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The concentration of gum component in saliva before and after swallowing during prolonged gum chewing

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Abstract OBJECTIVES: The concentration of the substances eluted from the gum into saliva before and after swallowing has not almost carried out. The purpose of this study was to measure the volume of saliva before (VMAX) and after (RESID) swallowing in the mouth and was also to measure the concentration of the component (sugar) eluted from the gum chewing. METHODS: The RESID was measured by a dilution method (Lagerlof and Dawes, 1984). It was computed by measuring the potassium concentration in saliva and in the expectorated after a five-second rinse with 10 m*l* of water immediately following a swallow. The volume swallowed was calculated as salivary flow rate divided by the swallowing frequency, and the VMAX was estimated as the sum of RESID and the volume of saliva swallowed. Swallows were registered by placing over the larynx an electrode which was connected to an EMG. The volume of sugar contained in the gum was 74.8% as a total weight of the gum. Subjects were seven males and 13 females who were all in good health for measuring the RESID and VMAX. For each of the six participants of them, the concentration of sugar in saliva expectorated was measured by frame photometer. RESULTS: VMAX, swallowing frequency and the volume of fluid swallowed increased as comparing with the values when the salivary flow rate was unstimulated. The mean volume of sugar in expectorated saliva as a percentage of the initial weight of sugar contained during gum chewing at the first swallowing was 16.5 ± 5.38% and at the 10th swallowing was 0.76 ± 0.06%. These were 3.6 times and 1.8 times of those of unstimulated saliva, respectively.

Key words
Chewing-gum,
Flow rate,
Gum component,
Saliva,
Salivary pH

Introduction

Saliva is important for oral and dental health[1]. The use of chewing-gum results in increased salivary flow, which will tend to promote food clearance from the mouth. As well as stimulating salivary flow, gum chewing raises salivary and plaque pH and promotes enamel re-mineralization. Dawes and Macpherson[2] showed that with six different types of chewing-gums and with gum base, the salivary flow rate peaked in the initial minutes of chewing and then fell with time towards a relatively constant value about three times greater than unstimulated flow rate. A recent study by Dawes and Kubieniec[3] also reported that when with the chewing-gums the flow rate increased initially and then, after 35–40 min, fell to similar plateau values which remained significantly higher than initial unstimulated flow rate and significantly higher than the flow rate at the corresponding time intervals when only unstimulated saliva was collected. They concluded that during prolonged chewing-gum use, both salivary flow rates and pH remained significantly above the values for

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Table 1 The result of each value on the flow rate of unstimulated saliva

(n = 20)

	unstimulated saliva flow rate (m*l*)	frequency of swallowing (swallows/min)	RESID (m*l*)	VMAX (m*l*)	volume of swallow (m*l*)
mean ± S.D.	0.44 ± 0.25	2.4 ± 0.89	0.70 ± 0.24	0.91 ± 0.72	0.19 ± 0.12
range	0.12–1.00	1.2–3.0	0.48–1.22	0.56–1.62	0.04–0.40

unstimulated saliva.

Recently, the trial of promoting the re-mineralization of the tooth has been made by chewing-gum which contains the re-mineralization material[4,5]. However, the study on the volume of the gum component which released in the oral cavity and the stagnant time of the component in the mouth has not been carried out. The purpose of this study was to measure the volume of saliva before (VMAX) and after (RESID) swallowing in the mouth and was also to measure the concentration of the component (sugar) eluted from the gum chewing.

Materials and Methods

Subjects

The subjects were seven males and 13 females who were all in good health and ranged in age from 20 to 30 (mean, 25 years). All the subjects had more than 28 natural teeth, and none wore dentures, bridges, or orthodontic appliances which might have retained saliva.

Determination of RESID

The volume of saliva left in the mouth after swallowing was measured by a dilution method[6]. After collecting about 0.5 m*l* of unstimulated whole saliva, the subject swallowed, and immediately afterward about 10 m*l* of distilled water in a beaker was used to rinse the mouth for five seconds prior to expectoration into another container. The volume of water used was determined by the difference in weight of the beaker before and after rinsing. On each subject, three such trials were performed.

The saliva and the expectorate were analyzed for potassium by atomic absorption spectrophotometry[7] and for chloride by a coulometric technique[8].

If V is the volume of water introduced into the mouth after swallowing, and Ci and Cf are the concentrations of potassium in the saliva and expectorate, respectively, then:

Table 2 RESID when the flow rate of saliva was unstimulated or stimulated by gum chewing

(n = 3)

Sub.	unstimulated (m*l*)	stimulated (m*l*)
1	1.21 ± 0.28	1.15 ± 0.04
2	0.72 ± 0.03	0.70 ± 0.05
3	1.22 ± 0.04	1.20 ± 0.05
4	1.05 ± 0.12	0.90 ± 0.14
5	0.75 ± 0.10	0.71 ± 0.09
6	0.61 ± 0.12	0.81 ± 0.16
7	0.43 ± 0.08	0.50 ± 0.12
8	0.48 ± 0.07	0.49 ± 0.02
9	0.91 ± 0.22	0.77 ± 0.10
10	0.94 ± 0.15	0.90 ± 0.03
11	0.63 ± 0.17	0.71 ± 0.18
12	0.71 ± 0.10	0.70 ± 0.06
13	0.50 ± 0.05	0.75 ± 0.21
14	0.63 ± 0.06	0.63 ± 0.05
15	0.48 ± 0.09	0.56 ± 0.09
16	0.54 ± 0.03	0.64 ± 0.08
17	0.59 ± 0.05	0.63 ± 0.15
18	0.51 ± 0.04	0.48 ± 0.03
19	0.60 ± 0.05	0.75 ± 0.08
20	0.50 ± 0.01	0.58 ± 0.05
mean ± S.D.	0.70 ± 0.24	0.73 ± 0.19

$$RESID = V \cdot Cf/(Ci - Cf)$$

X: RESID
V: Volume of water (5 m*l*)
Ci: Concentration of potassium in the saliva
Cf: Concentration of potassium in the expectorate

In this formula it is assumed that salivary secretion during the five seconds of rinsing is negligible, and preliminary studies on subjects wearing parotid cannula confirmed this[6].

Determination of the swallowed and VMAX

The volume swallowed was calculated as salivary

Table 3 The results of swallow time, volume of swallow, VMAX and sugar concentration

(n = 20)

	swallow time (s)	volume of swallow (m*l*)	VMAX (m*l*)	sugar concentration (%)
First swallow	33.5 ± 10.9	2.50 ± 1.29	3.26 ± 1.45	16.50 ± 5.38
2	58.4 ± 15.9	2.27 ± 1.12	2.98 ± 1.12	11.40 ± 3.43
3	85.0 ± 23.1	1.84 ± 0.69	2.57 ± 0.77	7.79 ± 0.48
4	113.6 ± 32.5	1.72 ± 0.72	2.32 ± 0.61	6.59 ± 0.72
5	146.0 ± 43.2	1.50 ± 0.53	2.21 ± 0.57	3.48 ± 0.48
6	173.9 ± 58.9	1.42 ± 0.60	2.14 ± 0.60	2.77 ± 0.24
7	216.7 ± 66.8	1.27 ± 0.49	1.97 ± 0.52	2.22 ± 0.16
8	256.7 ± 80.2	1.21 ± 0.53	1.90 ± 0.55	1.43 ± 0.15
9	288.7 ± 84.5	1.15 ± 0.44	1.88 ± 0.44	0.98 ± 0.06
10	324.6 ± 102.3	0.92 ± 0.40	1.65 ± 0.45	0.76 ± 0.06

(mean ± S.D.)

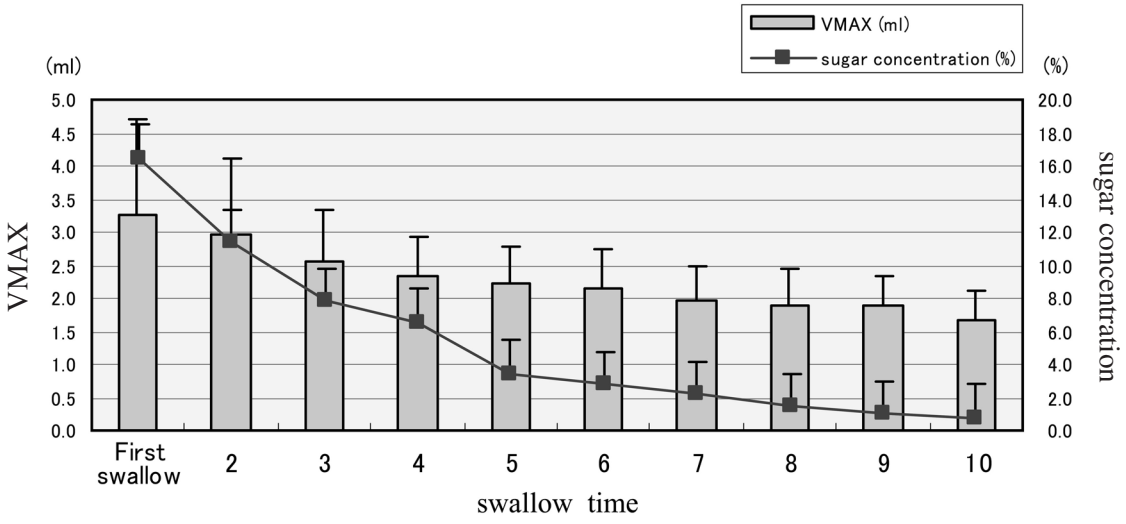

Fig. 1 The results of swallow time, VMAX and sugar concentration

flow rate divided by the swallowing frequency, and the VMAX was estimated as the sum of RESID and the volume of saliva swallowed. Swallows were registered by placing over the larynx an electrode which was connected to an EMG (Nippon Koden, Tokyo).

The unstimulated salivary flow rate was determined before and after each session. With the subject seated upright and with the head bent forward, the subject swallowed, and saliva was then allowed to drip off the lower lip into a weighed beaker for 5 min, at the end of which any remaining saliva in the mouth was expectorated into the beaker, and increase in weight was determined.

The initial volume of sugar contained in the gum was 74.8% as a total weight of the gum. The concentration of sugar in the saliva expectorate was measured by frame photometer (Cobas Mira, Swiss).

Statistical analyses

A paired *t* test was used to determine the difference of the mean values.

Results

Table 1 shows the results for the unstimulated salivary flow rate, frequency of swallowing, residual volume after swallowing (RESID), the volume of saliva in the mouth before swallowing (VMAX) and volume of swallow. There were no significant differences

between males and females in each value. For the five estimations of RESID on each subject, the mean coefficient of variation after swallows was 14.5%. VMAX (the sum of RESID plus the volume of swallowed) is 0.91 ± 0.72 m*l*.

Table 2 shows RESID when saliva is unstimulated flow rate and stimulated flow rate by gum chewing. Although the RESID at the stimulated flow rate showed a higher volume than that of the unstimulated, the differences were not statistically significant.

Table 3 and Fig. 1 show the mean values of swallowing time, volume of swallows, VMAX and sugar concentration during gum chewing. The intervals of the swallow time are gradually widens and the volume of swallow and VMAX are gradually decreases. The volume of sugar in expectorated saliva as a percentage of the initial weight of sugar contained in the gum is also decreased. The highest concentration occurred at the first swallow and then declined with time. At the 10th swallowing (324.6 ± 102.3 seconds), sucrose was still being released from chewing-gum, and volume of swallow was 4.8 times of unstimulated flow rate.

Discussion

Clearance of carbohydrates from the mouth appears to be one of the most important functions of saliva with respect to prevention of dental caries[9]. The concept of the importance for salivary clearance of the volume of saliva in the mouth immediately before and after swallowing was introduced during the development of a mathematical model of salivary clearance[10]. Computer simulations show that the lower the volumes in the oral cavity before and after swallowing, the faster is the sugar cleared from the mouth, thus resulting in a lower amount of acid production by the bacteria in the dental plaque. Therefore, individual variations in the values of RESID and VMAX could be of importance as determinants of susceptibility to dental caries.

Lagerlof and Dawes[6] determined the VMAX and RESID in unstimulated saliva flow rate for 40 adult subjects and concluded that the mean value of RESID was significantly higher in males (0.87 m*l*) than in females (0.66 m*l*). The mean value of VMAX (RESID plus volume of swallowed) in males was 1.19 m*l*, which was slightly but not significantly higher than that in females (0.96 m*l*). Our results were almost the same these values.

In recent years there has been increased interest in the effects on oral health of the use of chewing-gum[3,11–14]. The advertising claims by different chewing-gum manufacturers for the oral health benefits of gum chewing are mainly based on the increase in salivary flow above the unstimulated level which occurs during gum chewing. The increased salivary flow tends to promote clearances of food from the mouth, buffer the acid present in plaque (due to the increased bicarbonate in stimulated saliva), promote the clearance of acids because of the higher velocity of the salivary film flowing over the plaque, provide an increased amount of urea for base production in plaque, and promote the re-mineralization of teeth (due to the greater degree of saturation of stimulated saliva with respect to tooth mineral).

There are many studies which measured the salivary flow rate in every time during gum chewing[3,11–14], but the studies which measured it in every swallowing are not observed. The volume of saliva before (RESID) and after (VMAX) swallowing in the oral cavity was measured by the method of Lagerlof and Dawes[6]. They measured RESID in the resting condition in the mouth, but in this study, we measured it during gum chewing. The results showed no significant differences between them.

VMAX at the first swallow during gum chewing was 3.6 times of that at the unstimulated saliva flow rate, and at the 10th swallowing, it showed 1.8 times. VMAX is estimated as the sum of RESID and the volume of saliva swallowed, so this decrease is due to the reduction of the volume of saliva swallowed. Therefore the concentration of sugar in expectorated saliva is also decreased.

Recently, re-mineralizing of the teeth by chewing-gum has been carried out. Inaba *et al.*[4,5] has studied the effects of sugar-free chewing-gum containing Phosphoryl-Oligosaccharides (POs) on enamel re-mineralization *in situ* and concluded that the samples in the POs group indicated significantly lower demineralization values compared with the sucrose gum and the xylitol gum. But in that study, there were no records on the concentration of these contains in saliva supplied by chewing-gum. The stagnation time of these contains in oral cavity seems to become a future research.

In our study, we measured the concentration of sugar in the expectorated saliva, by considering the sugar to be a target (re-mineralization material), and showed the volume of the sugar at 10th swallowing is 0.76 ± 0.06% as a percentage of the initial weight of sugar contained in the gum. Our study seems to

be useful for considering how efficiently release the gum component into the oral cavity.

Conclusion

We could show the volume of saliva in the mouth before and after swallowing during prolonged gum chewing, and the mean volume of sugar in expectorated saliva at every swallowing.

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