ORIGINAL ARTICLE

Jaw-Opening Exercise for Insufficient Opening of Upper Esophageal Sphincter

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ABSTRACT. Wada S, Tohara H, Iida T, Inoue M, Sato M, Ueda K. Jaw-opening exercise for insufficient opening of upper esophageal sphincter. Arch Phys Med Rehabil 2012;93:1995-9.

Objective: To investigate the effects of the jaw-opening exercise on decreased upper esophageal sphincter (UES) opening while swallowing.

Design: Intervention study: before-after trial with 4-week follow-up evaluation.

Setting: A university school of dentistry dental hospital.

Participants: Patients with dysphagia (N=8; 7 men, 1 woman; average age ± SD, 70.5±11.3y; age range, 54–86y).

Interventions: All patients performed a jaw-opening exercise to strengthen the suprahyoid muscles. The exercise involved opening the jaw to its maximum and maintaining this position for 10 seconds. Each exercise set consisted of 5 repetitions, and 2 sets were carried out daily for 4 weeks. The effectiveness of the exercise was evaluated by a videofluorographic swallowing study (VFSS).

Main Outcome Measures: Hyoid elevation, UES opening, pharynx passage time, and pharyngeal residue after swallowing at preexercise and postexercise were compared by VFSS.

Results: Compared with before starting the exercise, significant improvements were observed in the extent of upward movement of the hyoid bone ($P<.05$), the amount of UES opening ($P<.05$), and the time for pharynx passage ($P<.05$) 4 weeks after initiating the exercise. Pharyngeal residue decreased in some subjects, and no increases were noted in any subjects.

Conclusions: The jaw-opening exercise is an effective treatment for dysphagia caused by dysfunction of hyoid elevation and UES opening.

Key Words: Deglutition disorders; Esophageal sphincter, upper; Exercise; Rehabilitation.

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THE UPPER ESOPHAGEAL sphincter (UES) is usually closed except while swallowing, and the most contracted zone corresponds closely with the location of the cricopharyngeal muscle. The cricopharyngeal muscle is attached to the cricoid cartilage and relaxes upon swallowing, but the UES does not open automatically.[1] Successful opening of the UES requires an anterior-superior traction of the hyoid and larynx,[2] and further UES relaxation and hyoid traction on the larynx precedes UES opening.[3] In other words, decreased hyoid and laryngeal elevation can cause dysphagia resulting from dysfunction of UES opening.

Many studies have reported on the treatment of UES dysfunction. Treatment can be classified into 2 types: invasive[4-9] procedures and noninvasive procedures.[10-14] However, there are currently no protocols for selecting specific treatments based on disease severity and patient needs. With respect to noninvasive procedures, the head-lifting exercise is frequently used.[13,14] The objective of these exercises is to retrain muscles that elevate the hyoid and larynx. The exercises consist of three 1-minute repetitions of sustained head raisings in a supine position, with a 1-minute rest period between repetitions. This is then followed by 30 consecutive repetitions of head raises in the same supine position. This exercise is thought to increase the anteroposterior diameter and cross-sectional area of the UES opening. Based on recent studies, however, the head-raising exercise places a strain on the sternocleidomastoid muscles rather than the targeted hyoid muscle group.[15] Accordingly, it is necessary to implement a procedure that places a greater load on the targeted muscles.

Jaw opening involves multiple muscles, including the suprahyoid muscle group. Some suprahyoid muscles are involved not only in hyoid elevation but also in jaw opening, by virtue of pulling the lower jaw down by contraction of the muscles. These muscles include the mylohyoid muscle, the anterior belly of the digastric muscles, and the geniohyoid muscle. During hyoid elevation, both the mylohyoid muscle and the anterior belly of the digastric muscles elevate the hyoid bone, while the geniohyoid muscle moves the hyoid bone forward. These muscles act in a concerted fashion to move the hyoid bone in an anterosuperior direction.

Given these mechanisms, we performed a jaw-opening exercise among patients with UES dysfunction. We then assessed the effect of this exercise on swallowing function with a videofluorographic swallowing study (VFSS).

METHODS

Participants

Participants were 8 patients with chronic dysphagia (7 men, 1 woman; average age ± SD, 70.5±11.3y; age range, 54–86y) who were admitted to the Department of Dysphagia Rehabilitation, Nihon University School of Dentistry Dental Hospital. The study was carried out with approval of the ethics commit-

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List of Abbreviations

UES	upper esophageal sphincter
VFSS	videofluorographic swallowing study

Table 1: Patient Details

Patient No.	Sex	Age (y)	History	Feeding Status Before Training	Feeding Status After Training
1	Woman	79	Cerebrovascular disorder	Puree	Puree
2	Man	78	Cerebrovascular disorder	Regular food	Regular food
3	Man	70	Cerebrovascular disorder	Soft food	Soft food
4	Man	54	Cerebrovascular disorder	Puree	Soft food
5	Man	64	Myelitis	Minced food	Cut food
6	Man	57	Angina pectoris	Soft food	Regular food
7	Man	86	Gastritis	Soft food	Soft food
8	Man	76	Without any disease	Regular food	Regular food

tee of Nihon University School of Dentistry, and informed consent was received from all participants.

Four patients had a history of cerebrovascular disorder, and the others had myelitis, angina pectoris, and gastritis. One patient had no disease (table 1). All were capable of oral ingestion, and food consistencies ranged from puree to regular food. None of the patients were at an acute stage of any disorder related to dysphagia, nor did they have difficulty controlling the underlying condition, but exhibited mild to midlevel dysphagia such as choking, coughing, or food remaining in throat. None had a history of oral or pharyngeal surgery, communication problems such as dementia, or temporomandibular arthrosis.

Inclusion and Exclusion Criteria

Based on results of the VFSS carried out before initiating the exercise, patients whose UES opening width was below 10mm at first VFSS were selected as participants. This width was chosen based on several studies[16,17] that reported an average UES opening width of 11mm in healthy elderly people.

Jaw-Opening Exercise

The jaw-opening exercise was carried out as follows. First, subjects opened their jaws to the maximum extent and maintained this position for 10 seconds. During the exercise, each patient was made aware that the suprahyoid muscles were strongly contracted. This open-and-hold exercise was repeated 4 more times after 10 seconds of rest, which constituted 1 set. Subjects were instructed to perform 2 sets of the exercise daily (fig 1). To determine whether the exercise was performed correctly, subjects were asked to complete a record sheet, which we collected 4 weeks later. Subjects were instructed to stop the exercise if they felt discomfort or pain in the temporomandibular joint during the exercise. Subjects were asked to perform the jaw-opening exercise for 4 weeks.

Data Analysis

The results of the VFSS carried out before and 4 weeks after initiating the exercise were analyzed. The Camper's plane was used as the standard plane during the VFSS.[18] This Camper's plane was used as the *x* axis, a straight line between the superior border of the tragus and inferior border of the nasal wing. The *y* axis was a vertical line drawn perpendicular to the intersection of the Camper's plane and superior border of the tragus. We measured the distances from the anterior superior border of the body of the hyoid bone relative to the *x* axis and *y* axis, at either a rest position or the most forward position, while the subject swallowed 5.0mL of nectar-like barium suspension as test food in a sitting position. Before taking the images, we placed lead balls (diameter, 5mm) at the superior border of the tragus and at the inferior border of the nasal wing to be used as markers for the plane. We also placed a metal ball (diameter, 12.6mm) at the neck for adjusting the magnification of radiographic images (figs 2 and 3). Various measurements were carried out.

The amount of upward movement of the hyoid bone was measured as the distance, relative to the standard plane, of the *y* coordinate of the hyoid bone at a rest position and the most forward position. The amount of forward movement of the

Fig 1. Subjects were asked to hold the jaw in the maximally opened position for 10 seconds. Each exercise set involved 5 repetitions of this 10-second motion with a 10-second rest period between each contraction. Each patient performed 2 sets daily.

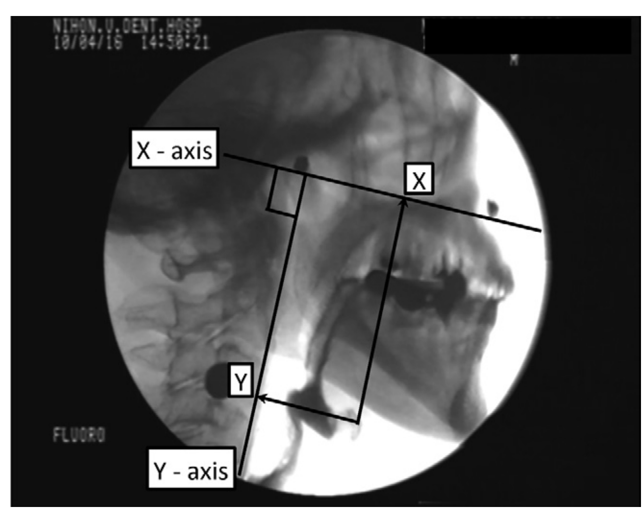

Fig 2. ***X*** **axis: Camper's plane connecting the inferior border of the nasal wing to the superior border of the tragus.** ***Y*** **axis: a vertical line perpendicular to the** ***x*** **axis from a marker on the superior border of the tragus.**

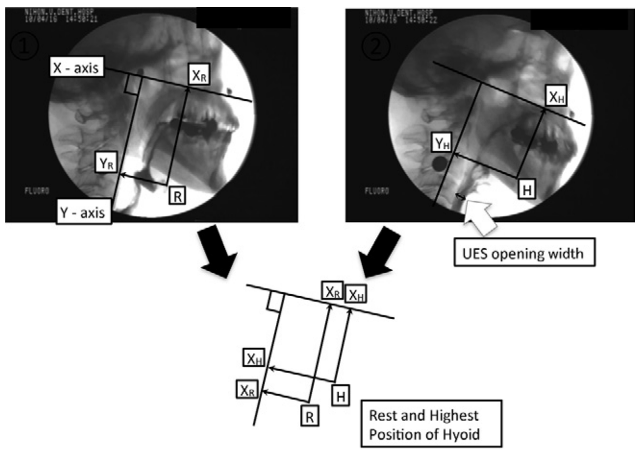

Fig 3. Measurements for the amount of upward and forward movements of the hyoid bone corresponding to distances from the hyoid bone to the *y* axis and *x* axis, respectively, in a relaxed or maximally elevated position. Measurement of UES opening width, corresponding to the anteroposterior diameter at the narrowest region at C3-6 during maximum opening. Abbreviations: H, highest position; R, rest position.

hyoid bone was the distance, relative to the standard plane, of the *x* coordinate of the hyoid bone at a rest position and the most forward position. The amount of UES opening was the anteroposterior diameter at the narrowest section of C3-6 with the maximum opening of the esophagus during barium swallowing.[19,20] The time for pharynx passage was measured from the arrival of the bolus head at the ramus of the mandible to the time the bolus tail passed through the UES.[21] Aspiration was evaluated as either present or absent. Residue of test food in the vallecula and piriform sinus was evaluated on a 4-point scale: 3, >50% of food bolus remained; 2, 25% to 50%; 1, <25%; and 0, 0%.[22] A single dentist blinded to patient information rated the VFSS.

We used a TOSHIBA Clearscope SXT-9000A[a] for imaging of deglutition. Recorded videos were loaded onto a computer for analysis. We used Adobe Premiere Pro CS4[b] and Apple iWork '09 Pages[c] to analyze the videos, and SPSS statistics 17.0[d] for statistical analysis.

RESULTS

The UES opening width at first VFSS was less than 10mm in all participants, and all were able to complete 2 sets of the daily exercises for 4 weeks without pain at the mandibular joint. All 8 patients were included in the following analysis.

Table 3: Comparison of Food Residue Before and After the Jaw-Opening Exercise

	Vallecula		Piriform Sinus	
Patient No.	Preexercise	Postexercise	Preexercise	Postexercise
1	1	1	3	2
2	1	1	1	1
3	1	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	2	1	1	1
8	1	1	1	1

NOTE. While the amount of food residue remaining in the pharynx after swallowing decreased in some cases after the jaw-opening exercise, in no case was an increase observed. None of the changes observed were significant.
Amount of residue. 3: >50% of bolus. 2: 25–50%. 1: <25%. 0: 0%.

Both the amount of upward movement of the hyoid bone ($P<.05$; Wilcoxon signed-rank test) and the amount of UES opening ($P<.05$) significantly increased after the exercise in all subjects, while the time for pharynx passage significantly decreased ($P<.05$) (table 2). The amount of forward movement of the hyoid bone increased, but not significantly ($P=.05$). While food residue in the vallecula and piriform sinus decreased in some subjects, it did not increase in any subject; none of these changes were significant (table 3). The VFSS showed no cases of aspiration. Food consistency before and after training was almost the same, although some patients were able to eat more difficult food after training (see table 1).

DISCUSSION

Effects of the Jaw-Opening Exercise

In this study, we found that the amount of upward movement of the hyoid bone significantly increased after the jaw-opening exercise, suggesting that the mylohyoid muscle and the anterior belly of the digastric muscles were strengthened. The amount of UES opening also significantly increased, and the time for pharynx passage significantly decreased, supporting the efficacy of the jaw-opening exercise.

While some reports[19,23] indicate that wide opening of the UES is related to the amount of forward movement of the hyoid bone, we did not observe a significant improvement in forward hyoid movement. Nonetheless, this exercise appeared effective, given that all other parameters significantly improved. It would be unlikely for the exercise to be ineffective, since it is impossible to selectively contract certain muscles during jaw

Table 2: Comparison of Swallowing Function Before and After the Jaw-Opening Exercise (N=8)

	Before			After				Effect Size	
		95% CI			95% CI				
Measure	Mean ± SD	Lower	Upper	Mean ± SD	Lower	Upper	*z* Score	*r*	*P**
Upward movement of the hyoid bone (mm)	6.05±4.16	2.57	9.52	10.60±4.52	6.83	14.38	2.52	.89	.012
Forward movement of the hyoid bone (mm)	7.17±5.66	2.44	11.90	9.82±4.04	6.44	13.20	1.96	.69	.050
UES opening width (mm)	6.30±2.20	4.47	8.14	7.22±2.60	5.05	9.39	2.10	.74	.036
Time for pharynx passage (s)	0.98±0.09	0.90	1.05	0.75±0.33	0.47	1.02	2.03	.74	.043

NOTE. The amount of upward movement of the hyoid bone, width of UES opening, and time for pharynx passage significantly improved after the jaw-opening exercise.
Abbreviation: CI, confidence interval.
*Wilcoxon signed-rank test, after exercise versus before exercise.

opening. To establish the efficacy of this exercise, further studies will need to be conducted with more patients.

Potential Contraindications

The lateral pterygoid muscle is also involved in jaw opening. However, when considering where this muscle runs, even if the exercise affects these regions, we speculate that the muscle will probably not affect swallowing function. On the other hand, excess contraction of the superior head of the lateral pterygoid muscle would pull the articular disk forward, and this forward translocation could cause jaw arthritis.[24] When the jaw is closed, the superior head of the lateral pterygoid muscle maintains contraction in order to properly position the articular disk. When the jaw is fully open, however, the superior head is controlled in a relaxed position. Thus, this exercise is probably safer when patients open their jaw to the fullest extent. However, dislocation of the mandibular joint could occur if aging has caused some wear of the articular fossa or condyle, or degeneration of the articular disk.[25] Accordingly, patients with a history of mandibular joint dislocation should not perform this exercise.

Appropriateness of the Jaw-Opening Exercise

The exercise used in this study involved full opening of the jaw in order to perform an isometric exercise. There are isotonic and isometric exercises for muscle strengthening, and isometric exercise is said to be effective.[26]

All patients were able to continuously perform the exercise without difficulty, which showed the advantage of the simple isometric nature of our exercise. While other isometric procedures exist, such as contracting the jaw-opening muscles with the jaw closed by holding the geniohyoid muscle by hand, it is difficult to keep the holding force constant and to steadily maintain the position of the closed jaw. Furthermore, attempting to open the jaw while holding it closed by hand would pull the disk of the mandibular joint forward and put greater stress on the joint.

In our exercise, we set the repetition and frequency so that 1 set consisted of five 10-second exercises separated by 10-second rest periods, with 2 sets performed daily. It will be necessary to determine the effects of different numbers of repetitions and frequencies. Although no subject developed pain at the mandibular joint during the course of this study, caution should be exercised when the exercise is performed by patients with a history of mandibular arthritis.

Study Limitations

This study found that the jaw-opening exercise improved the upward movement of the hyoid bone, the amount of UES opening, and time for pharynx passage. However, with respect to food residue remaining in the vallecula and piriform sinus, we did not observe any significant improvement. Subjects were patients with mild to midlevel dysphagia, and large amounts of food residue were seen in only a few subjects before the exercise, and this may explain the relative lack of significant improvement. Further, none of the subjects showed aspiration, and we cannot determine whether this exercise is effective for those with severe dysphagia symptoms, such as aspiration or the presence of large amounts of food residue, or both.

Even though effect sizes were large for each statistical test, the number of patients in our study was relatively small, and the sex proportion was unbalanced. Further studies of larger populations with more varied types of dysphagia are needed.

Moreover, VFSS evaluates structural movement, but not muscle strength or activity. Therefore, electromyographic measurements are needed to more directly assess the effectiveness of the jaw-opening exercise.

CONCLUSIONS

We observed improvements in the amount of upward movement of the hyoid bone, the amount of UES opening, and the time for pharynx passage with a jaw-opening exercise. Our results suggest that the jaw-opening exercise may effectively strengthen the suprahyoid muscles.

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