

# Voice Acoustic Changes after uvulopalatopharyngoplasty Surgery

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Received 28 May 2014  
Accepted 15 June 2014  
PAN Arab Journal of Rhinology  
2014, 4:75–80

**Background:** All surgical procedures for treatment of snoring and obstructive sleep apnoea modify the anatomical structure of the upper airways and the resonance characteristics of the vocal tract; this can lead to a modification in voice.

**Aim of the work:** Purpose of this study was to evaluate the possible modifications of the fundamental frequency (F0) and of the frequency and amplitude of the first (F1) and second (F2) formants of the 6 Arabic vowels after the surgical operation uvulopalatopharyngoplasty (UPPP) for snoring, to verify if and how this operation can influence changes of voice.

**Materials and Methods:** A total of 40 patients suffering from habitual snoring with or without mild to moderate obstructive sleep apnea syndrome due to upper airway obstruction at the palatal level, not affected by laryngeal, pulmonary or neurologic disorders likely to alter voice production, were selected for the study. All were submitted to acoustic voice analysis prior to surgery and again 1 month after discharge.

**Results:** F0 was unchanged. The frequency of F1 of the vowel /a/ vowel /æ / and F2 of the vowel /e/ were significantly higher, while F1 of /i/ and F2 of /o/ and /u/ were significantly lower compared to pre-operative values.

**Conclusions and Recommendations:** The modifications in the anatomical structure and volume of the vocal tract, induced by the surgical procedure used for the treatment of snoring, can modify the values of the formants and, as a consequence, change of the voice. This change can be detected not only by means of the acoustic analysis but also by the patient itself. For this reason, singers and all professional voice users about to undergo surgical treatment for snoring should be informed of this potential modification of the voice not only for clinical reasons but also for legal purposes.

**Keywords:** Snoring, Surgical treatment, Voice, Acoustic analysis.

## Introduction

All surgical procedures for the treatment of snoring and obstructive sleep apnoea syndrome (OSAS) modify the anatomical structure of the upper airways and the resonance characteristics of the vocal tract; this can lead to a modification in voice [1]. Acoustic analysis showed a significant rising of the fundamental frequency of up to 10 Hz and there was also a lowering of the second formant in two of the five English vowels after UPPP operations and these changes affect voice quality [3].

The size and shape of the acoustic spaces of the vocal tract (nasal, oral and pharyngeal cavities) and the coupling between those spaces determine areas of resonance, defined as “formants”[1,2]. Formant 1 (F1) is usually associated with the height of the tongue and the degree of closure of the oropharyngeal cavity; formant 2 (F2) is associated with the degree of advancement of the tongue with respect to its neutral position; formant 3 (F3) is associated with the degree of rounding of the lips [1, 2]. The frequencies and

amplitudes of the formants define each vowel and significantly contribute to the overall quality of voice and speech [1]. The phonatory characteristics after UPPP have been examined by different authors using objective (acoustical analysis) and subjective (perceptual evaluation) assessment techniques, but these studies mainly concentrated on the fundamental frequency, with contrasting results, and most of them investigated the effects of classical UPPP techniques [3]. Whereas a number of authors reported significant voice changes after UPPP, other authors found no differences in voice and speech characteristics. There are only a few studies that have tested changes in voice and speech quality in patients with OSA after different palatal surgical techniques [4].

Several studies have already examined the potential changes in the acoustic characteristics of vocal quality after upper airway surgery, with conflicting results [2–13]. In patients with obstructive sleep apnea (OSA), uvulopalatopharyngoplasty (UPPP) is the most commonly used surgical procedure for enlarging the

potential airspace in the oropharynx. The operation was first introduced by Fujita et al [14] as a new technique to correct anatomic abnormalities in OSA patients. Laser-assisted uvulopalatopharyngoplasty (LAUP), later developed by Kamami, [15] was aimed at progressively enlarging the oropharyngeal airspace by successive vaporizations of the uvula, soft palate, posterior tonsillar pillars and any redundant posterior pharyngeal mucosa.

### **Aim of the work**

The purpose of the present study was to evaluate the possible modifications in fundamental frequency (F0) and of the frequency and amplitude of the first and second formants of the 6 Arabic vowels after uvulopalatopharyngoplasty (UPPP) surgical procedure for snoring, to establish if and how this operation can influence voice quality and for this reason, singers and all professional voice users about to undergo surgical treatment for snoring should be informed of this potential modification of the voice not only for clinical reasons but also for legal purposes.

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## **Patients and methods**

All snoring or OSAS patients admitted to the Department of Otolaryngology of the University of Beni-Suef, in the period between September 2013 and February 2014. All patients are subjected to; history taking (Partner must be present), complete general examination, complete Otorhinolaryngological examination and are investigated to define the site and degree of obstruction or collapse by flexible nasopharyngoscopy with Muller's maneuver, polysomnography and magnetic resonance image (MRI). In this study, 40 patients (37 male, 3 female), aged between 23 and 65years (mean 46, median 48), suffering from habitual snoring with or without mild to moderate obstructive sleep apnea {diagnosed by polysomnography with the mean apnea hypopnea (AHI) index 24.7} due to upper airway obstruction at the palatal level {detected by Otorhinolaryngology examination, flexible nasopharyngoscopy with Muller's maneuver and magnetic resonance image} not affected by laryngeal, pulmonary or neurologic diseases, were selected. These patients were treated by UPPP (The procedure was explained to patients and operative consent was assigned) and were submitted to acoustic voice analysis before surgery and again 1 month after discharge. Moreover, in the event of UPPP, the amount of tissue removed was measured by dipping it into a fixed volume of saline

solution and calculating the quantity (in ml) of water removed. All were submitted to acoustic voice analysis before surgery and again 1 month after discharge.

### **Auditory perceptual assessment (APA)**

Standardized speech samples were recorded using a high-fidelity tape recorder in a sound-treated room. The speech samples included a standardized passage, counting from 1 to 10 and sustaining the vowels/a/, /i/ and/u/. The recorded speech samples were perceptually judged for voice changes by three experienced phoniatrists. Auditory perceptual assessment (APA) of voice was done according to the GRBAS (grade, roughness, breathiness, asthenia, strain) scale. Also, the parameters for overall grade of dysphonia, roughness and breathiness were rated on a five-point scale (0=normal and 4=severe).

### **Acoustical voice analysis**

A computerized speech lab (CSL model 4300 from Kay Elemetrics Corp., Lincoln Park, NJ, USA) was used for acoustic analysis of voice.

Each subject was asked to pronounce each of the 6 Arabic vowels /a/, /æ / /e/, /i/, /o/, /u/ three times, sustained for 5 seconds/ in a flat tone at a comfortable pitch and at constant amplitude. The acoustic signal was acquired with a microphone at a distance of 10 cm and 45° from the patient's mouth. Average pitch, intensity, jitter, shimmer and harmonic-to-noise ratio were measured. Formant frequencies were done for the vowels and the first 2 formants (F1 and F2) were tested for these vowels.

### **Statistical analysis**

Pre- and post-operative values of F0, F1, F2, A1, and A2 and of their absolute and percentual differences were analyzed. Data were expressed as mean (M) and standard deviation (SD). Comparisons pre-post were performed using Student t test for paired data or the non-parametric Wilcoxon Matched pair's test, as appropriate. Correlations between the differences in the frequency and amplitude values of the formants and the amount of tissue removed were analyzed with the Poisson "r" coefficient. P <0.05 was considered statistically significant. All tests were two-sided. No adjustment for multiple comparisons was made, as this study was intended as explorative rather than confirmatory.

## Results

Mean (M) and standard deviation (SD) of the pre- and post-operative values of F0, as well as the M and SD of their differences and statistical significance are outlined in Table 1. The mean values of F0, evaluated 1 month post-operatively, did not change significantly.

**Table 1 Mean (M) and standard deviation (SD) of pre- and post-operative values of fundamental frequency (F0) and differences ( $\Delta$ ), measured in Hertz**

	Pre-operative(F0) (M +,- SD)	Post-operative(F0) (M +,- SD)	( $\Delta$ ) FO (M+,-SD)	Statistical Significance p <0.05
HZ	120.1+,-29.5	120.63+-27.02	0.52+,-11.92	0.83

M and SD of the frequency and amplitude values of the formants, before and after surgery, as well as the M and SD of the differences between the values and statistical significance are outlined in Table 2.

**Table 2 Mean (M) and standard deviation (SD) of pre- and post-operative frequency (Hz) and amplitude (dB) values of different formants considered and of their differences ( $\Delta$ )**

	Pre-operative (M+,-SD)	Post-operative (M+,-SD)	(M+,-SD)	Statistical Difference P < 0.05
/a/ F1 Hz	722.12+ 92.77 -	759.93+-87.61	37.25+-74.07	0.003
F2 Hz	1215.07+-115.65	1215.26+-100.33	15.20+-79.92	0.67
A1 dB	25.11+-5.29	29.29+-5.92	0.18+-5.76	0.84
A2 dB	23.31+-6.07	24.33+-5.54	0.42+-6.43	0.67
/æ/ F1 Hz	819.11+-99.76	856.91+-89.59	47.23+-78.06	0.004
F2 Hz	1314.09+-214.61	1311.26+-200.31	25.21+-89.92	0.77
A1 dB	35.12+-6.38	30.29+-6.94	0.29+-6.87	0.94
A2 dB	33.32+-7.07	34.33+-6.55	0.53+-7.53	0.77
/e/ F1 Hz	394.33+-78.93	376.63+-73.36	-17.69+-58.85	0.06
F2 Hz	2045.53+-223.72	2097.49+-219.28	51.96+-177.72	0.04
A1 dB	31.91+-4.06	32.40+-3.15	0.49+-4.64	0.51
A2 dB	17.85+-5.66	16.44+-4.97	-1.41+-5.47	0.11
/i/ F1 Hz	266.42+-54.61	247.99+-43.53	-18.42+-45.33	0.02
F2 Hz	2262.66+-194.23	2287.29+-209.63	24.64+-144.00	0.28
A1 dB	33.21+-4.27	33.32+-3.33	0.11+-4.96	0.89
A2 dB	15.79+-5.45	14.54+-6.21	-1.25+-6.22	0.21
/o/ F1 Hz	533.90+-79.71	519.67+-87.80	-14.22+-75.64	0.24
F2 Hz	898.82+-123.107	859.12+-99.52	-39.70+-106.52	0.02
A1 dB	35.34+-5.30	33.42+-4.63	-1.91+-6.13	0.05
A2 dB	28.70+-5.53	28.70+-5.53	0.93+-7.49	0.44
/u/ F1 Hz	330.27+-79.89	316.99+-57.44	-13.27+-70.89	0.12
F2 Hz	681.67+-127.36	654.39+-111.00	-27.28+-108.26	0.04
A1 dB	37.42+-6.04	37.98+-4.40	0.56+-5.72	0.53
A2 dB	25.54+-6.21	26.01+-6.49	0.48+-6.97	0.66

F1 = first formant; F2 = second formant; A1 = amplitude first formant; A2= amplitude second formant.

Table 3 shows the APA results of the patients preoperatively and postoperatively. Differences in voice quality were not significant between the preoperative and postoperative evaluations for patients except for overall grade. The t test showed no statistically significant change in average pitch, jitter, shimmer and harmonic-to-noise ratio before and after UPPP for the sound/a/ Table 4.

**Table 3 Comparison of preoperative and postoperative auditory perceptual assessments of voice**

Parameter	UPPP		P
	Preop	Postop	
Overall grade	0.3 (3)	0.1 (1)	<.05
Roughness	1.2 (0.1)	1.5 (0.2)	>.05
Breathiness	0.4 (0.25)	0.51 (0.2)	>.05
Strain	0.8 (3)	0.6 (2)	>.05

Values are mean (standard deviation)

**Table 4 Comparison of preoperative and postoperative values of acoustic parameters of voice**

Parameter	UPPP		P
	Preop	Postop	
Average pitch (Hz)	167 (29)	165 (32)	>.05
Jitter (%)	0.21 (0.1)	0.19 (0.1)	>.05
Shimmer (%)	0.4 (0.25)	0.51 (0.2)	>.05
H/N (dB)	12.2 (3)	12.18 (3)	>.05

Values are mean (standard deviation)

The frequency values of F1 and F2 of the vowels /a/ and /æ / measured 1 month post-operatively increased; the difference in the F1 values, in particular, being statistically significant.

The frequency value of F1 of the vowel /e/ decreased, but the difference was not statistically significant; while the frequency value of F2 increased significantly.

F1 of the vowel /i/ was significantly lower compared to the pre-operative value, while F2 was higher, even if this difference was not statistically significant.

The post-operative frequency values of F1 and F2 of the vowels /o/ and /u/ decreased; the differences being statistically significant particularly for F2 of both vowels.

No statistically significant variations were observed for the amplitude values of the formants considered.

As far as concerns the correlation analysis between the amount of resected pharyngeal tissue and the variations in frequency of the formants of each vowel, the “r” coefficient did not exceed 0.25 Table 5.

**Table 5 Surgical procedure performed and amount of resected tissue**

patients	UPPP	Resected tissues (ml)
CF	X	4
SD	X	5
MH	X	4
KU	X	4
AB	X	4
DF	X	4
FT	X	6
BH	X	6
ACV	X	6
HL	X	4
GF	X	5
BR	X	5
KL	X	5
HT	X	5
BH	X	4
FG	X	4
HJ	X	4
ABD	X	6
LK	X	6
FD	X	5
SD	X	6
LK	X	4
AS	X	6
VF	X	6
BT	X	6
MH	X	5
NK	X	6
ABN	X	5
FDU	X	5
NA	X	6
MA	X	5
CFH	X	5
SDI	X	5
KK	X	6
KLI	X	6
AZ	X	6
BZ	X	5
DA	X	4
KS	X	5
KA	X	4

## Discussion

The fundamental frequency and the formants are influenced by the different muscular and aerodynamic characteristics of the vocal tract. The fundamental question is, whether the modification of the volume and the resonance of the supraglottic vocal tract can determine a significant variation in the quality of the vocal sound. The formants are features of the resonating cavities lying above the vocal folds. The formant is determined by the length and shape of the vocal tract, as these cavities are reshaped, the first and second formants (F1 and F2) that have frequencies for different vowels may change [16]. Over the last 15 years, several reports have been published on this topic. Lin et al [3] examined the formants of the five English vowels in 15 patients submitted to uvulopalatopharyngoplasty (UPPP). The fourth formant increased in all cases. Other authors [6,8] observed a decrease of the third formant, after tonsillectomy. In both studies, F0, F1 and F2 were unchanged. Other authors [4,5] presented the same results in patients submitted to UPPP with or without tonsillectomy. Brosch et al. [11] on the contrary, in 12 UPPP patients, observed an increase of F0 and a significant decrease of F2 of the vowels /o/ and /u/; while Nakai et al [7] constantly showed, in 12 UPPP patients, an increase of F1 and F2 of the vowel /e/ and a decrease in F1 and F2 values of the vowel /u/.

The post-operative acoustic analysis, in our patients, did not reveal significant modifications in the F0 values. This could be explained by the fact that the adduction of the vocal folds and the vibratory mucosal wave, which generate the F0, are not influenced by the surgical procedures used in the treatment of snoring problems.

Analysis of the formants, on the other hand, demonstrated a significant increase in the F1 value of the vowel /a/ /æ /and in F2 of the vowel /e/, a significant decrease in the F1 value of the vowel /i/ and in F2 of the vowels /o/ and /u/. The decrease in the values of these formants could depend on the increased volume of the oropharyngeal cavity caused by the anterior-posterior advancement of the tongue induced by the hyoid suspension and on the increasing of the palatal arch determined by the UPPP. The minimal changes (significant raising or lowering of formants) will probably have no significance for those who place no special reliance on their voice, but the possible post-operative changes should be made clear to singers and those relying on their voice for professional reasons [3]. The increased oropharyngeal cavity, however, should lower all the

formants, but this is not always the case. The absence of modifications or, even, the increase of the formant frequencies encountered in the literature, and confirmed by our study, could depend upon the compensatory mechanisms of contraction of the pharyngeal musculature and of tongue position induced by the new configuration of the oropharynx following the surgical treatment [4].

Probably, it is not the amount of resected tissue that determines the modification of the formants-frequency but rather the new size and shape of the vocal tract resulting from the operation, even if long-term results are needed to evaluate this possibility.

Theoretically, it might be useful to establish the effects of each type of surgical procedure on the acoustic spectrogram of the patients, to evaluate which operation exerts the major effects on the formants. In reality, instead, snoring and OSAS patients are often submitted to multilevel surgical procedures, and, therefore, this kind of evaluation becomes difficult.

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## Conclusions

The modifications in the size and shape of the vocal tract, resulting from surgical treatment for snoring, can modify the formants. This can lead to a change in voice quality that can be perceived not only by the acoustic analysis, but also by the patient him/herself. For this reason, singers and all professional voice users undergoing surgery for snoring should be informed of this potential voice modification, not only for clinical reasons, but also for legal purposes.

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