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A Randomized Study Comparing the Shaker Exercise with Traditional Therapy: A Preliminary Study

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Abstract

Seven institutions participated in this small clinical trial that included 19 patients who exhibited oropharyngeal dysphagia on videofluorography (VFG) involving the upper esophageal sphincter (UES) and who had a 3-month history of aspiration. All patients were randomized to either traditional swallowing therapy or the Shaker exercise for 6 weeks. Each patient received a modified barium swallow pre- and post-therapy, including two swallows each of 3 ml and 5 ml liquid barium and 3 ml barium pudding. Each videofluorographic study was sent to a central laboratory and digitized in order to measure hyoid and larynx movement as well as UES opening. Fourteen patients received both pre-and post-therapy VFG studies. There was significantly less aspiration post-therapy in patients in the Shaker group. Residue in the various oral and pharyngeal locations did not differ between the groups. With traditional therapy, there were several significant increases from pre- to post-therapy, including superior laryngeal movement and superior hyoid movement on 3-ml pudding swallows and anterior laryngeal movement on 3-ml liquid boluses, indicating significant improvement in swallowing physiology. After both types of therapy there is a significant increase in UES opening width on 3-ml paste swallows.

Keywords

Dysphagia; Shaker exercise; Upper esophageal sphincter; Deglutition; Deglutition disorders

Over the past 25 years, a number of laboratories around the world have studied and defined the factors responsible for the opening of the upper esophageal sphincter (UES) [1–4]. In all cases, the results were similar, i.e., the upward-forward movement of the hyoid pulls the upper sphincter open after the cricopharyngeal muscle relaxes, enabling the upward-forward movement of the larynx. Since this physiology was described, the Shaker exercise was defined [5,6]. The Shaker exercise is based on the upward and forward movement of the hyolaryngeal structures resulting from the pull of the thyrohyoid, mylohyoid, geniohyoid, and anterior belly of diagastric muscles contracting. This information was used to develop an isometric and isotonic exercise to strengthen these muscles and thereby increase the opening width of the UES. Research on this exercise began with examining how the exercise improved the duration and the width of the UES opening in the normal elderly [5]. The exercise was done over 6 weeks, 3 times per day, to strengthen muscles that pull the larynx and hyoid up and forward. Application of this exercise in normal elderly resulted in a wider UES opening. This was followed by a study of the effect of the exercise in tube-fed patients with severe oropharyngeal dysphagia secondary to an abnormal UES opening [6]. The natural next step in the study of the application of the Shaker exercise to patients with dysphagia was to complete a randomized multi-institutional clinical trial. Our trial compared the Shaker exercise with traditional swallowing therapy to determine if either treatment is better at reducing aspiration and improving swallow function in patients with documented aspiration.

Methods

For this study, we sought patients with prolonged oropharyngeal dysphagia and aspiration of at least 3-month duration. After IRB approval each speech-language pathologist at each institution searched their records for patients with dysphagia involving the UES or the tongue base and were instructed to be NPO by their clinician. These individuals were then invited to participate in this study for a 6-week period. A total of 19 patients were identified and agreed to participate; they were recruited between April 2004 and May 2006. All patients were randomized to either traditional swallowing therapy as described below or the Shaker exercise. Seven institutions participated in the trial: Northwestern University, Evanston Northwestern Healthcare, Froedtert Hospital, St. Joseph's Hospital of Atlanta, St. Joseph Regional Medical

Center, Walter Reed Army Medical Center, and H. Lee Moffitt Cancer Center. Data management and randomization were done by the Communication Sciences and Disorders Research Group within the American Speech Language and Hearing Association in Rockville, Maryland.

Patient Selection

The inclusion criteria were as follows and were all required:

1. Patients with pharyngeal phase dysphagia (as defined in points 2–4 below) of at least 3 months' duration due to stroke or chemoradiation for head and neck cancer (without surgical intervention to the strap muscles, including the mylohyoid, geniohyoid, anterior digastric, and thyrohyoid muscles). All head and neck cancer patients had chemoradiation and some had secondary surgical intervention after chemoradiation. Patients with head and neck cancer had to be at least 3 months post chemoradiation therapy and at 1 month postsurgery before study entry.
2. Incomplete UES opening and postdeglutitive aspiration, or incomplete UES opening with pre- and postdeglutitive aspiration, as defined on videofluorography (VFG).
3. Hypopharyngeal (pyriform sinus) residue or vallecular residue alone or in combination.
4. Videofluorographically documented aspiration of at least a 3-month duration.
5. Able to comply with protocol mandates, willing to perform the exercise programs, and ability to attend study sessions.

Exclusion criteria included:

1. Pharyngeal surgical procedures of the strap muscles (mylohyoid, geniohyoid, anterior digastric, and thyrohyoid muscles)
2. Lack of cognition
3. History of alcoholic neuropathy
4. Patients who could not lift their head and flex the neck
5. Individuals unable to exercise independently or with a caregiver
6. Currently using anticholinergics: benzodiazapine, antihistamines
7. Absent pharyngeal swallow on VFG
8. Aspiration during the swallow (intradeglutitive aspiration)
9. Other neuromuscular disorders such as metabolic myopathies, steroid myopathy, Kerns-Sayers Syndrome, oculopharyngeal and other dystrophies, or myasthenia gravis, which make active exercise inappropriate

Description of the Two Therapies

Patients were randomly assigned, stratified by etiology (head and neck cancer, stroke), to one exercise program and were seen by the speech-language pathologist (SLP) at each institution for swallowing therapy twice per week for 6 weeks. All SLPs were educated to provide both types of therapy with equal competence. The Shaker exercise consisted of three 1-min head lifts in the supine position with a 1-min rest between lifts [5]. These sustained head-raising exercises were followed by 30 consecutive repetitions of head raisings in the same supine position. For both sustained and repetitive head raising, volunteers were instructed to raise the head high enough to be able to observe their toes without raising their shoulders. The traditional

swallowing therapy involved a series of exercises, including the super-supraglottic swallow (holding the breath with effort while swallowing, followed by a cough) [7–10]; the Mendelsohn maneuver involving swallowing normally and as the larynx elevates, catching it with neck muscles and holding it at maximum elevation for a count of 6 while swallowing [2,11–13]; tongue base exercises, including pulling the tongue straight back and holding it in that extreme retracted position for a count of 5; yawning and holding the tongue in its backward position for a count of 5, pretending to gargle and holding the tongue in the extreme retracted position for the count of 5, and pulling the tongue straight back and holding it in the extreme retracted position for a count of 5 [14]. These traditional exercises were practiced for 5 min ten times per day for 6 weeks. Compliance with each regimen was documented in the participants' diaries which recorded the number of minutes per day of practice resulting in a total number of home practice minutes per patient.

Data Collection

Prior to beginning either therapy program, the patient underwent a videofluoroscopic evaluation of the oropharyngeal swallow using the modified barium swallow [15–17]. During this procedure, patients were seated and viewed in the lateral plane and had to swallow two each of 3 and 5 ml of liquid barium and 3 ml of barium pudding. The image clearly reflected the lips anteriorly, the soft palate superiorly, the seventh cervical vertebra inferiorly, and the cervical vertebrae posteriorly. Then patients were turned and examined in the anterior-posterior plane while performing two swallows each of 3 and 5 ml of barium liquid and 3 ml of barium pudding. This modified barium swallow procedure was repeated for both the pretherapy program assessment (Pre) and the post-therapy program assessment (Post).

The videotapes of each videofluoroscopic study, whether pre- or post-treatment, were sent to a central laboratory at the Medical College of Wisconsin where they were tested for quality control, i.e., for the appropriate image, number of swallows, and the clarity of the images. Then, each videofluoroscopic study was digitized to measure hyoid and larynx movement as well as the UES opening. Videofluoroscopic images were digitized onto compact discs from VHS tape using ADS hardware and Capture Wizard 3.8 DVD Xpress DX2 software (ADS Technologies, Cerritos, CA). Videofluoroscopic recordings were analyzed after the treatment group (traditional or Shaker) and exercise status (pre- or postexercise) were masked. Video loops of the swallows were reviewed by two blinded analysts. Swallows with sufficient image contrast and content were converted and saved as individual bitmaps onto a password-protected computer using VirtualDub 1.5.10 (Avery Lee, GPL, SourceForg) software. For each swallow, every third image (0.1 s) was analyzed using ImageJ 1.36b software (NIH, Bethesda, MD). Measurements were calibrated and standardized using the penny's diameter of 1.78 cm. Ten percent of the data were reanalyzed as a measure of reliability. Data were deemed in concordance if pairwise testing showed a greater than 95% chance of measuring statistically indistinguishable values in the two measurement sessions.

Outcome Measures

The primary swallow outcome measure was any occurrence of aspiration (preswallow, intraswallow, postswallow) at the 6-week follow-up period. Other outcomes included the occurrence of residue in the oral cavity, valleculae, or pyriform sinuses and the Performance Status Scale for Diet [18].

Video recordings were analyzed for the presence or absence of aspiration and pharyngeal residue by the swallowing clinician during the modified barium swallow study. In addition, the following measures were made by computer analysis of hyoid, larynx, and UES movements:

1. anterior hyoid movement: the distance of movement of the hyoid bone (the anterior superior corner of the body of the hyoid) in a forward direction;
2. superior hyoid movement: the vertical movement of the anterior superior corner of the hyoid bone;
3. anterior laryngeal movement: the forward movement of the larynx as defined by the point on the anterior superior portion of the subglottic air column;
4. superior laryngeal movement: measured by the vertical component of movement of the anterior superior corner of the subglottic air column;
5. the maximum width of the UES opening as defined by the line between the anterior and posterior walls of the pharyngoesophageal segment at its narrowest area during its maximum opening in a lateral view; and
6. the maximum width of the UES opening as viewed anteriorly.

These measures were made from each of the swallows taken during the pre- and post-therapy videofluoroscopic studies.

Statistical Analysis

Categorical and dichotomous patient characteristics and outcomes were compared between therapy groups using Fisher's exact test. Minutes of practice and the change in the diet performance status scale were compared between groups using the Wilcoxon rank sum test. Comparison of dichotomous outcomes within groups was done using McNemar's test. Continuous videofluorographic data were analyzed using two-factor repeated-measures analysis of variance (ANOVA), with therapy group as the between-group factor and time of observation as the within-group factor. *Post hoc* comparisons were done within the context of the ANOVA model, with independent sample *t* tests for between-group comparisons and paired *t* tests for within-group comparisons. All analyses were on an intent-to-treat basis. No adjustments were made for multiple significance testing. All patients were required to have postdeglutitive aspiration at baseline. The sample sizes in this study had 80% power to detect a difference in the aspiration elimination rate of 70%, meaning that 10% of patients in one group would eliminate their postdeglutitive aspiration at follow-up, compared with 80%in the other group. A one-tailed test and a Type I error rate of 5% was assumed. The original sample size calculations specified that a total of 204 patients completing the follow-up assessment were required, which would give a detectable rate difference of 10% vs. 24%.

Results

Limited patient availability and premature ending of funding resulted in fewer patients being recruited than were originally planned. Table 1 presents the demographic information on the 19 patients by therapy group. This number of patients is significantly less than was anticipated when the study began, but this was what an intensive search for patients who met the entry criteria found. There were no significant differences between the groups with respect to age, gender, race, ethnicity, education, and etiology of swallowing problem.

Of the 19 patients enrolled in the study (11 traditional, 8 Shaker), 14 (9 traditional, 5 Shaker) received both pre- and post-therapy fluoroscopic studies. Two subjects in the traditional group did not have follow-up assessments. One was lost to follow-up and one completed therapy but the follow-up videofluoroscopy evaluation was not available. Three subjects in the Shaker group did not have follow-up assessments. One subject withdrew during therapy and two subjects completed therapy but the follow-up videofluoroscopy evaluation was not available. This dropout rate of 5/19 (26%) was comparable to the 27% rate (7/26) seen in an 8-week

follow-up study of the Shaker exercise [19]. The remaining 14 patients had their videofluoroscopic studies viewed by the participating SLP, who recorded the presence of residue in the valleculae or pyriform sinuses, as well as any aspiration. Each SLP's observations were independently confirmed by research technicians in the central laboratory, who were blinded to the patient's treatment group and the SLP's observations. Three of these 14 patients (3 traditional, 0 Shaker) were excluded from complete analysis of their videotapes due to an inability to identify the necessary landmarks on fluoroscopic images. Therefore, 11 patients (6 traditional, 5 Shaker) had data from their fluoroscopic images analyzed. Patients in the Shaker group practiced a median of 792 min at home, while those in the traditional group practiced a median of 1079 min at home ($p = 0.20$).

Table 2 presents data for the 14 patients on frequency of aspiration pre- and post-treatment for both types of treatment and for each timing of aspiration: before, during, and after the swallow. There was a greater reduction in the occurrence of postswallow aspiration in the Shaker group patients (3/5, 60%) compared with the traditional group patients (0/9, 0%; $p = 0.028$).

Table 3 presents data on residue before and after each of the therapies. Residue in the various oral and pharyngeal locations did not differ between the groups. Median change in the Performance Status Diet Scale between baseline and follow-up was 0 in each group ($p = 0.90$).

Table 4 presents the swallow measurement data from 11 patients with evaluable videotapes divided into pre- and post-treatment for those who received the traditional therapy and those who received the Shaker therapy for each of the three bolus types: 3 ml liquid, 5 ml liquid, and 3 ml paste.

Before the treatment programs, measures of the swallow did not differ significantly between patients receiving the two therapies (traditional and Shaker), except for superior movement of the larynx on swallows of 3-ml paste boluses. After traditional therapy there were several significant increases from pre- to post-therapy, including superior laryngeal movement ($p = 0.009$) and superior hyoid movement ($p = 0.044$) on 3-ml paste swallows, and anterior laryngeal movement on 3-ml liquid boluses ($p = 0.026$), indicating significant improvement in swallowing physiology. After traditional therapy and Shaker therapy there was a significant increase from pre- to post-therapy in the width of the UES opening on 3-ml paste swallows.

Discussion

Nineteen patients with oropharyngeal dysphagia involving the cricopharyngeal region were randomized to one of two therapy procedures: Shaker exercise or traditional therapy that included a number of exercises. Patients in both groups underwent 6 weeks of therapy. The two patient groups were compared on biomechanical measures of swallow, timing of aspiration, and residue location after therapy. Results showed that the Shaker patients exhibited a reduction in postswallow aspiration. Postswallow aspiration occurs because of residue remaining in the pharynx after the swallow. Patients who received traditional therapy exhibited significant improvements in biomechanical measures. Only the location and not the amount of residue was observed. Table 3 indicates that the location of residue remained the same in the two groups. It is possible that the amount of residue decreased but this cannot be assessed with our data. A decrease in the amount of residue may have contributed to a reduction in aspiration. No functional benefit from either treatment as measured by the change in Performance Status Diet Scale was observed in this study.

We measured components that should have been affected by the Shaker exercise (laryngeal lifting, hyoid lifting, laryngeal and hyoid anterior movement, cricopharyngeal opening). Other measures such as airway closure duration and laryngeal vestibule closure that could be related to aspiration were not measured. There was little evidence of a relationship between etiology

and aspiration elimination, because in the three Shaker-treated patients in whom aspiration was eliminated, two had head and neck cancer and one had had a stroke. These observed overall differences may point to the optimal application of these two therapies.

Results of this clinical trial show that traditional therapy and Shaker exercise have very different effects. Both therapies result in significant but different changes in the swallow. The Shaker exercise significantly reduced postswallow aspiration to a greater degree than the traditional therapy. Traditional therapy also resulted in a number of improvements in swallow measures on 3-ml paste swallows. Paste requires greater pressure to swallow than liquid [20]. Traditional therapy often utilizes greater muscle effort than the Shaker exercise, which may explain the changes in paste swallows after traditional therapy.

Based on these results, when selecting therapy for a patient, the clinician should consider whether the patient aspirates, in particular, after swallowing, and should recommend the Shaker exercise. If the patient has reduced range of movement of structures in the pharynx, traditional therapy should be the choice.

Although this was a randomized study, potential sources of bias exist. The dropout of five patients (2 traditional, 3 Shaker) could lead to selection bias. Only two of these five were lost to follow-up, the remaining three completed therapy but the follow-up assessment was not available. This latter reason is not likely to be due to patient treatment preference, thereby minimizing overall dropout bias. The fact that not all potential measures relating to aspiration were measured in this study could lead to biased results in that the selected measures favored one therapy over the other. However, even though not all possible measures were observed in this study, for those that were observed there was no internal bias in that they were measured in a standardized and blinded manner for both treatment groups.

A much smaller number of patients were recruited for this study than anticipated, and this leads us to be cautious about the interpretation of our data. It was very difficult for participating clinicians to identify patients who met the entry criteria, especially those with at least 3 months of pharyngeal dysphagia with aspiration and a disorder of the upper esophageal sphincter. This may reflect the high rate of success in rehabilitation of oropharyngeal dysphagic patients. Or it may show that severely dysphagic patients simply disappear after failing to return to eating in at least 3 months. Longer follow-up of patients with severe oropharyngeal dysphagia is needed. Further research is also needed to determine whether the Shaker exercise is effective for other swallowing disorders.

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Table 1

Demographic characteristics for the two groups of patients

	Shaker		**Traditional**		***p* value**
	Mean (SD)	**Range**	**Mean (SD)**	**Range**	
Age (years)	63.1 (22.8)	26–84	70.9 (9.5)	56–81	0.29
	Frequency	Percent	Frequency	Percent	
Total	8	100.0	11	100.0	
Gender					0.55
Male	6	75.0	10	90.9	
Female	2	25.0	1	9.1	
Race					0.26
Asian	0	0	1	9.1	
Black	3	37.5	1	9.1	
White	5	62.5	9	81.8	
Hispanic					0.99
No	7	87.5	9	81.8	
Yes	0	0	1	9.1	
Unknown	1	12.5	1	9.1	
Education					0.99
Some high school	1	12.5	1	9.1	
High school	3	37.5	4	36.4	
College	4	50.0	4	36.4	
Graduate	0	0	1	9.1	
Unknown	0	0	1	9.1	
Diagnosis					
Head and neck cancer	5	62.5	7	63.6	0.37
Stroke	4	50.0	6	54.6	0.35
Feeding tube					0.34
No	1	12.5	4	36.4	
Yes	7	87.5	7	63.6	

Table 2

Frequency of preswallow, intraswallow, and postswallow aspiration for each therapy group at baseline (pretreatment) and follow-up (post-treatment)

	Shaker		Traditional		*p* value
	Frequency	**Percent**	**Frequency**	**Percent**	
Total	5	100.0	9	100.0	
Aspiration—preswallow					
Baseline Yes, Follow-up No (improvement)	1	20.0	1	11.1	0.99
Baseline No, Follow-up No (no change)	4	80.0	8	88.9	
Baseline Yes, Follow-up Yes (no change)	0	0.0	0	0.0	
Baseline No, Follow-up Yes (worsening)	0	0.0	0	0.0	
p value for within-group change	0.32		0.32		
Aspiration—intraswallow					
Baseline Yes, Follow-up No (improvement)	0	0.0	0	0.0	0.99
Baseline No, Follow-up No (no change)	4	80.0	8	88.9	
Baseline Yes, Follow-up Yes (no change)	0	0.0	0	0.0	
Baseline No, Follow-up Yes (worsening)	1	20.0	1	11.1	
p value for within-group change	0.32		0.32		
Aspiration—postswallow					
Baseline Yes, Follow-up No (improvement)	3	60.0	0	0.0	0.028
Baseline No, Follow-up No (no change)	0	0.0	0	0.0	
Baseline Yes, Follow-up Yes (no change)	2	40.0	9	100.0	
Baseline No, Follow-up Yes (worsening)	0	0.0	0	0.0	
p value for within group change	0.08		No test		
Aspiration—any					
Baseline Yes, Follow-up No (improvement)	3	60.0	0	0.0	0.028
Baseline No, Follow-up No (no change)	0	0.0	0	0.0	
Baseline Yes, Follow-up Yes (no change)	2	40.0	9	100.0	
Baseline No, Follow-up Yes (worsening)	0	0.0	0	0.0	
p value for within-group change	0.08		No test		

Table 3

Frequency of residue in various oral and pharyngeal areas for each therapy group at baseline (pretreatment) and follow-up (post-treatment)

	Shaker		Traditional		*p* value
	Frequency	**Percent**	**Frequency**	**Percent**	
Total	5	100.0	9	100.0	
Oral residue					
Baseline Yes, Follow-up No (improvement)	0	0.0	0	0.0	No test
Baseline No, Follow-up No (no change)	5	100.0	9	100.0	
Baseline Yes, Follow-up Yes (no change)	0	0.0	0	0.0	
Baseline No, Follow-up Yes (worsening)	0	0.0	0	0.0	
p value for within-group change	No test		No test		
Vallecula (V) residue					
Baseline Yes, Follow-up No (improvement)	1	20.0	1	11.1	0.99
Baseline No, Follow-up No (no change)	4	80.0	8	88.9	
Baseline Yes, Follow-up Yes (no change)	0	0.0	0	0.0	
Baseline No, Follow-up Yes (worsening)	0	0.0	0	0.0	
p value for within group change	0.32		0.32		
Pyriform Sinus (PS) residue					
Baseline Yes, Follow-up No (improvement)	0	0.0	0	0.0	No test
Baseline No, Follow-up No (no change)	5	100.0	9	100.0	
Baseline Yes, Follow-up Yes (no change)	0	0.0	0	0.0	
Baseline No, Follow-up Yes (worsening)	0	0.0	0	0.0	
p value for within group change	No test		No test		
V and PS residue					
Baseline Yes, Follow-up No (improvement)	1	20.0	1	11.1	0.99
Baseline No, Follow-up No (no change)	0	0.0	0	0.0	
Baseline Yes, Follow-up Yes (no change)	4	80.0	8	88.9	
Baseline No, Follow-up Yes (worsening)	0	0.0	0	0.0	
p value for within group change	0.32		0.32		

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Table 4

Descriptive statistics for videofluorographic measures by time (pre, post), bolus type (3 ml liquid, 5 ml liquid, 3 ml paste) and treatment (Shaker, traditional)

Measure	Bolus	Pre or post	Shaker			Traditional			*p* value
			n	Mean	SD	*n*	Mean	SD	
UES opening width (cm)	3 ml liquid	Pre	8	0.32	0.18	16	0.33	0.31	0.56
Lateral view		Post	12	0.49	0.33	19	0.41	0.27	0.60
		p value		0.09			0.74		
	5 ml liquid	Pre	4	0.20	0.28	4	0.38	0.27	0.99
		Post	4	0.69	0.47	6	0.47	0.31	0.67
		p value		0.23			0.33		
	3 ml paste	Pre	7	0.33	0.31	13	0.31	0.25	0.78
		Post	4	0.99	0.43	12	0.59	0.29	0.22
		p value		0.015			0.023		
Anterior hyoid movement (cm)	3 ml liquid	Pre	8	0.63	0.37	16	0.34	0.31	0.09
Negative means posterior to rest		Post	12	0.65	0.32	19	0.35	0.48	0.12
Positive means anterior to rest		*p* value		0.91			0.75		
Lateral view	5 ml liquid	Pre	2	0.14	0.02	4	0.68	0.56	0.34
		Post	4	0.53	0.39	5	0.41	0.43	0.67
		p value		0.45			0.40		
	3 ml paste	Pre	5	0.75	1.12	13	0.34	0.52	0.20
		Post	4	0.65	0.33	12	0.18	0.40	0.056
		p value		0.34			0.20		
Superior hyoid movement (cm)	3 ml liquid	Pre	8	0.78	0.51	16	0.77	1.17	0.94
Negative means inferior to rest		Post	12	0.72	0.41	18	0.81	1.06	0.88
Positive means superior to rest		*p* value		0.81			0.99		
Lateral view	5 ml liquid	Pre	2	0.50	0.41	4	0.84	1.39	0.73
		Post	4	1.17	0.48	5	0.74	0.25	0.98
		p value		0.25			0.12		
	3 ml paste	Pre	5	0.95	1.16	13	0.44	0.80	0.44
		Post	4	0.34	0.66	12	1.06	0.62	0.55
		p value		0.59			0.044		

Measure	Bolus	Pre or post	Shaker			Traditional			*p* value
			n	Mean	SD	*n*	Mean	SD	
Anterior larynx movement (cm)	3 ml liquid	Pre	7	0.44	0.33	16	0.06	0.35	0.067
Negative means posterior to rest		Post	11	0.52	0.28	18	0.36	0.42	0.40
Positive means anterior to rest		*p* value		0.64			0.026		
Lateral view	5 ml liquid	Pre	2	0.12	0.01	4	0.17	0.19	No
		Post	4	0.12	0.29	6	0.19	0.45	Test
		p value		No test			No test		
	3 ml paste	Pre	5	0.49	0.58	13	0.03	0.22	0.048
		Post	4	0.46	0.31	12	0.10	0.40	0.12
		p value		0.87			0.30		
Superior larynx movement (cm)	3 ml liquid	Pre	7	1.67	0.57	16	1.31	1.15	0.35
Negative means inferior to rest		Post	11	1.58	0.55	18	1.50	1.04	0.65
Positive means superior to rest		*p* value		0.73			0.55		
Lateral view	5 ml liquid	Pre	2	1.07	0.45	4	0.87	1.73	No
		Post	3	2.28	1.02	6	1.83	1.05	Test
		p value		No test			No test		
	3 ml paste	Pre	5	2.15	1.63	13	0.73	0.98	0.095
		Post	4	1.04	0.37	12	1.81	0.70	0.84
		p value		0.49			0.009		
UES opening width (cm)	3 ml liquid	Pre	4	0.47	0.33	7	1.14	0.66	0.26
Anterior view		Post	2	0.83	0.25	10	0.63	0.56	0.75
		p value		0.52			0.32		
	5 ml liquid	Pre	4	0.76	0.08	2	0.67	0.06	No
		Post	6	1.18	0.52	3	1.42	0.14	Test
		p value		No test			No test		
	3 ml paste	Pre	4	0.70	0.25	4	1.56	0.27	No
		Post	0	–	–	3	0.92	0.28	Test
		p value		No test			No test		

n = number of swallows

No test means the analysis of variance did not converge

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