

# Effects of Voice Therapy Using the Lip Trill Technique in Patients With Glottal Gap

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**Summary: Objectives.** Lip trills are widely used as a voice warm-up technique among singers. However, little is known about the effects of lip trills in cases of voice disorders. We examined the therapeutic effects of lip trills in patients with glottal gap.

**Methods.** Patients with glottal gap were classified into three groups according to the type of gap: gap-only, gap with muscle tension dysphonia (MTD), and a sulcus vocalis group. Patients underwent perceptual, acoustic/aero-dynamic analyses, stroboscopic evaluations, and subjective analyses using a questionnaire before and after lip trills. The results were analyzed before and after trills and according to and between the groups.

**Results.** The results in 42 patients were analyzed. Most of the parameters were improved and glottal gap was significantly reduced after trills in all patients. In the gap-only group ( $n = 19$ ), most of the parameters showed improvement and were within the respective normal ranges, and glottal gap was improved after trills. In the MTD group ( $n = 13$ ), although many parameters were improved, the improvement was not as prominent as in the gap-only group. In the sulcus vocalis group ( $n = 10$ ), only some of the parameters were improved and the improvement in glottal gap was limited.

**Conclusions.** Lip trills were an effective treatment for glottal gap. The therapeutic effect was prominent in the gap-only group, followed by the MTD and sulcus vocalis groups. Trills can be used as an adjuvant treatment option in voice therapy in cases of various voice disorders.

**Key Words:** Voice—Dysphonia—Glottal gap—Voice therapy—Lip trill.

## INTRODUCTION

Voice therapy with a semiocluded vocal tract (SOVT) has a long history. Lip trills, tongue trills, bilabial fricatives, humming, and phonation into tubes or straws have been used by voice coaches to train professional voice users, particularly singers, and also in speech clinics for treatment of dysphonia as a vocal warm-up.<sup>1–3</sup> Among these techniques, trill techniques, particularly lip trills, are most commonly used.<sup>4–6</sup>

The lip trill is similar to other SOVT techniques as the focus of phonation is on the anterior vocal tract. However, they differ from other SOVT techniques because lip trills rapidly alternate between occluded and nonoccluded postures at the lips, creating a low-frequency vibration at the lips in addition to the vibration of the vocal folds. For lips to vibrate, they must be firm enough to promote occlusion of the airway while being relaxed enough to vibrate so that the air pressure breaks the resistance and the vibration occurs. As with other SOVT techniques, there are interactions among the vocal tract, glottal vibration, and air exhaled from the lungs.<sup>1,7</sup> Lip trills pose a unique demand on the vocal mechanism, ie, the need for adequate subglottal pressure and airflow for sustained phonation as well as

adequate airflow to overcome the vibration threshold pressure of the occluded lips and cause them to oscillate continuously. Through this mechanism, airflow and subglottal pressure can be adjusted to regulate lip and vocal fold vibration.

Although the precise mechanism of action and physiology of lip trills have not been determined, the final effects, such as maintaining effective vibration of the vocal fold, enhancing glottal contact, relaxing oral and vocal muscles, and activating breath, are well known, and this technique has been widely used as a vocal warm-up by both singing and voice teachers.<sup>7</sup> This technique is so easy to perform that patients can practice freely on their own after receiving simple instructions.

Glottal gaps are permanent or transient, partial, or total insufficiencies on the membranous or cartilaginous portion of the glottis during phonation. Glottal gaps can be either physiological or pathological. The latter are multifactorial, predominantly organic in origin and often functional. Organic causes of glottal gaps include unilateral vocal fold paralysis, vocal cord scarring, sulcus vocalis, vocal polyps or nodules, benign or malignant tumors, and vocal cord atrophy particularly in older patients. The pathological form of glottal insufficiency and its resulting dysphonia (glottal incompetence dysphonia) usually produce marked phonation difficulties.<sup>8</sup> Treatment includes conservative voice therapy, phonosurgery, such as injection laryngoplasty, and laryngeal skeleton surgery. A huge glottal gap due to unilateral vocal fold paralysis, vocal polyp or nodule, and neoplasm can be easily treated with a surgical approach. Voice therapy is usually indicated in cases with a small glottal gap, eg,

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**FIGURE 1.** Stroboscopic findings of three groups. **A.** Gap-only group. **B.** MTD group. **C.** Sulcus vocalis group.

vocal scarring, vocal sulcus, and vocal atrophy. However, in many cases, voice therapy is not successful for such glottal gaps.

Based on the fact that lip trills are widely used as an effective vocal warm-up tool for professional voice users or singers, we applied this technique as a voice therapy technique instead of conventional hyperfunctioning techniques to determine the effects of treatment of glottal gaps not indicated for surgical intervention.

## MATERIALS AND METHODS

### Study design

Patients with glottal gaps with various causes and who had received voice therapy between July 2016 and January 2017 were enrolled. Patients with vocal mass lesions, such as polyps, nodules, cysts, papillomas, or tumors, were excluded. The patients were classified into three groups according to the type of glottal gap: a gap-only group, consisting of patients with glottis gap but no other functional or organic problems; a gap with muscle tension dysphonia (MTD) group, consisting of patients with glottal gap who also showed findings of MTD; and a sulcus vocalis group, consisting of patients with glottal gap due to sulcus vocalis (Figure 1).

Voice evaluations, including perceptual analyses, acoustic/aerodynamic analyses, stroboscopy, and the completion of a subjective questionnaire, were performed before and after voice therapy. Perceptual analyses were performed using the GRBAS scale by two speech therapists and one otolaryngologist. Acoustic and aerodynamic analyses were performed using a *Computerized Speech Lab* (model 4150, KayPENTAX, Lincoln Park, NJ) and a *multidimensional voice program* (model 5105, version 3.1.7, KayPENTAX). The parameters considered in the analyses were fundamental frequency, perturbations of fundamental frequency (jitter), amplitude (shimmer), glottal noise (ie, noise-to-harmonic ratio), speaking fundamental frequency, closed quotient (CQ), mean flow rate, subglottal pressure, and maximal phonation time (MPT). The whole larynx was examined by *videolaryngostroboscopy* (model 9200C, KayPENTAX). We focused on glottal closure during the videostroboscopic examination. Glottal closure was categorized as present or absent. Questionnaires designed to obtain data on the voice handicap index, reflux symptom index, and vocal tract discomfort were used as subjective voice evaluations.

Lip trills were performed in a comfortable voice with pitch gliding, scaling, singing, and reading. Supplementary Video Clip 1 shows an example of the lip trill exercise. Patients underwent two cycles of voice therapy within 1 week for 2 weeks. In addition to the scheduled voice therapy, patients were encouraged to perform lip trill exercises at home by themselves as many times as possible as instructed.

Voice evaluation results and questionnaire scores were compared before and after trills in all patients, according to the groups, and also compared among the groups. The institutional review board of our institution approved this study.

### Statistical analyses

All statistical analyses were performed using *SPSS* (SPSS Inc., Chicago, IL). The mean acoustic, aerodynamic evaluation, and questionnaire scores were compared before and after voice therapy using the chi square test, Fisher's exact test, and Student's *t* test, as appropriate. In all analyses,  $P < 0.05$  was taken to indicate statistical significance.

## RESULTS

### Effects of lip trills in all patients

Forty-two patients were enrolled in the study, consisting of 23 men and 19 women with a mean age of  $59.2 \pm 10.7$  years (range 22–84 years). In all, there were 19 patients in the gap-only group, 13 in the MTD group, and 10 in the sulcus vocalis group.

Parameters were compared before and after trills in all patients of the three groups. In perceptual analyses, the mean values of grade (G), roughness (R), breathiness (B), and strain (S) in the GRBAS scale were significantly lower after trills. In acoustic and aerodynamic analyses, the mean values of jitter and shimmer were lower, whereas the mean values of CQ and MPT were higher. Subjectively, the mean scores in the three questionnaires were significantly lower, which indicates that patients were satisfied with their voice quality after these exercises (Table 1).

In stroboscopic evaluations, the glottal gap disappeared in 16 patients (38.1%), decreased in 21 patients (50.0%), and remained in 5 patients (11.9%). Before treatment, 36 patients (85.7%) showed a moderately decreased mucosal wave. However, after trills, 19 patients (45.2%) showed a normal mucosal wave and 17 (40.5%) had a mildly

**TABLE 1.**  
**Comparison of Parameters Before and After Voice Therapy in All Patients**

Analyses	Parameters	Pretherapy	Posttherapy	Value	
Perceptual analyses	Grade	1.38	0.74	0.000*	
	Roughness	0.6	0.24	0.000*	
	Breathiness	1.14	0.62	0.000*	
	Asthenia	0.12	0.02	0.103	
	Strained	0.41	0.14	0.003*	
Acoustic and aerodynamic analyses	Jitter	2.546	1.496	0.000*	
	Shimmer	6.763	4.150	0.001*	
	Noise-to-harmonic ratio	0.176	0.125	0.016*	
	Closed quotient	45.06	46.58	0.024*	
	Fundamental frequency (F)	201	201	0.972	
	Speaking fundamental frequency (F)	194	197	0.429	
	Fundamental frequency (M)	143	137	0.421	
	Speaking fundamental frequency (M)	143	138	0.109	
	Mean flow rate	173	167	0.608	
	Subglottal pressure	8.06	8.48	0.235	
	Maximal phonation time	12.14	14.22	0.004*	
	Questionnaire	VHI score	38	23	0.000*
		RSI score	16	9	0.000*
VTD score		13	6	0.000*	

\* Statistically significant ( $P < 0.05$ ).

Note: All values are means of all patients. Abbreviations: F, female; M, male; VHI, voice handicap index; RSI, reflux symptom index; VTD, vocal tract discomfort.

decreased one, whereas only 6 patients (14.3%) had a moderately decreased one. Amplitude was markedly lower in 38 patients (90.5%) before therapy, but was normal in 15 patients (35.7%) and mildly lower in 20 patients (47.6%) after treatment (Figure 2).

### Effects of lip trills according to group

The same comparison was performed according to group. In the gap-only group, objective acoustic and aerodynamic parameters as well as subjective questionnaire scores were significantly improved after trills. Most of the parameters of perceptual analyses (grade, roughness, and breathiness) and acoustic and aerodynamic evaluations (jitter, shimmer, noise-to-harmonic ratio (NHR), CQ, and MPT) were improved. All three questionnaire scores were lower after therapy (Table 2). Patients in the MTD group showed similar improvements in objective and subjective parameters (Table 3). However, in the sulcus vocalis group, although subjective questionnaire scores were significantly lower, many objective parameters failed to show improvement. Only grade and roughness of GRBAS scale and MPT were significantly improved (Table 4).

Stroboscopic findings showed similar trends. All 19 patients in the gap-only group showed disappearance of (11 patients) or a decreased (8 patients) glottal gap. Among the 13 patients in the MTD group, 5 showed disappearance of the glottal gap, 6 showed a decreased gap, and only 2 (15.4%) still had a gap after therapy. Seven of the 10 patients in the sulcus vocalis group showed a decreased glottal gap, and no patients showed disappearance of the gap,

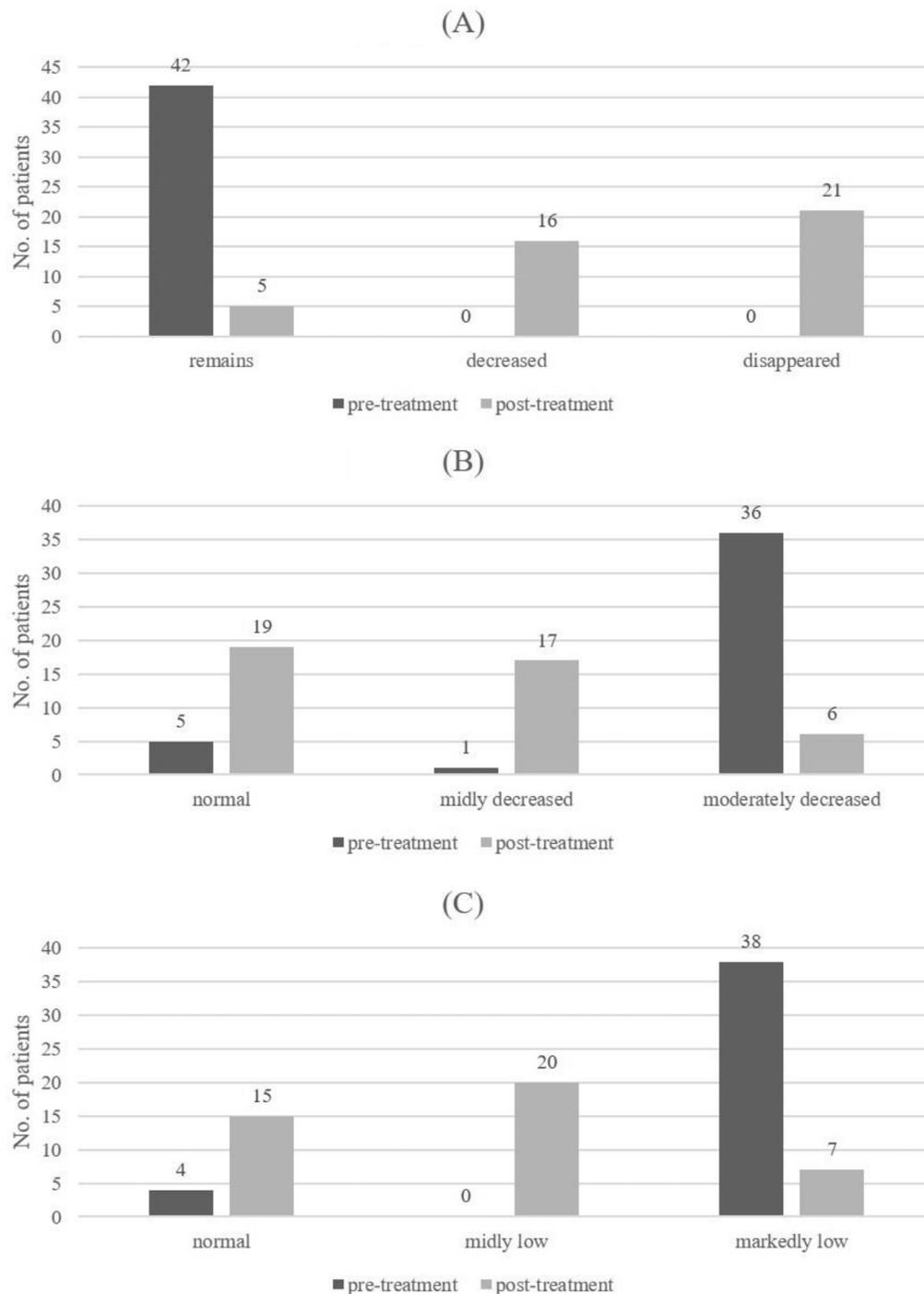
whereas the gap was unchanged in three patients (30%; Figure 3).

### Comparison among the groups

The results were compared among the three groups. In perceptual analyses, the gap-only group and the MTD group showed significant decreases in grade, roughness, and breathiness. However, in the sulcus vocalis group, only grade and breathiness showed improvement (Figure 4). In acoustic analyses, patients in the gap-only group and the MTD group showed improved results of jitter, shimmer, and NHR after treatment, whereas patients in the sulcus vocalis group failed to show significant improvement. After the treatment, the mean values of parameters in the gap-only group were within the respective normal ranges. However, in patients in the MTD and sulcus vocalis groups, the values of jitter and shimmer were still outside the normal ranges (Figure 5).

### DISCUSSION

Lip trills were originally used as a vocal warm-up by singing voice teachers. However, due to their positive effects on voice and other potential benefits, many speech-language pathologists apply this technique during voice therapy. Potential benefits of lip trills as an exercise include maintaining consistent breath flow and extending the upper range, adjusting subglottal pressure, relaxing the tongue and other muscles for articulation, and enhancing vocal cord configuration by preventing either hyperadduction or hypoadduction.<sup>4</sup> Consistent air flow is due to patients'



**FIGURE 2.** Comparison of stroboscopic findings before and after voice therapy in all patients. **A.** Glottal closure. **B.** Mucosal wave. **C.** Amplitude.

attention to produce steady and continuous lip vibration, and proper vocal cord configuration is due to adequate subglottal pressure for efficient phonation with a glottal configuration that is neither breathy nor pressed. This benefit is a desirable outcome for both vocal training and voice therapy in that an ideal combination of subglottal pressure and vocal cord configuration can be achieved. In addition to the therapeutic effects of lip trills, these exercises have the additional advantage that they can be performed easily by

patients on their own. The patients in this study were also encouraged to perform lip trills at home on their own as much as possible, and in fact, most of the patients could perform the exercises without difficulty. Therefore, implementation of lip trills is much easier than other voice therapy methods.

There is little experimental evidence regarding the effects of SOVT exercises, including lip trills, and little is known about their detailed mechanisms of action. Several

**TABLE 2.**  
**Comparison of Parameters Before and After Voice Therapy in the Gap-Only Group**

Analyses	Parameters	Pretherapy	Posttherapy	Value
Perceptual analyses	Grade	1.21	0.47	0.000*
	Roughness	0.31	0.05	0.021*
	Breathiness	1.00	0.37	0.001*
	Asthenia	0.16	0.05	0.331
	Strained	0.16	0.05	0.331
Acoustic and aerodynamic analyses	Jitter	1.922	0.911	0.014*
	Shimmer	6.693	3.241	0.005*
	Noise-to-harmonic ratio	0.140	0.115	0.029*
	Closed quotient	43.77	46.79	0.000*
	Maximal phonation time	12.68	15.48	0.019*
Questionnaire	VHI score	35	18	0.001*
	RSI score	16	10	0.002*
	VTD score	14	6	0.000*

\* Statistically significant ( $P < 0.05$ ).

Note: All values are means of all patients. Abbreviations: VHI, voice handicap index; RSI, reflux symptom index; VTD, vocal tract discomfort.

**TABLE 3.**  
**Comparison of Parameters Before and After Voice Therapy in the Gap with MTD Group**

Analyses	Parameters	Pretherapy	Posttherapy	Value
Perceptual analyses	Grade	1.46	0.84	0.005*
	Roughness	0.69	0.38	0.040*
	Breathiness	1.15	0.69	0.027*
	Asthenia	0.15	0.00	0.165
	Strained	0.38	0.07	0.040*
Acoustic and aerodynamic analyses	Jitter	2.822	1.906	0.024*
	Shimmer	7.114	4.791	0.009*
	Noise-to-harmonic ratio	0.181	0.133	0.032*
	Closed quotient	45.55	47.24	0.079
	Maximal phonation time	11.98	12.10	0.910
Questionnaire	VHI score	35	22	0.002*
	RSI score	17	10	0.002*
	VTD score	12	6	0.000*

\* Statistically significant ( $P < 0.05$ ).

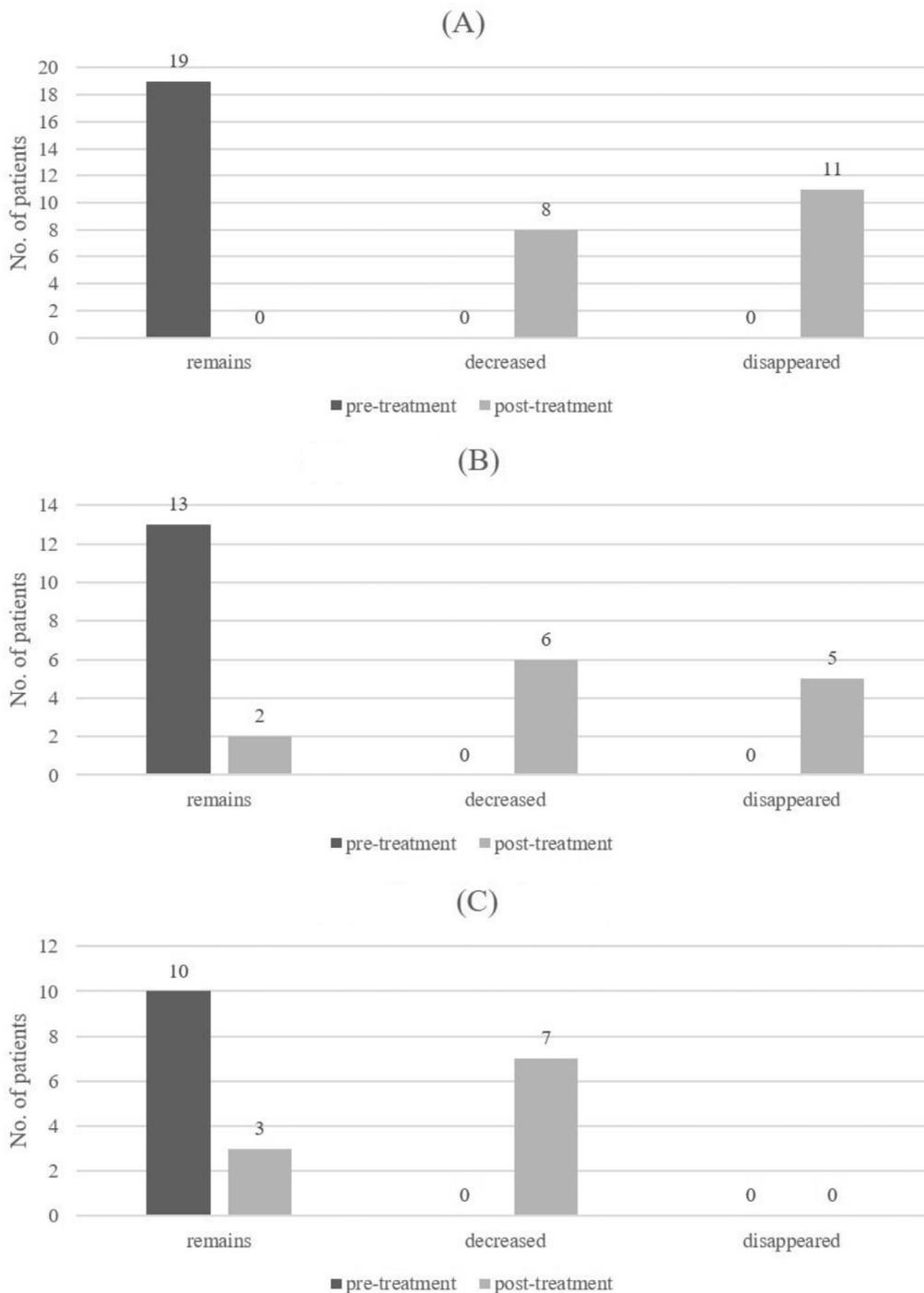
Note: All values are means of all patients. Abbreviations: VHI, voice handicap index; RSI, reflux symptom index; VTD, vocal tract discomfort.

**TABLE 4.**  
**Comparison of Parameters Before and After Voice Therapy in the Sulcus Vocalis Group**

Analyses	Parameters	Pretherapy	Posttherapy	Value
Perceptual analyses	Grade	1.60	1.10	0.015*
	Roughness	1.00	0.40	0.024*
	Breathiness	1.40	1.00	0.168
	Asthenia	0.16	0.11	0.147
	Strained	0.90	0.40	0.052
Acoustic and aerodynamic analyses	Jitter	3.372	2.072	0.108
	Shimmer	10.237	5.044	0.082
	Noise-to-harmonic ratio	0.238	0.134	0.225
	Closed quotient	46.84	45.41	0.488
	Maximal phonation time	11.32	14.56	0.046*
Questionnaire	VHI score	48	33	0.015*
	RSI score	14	8	0.007*
	VTD score	13.5	7	0.001*

\* Statistically significant ( $P < 0.05$ ).

Note: All values are means of all patients. Abbreviations: VHI, voice handicap index; RSI, reflux symptom index; VTD, vocal tract discomfort.

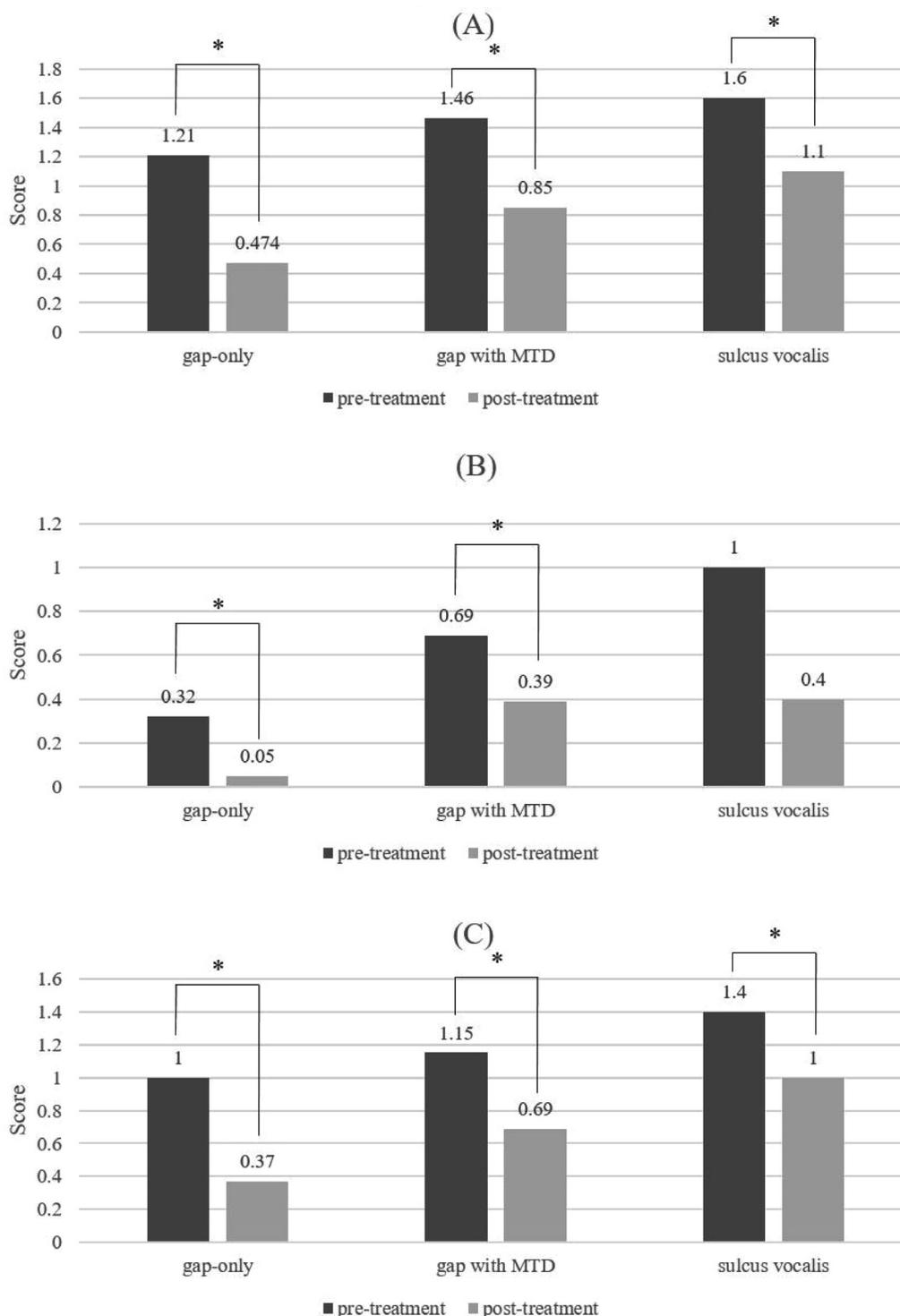


**FIGURE 3.** Comparison of glottal gap before and after voice therapy according to the three groups. **A.** Gap-only group. **B.** Gap with MTD group. **C.** Sulcus vocalis group.\*Statistically significant ( $P < 0.05$ ).

theoretical and experimental studies have produced ambiguous and contradictory results when assessed instrumentally. Story et al reported that partial occlusion of the vocal tract during lip or tongue trills increases the air pressure between the supraglottis and glottis, resulting in decreased glottal resistance and separated positioning of the vocal folds.<sup>9</sup> They performed computational modeling and showed that oral air pressure is substantially elevated during the task, resulting in back pressure, which decreases glottal resistance and slightly parts the vocal folds. Through this mechanism,

lip trills can result in efficient vocal fold vibration, minimizing vocal fold collision forces, and allows singers to warm up the voice across a range of pitches, registers, and loudness levels, while limiting vocal fold damage.<sup>10</sup> These results suggest that lip trills would not be suitable for the treatment of glottal gap.

However, there have been contradictory reports. Cordeiro et al investigated the effects of lip and tongue trills by stroboscopy, and found that higher frequencies produced higher CQs during lip trills.<sup>11</sup> This result suggests that lip or



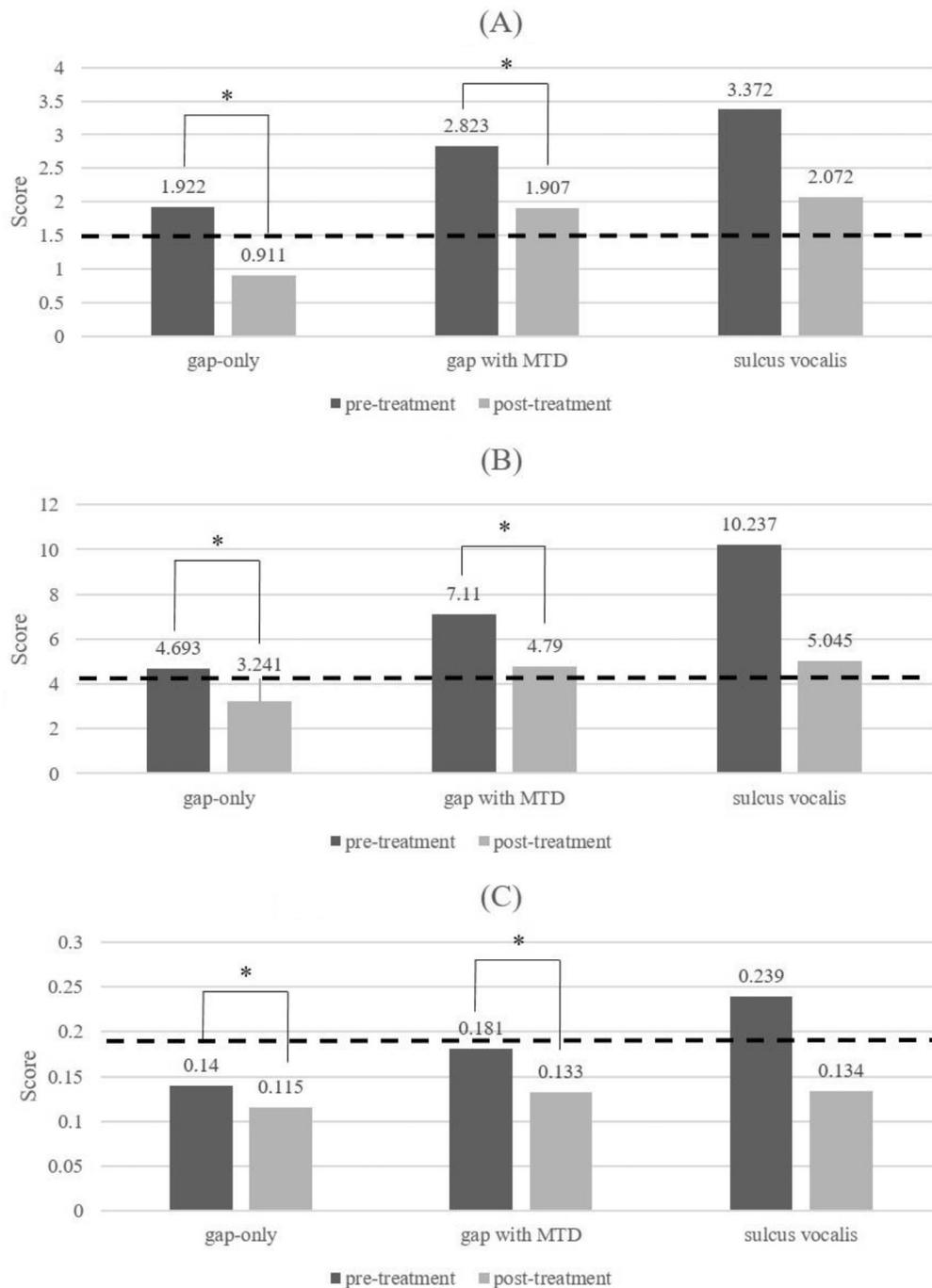
**FIGURE 4.** Comparison of perceptual analyses before and after voice therapy among the three groups. **A.** Grade. **B.** Roughness. **C.** Breathiness. \*Statistically significant ( $P < 0.05$ ).

tongue trills would be good treatment modalities for glottal gap by increasing glottis CQs.

Studies that have used electroglottographic evaluations have yielded conflicting results. Guzman et al found a decrease in the electroglottographic contact quotient during phonation after the SOVT task, which suggests less vocal fold contact would occur with a slight parting of the vocal folds.<sup>12</sup> A similar reduction in the contact quotient was

reported by Gaskill and Erickson.<sup>7</sup> Hamdan et al also reported a reduction in contact quotients, but in contrast to previous studies the reduction occurred only for trained participants and not those that were untrained.<sup>13</sup>

Based on these contradictory results, the precise effects of SOVT on glottal closure are unclear and difficult to define as a single mechanism. However, the acoustic effects of SOVT are clearly evident. Guzman et al



**FIGURE 5.** Comparison acoustic analyses before and after voice therapy among the three groups. **A.** Jitter. **B.** Shimmer. **C.** Noise-to harmonic ration. \*Statistically significant ( $P < 0.05$ ). Dotted line means upper limit of normal value.

identified increased singing power ratio (higher harmonic energy/lower harmonic energy) in the frequency region of a male singer's formant.<sup>12</sup> Another study revealed vocal tract lengthening as indicated by lowering the first four formant frequencies for better tuning of formants.<sup>14</sup> With regard to overall voice intensity, Dargin and Searl found despite the unclear mechanism of action and the contradictory results reported for lip trills, that sound pressure level tended to increase after completing SOVT in a group of four singers.<sup>15</sup>

Despite the unclear mechanism of action and the contradictory results reported for lip trills, this study clearly identified a therapeutic effect of lip trills on glottal gap. The mean values of parameters of perceptual and acoustic/aerodynamic analyses improved after trills, and all patients felt subjective improvement of their voice quality as indicated by improved questionnaire scores. Most importantly, MPT was significantly elongated after trills, which indicates that these exercises are effective for promoting glottal closure. In stroboscopic evaluations, 88.1% of patients showed improved

glottal gaps (disappearance in 38.1% and decreases in 50.5%). Other stroboscopic findings, such as mucosal wave and amplitude, were also improved after trills.

When we compared the results according to the groups, the gap-only group showed the greatest improvement followed by the MTD and sulcus vocalis groups. Patients in the gap-only group showed significant improvement in most of the parameters of perceptual and acoustic/aerodynamic analyses, and all parameters were within the respective normal ranges after voice therapy. In the MTD group, most of the parameters improved, but the elongation of MPT failed to show statistical significance. In the sulcus vocalis group, MPT was significantly elongated after voice therapy. However, other parameters except grade and roughness of GRBAS scale were not significantly improved. Comparing the results among the groups, although subjective questionnaire scores were improved in all three groups, the improvements of objective parameters were greatest in the gap-only group followed by the MTD and sulcus vocalis groups.

Lip trills are particularly effective for patients with a functional glottal gap rather than an organic gap. The treatment effect was most prominent in the gap-only group, with a less prominent effect in the MTD group, and small improvement in the sulcus vocalis group. As mentioned above, little is known about the precise mechanism of action of lip trills, and contradictory results have also been reported. Therefore, the precise reason why such trills improve acoustic results in patients with glottal gap is difficult to explain. However, lip trills adjust proper subglottal pressure and prevent hyper- or hypoadduction of the vocal cords, which can explain the improvement in functional glottal gap after trills. In the same way, for organic glottal gaps, such as sulcus vocalis, the effects of lip trills can be limited. In the MTD group, therapeutic effects could be maximized by adding other adjuvant voice therapies focusing on relaxation. Moreover, as this technique is easy to perform, it will more widely be indicated for the treatment of various voice problems.

To the best of our knowledge, this is the first study to identify the potential therapeutic effects of lip trills in voice disorders. Based on our results, lip trills can be used in combination with other voice therapy techniques for the effective treatment of various voice disorders. However, we could only observe the fact that lip trills were effective in the treatment of glottal gap without identifying the exact action mechanism. This is an important drawback of this study. Further studies to determine the precise mechanism of action of lip trills will expand the indication of these exercises for the treatment of various voice problems and disorders.

### CONCLUSIONS

This study identified the potential therapeutic effects of lip trills in glottal gap. Despite the unclear action mechanism, lip trills were an effective treatment for glottal gap. The therapeutic effect was prominent in the gap-only group, followed by the MTD and sulcus vocalis groups, which means

that lip trills are more effective in functional glottal gap. In addition to the therapeutic effects, lip trills have the advantage that they can be performed easily by patients on their own. Through further studies to determine the precise mechanism of action of lip trills, this technique can be widely used as an adjuvant treatment option in voice therapy in cases of various voice disorders.

Video Clip 1. A demonstration of voice therapy using lip trill techniques.

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### SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.jvoice.2018.07.013](https://doi.org/10.1016/j.jvoice.2018.07.013).

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