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Impact of Tonsillectomy and Associated Factors on Voice

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Abstract

Tonsillectomy is commonly performed to treat repetitive tonsillitis. Tonsillectomy changes the shape and characteristics of the pharynx. It could also alter the resonating characteristics of the pharynx and affect the voice of the patient. We examined voice changes in patients undergoing tonsillectomy. A total of 33 adult patients who underwent tonsillectomy at our institution between July 2020 and December 2021 were included in the study. The participants consisted of 16 men and 17 women, with a mean ± standard deviation age of 33.7 ± 10.7 years. We measured the maximum phonation time, acoustic analysis values (jitter%, shimmer%, and noise-to-harmonic ratio [NHR]), speaking fundamental frequency and vocal range, first four formants (F1–F4) in the sustained vowel /a/, and Voice Handicap Index (VHI). We examined whether any changes occurring 3 months after the surgery compared with the findings before the surgery. The shimmer% and NHR decreased significantly after surgery compared with the observations prior to surgery. Among women, the speaking fundamental frequency tended to increase, and the F2 significantly increased after the surgery compared with that prior to surgery. Removal of the swollen tonsils reduced the resistance of the supraglottic space and resulted in a lower laryngeal adduction force required for phonation. The decreases in the shimmer% and NHR were attributed to a reduction in the turbulence in the supraglottic space. The change in the shape of the pharynx caused changes in the speaking fundamental frequency and formants. The changes were thought to be influenced by the size of the patient's pharyngeal cavity, volume of the tonsils, and scarring of the pharyngeal mucosa. Patients should be informed before surgery of the possibility of voice changes.

Keywords
- tonsillectomy
- voice
- pharynx
- acoustic analysis
- speaking fundamental frequency

Introduction

Tonsillectomy is a frequently performed surgical procedure in otorhinolaryngology for the treatment of recurrent tonsillitis, obstructive sleep apnea caused by tonsillar hypertrophy, and tonsillar focal infections. When the palatine tonsils are removed, the shape and characteristics of the pharyngeal cavity change, leading to the possibility of postoperative changes in voice.[1] The voice is used in everyday communication and is an important factor that characterizes an

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individual. Furthermore, for individuals using their voice professionally, changes in voice postsurgery can pose several problems. However, only few studies have quantitatively examined changes in voice after tonsillectomy, and no definitive consensus has been reached. We conducted an observational study on the changes in voice after bilateral palatine tonsillectomy in adult patients. We particularly focused on evaluation items that showed postoperative changes and discussed their potential correlation with possible contributing factors, such as sex and height of the patient and weight of the excised tonsils.

Materials and Methods

The study included 33 adult patients who underwent bilateral palatine tonsillectomy at the Department of Otolaryngology at Okitama Public General Hospital between July 2020 and December 2021.

Voice was evaluated preoperatively and at 3 months postoperatively using the following parameters: maximum phonation time (MPT); acoustic analysis (jitter%, shimmer%, and noise-to-harmonic ratio [NHR]); speaking fundamental frequency (SFF); vocal range; formant frequencies (F1–F4) of the sustained vowel sound /a/; and the Voice Handicap Index (VHI). The results were used to examine voice changes at 3 months postoperatively and compared them with the preoperative levels. Sex-specific analysis was conducted for SFF, vocal range, and formant frequencies. Acoustic analysis and formant frequency data were obtained by recording in a soundproof environment using a linear pulse code modulation recorder (OLYMPUS LS-P4). Praat software was used to analyze a steady 3-second segment of the sustained vowel sound /a/. Recordings were made with the patient in the seated position while maintaining a consistent distance of approximately 30 cm between the mouth and the recorder's microphone. Significant postoperative changes in the evaluation parameters were analyzed in relation to age, sex, height, body mass index (BMI), Brodsky's grading, indication for surgery, vocal strain, and total weight of the excised palatine tonsils.

Statistical analysis was performed using StatMate V. The voice evaluation parameters before and after surgery were compared using the Wilcoxon signed-rank test. Changes in shimmer%, NHR, and SFF according to sex and vocal strain were compared using the Mann–Whitney *U* test, whereas changes due to Brodsky's grading and indication for surgery were compared using the Kruskal–Wallis test. Correlations with age, height, BMI, and total weight of the excised tonsils were examined using Spearman's rank correlation coefficient. The group with decreased SFF and the group with unchanged/increased SFF were compared according to sex, vocal strain, Brodsky's grading, conditions for which treatment is advised using the chi-squared test and according to age, height, BMI, and total weight of the excised tonsils using the Mann–Whitney *U* test. A *p*-value less than 0.05 was considered statistically significant.

This study was approved by the Institutional Review Board of Okitama General Hospital (Approval No. 229).

Table 1 Overview of patient characteristics

Sex (*n*)	
Male	16
Female	17
Total	33
Age (y), mean ± standard deviation	
Male	38.2 ± 10.8
Female	29.5 ± 8.8
Total	33.7 ± 10.7
Indication for surgery (*n*)	
Recurrent tonsillitis	20
History of abscess formation	5
Sleep apnea with hypertrophy	3
Focal tonsillar infection	5
Brodsky's grading (*n*)	
Grade 1	10
Grade 2	13
Grade 3	6
Grade 4	4
Vocal strain (*n*)	
Yes	21
No	14
Preoperative vocal assessment (mean ± standard deviation)	
MPT (s)	24.6 ± 7.9
Jitter%	0.421 ± 0.159
Shimmer%	6.164 ± 3.380
NHR	0.031 ± 0.022
VHI (points)	4.4 ± 8.0

Abbreviations: MPT, maximum phonation time; NHR, noise-to-harmonic ratio; VHI, Voice Handicap Index.

Results

Patient Overview

The study included 33 patients (16 men and 17 women), with an average age of 33.7 ± 10.7 years (mean ± standard deviation). Details of the conditions for which treatment is advised; Brodsky's grading; presence of voice strain in occupation or hobbies; and preoperative values of MPT, jitter%, shimmer%, NHR, and VHI are presented in ►**Table 1**.

Maximum Phonation Time

There were no significant differences in the median MPT between the preoperative and postoperative assessments (23.0 and 21.0 seconds, respectively; ►**Fig. 1**).

Acoustic Analysis

Compared with the preoperative assessment, the postoperative assessment showed no significant changes in median jitter

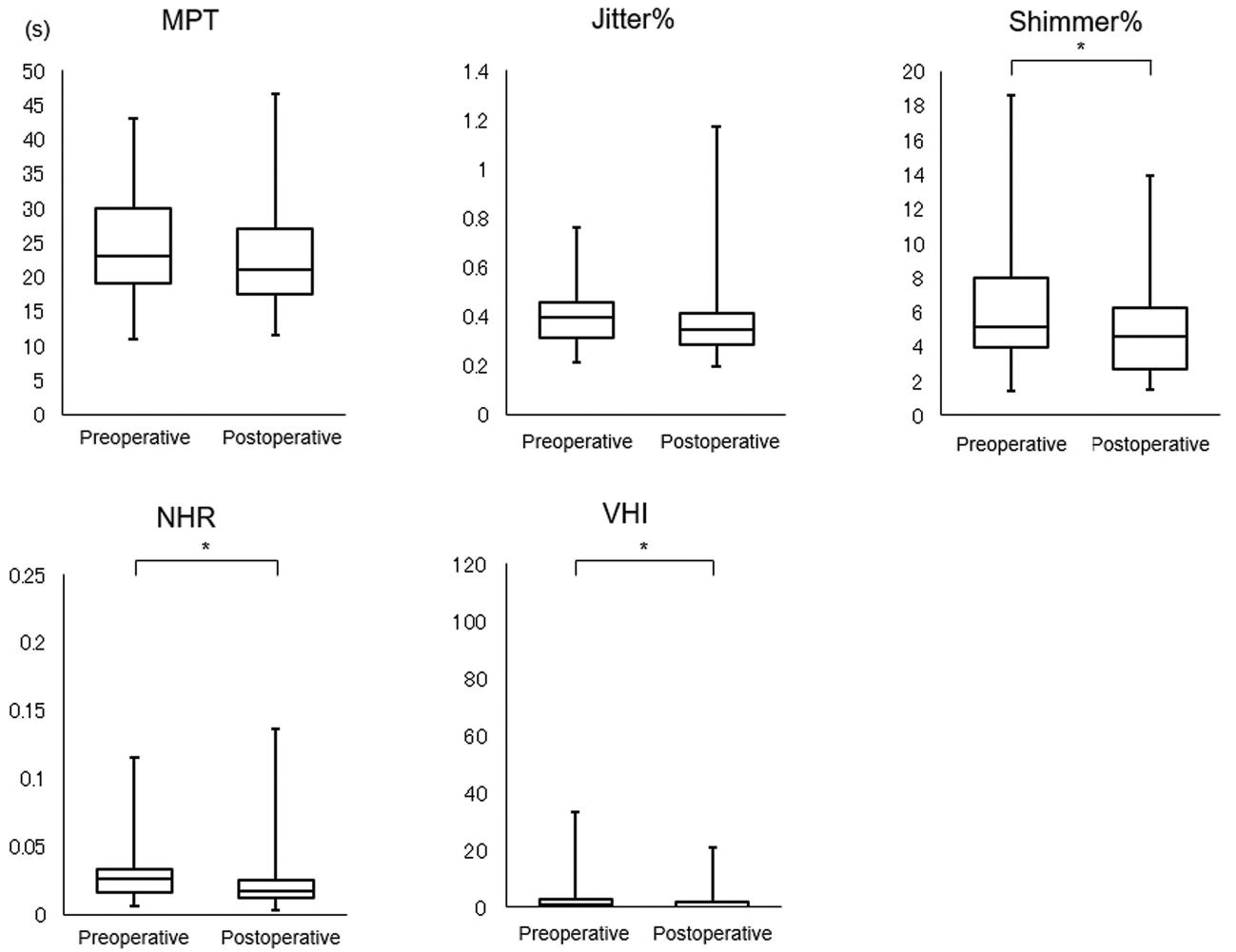

Fig. 1 Postoperative changes in MPT; acoustic analysis values (jitter%, shimmer%, and NHR); and VHI in all 33 cases. There were no significant changes in MPT between the preoperative and postoperative assessments. The acoustic analysis values shimmer%, NHR, and VHI significantly decreased postoperatively compared with the preoperative values. $^{*}p < 0.05$. MPT, maximum phonation time; NHR, noise-to-harmonic ratio; VHI, Voice Handicap Index.

% (0.397 vs. 0.348, respectively), significantly reduced median shimmer% (5.143 vs. 4.545, $p = 0.029$), and significantly reduced median NHR (0.026 vs. 0.017, $p = 0.021$; ►**Fig. 1**).

Voice Handicap Index

The median preoperative and postoperative VHIs were 1 (range: 0–33) and 0 (range: 0–21), respectively. Several patients exhibited a significant postoperative decrease in VHI ($p = 0.022$; ►**Fig. 1**). When the VHI was separated into functional, physical, and emotional subscales, the median preoperative values decreased postoperatively from 1 (highest value 11) to 0 (highest value 5) for the functional aspect, 0 (highest value 16) to 0 (highest value 8) for the physical aspect, and 0 (highest value 9) to 0 (highest value 8) for the emotional aspect.

Speaking Fundamental Frequency and Vocal Range

Among men, there were no significant differences between the preoperative and postoperative median SFF (120.01 and 120.01 Hz, respectively) and median vocal range (471.96 and 502.47 Hz, respectively). Among women, the median SFF values did not significantly change between the preoperative and postoperative assessments (220.00 Hz for both), but there was an overall slight upward trend. In particular, SFF decreased postoperatively in only one patient but remained unchanged or slightly increased by approximately 10 to 30 Hz in all other patients. The median vocal range was 699.80 Hz preoperatively and 733.17 Hz at 3 months postoperatively, with no significant changes observed (►**Fig. 2**).

Formant Frequencies

Among men, no significant changes in F1 to F4 were observed between preoperative and postoperative assessments. Among women, F2 significantly increased postoperatively ($p = 0.037$), but there were no significant changes in F1, F3, and F4 (►**Fig. 3**).

Examination of Postoperative Voice Evaluation Parameters and Related Factors

Compared with the preoperative values, the postoperative shimmer% and NHR significantly decreased, along with a

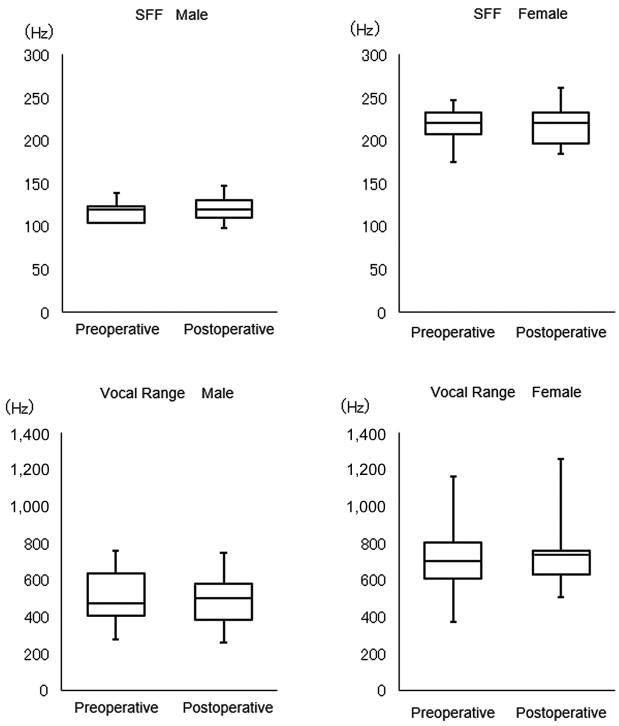

Fig. 2 Changes in SFF and vocal range according to sex. In both men ($n = 16$) and women ($n = 17$), there were no significant changes in SFF and vocal range between the preoperative and postoperative assessments. SFF, speaking fundamental frequency.

tendency for the SFF to increase in women. As shown in ►**Figs. 4** and **5**, none of the parameters significantly correlated with age, sex, height, BMI, Brodsky's grading, indication for surgery, vocal strain, or total weight of the excised tonsils. Compared with the group with unchanged/increased SFF, the group with decreased SFF comprised a significantly higher proportion of men ($p = 0.026$) and had significantly higher total weight of excised tonsils ($p = 0.046$; ►**Table 2**).

Discussion

Changes in Postoperative Evaluation Parameters

Palatine tonsillectomy is unlikely to directly affect the larynx because the surgical manipulation does not extend to the larynx. Therefore, changes in MPT and acoustic values are unlikely to be postoperatively affected. Previous reports have indicated that jitter%, shimmer%, and NHR remained unchanged in adults who underwent palatine tonsillectomy,[2,3] as well as in children who underwent adenoidectomy combined with palatine tonsillectomy, as shown by Lea et a1[4] and in the meta-analysis by Heffernan and Rafferty.[5] However, in this study, postoperative assessments showed no significant changes in MPT, significant reductions in shimmer% and NHR, and a tendency toward decreasing jitter%. Previous reports have demonstrated decreases in jitter% and shimmer % after palatine tonsillectomy.[6] Removal of enlarged palatine tonsils is considered to reduce turbulent airflow from the glottis to the pharyngeal cavity during phonation, thereby decreasing noise components, resistance, and the excessive force required for glottic closure.[6] In this study, the decreasing trend in jitter% and the reduced shimmer% and NHR might be related to these postoperative physiologic changes. Mora et al reported increased jitter% and shimmer% 1 month postsurgery, with values returning to presurgery levels by 3 months after surgery, suggesting early postoperative changes due to surgical trauma and inflammation at the surgical site up to the larynx. However, it is believed that improvements in acoustic analysis values occur as granulation tissue and fibrosis at the site of injury and inflammation improve.[2] Furthermore, early postoperative pharyngolaryngeal inflammation has been reported to be caused by factors such as intubation during general anesthesia and contact with the intubation tube during surgery. In this study, shimmer% and NHR decreased by the third month postoperatively, when wounds are considered to have healed and inflammation has resolved.

Moreover, we observed a significant postoperative decrease in VHI, including its functional, physical, and emotional subscales. Previous studies have shown tendencies for VHI scores to decrease and Voice-Related Quality of Life scores to increase, indicating improvements in the psychological and social aspects of self-assessed voice scores.[3,6] These reports indicated that improvements in self-assessment of voice did not necessarily coincide with improvements in acoustic analysis values. Other studies that evaluated quality of life beyond voice changes reported improvements in symptoms, which are directly affected by surgery, such as recurrent tonsillitis-induced throat pain and eating difficulties, as well as in overall health status and vitality, after tonsillectomy.[7,8] In this study, the decrease in VHI may have reflected the decrease in shimmer% and NHR and improvements in overall physical and mental health and psychological anxiety after resolution of the underlying conditions, such as recurrent tonsillitis.

SFF is considered to reflect the frequency of vocal fold vibration and resonance in the vocal tract. Considering that tonsillectomy does not directly affect the larynx, changes in SFF may be attributed to changes in the pharyngeal cavity structure, which can alter resonance during phonation.[9,10] In this study, postoperative assessments demonstrated that SFF, vocal range, and formant frequencies did not significantly change in men, but there was a tendency for the SFF to increase and the F2 significantly increased in women. Previous studies reported varying results on postoperative SFF, including no change,[4] decrease,[6] and temporary decrease followed by return to preoperative levels as the wounds healed.[2] In terms of formant frequencies, one study reported only a decrease in F3,[3] and another observed an increase in F1 but a decrease in F2 to F4.[11] These changes after tonsillectomy were assumed to be due to changes in the resonance chamber, although no common trend has been identified. Changes in vocal tract resonance are believed to be influenced by changes in the size of the pharyngeal cavity and mucosal stiffness secondary to scarring of the tonsillar bed.[11] The varying sizes of the preoperative pharyngeal cavity and the tonsils removed could explain various changes in the size

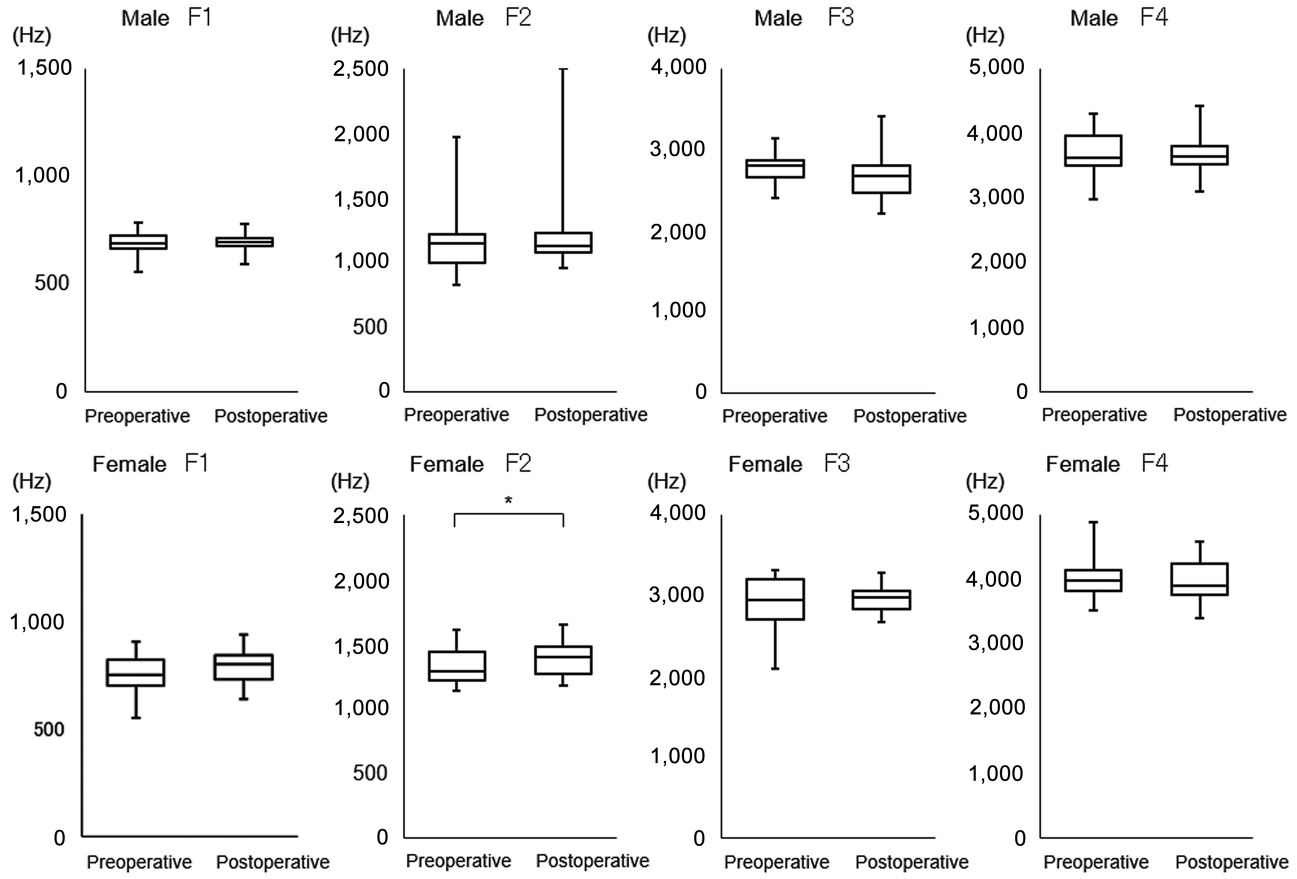

Fig. 3 Changes in F1 to F4 according to sex. In men, there were no significant changes in F1 to F4 between the preoperative and postoperative assessments. In women, F2 significantly increased postoperatively, compared with the F2 preoperatively. $^{*}p < 0.05$.

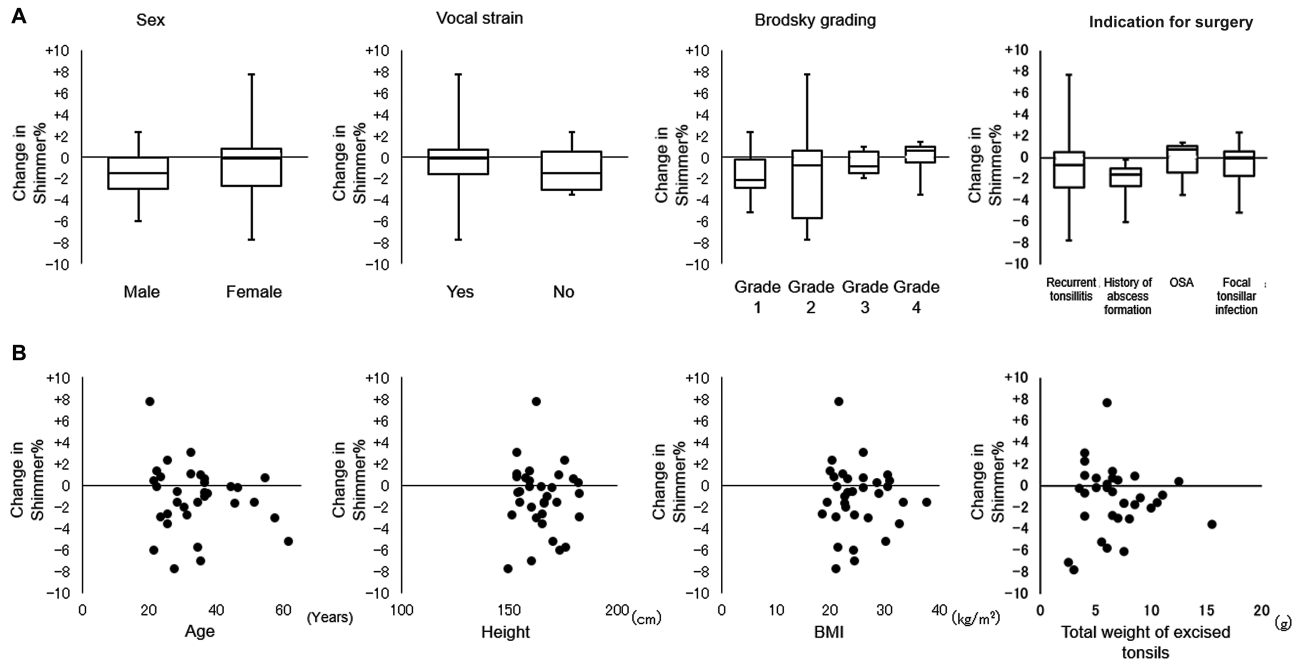

Fig. 4 Correlation between changes in shimmer% and NHR and various factors. Changes in (**A**) shimmer% and (**B**) NHR were not significantly correlated with the various examined factors. NHR, noise-to-harmonic ratio; OSA, obstructive sleep apnea.

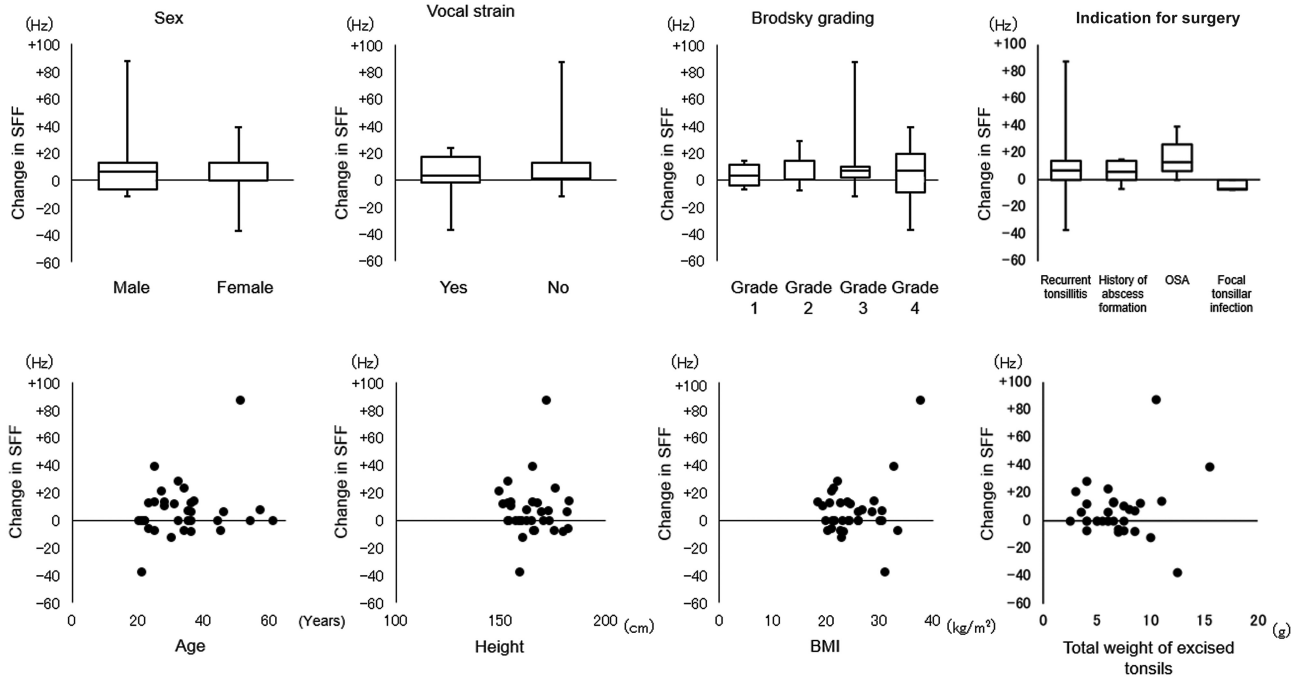

Fig. 5 Correlation between changes in SFF and various factors. The changes in SFF were not significantly correlated with the various examined factors. SFF, speaking fundamental frequency.

of the pharyngeal cavity among individuals. In addition, the degree of cauterization during surgery and the patient's constitution can also account for variations in the extent of scarring. Thus, changes after tonsillectomy may vary according to various factors, such as body shape, specific disease being treated, devices used during surgery, and degree of cauterization. Furthermore, SFF and formant frequencies are influenced by the length of the vocal tract, with longer vocal tracts resulting in lower frequencies and shorter vocal tracts resulting in higher frequencies.[12,13]

In some cases, postoperative pain and other related factors can cause tension in the extralaryngeal muscles, leading to a positional change of the larynx and possible changes in SFF and formant frequencies. These varying factors may explain the inconsistent trends in postoperative changes in SFF and formant frequencies. Among the women in this study, the increase in postoperative F2 could be attributed to further scarring of their typically narrower pharyngeal cavity compared with that in men, and the upward trends in SFF, F1, and F3 might be explained by changes in muscle tension and position of the larynx during phonation. Moreover, F1 is said to be affected by the space from the glottis to the narrow part of the tongue, and F2 is affected by the space between the

Table 2 Comparison between groups according to changes in SFF

		Decrease in SFF	No change/increase in SFF	*p*-value
		$n = 7$	$n = 26$	
Sex	Male:female (*n*)	06:01	10:16	0.026[a]
Age	(Age[b])	30.0 (24.0–35.0)	33.0 (25.5–36.8)	0.233
Height	(cm[b])	165.8 (162.8–177.5)	162.2 (154.5–169.8)	0.059
BMI	(kg/m^{2}[b])	22.7 (22.7–26.9)	24.2 (21.3–28.0)	0.456
Brodsky grading	Grade 1:2:3:4 (*n*)	3:2:1:1	7:11:5:3	0.871
Total weight of excised tonsils	(g[b])	7.5 (7.0–9.3)	6.0 (4.3–7.5)	0.046[a]
Vocal strain	Yes:no (*n*)	04:03	17:09	0.687
Applicable disease	Recurrent tonsillitis:history of abscess formation: OSA:focal tonsillar infection	3:1:0:3	17:4:3:2	0.21

Abbreviations: BMI, body mass index; OSA, obstructive sleep apnea; SFF, speaking fundamental frequency.
[a]$p < 0.05$.
[b]Median (interquartile range).

tongue and the lips.[1] Therefore, the increase in F2 may be attributed to cases with a narrowed pharyngeal cavity, which corresponds to the space from the glottis to the tongue, due to scarring after tonsillectomy. In addition, auditory feedback may have contributed to the increase in F2 by compensating for and moving the tongue position forward during phonation, thereby narrowing the tongue-to-lip space.

Factors Correlated with Postoperative Voice Changes

Postoperatively, there were significant changes in shimmer % and NHR and an increase in SFF in women. Notably, none of the factors significantly correlated with these changes. However, our findings on the higher proportion of men and higher total weight of the excised tonsils in the group with decreased SFF than in the group with unchanged/increased SFF suggested that the postoperative changes in SFF might be influenced by pharyngeal cavity size. In particular, a relatively large pharyngeal cavity tends to decrease the SFF. In patients with relatively heavy excised tonsils, the volume of the tonsils removed is also likely to be substantial. In such cases, the pharyngeal cavity size may significantly change after surgery. Conversely, in patients with relatively lighter excised tonsils, changes in pharyngeal cavity size after surgery may be relatively minor. After the removal of a large volume of tonsillar tissue, the expansion of the pharyngeal cavity dramatically affects the voice. In contrast, in cases of smaller tonsils, postoperative granulation and scar formation may prevent any changes or, in some cases, may even reduce pharyngeal cavity size. Moreover, differences in the pharyngeal cavity size between men and women can lead to variations in voice changes. Men are likely to show more pronounced effects because of broader pharyngeal cavity expansion, whereas women might experience easier reflection of effects due to granulation or narrowing. Notably, decreased postoperative SFF tended to be more common among taller individuals than among shorter individuals, which may be attributable to differences in pharyngeal cavity size. The median weight of the excised tonsils was 7.5 g (range: 3.5–11 g) in men and 6.0 g (range: 2.5–15.5 g) in women. Furthermore, the excised tonsils tended to be heavier in men than in women. Based on these results, SFF is likely to decrease in men and increase in women.

In this study, the postoperative changes in SFF were not significantly correlated with the Brodsky grading. One reason for this observation could be the fact that the Brodsky grading does not directly reflect the volume of the tonsils to be excised because it only categorizes the degree to which the tonsils protrude inward from the palatine arches and does not consider the part of the tonsils buried beneath the mucosa. Although the Brodsky grading can be easily assessed preoperatively by visual inspection and is thought to somehow correlate with tonsillar volume, our study suggested that predicting voice changes based on the Brodsky[14] grading may be challenging. Although not commonly performed before tonsillectomy, preoperative measurement of tonsillar volume by imaging, such as computed tomography and magnetic resonance imaging, might allow the prediction of voice changes in some cases. Previous reports have noted that ultrasonographic images generated by an electronic linear transducer were significantly correlated with the actual volume of the tonsils.[15] Therefore, preoperative measurement of tonsillar volume by ultrasonography might be a useful method for predicting postoperative voice changes; however, further investigation is necessary.

Clinical Considerations Related to Voice Changes before and after Palatine Tonsillectomy

Voice changes after tonsillectomy are attributed to a combination of factors and may not exhibit uniformity. Factors such as weight and volume of the excised tonsils, sex of the patient, and pharyngeal cavity width are potential predictors of postoperative voice changes. Considering these aspects, it is important to thoroughly inform patients and their families about the possibility of voice changes after surgery.

Furthermore, it is advisable to determine the appropriateness of surgery based on the patient's occupation and hobbies and to assess how voice changes might affect their life. During the postoperative examination, the extent of wound healing, presence of incidental damage, and changes in voice should be evaluated. Postoperative changes in voice in the early phase (i.e., ~1 month) are secondary to postoperative inflammation and may be temporary, whereas those occurring after wound healing (i.e., ~3 months) may persist longer. Therefore, according to the patient's background, such as occupation and hobbies, and preferences, careful attention should be paid to postoperative voice changes and continuous postoperative monitoring for greater than 3 months.

Conclusion

This study showed significant changes in voice, particularly reductions in shimmer% and NHR, after palatine tonsillectomy. Therefore, before palatine tonsillectomy, patients and their families should receive an adequate explanation regarding the potential for voice changes. Furthermore, continuous follow-up observations, including monitoring of voice changes, for greater than 3 months after surgery are advisable. These changes may be explained by reduced turbulence above the vocal folds and decreased tension in the larynx after removal of the enlarged tonsils. In women, there was a tendency for the speaking pitch to increase after surgery, and some changes in formant frequencies were noted. Changes in speaking pitch and formant frequencies may be inconsistent and may be influenced by various factors, including pharyngeal cavity size, volume of the tonsils removed, and scarring from surgery.

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Conflict of Interest
None declared.

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