Original Article

Effects of septoplasty on the acoustic parameters of voice

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Keywords

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Abstract

Objectives: To study the effects of nasal septal deviation and the effects of septoplasty on voice using acoustic analysis.

Study design: Prospective case–control study.

Setting: Yenepoya Medical College Hospital, a tertiary referral hospital.

Methods: A total of 45 subjects comprising 15 patients (study group) who underwent septoplasty and 30 normal adults (control group) were enrolled into the study. Acoustic analysis of voice was performed on all patients one day prior and one month after surgery. Controls were also subjected to voice analysis.

Results: Nasalance was observed to be significantly lower in patients with septal deviation. Postoperatively nasalance scores increased.

Conclusions: Findings of this study indicate that nasal obstruction due to septal deviation contributed to hyponasality in voice. Nasalance scores increased in the post operative group suggesting an increase in nasal acoustic energy due to a decrease in nasal airway resistance and an increase in nasal area following corrective surgery on the septum.

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1. Introduction

The commonest cause for nasal obstruction is deviation of the nasal septum. Nasal obstruction can lead to a hyponasal voice. Changes in the nasal volumes either due to septal deviation or following septoplasty may produce changes in nasal resonance. The decreased tissue surface area and widened nasal passages after septoplasty would be expected to result in a general decrease in acoustic damping and an increase in acoustic coupling with the paranasal sinuses, thereby increasing the amplitude, or energy of the voice.

Knowledge of changes in the acoustic parameters of voice using acoustic analysis would aid in a comprehensive and superior depiction of vocal function and also the effects of surgery on voice.
vocal function. It would help understanding of how this surgery affects nasal resonance and voice quality. There are very few studies in literature which have objectively studied the effects of septoplasty on voice. This study was undertaken to study the effects of this commonly performed operation on the acoustic parameters of voice in patients from Coastal Karnataka.

2. Methodology

A prospective case-control observational study was conducted to study the effects of septoplasty on the acoustic parameters of voice. Clearance was obtained from the Institutional Ethics Committee. A total of 45 subjects in the age range 18–40 years were enrolled in the study. Fifteen patients with septal deviation who underwent previous nasal surgery or had any other pathology in the nose such as granulomatous diseases, polyps or neoplastic lesions were considered for inclusion in the study group. Additional exclusion criteria included those who did not have nasal obstruction and in whom anterior rhinoscopy did not show nasal–septal deviation were also excluded from the study. Thirty adults, age and sex matched with the study group, who underwent septoplasty were included in the study group. Patients were excluded if they were below the age of 18 years, who underwent septoplasty were included in the study group. A total of 45 subjects in the age range 18–40 years were enrolled in the study. Fifteen patients with septal deviation who underwent previous nasal surgery or had any other pathology in the nose such as granulomatous diseases, polyps or neoplastic lesions were considered for inclusion in the study group. Patients were excluded if they were below the age of 18 years, who did not have nasal obstruction and in whom anterior rhinoscopy did not show nasal–septal deviation were also excluded from the study.

2.1. Voice Recording

Voice samples were recorded in two sessions for subjects in the study group. In the first session, samples were recorded one day before the subject underwent surgery (pre-operative) and in the second session the voice samples were recorded one month after the surgery (post-operative). The same technique of voice recording and analysis was used in the selected control group individuals.

The following parameters were measured:

1. **Formant frequencies** are the spectral peaks of the sound spectrum. Formants result from selective enhancement of particular frequencies, depending on the resonance characteristics of the human vocal apparatus. The formant with the lowest frequency is called \( f_1 \), the second \( f_2 \), the third \( f_3 \) and the fourth \( f_4 \).

2. **Bandwidths** are range of frequencies, centred around the centre frequency of the formant, between intensity maximum and intensity maximum minus 3 dB. Thus the band widths measured were bandwidth 1, 2, 3 and 4.

3. **Fundamental frequency** \( (F_0) \) represents the vibratory rate of the vocal folds during phonation and is quantified in Hertz (Hz). It is closely correlated, though not linearly, with perceived pitch. Fundamental frequency \( (F_0) \) is measured by identifying a cyclic (periodic) pattern in the acoustic signal, measuring the duration of each cycle, and estimating how many cycles can be produced per second.

4. **Intensity** \( (I_0) \) is the acoustic correlate of the perceptual impression of loudness of a sound measured in Decibels (dB).

5. **Peak amplitude variation or standard deviation** \( vAm \) (%) represents the relative SD of the period-to-period calculated peak-to-peak amplitude. It reflects the very long-term amplitude variations within the analysed voice sample.

6. **Jitter** designates small, random, involuntary perturbations of the glottal cycle length observed as a baseline phenomenon in all voiced speech sounds. It is usually measured as the cycle to cycle variation in fundamental frequency of voice.

7. **Shimmer** also known as amplitude jitter, refers to the cycle to cycle variation in the amplitude of successive glottal cycles.

8. **Harmonics to noise ratio** (HNR) is the ratio between the sound pressure level of the harmonics and noise in a glottal signal. This measure assumes that an acoustic signal consists of two components; the harmonic component that is the common pattern that repeats from cycle to cycle and an additive noise component that produces cycle to cycle irregularity. Long Term Average Spectrum (LTAS) is a display of the overall spectral characteristics of voice which demonstrates the amount of energy present at each frequency pooled across time. The ratio of mean intensities of the peaks between 0–1 kHz and 1–8 kHz is the Alpha ratio, that between 0–2 kHz and 2–8 kHz is the Beta ratio and that between 2–5 kHz and 5–8 kHz is the Gamma ratio.

9. **Soft Phonation Index** (STI) is not a measurement of noise, but rather the harmonic structure of the spectrum. Soft Phonation Index is an average ratio of the lower frequency harmonic energy (70–1600 Hz) to the higher frequency (1600–4500 Hz) harmonic energy.

10. **Voice Turbulence Index** (VTI) is an average ratio of the spectral inharmonic high frequency energy in the range 2800–5800 Hz to the spectral harmonic energy in the range 70–4500 Hz in areas of the signal where the influence of the frequency and amplitude variations, voice breaks and sub-harmonic components are minimal. VTI measures the relative energy level of high frequency noise.

11. **Nasalance** is the ratio of the nasal acoustic energy to the nasal + oral acoustic energy expressed in percentage. This was measured for sustained vowels \( /a/, /i/, /u/ \) and sustained consonants \( /m/, /n/ \), oral sentence, nasal sentence and passage reading.
The empirical values obtained thereof were compiled, tabulated and analysed statistically with the Windows SPSS software programme (SPSS Inc, Cary, North Carolina). Analysis was performed using Student’s t-tests.

3. Results

There was no significant difference observed on comparison of formant frequencies between control and pre-operative as well as post-operative group. There was no much difference on comparison of pre-operative values with post-operative values of formant frequencies as well. Formant bandwidths were lower in the study group pre-operatively as well as post-operatively as compared to the controls. However, a significant difference was observed only in bandwidth 1 on comparison of pre-operative values with post-operative values. Mean fundamental frequency was observed to be slightly lower in the study group (pre and post-operative) as compared to controls. There was no significant difference on comparison of its pre-operative values with post-operative values. Mean nasalance values were also lower in the study group pre-operatively as well as post-operatively than that of controls. The differences in pre-operative and post-operative mean LTAS values were minimal and insignificant. Higher SPI and VTI values were seen in patients with septal deviation as compared to controls. Postoperatively, SPI and VTI values lowered. Mean nasalance values for sustained vowels and consonants, oral and nasal sentences and passage were significantly lower in patients with septal deviation as compared to controls. An increase in mean nasalance scores was noted 1 month after surgery (Table 1).

4. Discussion

The nasal cavity is important in shaping the quality of voice. The size and configuration of the internal nasal cavities influence the nasal resistance to airflow. Approximately two thirds of the resistance occur at the liminal valve located at the junction of the upper lateral cartilage and nasal septum. A decrease in nasal airway patency caused by anterior nasal obstruction increases the resistance to nasal airflow and sound transmission. Nasal obstruction due to septal deviation may

<table>
<thead>
<tr>
<th>Sl no.</th>
<th>Parameter</th>
<th>Group</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control (Mean ± S.D.)</td>
<td>Pre-op</td>
</tr>
<tr>
<td>1</td>
<td>Formant frequency f1</td>
<td>537.85 ± 190.77</td>
<td>482.21 ± 179.11</td>
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<td></td>
<td>Formant frequency f2</td>
<td>1346.25 ± 605.39</td>
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<td></td>
<td>Formant frequency f3</td>
<td>2576.29 ± 454.47</td>
<td>2637.47 ± 342.61</td>
</tr>
<tr>
<td></td>
<td>Formant frequency f4</td>
<td>3428.77 ± 219.53</td>
<td>3443.47 ± 232.26</td>
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<tr>
<td>2</td>
<td>Bandwidth 1</td>
<td>245.88 ± 168.82</td>
<td>131.34 ± 125.96</td>
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<td></td>
<td>Bandwidth 2</td>
<td>338.81 ± 330.50</td>
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<td></td>
<td>Bandwidth 3</td>
<td>559.81 ± 447.44</td>
<td>505.43 ± 495.00</td>
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<td></td>
<td>Bandwidth 4</td>
<td>522.81 ± 241.08</td>
<td>424.04 ± 226.48</td>
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<tr>
<td>3</td>
<td>Mean F0</td>
<td>149.12 ± 21.14</td>
<td>146.67 ± 23.47</td>
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<tr>
<td>4</td>
<td>Mean l0</td>
<td>91.04 ± 10.46</td>
<td>90.49 ± 7.94</td>
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<td>5</td>
<td>Peak amplitude</td>
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<td>1.28 ± 1.04</td>
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<td>6</td>
<td>Jitter Tc</td>
<td>2.38 ± 3.15</td>
<td>3.48 ± 3.09</td>
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<tr>
<td>7</td>
<td>Shimmer (linear)</td>
<td>2.20 ± 1.48</td>
<td>6.69 ± 7.44</td>
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<td>8</td>
<td>HNR (linear)</td>
<td>17.08 ± 5.24</td>
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<td>9</td>
<td>LTAS Alpha ratio</td>
<td>13.41 ± 5.08</td>
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<tr>
<td></td>
<td>LTAS Beta ratio</td>
<td>15.58 ± 6.06</td>
<td>20.27 ± 5.94</td>
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<tr>
<td></td>
<td>LTAS Gamma ratio</td>
<td>20.42 ± 8.09</td>
<td>24.62 ± 7.19</td>
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<tr>
<td>10</td>
<td>SPI</td>
<td>21.44 ± 10.37</td>
<td>23.37 ± 9.17</td>
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<tr>
<td>11</td>
<td>VTI</td>
<td>24.53 ± 9.01</td>
<td>25.69 ± 9.28</td>
</tr>
</tbody>
</table>

Table 1 Comparison of acoustic parameters between control group and study group.

Values highlighted in bold represent statistical significance (p < 0.05).
create enough impedance to reduce or even prevent sound from entering the nasopharynx, even when the velopharyngeal port is open during speech. Anterior nasal cavity obstruction could result in ‘cul-de-sac’ resonance due to the addition of acoustic aspects to the speech signal. Upper airway surgeries such as septoplasty, turbinectomy, uvulopalatopharyngoplasty and tonsillectomy have the potential to affect voice quality by altering the resonant characteristics of the vocal tract. A reduction in the tissue surface area and widening of nasal passages following surgery would be expected to result in a general decrease in acoustic damping and an increase in acoustic coupling with the paranasal sinuses and therefore increase the amplitude or energy of the voice. Acoustic features have been observed to become more representative of normative data than the pre operative values and so patients are unlikely to perceive a change in voice as a result of upper airway surgeries, but in those cases where a difference is perceived, it is likely to be a positive change.

Formants and formant bandwidths are a representative of the supralaryngeal characteristics of voice. Changes in formant frequencies were also not observed to be significant across groups. Formant bandwidths were lower in the study group pre-operatively as well as post-operatively as compared to the controls. However a significant difference was observed only in bandwidth 1 on comparison of controls with study group. No significant change was observed after surgery. Significant change was not observed in the mean fundamental frequency following surgery. Intensity was not observed to vary in any of the groups studied. vAm did not differ much in the study group as compared to control group.

In a recent study, where formant frequencies and acoustic energy across different bandwidths were measured using spectrographic analysis on patients who underwent septal correction, no change was observed in measures taken before and after surgery. Septoplasty is not a procedure which directly affects the larynx and therefore should not affect the rate at which the vocal folds open and close during phonation and so findings of this study with respect to mean $F_0$ concur with those of a recent study. This is in contrast to the study by Mora et al. who observed lowering of $F_0$ and explain that reduced pitch would decrease resonance and hence improve speech quality.

Jitter and shimmer were higher in the study group both pre and post-operatively as compared to controls indicating roughness and hoarseness in voice. Postoperatively jitter and shimmer measures showed a declining trend. Decreased HNR values were seen in all cases of the pre-operative group in comparison to controls although mean differences were not statistically significant. HNR values were also lower in the study group than in controls postoperatively. This aspect clearly reveals that the pathological process does have a bearing on voice. The post operative values of HNR did not differ significantly from that of the pre operative values in the present study although they were slightly lower. The improvement in values of jitter and shimmer, postoperatively have been attributed to the regularization of loudness following surgery.

Follow up of these parameters in the long term would perhaps reveal the significant positive outcome of surgery.

Mean LTAS values were higher in the study group both pre and post-operatively as compared to controls. This was also statistically significant for the Alpha and Beta ratio on comparison of controls with pre operative values. This aspect needs to be further studied on a larger sample size. There was no significant difference on comparison of pre-surgical values with post surgical values. A study which compared the pre operative and post operative voices of 32 uvulopalatopharyngoplasty patients using Fast Fourier Transform analyses of long-term spectra of a reading passage and the resonant characteristics of three vowels found pre-operative and post-operative spectral differences were to be minimal.

Higher SPI and VTI values were seen in patients with septal deviation as compared to controls. Postoperatively, SPI and VTI values lowered. Glottal flow gets skewed by the augmentation of inertness while incomplete closure of glottis leads to air leak from glottis during phonation, thus leading to a higher resistance and a non-linear pressure-flow relation in the glottis. Post-operative values of SPI and VTI represent altered dynamics in the structure of the resonator following surgery resulting in a greater acoustical quality of voice. Regularization of supraglottic flow with a reduction in vocal tract inertness and resistance, resulting in less laryngeal adductory force necessary for phonation is highlighted by the post-operative decline in the values of jitter, shimmer, HNR, SPI and VTI. This observation is similar to the observations of previous studies.

Mean nasalance values for sustained vowels and consonants, oral and nasal sentences and passage were lower in patients with septal deviation as compared to controls. This was also statistically significant ($p<0.05$). This indicates that nasal obstruction due to septal deviation impedes or reduces entry of sound into nasopharynx, even when the velopharyngeal port is open. An increase in mean nasalance scores 1 month after surgery was noted in this study. Studies of nasalance scores using the Glatzel and the Gutzmann tests demonstrated significant increases in nasalance scores after septoplasty, suggesting an increase in nasal acoustic energy. This has been attributed to the decrease in nasal airway resistance and an increase in nasal area as a result of septal correction.

5. Conclusion

Septal deviation caused a significant reduction in nasalance scores giving an indication of hyponasal voice. Although, post operative changes in the voice parameters were minimal and not significant, they were indicative of greater acoustical quality of voice and lesser nasalised speech, thus reflecting the positive outcome of surgery. It would hence be imperative to counsel patients, particularly professional voice users about the possible changes in voice following septal surgery. Objective quantification of voice using acoustic analysis would help the specialist to offer wise counsel to patients regarding the effects of this commonly performed surgical procedure on voice and alleviate their anxiety.

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Conflict of interest

None declared.
References