Aging Clinical and Experimental Research (2021) 33:1023–1031
https://doi.org/10.1007/s40520-020-01606-z

ORIGINAL ARTICLE

Simple oral exercise with chewing gum for improving oral function in older adults

Hyo-Jung Kim[1] · Joo-Young Lee[1] · Eun-Song Lee[1] · Hyo-Jung Jung[2] · Hyung-Joon Ahn[2] · Hoi In Jung[1] · Baek-Il Kim[1]

Received: 6 March 2020 / Accepted: 18 May 2020 / Published online: 31 May 2020

Abstract

Background As general and oral health are closely interrelated, promoting oral health may extend a healthy life expectancy.
Aims To evaluate the long-term effects of simple oral exercise (SOE) and chewing gum exercise on mastication, salivation, and swallowing function in adults aged ≥ 65 years.
Methods Ninety-six participants were assigned to control, SOE, and GOE (chewing gum exercise with SOE) groups. The SOE comprised exercises to improve mastication, salivation, and swallowing function. Control group participants performed no exercises. The intervention period was 8 weeks, followed by a 3-week maintenance period. The Mixing Ability Index (MAI), occlusal force, unstimulated saliva, and repetitive saliva swallowing test were evaluated at baseline and 2, 5, 8, and 11 weeks later. Self-reported discomfort was re-evaluated after 8 weeks.
Results After 8 weeks, mean MAI differences from baseline significantly increased in both groups; the increase in the GOE group was largest and four times higher than in the control group. Mean differences of occlusal force from baseline increased by 56 N (SOE group) and 60 N (GOE group). The increase of salivation was greater in the SOE (3.6-fold) and GOE (2.2-fold) groups than in the control group. Furthermore, 27% and 18% of SOE and GOE group participants, respectively, were re-categorized as having good swallowing function. Participants reported less discomfort as oral functions improved.
Discussion These findings may facilitate the development of clinical practice guidelines for optimal oral care in older adults.
Conclusion While both SOE and GOE may improve oral function in older adults, GOE is recommended for those with impaired mastication.
Trial registration KCT0003305, retrospectively registered 31/10/2018.

Keywords Chewing gum · Dry mouth · Mastication · Older adult · Swallowing · Xerostomia

Introduction

Healthy life expectancy, which is an estimate of the number of years an individual may live in a healthy state, has become an increasingly important concern at the societal and individual levels [1]. This is in contrast to the more traditional concept of life expectancy, which does not take into account health status and functional disability [2]. Since general health and oral health are closely interrelated, promoting oral health can extend both the lifespan and healthspan [3, 4]. In particular, the masticatory function has a significant correlation with the prevalence of metabolic syndrome, as well as the progression of frailty in older adults [5, 6].

As age increases, the overall masticatory performance decreases, along with a reduced bite force and tongue activity. The cross-sectional areas of the masseter, and medial and lateral pterygoid muscles have also been shown to decrease [7–9]. Therefore, physical exercises have been proposed to improve masticatory performance in older adults [10, 11]. Among these exercises, chewing gum is particularly easy to perform, and has been demonstrated to relieve stress and have a positive effect on sustained attention and mood [12]. While a number of studies investigating the effects of chewing gum exercises on masticatory performance have reported changes in occlusal force as an

✉ Baek-Il Kim
drkbi@yuhs.ac

[1] Department of Preventive Dentistry and Public Oral Health, BK21 PLUS Project, Yonsei University College of Dentistry, 120-752, 50 Yonsei-ro, Seodaemun-Gu, Seoul, Republic of Korea

[2] Department of Orofacial Pain and Oral Medicine, Yonsei University College of Dentistry, Seoul, Republic of Korea

outcome [11, 13], it must be recognized that mastication is a series of motions which include not only biting, but also cutting, chewing, grinding, and mashing of food. As occlusal force only reflects a static state and the strength of masticatory muscle contraction [14], a more valid evaluation of masticatory performance necessitates an assessment of dynamic chewing function. An example is the Mixing Ability Index (MAI), which involves the chewing of wax cubes of two different colors, and closely simulates the actual mastication process [14].

A healthy diet requires not only an adequate masticatory ability but also other critical oral functions [15]. The main purpose of mastication is to prepare a food bolus for swallowing [16]. In addition to the breakdown of food items into smaller particles, the food bolus is mixed with saliva and subsequently transported to the oropharynx for swallowing [17]. Therefore, oral interventions for the improvement of nutritional status must target not only masticatory performance but also a comprehensive set of additional oral functions.

We previously reported the immediate effect of a simple oral exercise (SOE) for the improvement of oral function [18]. This involved stretching and strengthening of the tongue, cheeks, and masticatory muscles over a 2 min period, which improved masticatory performance, salivation, and swallowing function in older adults. The purposes of this study were to (1) assess the effects of SOE with chewing gum (GOE) on mastication, salivation, and swallowing function and (2) observe the long-term (11 weeks) effect of SOE on elderly people aged over 65 years.

Material and methods

Participants

Adults aged 65 years or older were recruited from senior citizen centers or senior culture centers located in a metropolitan area of Korea. Older adults willing to participate, but not associated with any of these centers, were also recruited. A total of 111 participants from five centers, as well as five non-affiliated participants, were screened (Fig. 1). Participants were excluded if they were: (1) edentulous and did not wear dentures; (2) missing three or more posterior teeth on one side; or (3) diagnosed with a temporomandibular disorder or severe periodontal disease. Those who subsequently received dental treatment during the study period were also excluded from the analysis. Participants were randomly assigned, based on their recruitment center, to either the control group ($n=21$), SOE group ($n=41$), or GOE (SOE plus chewing gum exercise) group ($n=40$).

After 11 weeks, two participants had been lost to follow-up from the control group. Three participants were lost from the SOE group, and a single participant was lost from the GOE group. The reason for these losses was acute illness and dental treatment provided during the intervention period. A total of 96 participants were included in the final analysis.

This study was conducted at Yonsei University Dental Hospital between May and September 2018 and was in compliance with the Declaration of Helsinki. The study protocol was approved by the Yonsei University Institutional Review

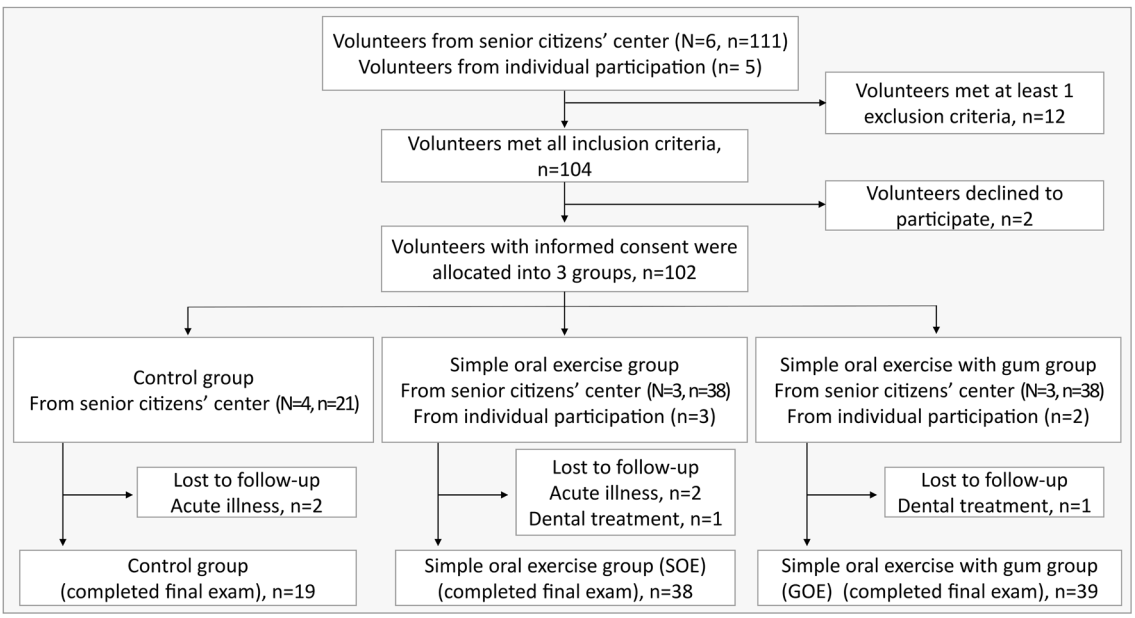

Fig. 1 Participant recruitment and flow. *N* the number of recruiting institutions, *n* the number of subjects

Board (IRB No. 2-2016-0034). All participants provided written informed consent.

Intervention

Participants in the SOE group performed SOE to improve mastication, salivation, and swallowing function. These comprised lip stretching, tongue stretching, and cheek stretching, as well as a masticatory and swallowing exercise [18]. A dental hygienist provided a brief oral health education session for the participants and training on how to perform the exercises. The subjects were instructed to perform the SOE for approximately 2 min, twice a day (morning, afternoon). Leaflets with illustrations of all the proper motions were distributed to the subjects.

In addition to these exercises, participants in the GOE group performed a chewing gum exercise using a prototype chewing gum (OURHOME Co., Ltd. Korea) specifically developed for this study. The chewing gum included flavor and artificial sweeteners to improve participant compliance. To test the perceived hardness and acceptability of the chewing gum before the start of the clinical trial, a preliminary test was conducted among 22 adults aged 65 years or older. The gum properties were measured five times with the Texture Analyzer (TXAT2, Stable Micro System LTD. England). The subjects were instructed to chew the gum in a habitual manner twice a day for 10 min. Participants in the control group were not instructed to perform any oral exercises.

Data collection

The 11-week study included an 8-week intervention period, followed by a 3-week maintenance period. All oral function tests and surveys were performed at baseline. The oral function tests were repeated after 2, 5, 8, and 11 weeks, while the survey was only repeated after 8 weeks. All participants were prohibited from chewing gum for 4 weeks prior to the trial, and participants in the SOE and GOE groups were instructed to refrain from performing the oral exercises after the 8-week intervention period.

Evaluation of masticatory performance

The Mixing Ability Index (MAI), which was developed by Sato et al. [19] and modified by Jeong et al. [20], was used as an objective measure of masticatory performance. Subjects chewed wax cubes of two different colors (with dimensions of $12 \times 12 \times 12$ mm^3, and made from red and green utility wax rods) a total of 10 times, in a habitual manner. Specimens were photographed on both sides with a digital single-lens reflex (DSLR) camera (D80, Nikon Co., Tokyo, Japan) at a predetermined distance and under standardized illumination conditions. All images were saved as JPEG files and analyzed using an image analysis program (Image-Pro plus® v6.0, Media Cybernetics Inc., Bethesda, MD, USA). The following parameters were assessed in each image: the total area of the specimen; the total area with a thickness of less than 50 μm; the maximum length; and the maximum width. These variables were used to determine the MAI score, in accordance with a protocol described in previous studies [20, 21]. The average MAI score of two specimens was deemed to be the representative value at the specified time point. The MAI score ranges from 0 to 100 points, with higher scores indicating better masticatory performance.

Occlusal force

The occlusal force was measured using a Dental Prescale® (Fuji Film Corp., Tokyo, Japan), with the participant sitting comfortably in a chair. An appropriately sized pressure-sensitive sheet (Dental Prescale® 50H, type R, Fuji Film Corp., Tokyo, Japan) was selected and placed over the occlusal surfaces of the teeth. The participants were instructed to occlude onto the sheets with maximal force. The sheet was read by a CCD camera (Occluzer® FPD 707, Fuji Film Corp., Tokyo, Japan) to measure the occlusal force.

Measurement of salivary flow rate

Unstimulated saliva was collected by asking participants to expectorate saliva into a test tube once every minute for 5 min, while in a stable sitting position. Eating, drinking, and smoking were prohibited for 1 h prior to saliva collection.

Repetitive saliva swallowing test (RSST)

Participants were instructed to swallow saliva continuously for up to 30 s, while sitting comfortably. One trained investigator recorded the number of movements of the laryngeal prominence and elevations of the hyoid bone during each swallow. In accordance with previous studies, participants with less than three recorded swallows were judged as having a poor, as opposed to a good, swallowing function [22, 23].

Questionnaire

The sociodemographic characteristics of the participants were surveyed. Self-reported discomfort during mastication, aspiration during swallowing, and symptoms of dry mouth were assessed using a questionnaire modified after Torres et al. [24] and Fox et al. [25] Responses were recorded on a nominal scale as either "yes" or "no."

Statistical analysis

One-way analysis of variance (ANOVA) and Chi-square tests were used to compare participant characteristics between groups at baseline. Changes in oral function were compared between groups with one-way ANOVA at each time point. Linear mixed models or generalized estimating equations were performed to investigate the change in each oral function over time. Subjective changes after the end of the intervention period were analyzed with the McNemar test. The level of statistical significance was set at $P < 0.05$.

Results

Participant characteristics

All participants were in their mid-70 s, and there was no significant difference in mean age between the three groups (Table 1). The majority of participants did not wear dentures, and the average body mass index (BMI) across all participants was categorized as overweight (23–24.9 kg/m^2), according to the Asia–Pacific standard for BMI [26]. In terms of masticatory performance, the mean MAI score was approximately five points higher in the control group, compared to the SOE and GOE groups; however, this did not reach statistical significance. The mean unstimulated saliva flow rate in the three groups ranged between 0.24 and 0.31 mL/min; this was within the normal range [27].

Chewing gum properties

Following the preliminary test for perceived hardness of the chewing gum, all 22 participants responded that the test gum had an adequate hardness, which was greater than that of conventional gums. Table 2 shows the properties of the test gum used in this study, as determined by the TXAT2, texture analyzer. The test gum was 3.4 times harder ($P < 0.001$) than the commercial gum (Lotte Co., Ltd. Korea), which has the largest market share. In addition, the commercial gum was 2.1 times more adhesive than the test gum, but this difference was not statistically significant.

Table 1 Baseline demographic and background characteristics according to test groups

Variable	Control, ($n = 19$)	SOE, ($n = 38$)	GOE, ($n = 39$)	P value
Age	78.2 (75.5, 80.9)	75.3 (73.0, 77.5)	75.5 (74.1, 76.9)	0.157†
Sex				
Male	9 (47.4)	9 (23.7)	4 (10.3)	0.008‡
Female	10 (52.6)	29 (76.3)	35 (89.7)	
Education				
Elementary school or less	8 (42.1)	14 (36.8)	25 (64.1)	0.149‡
Middle school graduate	5 (26.3)	14 (36.8)	8 (20.5)	
High school or more	6 (31.6)	10 (26.3)	6 (15.4)	
Number of medications				
None	2 (10.5)	8 (21.1)	6 (15.4)	0.593‡
1	5 (26.3)	15 (39.5)	14 (35.9)	
≥ 2	12 (63.2)	15 (39.5)	19 (48.7)	
Denture wear				
None	13 (68.4)	22 (57.9)	28 (71.8)	0.732‡
Removable partial denture	3 (15.8)	10 (26.3)	7 (17.9)	
Complete denture	3 (15.8)	6 (15.8)	4 (10.3)	
Body mass index, kg/m^2	23.2 (21.5, 24.9)[ab]	22.4 (21.6, 23.1)[a]	24.3 (23.2, 25.3)[b]	0.017†
Masticatory performance	67.00 (63.10, 70.91)	61.41 (57.07, 65.74)	61.36 (56.64, 66.07)	0.260†
Occlusal force	149.55 (92.80, 206.30)	151.77 (110.00, 193.54)	156.01 (116.52, 195.49)	0.979†
Unstimulated saliva	0.24 (0.18, 0.31)	0.31 (0.24, 0.38)	0.24 (0.19, 0.29)	0.181†
Swallowing function				
Good	12 (63.2)	22 (59.5)	26 (66.7)	0.855‡
Poor	7 (36.8)	15 (40.5)	13 (33.3)	

SOE Simple oral exercise, *GOE* A combination of SOE and chewing gum exercise

†One-way ANOVA, Mean (95% confidence interval), the different letters denote significant differences between the groups by Scheffe post hoc analyses. ‡ Chi-square test, *N* (%)

Table 2 Test gum properties

	Test gum	Commercial gum	*P* value
Hardness (g)	38,748.22 ± 3888.85	11,448.24 ± 246.29	< 0.001
Adhesiveness (g s)	− 0.57 ± 0.44	− 1.20 ± 0.33	0.050
Size[a] (mm)	28 × 12 × 5	17 × 13 × 8	

Data are presented as mean ± standard deviation. *P* values were calculated based on the *t* test

[a]Length × width × height

Changes in oral functions

Mastication

Mean differences in MAI with baseline significantly increased during the intervention period in both the SOE and GOE groups ($P < 0.001$, Table 3). In particular, the largest increase was observed at 8 weeks, with differences of 9.44 points (an increase of 15%) and 11.14 points (an increase of 18%) in the SOE and GOE groups, respectively, compared to the baseline. These values were four times higher than that of the control group ($P = 0.044$). The increase in the mean MAI score plateaued following the end of the intervention period in both experimental groups; however, the mean score at 11 weeks was still higher than that documented at baseline (4.97 in the SOE group and 7.87 in the GOE group).

Mean differences in occlusal force with the baseline in the control group decreased by 14.06 N after 8 weeks (Table 3). In contrast, the mean differences of occlusal force with baseline in the SOE and GOE groups increased by 56.16 N and 60.3 N, respectively, after the 8-week intervention period. Both experimental groups still exhibited increases in mean occlusal force during the maintenance period. Nevertheless, no statistically significant differences were observed either between groups, or within groups over time.

Salivation

A significant increase in mean differences in the unstimulated saliva flow rate with baseline was observed in the SOE group during the intervention period ($P < 0.001$) (Table 4). At 8 weeks, mean differences in unstimulated saliva flow rate with baseline were 3.6-fold (0.18 mL/min) and 2.2-fold (0.11 mL/min) greater in the SOE and GOE groups, respectively, than in the control group ($P < 0.045$). Although there was a trend for an increased unstimulated saliva flow rate during the intervention period in the GOE group, this did not reach statistical significance.

Swallowing

Approximately 60% of all participants were categorized as having a good swallowing function at baseline (Fig. 2). While this proportion was maintained at 60% in the control group at 8 weeks, an increase to 80% was observed in both the SOE and GOE groups. By the end of the 8-week

Table 3 Mean differences in masticatory performance between each study time point and baseline

Group	Weeks				*P* value[‡]
	2	5	8	11	
MAI					
Control	0.87 (− 3.12, 4.87)	1.48 (− 3.06, 6.03)	2.66[a] (− 0.82, 6.13)	1.18 (− 3.17, 5.52)	0.537
SOE	1.76[A] (− 2.18, 5.71)	5.74[B] (1.37, 10.12)	9.44[abBC] (5.77, 13.10)	4.97[AB] (0.96, 8.99)	< 0.001
GOE	3.58[A] (− 0.26, 7.42)	5.76[AB] (1.03, 10.49)	11.14[bC] (6.59, 15.69)	7.87[B] (3.25, 12.49)	< 0.001
P value[†]	0.645	0.470	0.044	0.172	
Occlusal force					
Control	11.13 (− 33.59, 55.85)	6.32 (− 61.63, 74.27)	− 14.06 (− 75.75, 47.62)	13.97 (− 22.59, 50.52)	0.373
SOE	46.41 (4.64, 88.17)	55.34 (9.36, 101.32)	56.16 (17.82, 94.50)	68.58 (23.52, 113.63)	0.837
GOE	66.29 (23.00, 109.58)	65.78 (23.49, 108.07)	60.3 (24.73, 95.87)	77.73 (42.84, 112.62)	0.727
P value[†]	0.266	0.283	0.059	0.171	

SOE Simple oral exercise, *GOE* A combination of SOE and chewing gum exercise

[†]One-way ANOVA, Mean (95% confidence interval), within the same column, the different small letters denote significant differences between the groups by Scheffe post hoc analyses. [‡]Linear mixed model, within the same row, the different capital letters denote significant differences between the time point by Bonferroni post hoc analyses. The maintenance period took place between weeks 8 and 11

Table 4 Mean differences in unstimulated saliva secretion between each study time point and baseline

Group	Weeks				*P* value‡
	2	5	8	11	
Control	0.01 (−0.05, 0.08)	0.03 (0.00, 0.06)	0.05[a] (0.02, 0.09)	0.06 (−0.01, 0.13)	0.386
SOE	0.08[A] (0.00, 0.16)	0.11[AB] (0.04, 0.18)	0.18[bB] (0.10, 0.26)	0.16[B] (0.09, 0.22)	<0.001
GOE	0.07 (0.04, 0.10)	0.10 (0.05, 0.14)	0.11[ab] (0.07, 0.15)	0.11 (0.07, 0.16)	0.281
P value†	0.398	0.222	0.045	0.117	

SOE Simple oral exercise, *GOE* A combination of SOE and chewing gum exercise

†One-way ANOVA, Mean (95% confidence interval), within the same column, the different small letters denote significant differences between the groups by Scheffe post hoc analyses. ‡Linear mixed model, within the same row, the different capital letters denote significant differences between the time point by Bonferroni post hoc analyses. The maintenance period took place between weeks 8 and 11

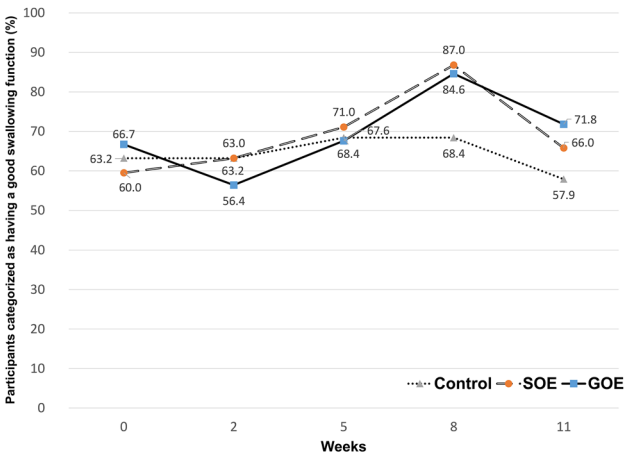

Fig. 2 The proportion of participants with good swallowing function. The maintenance period took place between weeks 8 and 11. *SOE* simple oral exercise, *GOE* A combination of SOE and chewing gum exercise

intervention period, an additional 27% and 18% of participants in the SOE and GOE groups, respectively, had a swallowing function that was categorized as good, as opposed to poor. The time-dependent changes in the SOE and GOE groups during the intervention period were statistically significant ($P = 0.014$ and 0.024, respectively; data not shown). Although the proportion of participants with a good swallowing function tended to decrease in the SOE and GOE groups during the 3-week maintenance period, it was still higher than that observed at baseline.

Changes in subjective discomfort

Table 5 presents the subjective changes in mastication, swallowing, and symptoms of dry mouth at baseline and 8 weeks. By the end of the intervention period, the proportion of participants who felt discomfort while eating hard foods had decreased by 21.1% in the SOE group ($P = 0.008$), and by 23.1% in the GOE group ($P = 0.004$). The proportion of participants who experienced aspiration when drinking liquids also decreased by 21% in the GOE group ($P = 0.008$). While the proportion of participants experiencing discomfort due to oral dryness tended to decrease in the SOE and GOE groups, no significant differences were found.

Table 5 Changes in the number of subjects who experienced discomfort after the end of the intervention period

Question	Control			SOE			GOE		
	Baseline	8 weeks	*P* value	Baseline	8 weeks	*P* value	Baseline	8 weeks	*P* value
Mastication									
Difficulties in chewing hard food	11 (57.9)	11 (57.9)	1.000	12 (31.6)	4 (10.5)	0.008	14 (35.9)	5 (12.8)	0.004
Swallowing									
Aspiration when drinking liquid	7 (36.8)	7 (36.8)	1.000	5 (13.2)	3 (7.9)	0.500	10 (25.6)	2 (5.1)	0.008
Oral dryness									
Feeling oral dryness when eating a meal	5 (26.3)	5 (26.3)	1.000	6 (15.8)	3 (7.9)	0.250	9 (23.1)	5 (12.8)	0.219
Difficulties in swallowing food due to oral dryness	1 (5.3)	1 (5.3)	1.000	2 (5.3)	2 (5.3)	1.000	2 (5.1)	2 (5.1)	1.000
Needing liquids when swallowing dry foods	13 (68.4)	13 (68.4)	1.000	11 (28.9)	6 (15.8)	0.125	10 (25.6)	9 (23.1)	1.000

SOE simple oral exercise, *GOE* A combination of SOE and chewing gum exercise

Data are presented as *N* (%). *P* values were calculated based on the McNemar test

Discussion

In this study, both a combination of an SOE and a chewing gum exercise and an SOE alone improved a range of oral functions among older adults. These improvements were maintained for at least 3 weeks after the end of the intervention period. Although the effects of chewing gum exercises have been reported in children and young adults, few studies have been conducted among older adults who have a significantly decreased masticatory performance [28, 29]. This is the first study to combine a chewing gum exercise and oral exercise for the improvement of overall oral function in older adults. In contrast to previous studies that assessed treatment outcomes based on improvements in masticatory strength, which reflect a static measure, the present study assessed dynamic masticatory performance and overall oral functions such as salivation and swallowing, which have hitherto not been reported among older adults.

The combination of gum exercise and SOE can help to improve masticatory performance in older adults. In the present study, the dynamic masticatory performance, as evaluated by the MAI, increased by 15% in the SOE group and 18% in the GOE group after 8 weeks of intervention. While no prior studies have evaluated changes in dynamic chewing ability after a chewing gum exercise intervention in older adults, a study conducted among preschool children reported a 20% improvement in masticatory ability (as assessed by a color-changeable chewing gum) [28]. This is similar to the improvement observed in the GOE group in the present study. In addition, the MAI score in the GOE group increased by approximately 11 points after 8 weeks of intervention, compared to the baseline. A previous study reported a similar difference (MAI of 12) among healthy adults with less than two missing posterior teeth [20]. Therefore, it suggests that the improvement of MAI in the GOE group (MAI 11.14) was similar to the recovery of functions of the 1–2 posterior teeth. While the masticatory performance of the SOE and GOE groups decreased slightly during the maintenance period, mean MAI was still higher compared to baseline. Increased MAI in the GOE group at the end of the maintenance period was higher than that of the SOE group and control group, as well as that reported among healthy adults without posterior tooth loss in a previous study (mean MAI of 67) [20]. Nevertheless, the decrease in masticatory performance observed after the end of the intervention period suggests that continuous exercise is necessary.

In the present study, a greater increase in occlusal force was observed in the GOE group than that reported in previous studies which evaluated chewing gum exercises. Nakagawa et al. [11] reported a 6% increase in occlusal force among older adults after performing chewing gum exercises for 2 weeks. Other studies have reported increases of 26% and 23% among preschool children [28] and adults [13], respectively, after 4 weeks. As the increase in occlusal force in the GOE group was larger than that observed among younger age groups in prior studies, this suggests that the SOE may provide additional benefits above and beyond that of chewing gum exercises alone. The increase in occlusal force decreased slightly with time in both the SOE and GOE groups. Notably, the occlusal force was observed to have increased by more than 200 N in both the SOE and GOE groups at 8 weeks. This is pertinent, as a previous study has defined an occlusal force below 200 N as a criterion for the diagnosis of oral hypofunction [32].

The mechanism for the improvement of masticatory performance through SOE and GOE can be explained as follows. The improvement of masticatory performance through gum chewing can be attributed to the use of hard gum, as opposed to commercial gum. Exercises involving hard chewing gums could facilitate the recovery of masseter muscle fibers. Kitagawa et al. [33] reported that increased masticatory movements cause changes in the enzyme histochemical profile of the masseter muscle, leading to neuromuscular alterations associated with chewing function. Indeed, resuming a solid diet was found to restore the diameter and composition of atrophied masseter muscle fibers in a rabbit model [34]. Performing only SOE can also induce some muscle strengthening. Tecco et al. [35] reported that the activity of the masseter muscle was increased by physical oral exercise. Other studies have also observed an increase in maximum mouth opening and bite force with oral exercise [23, 36]. Therefore, the increase in masticatory performance in the SOE and GOE groups in the present study could be attributable to an increase in both muscle strength and dexterity.

In this study, we confirmed that the increase in unstimulated saliva secretion after GOE was superior to that of the previous study in which only the gum exercise was performed alone. After 2 weeks of GOE, unstimulated saliva secretion increased by 0.07 mL/min compared to the baseline. Unstimulated saliva secretion was reported to have increased by 0.03 g (i.e. from 0.07 to 0.10 g) among older adults, after a 2-week chewing gum exercise [11]. This may be attributed to the additional benefits of the SOE. Although chewing is thought to have stimulatory effects on saliva secretion, the exact mechanism has not yet been elucidated. Therefore, these results should be interpreted with caution. The mean unstimulated saliva secretion increased significantly in the SOE group during the intervention period, compared to the baseline. Unstimulated saliva secretion increased by 0.18 mL at 8 weeks; this was higher than the increase of 0.08 mL (i.e. from 0.26 to 0.34 mL) observed

after 1 week of SOE in our previous study [18]. This suggests that the SOE is more effective in increasing saliva secretion when performed over a longer time frame.

In addition to improving masticatory performance and unstimulated saliva secretion, the combination of a chewing gum exercise and SOE can improve swallowing function in older adults. These improvements are greater than those reported by a previous study, in which 16% of the participants had an improved swallowing ability after 1 week of SOE [18]. In the present study, 27% and 18% of the subjects in the SOE and GOE groups, respectively, had an improved swallowing function after the 8-week intervention period. These results reflect the increased effectiveness of SOE when performed on a longer-term basis. Notably, improvements in the swallowing function were greater in the SOE group compared to the GOE group. This suggests that chewing gum exercises do not have a beneficial effect on swallowing function, as measured by the RSST. Nevertheless, it must be acknowledged that chewing gum increases tongue pressure, which in turn facilitates the breakdown of food items, and the transport of the food bolus to the oropharynx for swallowing [16, 37]. Furthermore, the proportion of participants who reported discomfort upon swallowing decreased by 21% in the GOE group after the intervention period. Thus, while improvements based on an objective swallowing assessment (i.e. RSST) were not observed, chewing gum exercises did have a positive impact on subjective swallowing function.

Subjective discomfort also tended to be lower in the oral exercise groups compared to the control group. In particular, a significantly greater number of subjects in the oral exercise groups reported decreased difficulties in chewing hard food, as well as a reduced frequency of aspiration when drinking liquids. These results were consistent with improvements indicated by the objective assessments of masticatory ability (MAI) and swallowing function (RSST). There was no statistically significant change in dry mouth symptoms. While improvements were expected, given the objective increases in salivary flow, this result may have been due to the small number of subjects who experienced dry mouth symptoms at baseline.

The chewing gum developed for the present study may be more suitable for use in masticatory exercises compared to commercial gums, as it is harder and less adhesive. The chewing gum developed specifically for this study was approximately three times harder and two times less adhesive than commercial gums. It has previously been reported that chewing hard foods requires an increase in masseter muscle activity [30], and that this, in turn, is related to the hardness of the gum used [31]. In a study conducted among older adults, Nakagawa et al. [11] found that gum hardness was critical for the improvement of occlusal force. In addition, the preliminary test conducted for the present study confirmed the acceptability of the test gum among older adults, and their ability to chew it without difficulty. Moreover, it can be easily chewed by denture wearers due to its lower adhesiveness.

Some limitations should be acknowledged in the present study. As this study assessed the combined effect of SOE and the chewing gum exercise, the independent effect of the latter intervention could not be determined. In addition, the participants were comprised of mainly healthy older adults, as they were required to visit the dental hospital at pre-determined intervals for assessment. Additional studies are required to evaluate the effects of oral exercises in frail older adults.

Conclusion

The SOE and GOE may improve oral function in older adults. While SOE can be a general recommendation for older adults, GOE is particularly advised for those with impaired masticatory performance.

Acknowledgements This work was supported by the Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, Forestry and Fisheries (IPET) through the High Value added Food Technology Development Program, funded by the Ministry of Agriculture, Food and Rural Affairs (MAFRA) (316071031HD020).

Author contributions All authors contributed to the study conception and design. HJK and HJJ carried out collection, assembly, and analysis of data. HJK and JYL were responsible for construct design for this data, helped by ESL, and directed by BIK. HJK, HIJ and BIK interpreted data and HJK wrote the manuscript helped by ESL. HJJ and HJA performed administrative and technical support. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest The author reports no conflicts of interest in this work.

Ethical approval This study was approved by the Yonsei University Institutional Review Board (IRB No. 2-2016-0034).

Statement of human and animal rights All procedures performed in this study involving human participants were in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments.

Informed consent Written informed consents were obtained from all the participants.

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