a series of mesh sieves. A sieve method using peanuts was developed in 1950 and has been used until recently. Both real foods, including peanuts or carrots, and artificial materials, such as gelatin or silicone, have been used to measure masticatory performance. Finding a universally accepted test food or material has been difficult and is still unresolved. Therefore, new methods are being introduced to simplify the procedure, reduce the time involved in testing, and provide more relevant measures for assessing masticatory function.

Yamamoto developed an assessment of masticatory performance using the test gummy jelly test method of evaluating the surface area of the comminuted jelly from the dissolved gelatin concentration. This method offers considerable advantages such as speed, accuracy and hygiene, compared to the sieve method of analysis. However, to measure the gelatin concentration, a specific laboratory setting with a spectrophotometer and more than 40 minutes' drying time is necessary. Therefore, it is difficult to obtain results in the usual clinical environment.

The purpose of this study was to establish a simpler and more accurate method of measuring masticatory ability in routine dental practice compared to conventional methods.

MATERIALS AND METHODS

Reproducibility of Measurements

Masticatory performance was evaluated by measuring the increase in the surface area (mm²) of the comminuted pieces of comminuted jelly (Fig. 1). Subjects were instructed to chew one block of the jelly (10 × 10 × 20 mm) at their own pace on their preferred chewing side (left, right or both) and to expectorate the bolus of the comminuted jelly as thoroughly as possible onto a sheet of gauze (Fig. 2). The collected particles of the comminuted jelly were rinsed with running water to remove the saliva. Then the particles were soaked in 15 ml of distilled water and stirred. The supernatant fluid of the solution was sampled, and the concentration of dissolved glucose from the jelly was measured with a blood glucose meter (Glutest, Sanwa Kagaku Kenkyusho, Nagoya, Japan) intended for home use by diabetic patients (Fig. 3).

To find the most suitable condition for assessing masticatory performance using test gummy jelly, variable factors were investigated, such as

Subject chews one block of gummy jelly

↓

Comminuted jelly is rinsed with running water

↓

Distilled water with the comminuted jelly is stirred

↓

Supernatant is sampled, and concentration of glucose (mg/dl) measured

↓

Increase of surface area (mm²) is calculated

Fig. 1 Procedure for measuring masticatory performance using the test gummy jelly
Fig. 2  Chewing one block of the test gummy jelly
1) One block of the jelly is chewed using 30 strokes
2) Particles of the jelly are collected
3) Particles are rinsed in running water
4) Original and comminuted test gummy jelly

Fig. 3  Measuring glucose concentrations with blood glucose meter
1) Particles of the comminuted test gummy jelly were soaked in distilled water and stirred
2) The measuring tip is inserted into the blood glucose meter (Glutest™)
3) The supernatant fluid is touched with the tip
4) The meter displays the concentration of glucose (mg/dL)
the temperature and length of rinsing time, temperature of the distilled water, and dissolution time of the glucose.

The preliminary conditions were defined as follows: the temperature of the water used to rinse the particles of jelly was 18°C; the rinsing time was 30 seconds; the temperature of the distilled water for dissolution was 35°C; and the dissolution time was 20 seconds. One of these variable factors was changed during each test, and then the concentration of glucose was measured and compared for each condition.

Five jellies were used for each condition, and the glucose concentration was measured once for each sample. The statistical analysis was performed using a student's t-test or ANOVA at the 5% level of significance. The Bonferroni method was used for multiple comparisons. The data analyses were done using the SPSS 12.0 for Windows (SPSS Inc., Chicago, USA).

Accuracy of the Examination

The accuracy of this test was confirmed by correlating the surface area of the jelly and the glucose concentration.

The original form of the test gummy jelly (20×20×10 mm; surface area: 1,600 mm²) was divided to make surface areas totaling 2,000, 2,400, 3,200, 4,000, and 4,800 mm² (Fig. 4), and then the glucose concentrations dissolved from the divided jellies were measured. A linear regression analysis of the total surface area of the divided jelly (mm²) and the glucose concentration (mg/dl) was subsequently conducted. The glucose concentrations were measured from five jellies for each surface area. The increase in the surface area, which indicated masticatory performance, was calculated by subtracting the original surface area (1,600 mm²) from the total surface area of the divided jelly.

RESULTS

The glucose concentration was not significantly different between the 18°C and the 40°C rinse water conditions (Fig. 5). However, as the rinsing time increased, the glucose concentration decreased gradually and tended to remain unchanged at 30 sec. or more (Fig. 6). After a rinsing time of 20 sec., the glucose concentration was significantly higher than after rinsing times of 30, 40 or 60 seconds. On the other hand, there was no significant difference in the glucose concentration after rinsing times of 30, 40 and 60.
Fig. 5  Influence of rinse water temperature on concentration of glucose
Rinsing time for the comminuted jelly was 30 seconds; dissolution temperature was 35°C; dissolution time was 20 seconds.

Fig. 6  Influence of rinsing time on glucose concentration

Fig. 7  Influence of temperature of distilled water for dissolution on glucose concentration

Fig. 8  Influence of dissolution time on glucose concentration

increased constantly (Fig. 8). The standard deviation for the glucose concentration after dissolution of 10 seconds was larger than for longer periods.

The linear regression analysis showed that the concentration of glucose had a significantly high correlation with the surface area (mm²) of the comminuted jelly (r=0.993, p<0.001, Fig. 9).

DISCUSSION

It is recognized that a reliable assessment of
masticatory performance may be a valuable contribution to the practice of evidence-based dentistry\textsuperscript{39}. Objective evaluations of masticatory performance have usually involved subjects chewing sample food, and then the particle size distribution of comminuted food was measured with a series of mesh sieves. However, most of these measurement methods are complicated, and therefore, assessment is difficult during routine chair-side work. In addition, reproducibility of these sieving methods to determine particle breakdown is poor and prone to experimental error due to the complicated procedures\textsuperscript{18,19}.

We have been utilizing test gummy jellies as food for assessment of masticatory performance since 1993\textsuperscript{18}. Evaluation using the jelly is based on the calculation of the surface area increased by chewing, which was obtained by measuring the concentration of the glucose dissolved from the jelly. Previously, absorptiometry was used to assess the quantity of gelatin extracted from the jelly. However, the absorbance meter was large and expensive, and the total measurement time took more than one hour, which is too long for clinical use. To solve these problems, a relatively cheaper and smaller commercially available blood glucose meter was selected for this study.

The test gummy jelly to be examined after comminution was rinsed to remove the saliva, including glucose, which adhered during mastication. The temperatures of the running water tested were 18°C, which was cool enough to prevent the dissolution of the glucose, and 40°C, which was higher than the maximum room temperature of the clinic. It was found that the temperature of the running water did not significantly affect the concentration of the dissolved glucose, indicating that the surface area of the jelly had not changed up to 40°C. As the rinsing time increased, the glucose concentration decreased gradually and finally stabilized, suggesting that the saliva was thoroughly removed in 30 seconds. In other words, the glucose that adhered during mastication might remain if the rinsing time was less than 30 seconds, in which case the surface area might be overestimated. Therefore, the jelly should be rinsed for more than 30 seconds to obtain an accurate value.

The concentration of glucose dissolved from the jelly depended on both the temperature of the distilled water and the dissolution time. A dissolution time of less than 20 seconds or a dissolution temperature lower than 30°C made the glucose concentration unstable or too low to measure using a blood glucose meter, probably due to technical error. Therefore, in order to obtain accurate and reproducible data, the temperature and the dissolution time should be watched carefully.

Yamamoto\textsuperscript{18} already reported that the concentration of gelatin dissolved from the test gummy jelly correlated closely to the number of masticatory cycles. With respect to accuracy, the regression analysis showed that the glucose concentration and the surface area of the jelly, which involved the physiological significance of mastication, had a strong linear correlation, suggesting this assessment could precisely calculate the masticatory performance.
CONCLUSIONS

1. The concentration of glucose dissolved from comminuted particles of the test gummy jelly indicated high reproducibility when the rinsing time, temperature of the distilled water, and dissolution time of the glucose were strictly prescribed.

2. The increase in the surface area of the comminuted test gummy jelly particles was accurately calculated from the glucose concentration dissolved from the jelly.

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