Original Article

The effect of mouth breathing on chewing efficiency

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ABSTRACT

Objective: To examine the effect of mouth breathing on chewing efficiency by evaluating masticatory variables.

Materials and Methods: Ten adult nasal breathers with normal occlusion and no temporomandibular dysfunction were selected. Subjects were instructed to bite the chewing gum on the habitual side. While breathing through the mouth and nose, the glucide elution from the chewing gum, number of chewing strokes, duration of chewing, and electromyography (EMG) activity of the masseter muscle were evaluated as variables of masticatory efficiency.

Results: The durations required for the chewing of 30, 60, 90, 120, 180, and 250 strokes were significantly ($P < .05$) longer while breathing through the mouth. There was no significant difference in the glucide elution rate (%) for each chewing stroke between nose and mouth breathings. The glucide elution rates for 1- and 3-minute chewing were significantly ($P < .05$) lower while breathing through the mouth. However, there was no significant difference in the glucide elution rate for 5-minute chewing between nose and mouth breathings. While chewing for 1, 3, and 5 minutes, the chewing stroke and EMG activity of the masseter muscle were significantly ($P < .05$) lower during mouth breathing.

Conclusions: It takes a longer amount of time to complete chewing to obtain higher masticatory efficiency when breathing through the mouth. Therefore, mouth breathing will decrease the masticatory efficiency if the duration of chewing is restricted in everyday life. (*Angle Orthod.* 2016;86:227–234.)

KEY WORDS: Mouth breathing; Chewing gum; Glucide elution rate; Chewing stroke; Chewing duration

INTRODUCTION

Masticatory efficiency[1,2] represents the abilities to crush down, grind out, and mix food with saliva[3] and as well as the ability to make an alimentary bolus. This efficiency is evaluated indirectly and directly through various parameters. The rhythm of mastication or jaw movement, the number of chewing strokes, duration of chewing,[4–7] electromyography (EMG) activity of the masticatory muscle,[8] occlusal contact point and area,[9] and occlusal force[10,11] are evaluated in the indirect method. The methods used to evaluate masticatory efficiency directly evaluate the particulate distribution of a piece of peanut crushed by chewing[12] and the amount of glucide elution from the chewing gum.[13,14] The degree of the occlusal force and the duration of masticatory work are important factors to consider in determining masticatory efficiency.[1,2] On the other hand, the masticatory function competes with respiration when nasal obstruction causes a person to breathe through the mouth, and the masticatory function may be inhibited. Hsu and Yamaguchi[15] reported that the activity of the masticatory muscles decreased and the duration of masticatory muscle activity was reduced when chewing gum for 3 minutes while breathing through the mouth. Ikenaga et al.[16] reported that the duration of chewing a rice ball before swallowing was prolonged while breathing through the mouth. These researchers concluded that breathing

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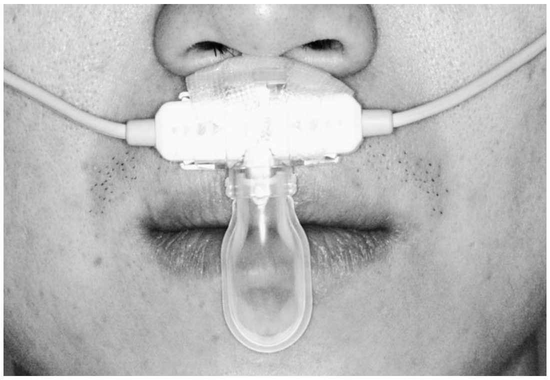

Figure 1. Estimation of breathing mode. Airflow from the mouth was recorded for 5 minutes using a CO_2 sensor, according to the method of Fujimoto et al.[17]

through the mouth could reduce the degree and duration of vertical occlusal force on the posterior teeth, and it could be an environmental factor inducing vertical problems in the malocclusion.

Thus, we hypothesized that decreased degree of occlusal force and reduced duration of masticatory time could decrease masticatory efficiency when breathing through the mouth. Real mouth breathing should be differentiated with incompetent lip subjects who open the lips at rest.[17] Nasal resistance to the airflow is always changing and not stable, and the strength of the nasal resistance to break the posterior oral seal varies with subjects.[17] Therefore, mouth breather is not always mouth breather in a day, and when the mouth breather makes breath through the mouth may be irregular and unstable.

In this study, we examine the effect of full-time mouth breathing for the normal nasal breathers on masticatory efficiency or chewing ability (ability to crush and mix food) by evaluating both direct and indirect variables.

MATERIALS AND METHODS

Subjects

Among adult volunteers with normal occlusion and no functional abnormalities, 10 normal nasal breathers (four males, six females) were selected by recording airflow from the mouth for 5 minutes using a CO_2 sensor, according to the method of Fujimoto et al.[17] (Figure 1). The average age of subjects was 30.2 years. The occlusal condition of each subject was examined using a dental prescale. The average occlusal contact area, the masticatory pressure, and the occlusal force at the centric occlusion were 24.0 $\pm$ 10.1 mm^2, 38.2 $\pm$ 3.6 MPa/mm^2, and 897.9 $\pm$ 326.3 N, respectively. These values were equal to the normal values reported by previous authors.[18,19]

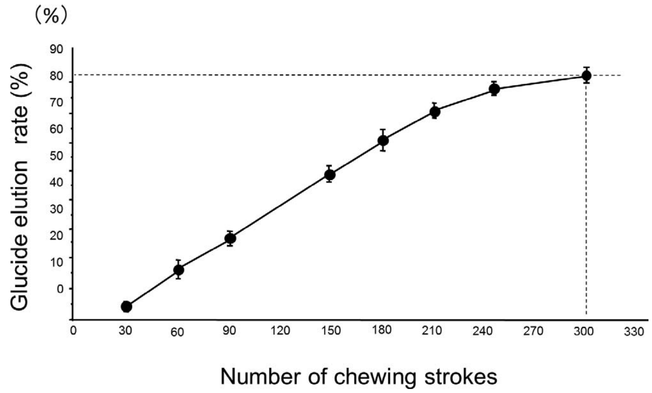

Figure 2. Increase in the glucide elution rate with increased chewing strokes. The amount of glucide elution (g) and the glucide elution rate (%) increased logarithmically and reached a plateau after 250 to 350 chewing strokes.

Methods

We instructed subjects to bite the chewing gum (chewing gum, Ltd Crasie Food Research Institute, Osaka, Japan) on the habitual side. We measured the gum weight before and after chewing using the following procedures and calculated the amount of gum glucide elution after chewing. The average weight of the gum was 2.992 $\pm$ 0.033 g, and the glucide component was 2.058 g.

The subjects gargled with distilled water and completely swallowed their saliva before they began chewing the gum.[13] After chewing the gum for the prescribed number of chewing strokes or after the duration of chewing was completed, the gum was promptly removed from the mouth. The saliva attached to the chewing gum was removed under running water. After having removed the water, the gum was weighed. The difference in the weight of the gum before and after chewing was equivalent to the amount (g) of glucide elution,[13] and the glucide elution rate (%) was calculated. This study was approved by the ethics committee of Kyushu Dental University (No. 14-3).

Examination with the Prescribed Number of Chewing Strokes

In two subjects with normal nasal breathing, the amount of glucide elution from the chewing gum was recorded according to the increased number of chewing strokes. The amount of glucide elution (g) and the glucide elution rate (%) increased logarithmically and reached a plateau after 250 to 350 chewing strokes (Figure 2). Based on this finding, we compared the glucide elution rate (%) during 30, 60, 90, 120, 180, and 250 chewing strokes while the subject performed nasal or mouth breathing. We measured the duration (in seconds) required for each number of chewing strokes. We placed surface electrodes on the skin over

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Table 1. Examination of Reliability for the Measurement of the Amount of Glucide Elution (g) After Chewing for 60 and 180 Strokes During Nasal and Mouth Breathing[a]

	First Day				Second Day				
	Trial 1	Trial 2	Trial 3	*P*	Trial 1	Trial 2	Trial 3	*P*	Day 1 vs Day 2 *P*
				60 Times Chewing During Nasal Breathing					
Subject 1	0.493	0.432	0.468		0.419	0.500	0.499		
Subject 2	0.549	0.504	0.502		0.444	0.522	0.462		
Subject 3	0.463	0.393	0.539		0.470	0.461	0.487		
Mean ± SD	0.502 ± 0.044	0.443 ± 0.056	0.505 ± 0.036	ns	0.473 ± 0.046	0.476 ± 0.041	0.473 ± 0.013	ns	ns
				60 Times Chewing During Mouth Breathing					
Subject 1	0.443	0.502	0.464		0.490	0.380	0.431		
Subject 2	0.613	0.581	0.586		0.485	0.456	0.462		
Subject 3	0.492	0.440	0.462		0.460	0.554	0.517		
Mean ± SD	0.516 ± 0.088	0.508 ± 0.071	0.504 ± 0.071	ns	0.434 ± 0.055	0.468 ± 0.015	0.510 ± 0.047	ns	ns
				180 Times Chewing During Nasal Breathing					
Subject 1	1.319	1.276	1.295		1.268	1.317	1.302		
Subject 2	1.319	1.272	1.277		1.319	1.279	1.283		
Subject 3	1.288	1.313	1.314		1.329	1.324	1.288		
Mean ± SD	1.297 ± 0.022	1.289 ± 0.026	1.305 ± 0.015	ns	1.296 ± 0.025	1.294 ± 0.022	1.314 ± 0.022	ns	ns
				180 Times Chewing During Mouth Breathing					
Subject 1	1.254	1.252	1.286		1.284	1.324	1.310		
Subject 2	1.326	1.310	1.310		1.251	1.295	1.300		
Subject 3	1.342	1.349	1.344		1.384	1.360	1.343		
Mean ± SD	1.264 ± 0.019	1.315 ± 0.009	1.345 ± 0.004	ns	1.306 ± 0.020	1.282 ± 0.027	1.362 ± 0.021	ns	ns

[a] SD indicates standard deviation; ns, not significant; day 1, first day; and day 2, second day.

the masseter muscle while the subjects chewed gum, and the chewing strokes were obtained from the root square mean of the EMG activity.[20]

Each measurement was performed three times. The amount of glucide elution, the glucide elution rate, and the duration (in seconds) of chewing for each chewing stroke were compared using the paired *t*-test. Mouth breathing was induced by closing the nostrils with a nose clip; subjects started chewing the gum 10 minutes later.

Examination with the Prescribed Duration of Chewing

As previously described, the gum's glucide elution rate (%) increased logarithmically and reached a plateau after 350 chewing strokes (Figure 2). The amount of glucide elution after 250 to 350 chewing strokes while performing nasal breathing is approximately equivalent to that obtained after chewing for 5 minutes. Therefore, we asked the subjects to chew the gum for 1, 3, and 5 minutes, and the amount of glucide elution (g), glucide elution rate (%), number of chewing strokes, and integrated EMG activity (μV • s) were recorded. This process was repeated three times, and each variable was compared using the paired *t*-test while the subjects performed nose and mouth breathing.

Reproducibility and Reliability of the Measurements

Three subjects were selected using the same criteria, and the duration of chewing (in seconds), amount of glucide elution (g), glucide elution rate (%), and EMG activity (μV • s) were recorded three times while chewing for 60 and 180 strokes while the subject performed nasal and mouth breathing, respectively.

To prove the reliability and reproducibility, we recorded at nasal breathing earlier and we put the interval of 10 minutes and recorded at mouth breathing. The same recordings were repeated on another day. The reproducibility and reliability of the measurement of these variables were examined using repeated two-way analysis of variance. As a result of reproducible testing, there were no significant differences in the measurements after 60 and 180 chewing strokes while subjects performed nasal and mouth breathing, respectively (Tables 1 through 3).

RESULTS

Prescribed Chewing Strokes

In each of the chewing strokes, the duration required for chewing the gum was significantly ($P < .05$) longer while subjects performed mouth breathing vs nasal

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Table 2. Examination of Reliability for the Measurement of the Duration of Chewing (seconds) During Chewing for 60 and 180 Strokes During Nasal and Mouth Breathing[a]

	First Day				Second Day				
	Trial 1	Trial 2	Trial 3	*P*	Trial 1	Trial 2	Trial 3	*P*	Day 1 vs Day 2 *P*
				60 Times Chewing During Nasal Breathing					
Subject 1	52	51	48		49	47	51		
Subject 2	41	40	38		41	39	37		
Subject 3	46	47	51		47	48	48		
Mean ± SD	46.3 ± 5.5	46.0 ± 5.6	45.7 ± 6.8	ns	45.7 ± 4.2	44.7 ± 4.9	45.3 ± 7.4	ns	ns
				60 Times Chewing During Mouth Breathing					
Subject 1	59	55	55		54	56	53		
Subject 2	46	43	51		42	41	42		
Subject 3	55	51	53		53	57	57		
Mean ± SD	53.3 ± 6.7	49.7 ± 6.1	53.0 ± 2.0	ns	49.7 ± 6.7	51.3 ± 9.0	50.7 ± 7.8	ns	ns
				180 Times Chewing During Nasal Breathing					
Subject 1	138	133	137		121	139	142		
Subject 2	133	117	120		125	118	116		
Subject 3	171	165	164		173	163	160		
Mean ± SD	147.3 ± 20.6	138.3 ± 24.4	140.3 ± 22.2	ns	139.7 ± 28.9	140.0 ± 22.5	139.3 ± 22.1	ns	ns
				180 Times Chewing During Mouth Breathing					
Subject 1	137	129	144		130	137	135		
Subject 2	128	124	126		122	122	121		
Subject 3	200	184	183		193	189	183		
Mean ± SD	155.0 ± 39.2	145.7 ± 33.3	151.0 ± 29.1	ns	148.3 ± 38.9	149.3 ± 35.2	146.3 ± 32.5	ns	ns

[a] SD indicates standard deviation; ns, not significant; day 1, first day; and day 2, second day.

breathing (Figure 3). The amount of gum glucide elution and the glucide elution rate for every chewing stroke were not significantly different when subjects performed nasal breathing vs mouth breathing (Figure 4).

Prescribed Duration of Chewing

For 1- and 3-minute gum chewing periods, the glucide elution rate was significantly ($P < .05$) lower while subjects performed mouth breathing vs nasal breathing (Figure 5). However, there was no significant difference in the glucide elution rate during the 5-minute gum chewing period while breathing through the nose vs the mouth. While chewing the gum for 1-, 3-, and 5-minute periods, the chewing stroke and integrated EMG activity of the masseter muscle were significantly ($P < .05$) reduced during mouth breathing vs nasal breathing (Figures 6 and 7).

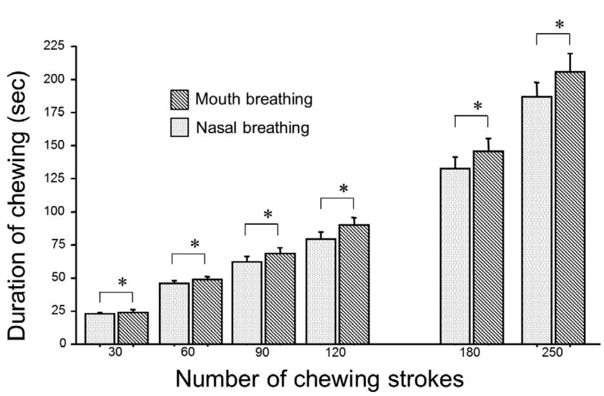

Figure 3. Comparison of the duration of chewing. In each of the chewing strokes, the duration required for chewing the gum was significantly ($P < .05$) longer during mouth breathing than during nasal breathing.

DISCUSSION

It is reported that mouth breathing caused by nasal obstruction inhibits normal masticatory function.[15,16,21,22] Inhibited masticatory function could introduce vertical problems in the malocclusion due to the reduced degree and duration of vertical occlusal force on the posterior teeth.[18,23] This is one of the harmful effects that mouth breathing has on dentofacial growth and development. In this study, another effect of mouth breathing, the masticatory function inhibited by mouth breathing, was hypothesized to decrease the efficiency of mastication. The amount of glucide elution from the gum during chewing is considered a direct factor representing masticatory efficiency, and the EMG of the masticatory muscle, chewing stroke count, and duration of chewing are considered indirect factors representing masticatory efficiency.

To test our hypothesis, these variables were compared while subjects performed normal nose breathing vs mouth breathing. The occlusal contact point and area and occlusal force are considered to be

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Table 3. Examination of Reliability for the Measurement of Integrated Electromyography (EMG) Activity (μV • s) During Chewing for 60 and 180 Strokes During Nasal and Mouth Breathing[a]

	First Day				Second Day				
	Trial 1	Trial 2	Trial 3	*P*	Trial 1	Trial 2	Trial 3	*P*	Day 1 vs Day 2 *P*
60 Times Chewing During Nasal Breathing									
Subject 1	12,356	13,856	15,467		12,428	9604	12,484		
Subject 2	9961	6879	8785		6328	6915	6815		
Subject 3	2730	2116	2894		4133	4823	4512		
Mean ± SD	8349.0 ± 5011.4	7617.0 ± 5904.7	9048.7 ± 6290.6	ns	7629.7 ± 4298.0	7114.0 ± 2396.7	7937.0 ± 4102.7	ns	ns
60 Times Chewing During Mouth Breathing									
Subject 1	11,643	13,174	11,450		10,582	11,847	11,791		
Subject 2	7815	8468	8887		6368	6311	6424		
Subject 3	1978	2625	2743		4169	4264	4628		
Mean ± SD	7145.3 ± 4867.2	8089.0 ± 5284.7	7693.3 ± 4474.5	ns	7039.7 ± 3258.8	7474.0 ± 3923.0	7614.3 ± 3726.9	ns	ns
180 Times Chewing During Nasal Breathing									
Subject 1	29,153	25,499	24,750		29,138	27,513	32,707		
Subject 2	25,932	26,213	25,777		19,345	19,116	18,469		
Subject 3	7523	9297	7978		8669	8448	9760		
Mean ± SD	20,869.3 ± 11,669.9	20,336.3 ± 9597.0	19,501.7 ± 9993.0	ns	19,050.7 ± 10,237.7	18,359 ± 9555.0	20,312 ± 11,584.0	ns	ns
180 Times Chewing During Mouth Breathing									
Subject 1	24,575	24,140	23,265		22,338	31,426	29,817		
Subject 2	24,733	27,252	25,208		19,424	17,451	17,584		
Subject 3	8495	7601	7550		9837	9178	9400		
Mean ± SD	19,267.7 ± 9329.7	19,664.3 ± 10,562.4	18,674.3 ± 9682.8	ns	17,199.7 ± 6540.6	19,351.7 ± 11,245.1	18,933.7 ± 10,275.2	ns	ns

[a] SD indicates standard deviation; ns, not significant; day 1, first day; and day 2, second day.

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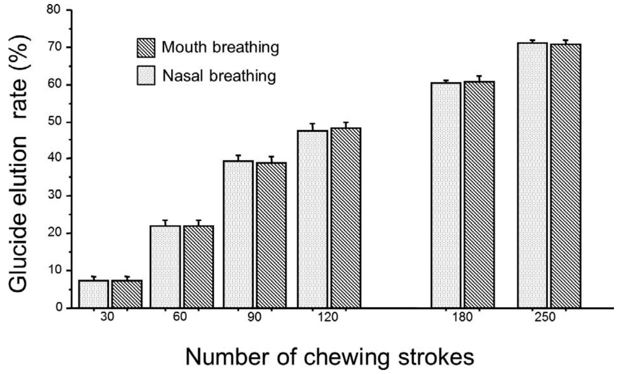

Figure 4. Comparison of glucide elution rates. The amount of gum glucide elution and the glucide elution rate with every chewing stroke were not significantly different between subjects who were nasal breathing and those who were mouth breathing.

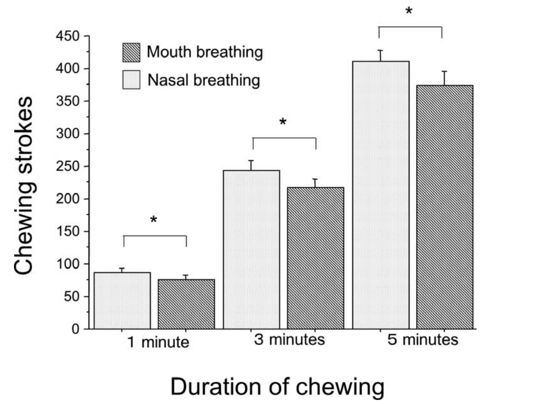

Figure 6. Comparison of chewing strokes. After 1, 3, and 5 minutes of gum chewing, the chewing stroke was significantly ($P < .05$) less during mouth breathing than during nasal breathing.

indirect factors, and these factors were standardized in subjects that had an occlusal contact area and occlusal force of the centric occlusion within the normal range.

There were no significant differences in the glucide elution rate of the gum between nasal and mouth breathing for the same number of chewing strokes. This means that the number of chewing strokes is an important factor in determining masticatory efficiency. If there is enough time to eat a meal, subjects can achieve enough chewing strokes. Therefore, masticatory efficiency is accomplished regardless of breathing style when it does not limit the duration of chewing.

However, unfortunately, a longer time was needed to maintain the same number of chewing strokes during mouth breathing. Ikenaga et al.[16] showed that it took longer to make an alimentary bolus and initiate swallowing of this bolus while mouth breathing. This is because it is necessary to stop the chewing movement temporarily when breathing through the mouth because of a nasal obstruction.

In this study, when the prescribed duration of chewing was a 1- or 3-minute period, the number of chewing strokes and EMG activity of the masseter muscle were significantly reduced during mouth breathing, resulting in a decreased glucide elution rate from the gum. However, there was no significant difference in the glucide elution rate from the gum during nasal vs mouth breathing when the prescribed duration of chewing was 5 minutes. As described earlier, 1, 3, and 5 minutes of gum chewing equated to approximately 80, 200, and over 300 chewing strokes, respectively. The elution rates of glucide from the gum increased logarithmically with an increased number of chewing strokes and reached a plateau when the number of chewing strokes exceeded 250 strokes. Therefore, there was no

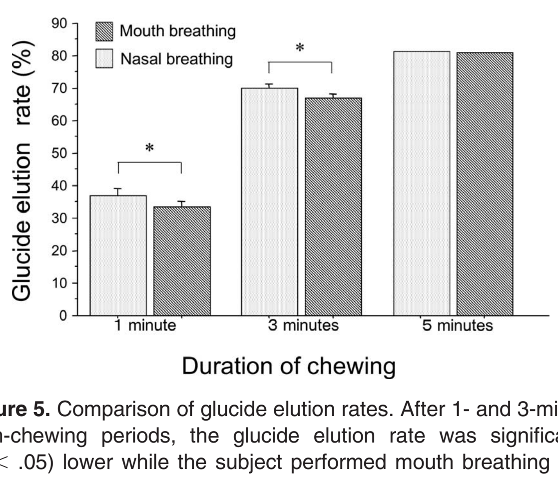

Figure 5. Comparison of glucide elution rates. After 1- and 3-minute gum-chewing periods, the glucide elution rate was significantly ($P < .05$) lower while the subject performed mouth breathing than while performing nasal breathing. However, there was no significant difference in the glucide elution rate during the 5-minute gum-chewing period between those who were nasal and those who were mouth breathing.

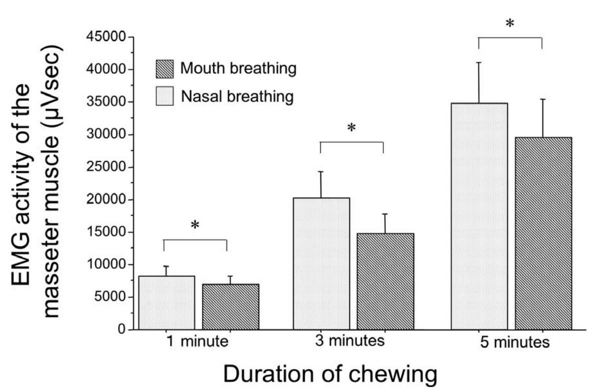

Figure 7. Comparison of electromyography (EMG) activity. After 1, 3, and 5 minutes of gum chewing, the integrated EMG activity of the masseter muscle was significantly ($P < .05$) less during mouth breathing than during nasal breathing.

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significant difference in the glucide elution rate from the gum between nasal and mouth breathing after chewing the gum for 5 minutes.

Clinical Implication

Increased nasal resistance to the airflow due to the common cold, nasal allergies, prolonged rhinitis, and adenoidal hypertrophy breaks the posterior oral sealing with the soft palate and the tongue,[24,25] and breath flows into the oral cavity, resulting in the opening of the lips. This is real mouth breathing. Whenever making a breath through the mouth, the chewing activity should be stopped.

As the purpose of this study was to examine the effect of mouth breathing on masticatory efficiency, subjects should mouth breathe all the time. However, real mouth breathers are sometimes confused with incompetent lip subjects, who open the lips at rest, and with subjects who complain of stuffy noses and snoring. These latter are not necessarily mouth breathers.[17] It has been found[17] that nasal resistance to the airflow is not stable and is always changing and that the strength of the nasal resistance to break the posterior oral seal varies with subjects. The actual times during which real mouth breathers make breath through the mouth may be irregular, unstable, and unclear. In addition, real mouth breathing is initiated by breaking the posterior oral sealing as a result of increased nasal resistance to the airflow. However, the posterior oral sealing is possibly adapted to be broken easily with lower nasal resistance to the airflow.[17,26,27] For those reasons, mouth breathing was objectively differentiated with incompetent lip using a CO_2 sensor, and normal nasal breathers were selected as subjects. Full-time mouth breathing was induced by occluding the nostrils with a nose clip. The important difference between real mouth breathing and experimental mouth breathing is the duration in terms of how long the subjects make breaths through the mouth while chewing foods. A further research project will focus on how long each mouth breather is making breath through the mouth in a day. Recently there have been many reports[28–32] on the epidemiological incidence of chronic rhinitis, chronic rhinosinusitis, perennial allergic rhinitis, and respiratory infections, which introduce habitual mouth breathing in the younger generation. In addition, the meal times of children should have decreased because of the following factors: the time required to attend school far away from home has increased and the time it takes to eat breakfast has become shorter. Because of participation in a private supplementary school downtown after school, school-age subjects return home late in the evening and have supper later at night.[33,34]

Therefore, these conditions suggest that children were shown to have little opportunity to increase the duration of their meal times. The recovery of normal nasal breathing and the promotion program for the food and nutrition education (Shokuiku) have been recommended as a measure to improve these problems.

CONCLUSIONS

- Chewing activity is disturbed while breathing through the mouth, and it takes a longer amount of time to complete enough chewing strokes to obtain higher chewing efficiency when breathing through the mouth.
- Therefore, if the duration of chewing is restricted in everyday life, mouth breathing due to nasal obstruction will further decrease masticatory efficiency.

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