Improvement of salivary flow and oral wetness by a lip trainer device and sonic toothbrush in older Japanese men and women with dry mouth

Murtaza Saleem1), Nobuo Yoshinari1,2), Suguru Nakamura2), Yasunori Sumi3), Yukiko Iwai2), Yuki Ozaki2), Yuji Masuda4), Keiichi Uchida5), and Akira Taguchi5)

1)Department Oral Health Promotion, Graduate School of Oral Medicine, Matsumoto Dental University, Shiojiri, Japan
2)Department of Operative Dentistry, Endodontology and Periodontology, School of Dentistry, Matsumoto Dental University, Shiojiri, Japan
3)Department of Center for Development of Advanced Medicine for Dental Diseases, National Center for Geriatrics and Gerontology, Obu, Japan
4)Division of Oral and Maxillofacial Biology, Institute for Oral Science, Matsumoto Dental University, Shiojiri, Japan
5)Department of Oral and Maxillofacial Radiology, School of Dentistry, Matsumoto Dental University, Shiojiri, Japan

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Abstract: Dry mouth, caused by decreased salivary gland function and/or weak salivary stimulation, can severely affect oral health in older individuals. Therefore, the aim of this study is to evaluate whether a lip trainer device and sonic toothbrush can improve salivary flow and oral wetness in older patients complaining of dry mouth. Overall, 39 subjects aged ≥60 years who had at least 20 natural teeth were randomly assigned to use a lip trainer device (group P, n = 13) or a sonic toothbrush (group S, n = 13). The subjects who did not experience oral dryness were included as controls (group C; n = 13). The unstimulated and stimulated salivary flow rates and oral wetness were measured at baseline, 1 and 6 months. The unstimulated salivary flow significantly increased in both groups at 1 and 6 months (P < 0.05). The stimulated salivary flow was also significantly increased in group P (P < 0.01) compared with the level at baseline. However, no significant difference was observed over time in group S. Oral wetness of the tongue and buccal mucosa in group P had significantly improved at 1 and 6 months (P < 0.05). Dry mouth in older individuals may be improved by using a lip trainer device or a sonic toothbrush.

Keywords: older; lip trainer; sonic toothbrush; salivary flow rate; wetness.

Introduction

Saliva is an important body fluid secreted by three major salivary glands (parotid, submandibular, and sublingual) and numerous minor salivary glands. The amount of saliva secreted daily is higher than the amount of any other body fluid. Saliva constantly bathes the soft and hard tissues of the oral cavity and controls microbial growth to counter opportunistic infections, including oral candidiasis. It also regulates the mineral balance of the mouth to maintain dental enamel integrity. The washing effect of saliva removes food debris and plaque, thereby
assisting in the prevention of dental caries and halitosis (1).

Oral dryness or xerostomia is a significant health problem because it disturbs the oral environment and causes psychological and physical distress, particularly in older individuals. Those suffering from dry mouth can find it difficult to maintain good oral hygiene, and their oral health can rapidly deteriorate. Several studies have shown that the discomfort due to xerostomia may influence scores on surveys of oral health-related quality of life (2-4).

The causes of xerostomia include age, the adverse effects of certain medicinal treatments, stress, Sjögren syndrome, radiation therapy of head and neck cancer, and autoimmune diseases (5,6). Among these, it has been reported that xerostomia is closely associated with age (7-12). Aging is defined as alteration in the form of life (2-4). The degeneration of elastic and nervous tissue leads to the hypofunction of body organs with age. Therefore, low salivary gland function and weak salivary stimulation in older individuals could be potential causes of xerostomia. In Japan, individuals aged ≥65 years account for 27.3% of the population. This high percentage could be attributed to the higher potential for oral dryness in the population.

Several salivary flow enhancing products that provide an element of relief for dry mouth are currently available. These include saliva substitutes, saliva stimulants (also termed sialagogues), dentifrices, and pilocarpine medication. Mechanical sialagogue therapy, which involves the induction of salivation by oral and masticatory muscle exercise using a hyperboloid, has been tested (14). Similarly, another study has demonstrated that mastication exercises, including gum chewing, can increase salivary flow (15). Additionally, the Patakara lip trainer device (Patakara, Ltd., Tokyo, Japan) has been used in a health promotion program for facial mimetic muscle training (16), demonstrating its capability for mechanical sialagogue therapy.

Transcutaneous electrical nerve stimulation, in which salivation is induced by electrodes placed on skin, has recently been shown to be effective on whole saliva (17). This suggests that salivary flow can be enhanced by the stimulation of adjacent oral structures. Similarly, the use of electric toothbrushes for salivary stimulation has been investigated (18). However, the study duration was short and use of sonic toothbrushes was limited to once daily. Nevertheless, the intraoral use of sonic toothbrushes could be helpful for salivary flow stimulation.

In the present study, it was hypothesized that facial mimetic muscle training using a device or stimulation of the gingiva using a sonic toothbrush increases salivation and oral wetness. Therefore, the aim of this study was to evaluate salivary flow and oral wetness following the use of a lip trainer or sonic toothbrush in older individuals with complaints of oral dryness.

Materials and Methods
Overall, 39 patients with chief complaints of periodontal disease who were referred to the Department of Periodontology at Matsumoto Dental University Hospital between April 2013 and December 2016 were enrolled in the present study. Patients affected by Sjögren syndrome, smokers, unmotivated patients, and those on medications known to affect salivary flow were excluded from the study. All subjects were ≥60 years of age and had at least 20 natural teeth. They were systemically healthy, and when entering a supportive periodontal therapy (SPT) phase (19), they belonged to the low-risk group in the risk assessment in SPT (20). All subjects had received routine periodontal therapy. Of the 39 subjects, 26 had remnant sensations of oral dryness, whereas 13 were unable to experience thirst. The former 26 subjects were randomly assigned using block randomization to the following two groups: group P, in which a lip trainer was used (n = 13) and group S, in which a sonic toothbrush was used (n = 13). The 13 subjects who reported no experience of oral dryness and were not treated for oral dryness were used as a control (group C; n = 13). No changes were made in induction criteria following study commencement.

In group P, the subjects performed facial mimetic muscle training using the Patakara lip trainer device thrice daily for 6 months. The flexible plastic and rubber device was placed in the oral vestibule between the upper and lower lips. Subsequently, the subjects closed his/her lips against the pressure of the device without teeth contact for 3 min; the resilience enabled direct conditioning of the oral muscles. In group S, the subjects used the Sonicare toothbrush (Diamond Clean, Phillips Electronic, Ltd, Amsterdam, The Netherlands) thrice daily for 2 min for a duration of 6 months. According to the manufacturer’s instructions, the subjects were instructed to move the brush head slowly along their dentition with small forward and backward movements. Although a light pressure may be applied, the individuals were advised against scrubbing as with a manual toothbrush. In group C, the subjects received only SPT and no facial training was performed; data were collected.
to serve as control values for comparison. The saliva volume and oral wetness were measured at baseline and at 1 and 6 months by a blinded examining clinician or a hygienist in the presence of the experimenting clinician who remained silent during measurement.

Subject appointments were scheduled between 9 a.m. and 12 p.m. to avoid salivary circadian rhythms. The subjects were advised to have an early breakfast and not to drink any liquid at least 60-90 min prior to saliva collection. They were also advised not to drink alcohol for at least one night prior to the collection day.

The purpose and procedure were explained to all subjects. The methods were performed in accordance with the relevant guidelines. Written informed consent was obtained from all subjects. This study was reviewed and approved by the ethical committee review board of Matsumoto Dental University (approval number: 0181). The clinical trial was registered with University Hospital Medical Information Network Clinical Trials Registry (UMIN000021513).

Unstimulated salivary flow

The unstimulated salivary flow collection at rest was performed using the passive drool method (21). The subjects were instructed to clean their oral cavity and swallow residual saliva. Following the clearing of their saliva, the subjects were instructed to adopt a slightly head-down position. A container was provided and the subjects were instructed to allow saliva to pool in their mouth and perform a gentle spitting maneuver to collect saliva for 10 min. The subjects were monitored and advised to keep movement of the tongue and oral musculature to a minimum to avoid any stimulation of salivary production. The normal value was determined as >1 mL/10 min.

Stimulated salivary flow

Stimulated salivary flow rate was measured using the Saxon method (22). Sterile gauze (7.5 × 7.5 cm) was placed in a container and weighed. The subjects were advised to clean their oral cavity and swallow residual saliva to remove all pre-existing oral fluid. The subjects were then advised to chew on the gauze piece for exactly 2 min, at their own eating pace, using a digital timer and to spit out the gauze with saliva into a container. The difference in container weight was calculated using an electronic scale (KP103, Tanita, Tokyo, Japan). The normal value was determined as >2 g/2 min.

Wettability

Wettability, defined as the percentage of oral wetness, was measured using an oral moisture meter (MUCUS, Life Co., Ltd., Saitama, Japan) (23) on the dorsal surface of the tongue and buccal mucosa. The subjects were advised to sit in a comfortable position. The sensor was then placed with gentle pressure (200 g) on the dorsal surface of tongue (10 mm from the tip) or on the buccal mucosa (10 mm from the angle of the mouth). Measurements were taken thrice and mean value was considered as the final result. The normal value of oral wettability was determined as ≥25%.

Lip closing force

The difference in lip closing force before and after training was measured using a multidirectional lip closing force measurement system (24). The measurement probe comprised eight phosphor bronze plates—each holding a strain gauge surrounding a plastic octagonal prism—and was capable of determining directional forces in eight directions. Before the measurements were taken, the subjects were given brief instructions regarding use of the apparatus. The head of each subject in group P was fixed so that Camper’s plane was parallel to the measurement probe. The metallic plates of the measurement probe were covered by a thin plastic cover to prevent salivary contamination and provide infection control. In each recording session, measurements were taken thrice with 3-min intervals between each set of measurements to avoid oral muscle fatigue.

Statistical analysis

Results are expressed as mean ± standard error of the mean. It was used Shapiro-Wilk test to clarify the normality of each data set. Additionally, Levene test was used to demonstrate the homoscedasticity of the dataset. Chi-squared test or one-way analysis of variance (ANOVA) was used to evaluate the differences in characteristics of the study subjects. Repeated ANOVA was used to calculate the differences in salivary flow rates (unstimulated and stimulated) and wettability of all groups, and the lip closing force of group P at baseline and at 1 and 6 months. Comparisons among the means of individual groups were made with the Bonferroni correction if the overall F-value was significant at 0.05. One-way ANOVA also was used to evaluate the differences in salivary flow rates (unstimulated and stimulated) and wettability among groups P, S, and C at each time point (baseline, 1 month, and 6 months). If non-homoscedasticity of the dataset was shown by Levene test, Kruskal-Wallis and Friedman tests were used instead of one-way ANOVA and repeated ANOVA for multiple comparisons. Data were analyzed using the
Statistical Package for the Social Sciences for Windows (version 15.0; SPSS, Inc., Chicago, IL, USA). A $P$ value of <0.05 was considered statistically significant.

**Results**

All 39 subjects completed the study. The characteristics of the subjects are shown in Table 1. There were no significant differences in gender, age, and the number of present teeth in the subjects among the three groups, when analyzed using one-way ANOVA or generalized Fisher exact test.

Table 2 shows the salivary flow and wettability data in all groups. With respect to the values of the unstimulated and stimulated salivary flow in both groups at baseline, 9/13 (69.2%) and 8/13 (61.5%) subjects in group P, respectively, and 5/13 (38.5%) and 5/13 (38.5%) subjects in group S, respectively, had values of salivary flow below the normal range.

For the unstimulated salivary flow, one-way ANOVA revealed no significant differences among the three groups at each time point (baseline, 1 month, and 6 months). In group P, the unstimulated salivary flow at baseline ($1.4$ mL/10 min) was lower than that at 6 months ($2.6$ mL/10 min).

<table>
<thead>
<tr>
<th>Table 1 Demographic profile of subjects participated</th>
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<tbody>
<tr>
<td><strong>Group P</strong></td>
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<tr>
<td>---</td>
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<tr>
<td>Number of subjects ($n$)</td>
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<tr>
<td>Sex</td>
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<tr>
<td>male (%)</td>
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<tr>
<td>female (%)</td>
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<tr>
<td>Age (years)</td>
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<td>Number of teeth</td>
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Table 2 Mean values of salivary flow and oral wettability in all groups

<table>
<thead>
<tr>
<th></th>
<th>Group P baseline</th>
<th>Group P 1 month</th>
<th>Group P 6 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unstimulated saliva (mL/10 min)</td>
<td>1.4 ± 1.5</td>
<td>2.0 ± 1.5</td>
<td>2.6 ± 1.0</td>
</tr>
<tr>
<td>Stimulated saliva (g/2 min)</td>
<td>1.8 ± 0.8</td>
<td>2.3 ± 0.8</td>
<td>2.4 ± 0.6</td>
</tr>
<tr>
<td>Wettability at tongue (%)</td>
<td>26.7 ± 2.0</td>
<td>28.6 ± 1.2</td>
<td>28.5 ± 1.4</td>
</tr>
<tr>
<td>Wettability at buccal mucosa (%)</td>
<td>28.1 ± 2.2</td>
<td>29.6 ± 1.1</td>
<td>29.3 ± 1.2</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th></th>
<th>Group S baseline</th>
<th>Group S 1 month</th>
<th>Group S 6 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unstimulated saliva (mL/10 min)</td>
<td>1.7 ± 1.0</td>
<td>2.4 ± 1.5</td>
<td>2.3 ± 1.8</td>
</tr>
<tr>
<td>Stimulated saliva (g/2 min)</td>
<td>2.1 ± 0.7</td>
<td>2.6 ± 1.1</td>
<td>2.1 ± 0.6</td>
</tr>
<tr>
<td>Wettability at tongue (%)</td>
<td>26.7 ± 2.2</td>
<td>26.5 ± 1.5</td>
<td>26.9 ± 1.9</td>
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<tr>
<td>Wettability at buccal mucosa (%)</td>
<td>26.2 ± 2.4</td>
<td>26.6 ± 2.5</td>
<td>26.0 ± 3.3</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Group C baseline</th>
<th>Group C 1 month</th>
<th>Group C 6 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unstimulated saliva (mL/10 min)</td>
<td>1.8 ± 0.7</td>
<td>1.7 ± 0.8</td>
<td>2.1 ± 0.9</td>
</tr>
<tr>
<td>Stimulated saliva (g/2 min)</td>
<td>3.5 ± 1.5</td>
<td>3.2 ± 1.8</td>
<td>4.0 ± 1.7</td>
</tr>
<tr>
<td>Wettability at tongue (%)</td>
<td>26.8 ± 1.9</td>
<td>27.1 ± 1.4</td>
<td>27.7 ± 1.0</td>
</tr>
<tr>
<td>Wettability at buccal mucosa (%)</td>
<td>26.8 ± 1.7</td>
<td>27.6 ± 1.7</td>
<td>28.1 ± 1.2</td>
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**Fig. 1** Salivary flow rate. (a) Unstimulated salivary flow in all groups. (b) Stimulated salivary flow in all groups. (a) For the unstimulated salivary flow, one-way ANOVA revealed no significant differences among the three groups at each time point (baseline, 1 month, and 6 months). Repeated ANOVA revealed significant differences among the three time points (at baseline, 1 month, and 6 months) in groups P and S ($P < 0.05$). Multiple comparisons for repeated ANOVA: * $P < 0.05$.

(b) For the stimulated salivary flow, Kruskal-Wallis test revealed significant differences among the three groups at baseline and at 6 months ($P < 0.05$). Friedman test revealed significant differences among the three time points (at baseline, 1 month, and 6 months) in group P ($P < 0.01$).
± 1.5 mL/10 min) was lower than that at 1 month (2.0 ± 1.5 mL/10 min) and at 6 months (2.6 ± 1.0 mL/10 min). Similarly, in group S, the unstimulated salivary flow at baseline (1.7 ± 1.0 mL/10 min) was lower than that at 1 month (2.4 ± 1.5 mL/10 min) and at 6 months (2.3 ± 1.8 mL/10 min). Repeated ANOVA revealed significant differences among the three time points (baseline, 1 month, and 6 months) in groups P and S (P < 0.05). No significant differences were observed over time in group C (Table 2, Fig. 1a).

For the stimulated salivary flow, Kruskal-Wallis test revealed significant differences among the three groups at 1 month (P < 0.01) and at 6 months (P < 0.05). In group P, the stimulated salivary flow at baseline (1.8 ± 0.8 g/2 min) was lower than that at 1 month (2.3 ± 0.8 g/2 min) and at 6 months (2.4 ± 0.6 g/2 min). Friedman test revealed significant differences among the three time points (baseline, 1 month, and 6 months) in groups P and S (P < 0.01). No significant differences were observed over time in group C (Table 2, Fig. 1b).

In terms of the wettability of the tongue mucosa, one-way ANOVA revealed significant differences among the three groups at 1 month (P < 0.01) and at 6 months (P < 0.05). In group P, the wettability of the tongue mucosa at baseline (26.7 ± 2.0%) was lower than that at 1 month (28.6 ± 1.2%) and at 6 months (28.5 ± 1.4%). Repeated ANOVA revealed significant differences among the three time points (baseline, 1 month, and 6 months) in group P (P < 0.01). No significant differences were observed over time in groups S and C (Table 2, Fig. 2a).

The lip closing force was measured in group P only. The results of the lip closing force were calculated at baseline as 4.25 ± 0.47 N.s and increased to 8.12 ± 1.56 N.s at 1 month and 6.33 ± 0.71 N.s at 6 months (Fig. 3). Friedman test revealed significant differences among the three time points in group P (P = 0.05).
Discussion

The primary objective of the present study was to evaluate the efficacy of different techniques to relieve oral dryness in a small population of older people living in the Japanese countryside.

Saliva stimulation involves multiple systems. Salivation is controlled by three components of the reflex arch (afferent receptors and nerves, central connection and nucleus, and the efferent arm) (25). The loss of cells from the motor nervous system, which causes a reduction in the complement of motor neurons and nerve fibers, is an aspect of the aging process (26). The repeated movement of facial muscles with a lip trainer is reported to trigger stimulation in afferent receptors and nerves in the facial muscles, thereby resulting in increased salivation. The facial muscles and two of the three major salivary glands are innervated by branches of the facial nerve (CN VII). Therefore, the induced activity in facial muscles may be responsible for activation of the superior salivatory nucleus and submandibular ganglion, leading to increased salivary flow. Facial muscle training and stretching during chewing may act to rehabilitate the deglutition organ and activate salivation.

Several disadvantages of the long-term use of a training device include potential desensitization to stimulation and the necessity to perform exercises that are inconvenient. Therefore, the present study was designed to test short-term daily facial muscle training for 6 months. An earlier study has reported that sonic toothbrushes stimulate salivary flow in a xerostomic population (17). The results of this study are also consistent; however, the precise mechanism remains unclear. One potential explanation is that sonic toothbrushes provide vibrotactile stimulation to the gingiva, thereby activating parasympathetic activity (27) in the parotid or submandibular region and stimulating salivary flow. The results of this study showed that the repeated use of a sonic toothbrush provided a repetitive vibrotactile stimulus on the gingiva, leading to an improvement in the unstimulated salivary flow.

The different modes of stimulation in groups P and S demonstrated varying results. These findings suggest a relationship between oral dryness and lip closing force, which is consistent with a previous study that showed a relationship between bite force and salivary flow in older adults (28). Therefore, it is suggested that the lip trainer device and sonic toothbrush are clinically useful for certain elderly individuals who experience oral dryness. Generally, the comprehensive management of xerostomia and hyposalivation should emphasize patient education and lifestyle modifications. Although the two devices tested in the present study are useful, easy to use, and are effective in a relatively short period of time, it is necessary to ensure continued training and use, for which motivating the patients is crucial. This study period was set for 6 months, which is the use limit of the lip trainer device; however, patients should be encouraged to continue its use to maintain the improved effect after this period. Therefore, patients should receive detailed information on the potential causes of dry mouth and the potential sequelae of impaired salivary secretion, including dental caries, candidiasis, and mucosal complications, and the dentist should educate the patient in a way to maintain patient motivation. Furthermore, these methods will contribute to improvement in the quality of life of patients because such devices can improve symptoms of thirst.

It has also been reported that older patients on medication are more prone to develop hyposalivation, and the incidence of hyposalivation increases with the number of medications taken (29). Therefore, in the present study, patients taking medication were excluded. These results also highlight the need to develop a technique for stimulating salivary flow without the use of pharmaceutical products.

The results of this study showed a marginal but significant improvement in mean values of the unstimulated and stimulated salivary flow and oral wettability. These results are consistent with a previous study in which the pattern of mucosal wetness was not affected by salivary flow rate, whereas lower salivary flow was associated with lower mucosal thickness of saliva (30). However, oral wettability was improved or maintained in hyposalivators in the present study. Another explanation may be the role of minor salivary gland secretion. Lee et al. concluded that the functions of minor salivary glands are less affected and well preserved in patients with dry mouth (31). However, the degenerative effects of aging are not as apparent in minor salivary glands compared to major salivary glands (32). Moreover, minor salivary gland secretion could be stimulated by strong stimuli, including lemon drops (33). Therefore, a tentative hypothesis is that using the Patakara lip trainer device or Sonicare toothbrush causes minor salivary gland secretion, which is responsible for oral wetness. However, only marginal improvement in wettability was observed in this study; therefore, its clinical relevance remains unclear.

As mentioned above, oral dryness rapidly deteriorates oral health. Therefore, it was also evaluated clinical parameters at 6 months and compared these with values at baseline. Neither test groups showed deterioration in clinical parameters; parameters were well maintained.
with increased wettability in group P, and periodontal parameters improved despite a marginal decrease in wettability in group S. This improvement observed in group S may be the result of use of the sonic toothbrush leading to improved oral hygiene (data not shown).

There are certain limitations associated with the present study. First, the sample size was comparatively small to achieve definitive conclusions. Second, the assessment of adherence to the assigned treatment and proper device use was performed verbally and self-assessments were completed by patients, as advised, but not verified by experimenting clinicians. Third, a small group of older Japanese patients living in specific weather conditions and consuming a typical Japanese diet were evaluated. Previous studies have reported that meat-based diets, which are harder to chew, cause more salivation than vegetarian diets (34). Therefore, results of the present study should be carefully considered during comparison with studies involving subjects with other racial or cultural backgrounds. Finally, the experimental protocol was designed to use the Patakara lip trainer device according to manufacturer’s guidelines. However, different patterns of usage should be evaluated, i.e., longer time intervals or increased daily sessions.

In conclusion, findings of the present study suggested that the unstimulated and stimulated salivary flow rates and oral wettability were marginally but significantly improved using a lip training device and to a lesser extent using a sonic electric toothbrush. Although the Patakara lip trainer device or Sonicare toothbrush may be helpful for older patients experiencing oral dryness, they cannot alleviate oral dryness alone. These devices may be used as an adjunct to other salivary stimulation therapies for older patients complaining of oral dryness. Additionally, no adverse effects of oral dryness on periodontal health were observed in the subjects using the Patakara lip trainer device or Sonicare toothbrush, suggesting their safety.

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Conflict of interest
The authors declare that they have no conflict of interest.

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