Changes in nasal resonance following septoplasty in adults: Acoustic and perceptual characteristics

ANASTASIA LIAPI¹, SHASHIVADAN HIRANI² & JOHN RUBIN³

¹Department of Otolaryngology Head and Neck Surgery, ‘Sotiria’ General Hospital, Athens, Greece, ²Centre for Health Services Research, School of Health Services, City University, London, UK, and ³University College London Hospitals NHS Trust and University College London, London, UK

Abstract
Objectives. Patients undergoing surgery for a deviated nasal septum (septoplasty) often report that their voice sounds different or less hyponasal. However, such a relationship between septoplasty and vocal resonance remains without scientific evidence. The purpose of this work is to investigate whether nasal septal surgery has any effect on nasal resonance, both in terms of objective measurements and patient perception.

Methods. The research carried out was a prospective case-control study. We recruited patients who underwent septoplasty (study group) and healthy volunteers (control group). We obtained voice recordings of the nasal consonant /m/ pre- and four weeks postoperatively and twice at similar time intervals in the control group. We investigated objective changes by means of acoustic analysis of the voice recordings and calculated the total amount of acoustic energy in different bandwidths on a wide-band spectrogram. We also utilized a questionnaire to explore patient perception.

Results. A total of 34 participants entered the study. ANOVA testing revealed significant changes in average total acoustic energy, phlegm, and throat dryness postoperatively. Regarding patient perception, a considerable number of our patients felt that their voice had changed for the better upon direct questioning. However, statistical analysis of the questionnaire items related to nasality of voice did not show a significant change.

Conclusions. In this study it has been demonstrated that surgical correction of septal deviation causes significant spectrographic changes. In particular it causes changes in the average total acoustic energy during the production of a nasal consonant. A considerable number of our patients reported change in their vocal resonance for the better. We recommend that patients be advised that their voice may sound different after surgery, or less hyponasal.

Key words: Acoustic analysis, nasal surgery, resonance, septoplasty, voice

Introduction

The nose and paranasal cavities are part of the vocal tract and as such act as resonators to alter the original sound produced by the vocal folds. Nasal resonance has historically been difficult to quantify, although nasalized speech is a common perception. Strictly speaking, nasal resonance relates to vocal amplification in the oral and nasal cavities and is classified into hypernasality, hyponasality, and mixed resonance. Hypernasality is the predominant characteristic of cleft palate speech due to velopharyngeal insufficiency and inadequate velopharyngeal closure during phonation. Hyponasality, on the other hand, is the perceptual correlate of a blocked nose. Patients often report resonance changes following surgery in the nose and paranasal sinuses, and this topic has had limited attention in the literature in recent years. Most studies have evaluated the impact of sinus surgery on voice and have employed a variety of objective and subjective measurements (1–3).

The effect of septal surgery on nasal resonance has received far less attention (4–7). Septoplasty is a procedure that aims to correct septal deformities and effectively lift nasal blockage. A deviated nasal septum is the most common cause of nasal obstruction. Around one-third of the population complains of some nasal obstruction, and 25% of these patients will seek surgical treatment. Often a deviated septum
is acquired after nasal injury; however, many times, there is not a clear history of trauma to the nose. The initial insult may have been caused by birth trauma or even in utero. ‘Silent’ fractures occurring early in life may also lead to asymmetric growth of the septal cartilage. The efficacy of a septoplasty to lift nasal obstruction has been studied extensively both in terms of patient satisfaction (8,9) and by quantitative measurements of postoperative decrease in nasal airway resistance by means of rhinomanometry (10,11). The procedure entails remodelling and excision of the deviated septal cartilage and bone to improve nasal airflow. It is often combined with surgery to the inferior turbinates to improve patency of the nasal passages even more (septoturbinoplasty). More and more frequently voice professionals ask their surgeons whether septoplasty will alter their resonance. Certainly anecdotal accounts of patients seem to suggest that the voice will sound less hyponasal following nasal septal surgery. However, such a relationship between septoplasty and perceived nasalityization remains without scientific evidence. The purpose of this work was to investigate whether nasal septal surgery has any effect on the nasality of voice. We wished to evaluate objective changes as well as patient perception.

Methods

Design

This pilot study was a research project undertaken as part of the course requirements of the Masters in Voice Pathology Course at University College London. All patient work was undertaken at the John Radcliffe Hospital, Headington, Oxford and at the Stoke Mandeville Hospital, Aylesbury, United Kingdom. Ethical approval was sought and granted by the Oxfordshire Research Ethics Committee B. The research carried out was a prospective case–control study. We examined if vocal characteristics are altered over time and whether this occurred differentially for each group (see below).

Sample recruitment

Our project included one study group and one control group, both convenience samples within the National Health System (NHS) of the UK. For the study group we sequentially recruited patients who had already been listed for a septoplasty to correct their nasal obstruction (surgical patients). The inclusion criteria comprised: adults listed for septoplasty aged 18–75, English speakers (to facilitate measures completion), and a signed consent form. Exclusion criteria were: presence of neurologic and/or craniofacial abnormalities, sinus pathology, known voice problems, and previous nasal surgery. The control group comprised healthy volunteers, meeting the same criteria except being listed for surgery. Outcome variables compared between groups included acoustic parameter changes and patient perception.

Procedures

Voice recordings were carried out before and four weeks after the operation in the surgical group and twice at similar time intervals in the control group. The voice sample we used for the purpose of this work consisted of a sustained nasal consonant /m/, in variable pitch for acoustic analysis. In order to obtain a reproducible sample our subjects were asked to hum ‘Happy Birthday’. This is a well-known and popular tune, and humming it produces a nasal consonant in different pitches. This particular tune would ensure inter- and intra-subject reliability of our acoustic samples. Recordings were carried out in an isolated, quiet room inside the hospital premises. The participants were encouraged to phonate at a comfortable pitch and loudness level. All acoustic samples were directly recorded on a password-protected laptop using a USB Condenser microphone (Samson C03U USB multi-pattern condenser microphone) at a constant distance from the lips (15 cm). The SFS/WASP Version 1.41 software for recording was used (Speech Filing System, SFS © 2007 Mark Huckvale, University College London).

Acoustic analysis procedures

We investigated objective changes by means of acoustic analysis of the voice recordings. Digital processing of the acoustic signal was accomplished using the Speech Filing System (SFS, version 4.10 for Windows). SFS is a software tool for signal processing, synthesis, and recognition. It performs operations such as acquisition, replay, display and labelling, spectrographic and formant analysis, and fundamental frequency estimation. We processed our voice samples in order to measure the average acoustic energy in dB in different bandwidths pre- and postoperatively. To do that, we first normalized the overall power (energy) of the recording and then computed an average power spectrum (frequency–amplitude plot) over voiced regions using a third-octave filterbank. Third-octave banks have been internationally standardized for use in audio analysis. We then calculated the mean energy in those channels over frequency. It was anticipated that there would be more acoustic energy in postoperative samples as nasal obstruction is corrected. The specific steps followed in our analysis are outlined below:
1. The sampling rate was changed to 22,050 Hz.
2. The level of recording was changed from relative to absolute level of –20 dB. Normalizing the level to –20 dB was done to make the different recordings equal in terms of level.
3. Fundamental frequency tracks (voiced regions) were selected. This was to allow analysis only of the voiced segments of the recorded samples and not gaps or silences.
4. The sound file was then put through a filterbank of 20 third-octave filters. The bandwidths and centre frequencies of the 20 channels are seen in Table I.
5. The sound file was digitally analysed with the appropriate function to obtain the average energy in dB in a third-octave filterbank (average total acoustic energy).

**Analysis of patient perception**

Our participants were asked to fill in a questionnaire, which was designed for the study (see Supplementary material to be found online at http://informahealthcare.com/doi/abs/10.3109/14015439.2015.1007160, for which further validity work is in progress). The questions focus specifically on perception of resonance and throat symptoms related to nasal obstruction, which are frequently reported by the patients. We feel, however, that they are rarely addressed in the existing questionnaires. We have also selected items from the Voice Activity and Participation Profile (VAPP) (12), in order to detect the impact of hypo- nasality on emotional, social, and professional level.

We included 13 questions. Questions 1–7 mainly focus on symptoms related to nasal obstruction, whereas questions 8–13 deal with socio-economic impact and emotions. The participants were asked to rate the severity of their symptoms on a five-item Likert scale (never–rarely–sometimes–often–always). Questionnaire responses were obtained pre- and post-operatively in the study group to check for differences and also on two similarly spaced intervals in the control group to check for internal validity. Answers to the nasality questionnaire were assigned a number from 0 (‘never’) to 4 (‘always’).

**Statistical analysis**

SPSS 19.0 for Windows was used for statistical analysis. Data were treated accordingly for statistical analysis.

Differences between groups on age, gender, and outcome variables at each time point were examined using univariate ANOVAs for continuous measures and chi-square analyses (with Cramer’s V) for categorical data. If the homogeneity of variance assumption was violated, the Brown–Forsythe test was utilized. Change scores, in acoustic and perceptual outcomes, were also examined to see if they differed between the two groups. Additional single sample t tests were conducted to see if the mean change scores from pre to post operation were significantly different from zero for each group.

**Results**

A total of 34 participants were successfully recruited to this pilot study; 15 belonged to the surgical group and 19 to the healthy control group. There were 14 females and 20 males, with significantly more males in the study group than in the controls (chi-square = 0.4970, df = 1, P = 0.026, Cramer’s V = 0.382). The mean age of the participants was 38.32 years, standard deviation 10.4 (range 23–65 years), with similar ages in the study and health controls (F (1, 32) = 0.808, P = 0.375).

**Questionnaire responses and patient perception of resonance**

**Preoperative group differences.** One-way ANOVA testing across groups preoperatively showed significant differences in questionnaire responses on items related to nasal resonance (Table II). Patients with septal deviation perceived that their voice sounded as if they had a blocked nose (P < 0.001) and as though the sound was coming through their nose (P = 0.045) significantly more often than their con-
control counterparts. They also reported significantly more symptoms of phlegm \((P < 0.001)\) and throat dryness \((P = 0.022)\). Questions dealing with emotion and socio-economic handicap did not show significant group differences.

**Postoperative group differences.** Scores between the groups postoperatively only exhibited statistically significant differences on two outcomes, with the surgical group still reporting that their voice sounded as if they had a blocked nose \((P = 0.001)\) and as though it was coming through their nose \((P = 0.017)\) significantly more often than the controls (Table III).

**Change scores.** Analysis showed that the study group had significantly \((P < 0.001)\) greater change on phlegm scores (reduction in phlegm) compared to the healthy control group. Closer examination of change score within groups show that while the healthy controls did not show changes significant from zero in any of the measures, the study group showed significant changes from zero on scores related to dry throat \((P = 0.028)\) and phlegm \((P < 0.001)\). A large number of our patients (46.7%) felt that their voice had changed after surgery, and the vast majority of those (87.5%) thought that this change was positive (Figures 1 and 2).

**Acoustic data**

Analysis of the difference between the pre- and postoperative average total acoustic energy (ATAE) for each subject for the two groups showed that this significantly increased postoperatively for the study group (Table IV). Examination of change scores also showed that there was a significant increase in total energy within the study group at second testing, whereas it was close to zero for the control group (Table V).

**Discussion**

Nasality is not an easy concept to quantify, and this has been recognized for over 50 years (13). Curtis in his pioneering presentation emphasizes that nasal resonance is not independent of the remainder of the vocal tract. In fact nasal resonance is the product of a combination of events, i.e. velum lowering which controls the coupling between the vocal tract and the nasal tract, anatomy of the nasal passages, and side branching of the sound to the paranasal sinuses (14). Fujimura and Lindqvist tried to study the spectral characteristics of these components separately by exciting the vocal tract through an external sweep.

---

**Table II. Means, SDs, and differences in responses to nasality questionnaire at first testing.**

| Item                                                                 | Time 1 mean | Effect for group (not controlling for age and gender) |
|----------------------------------------------------------------------|-------------|------------------------------------------------------|
| Study group | Healthy group | \(F\) | \(df\) | \(P\)  |
| 1 Do you think that when you speak it sounds like you have a blocked nose? | 2.000 | 0.316 | 31.564 | 1 | 32 | 0.000 |
| 2 Do you think that when you speak it sounds like a lot of sound is coming through your nose? | 1.267 | 0.526 | 4.367 | 1 | 32 | 0.045 |
| 3 Does your voice get tired during the day? | 0.733 | 0.737 | 0.000 | 1 | 32 | 0.993 |
| 4 Do you have a dry throat? | 1.533 | 0.737 | 5.785 | 1 | 32 | 0.022 |
| 5 Do you have tickling in your throat? | 1.000 | 0.632 | 1.491 | 1 | 32 | 0.231 |
| 6 Do you have phlegm? | 1.800 | 0.526 | 22.739 | 1 | 32 | 0.000 |
| 7 Do you find it uncomfortable to speak for a prolonged period of time? | 0.800 | 0.632 | 0.307 | 1 | 32 | 0.584 |
| 8 Do people have difficulty in understanding you because of your voice? | 0.600 | 0.263 | 2.697 | 1 | 32 | 0.110 |
| 9 Is your job affected by your voice? | 0.400 | 0.421 | 0.004 | 1 | 32 | 0.952 |
| 10 Does your voice affect you in social activities? | 0.667 | 0.211 | 3.018 | 1 | 32 | 0.092 |
| 11 Is your family, friends, or co-workers annoyed by your voice? | 0.267 | 0.105 | 0.907 | 1 | 20.153 | 0.352 |
| 12 Are you worried about your voice? | 0.200 | 0.211 | 0.004 | 1 | 32 | 0.950 |
| 13 Do you feel dissatisfied because of your voice? | 0.200 | 0.263 | 0.106 | 1 | 32 | 0.747 |

\*Brown–Forsythe F test.

Bold entries indicate the statistically significant scores.
tone signal (15). Most researchers have attempted to quantify acoustic changes by using spectrographic analysis. The first attempt to evaluate the impact of nasal airway surgery on speech seems to be by Chen and Metson (1). For their spectral analysis they make use of the value (A1–p1n), previously developed by Chen (1997) as an acoustic correlate of nasality (16). They rate A1 the amplitude of the first formant F1 on the spectrum of a nasal consonant, whereas p1 is the amplitude of a nasal peak at approximately 1 kHz. Behrman, Shikowitz, and Dailey used the same ‘relative formant amplitudes’ as above but on a larger group of 44 patients (2), whereas Hosemann et al. looked into the influence of endoscopic sinus surgery on voice quality concentrating on changes in centre frequency or bandwidth of the first four formants of nasalized vowels [aː], [iː], and [uː], as well as variations in formant frequencies and amplitudes (3). All the above studies concluded that postoperative changes in spectrographic measures were either accidental or insignificant. Other researchers have avoided the complexity of spectrographic analysis and employed different means in order to detect changes in nasal acoustic energy after surgery, such as the nasometer, a device that measures nasalance scores (17–19).

In our study we attempted to quantify nasality by measuring average total acoustic energy during the production of the nasal consonant /m/. Formant frequencies during vowel production do not usually reflect acoustic changes within the nasal resonating chamber. There is, however, evidence that there is sometimes transnasal airflow during certain vowels. Many professional operatic singers sing the vowel /a/ with a velopharyngeal opening as shown by the existence of nasal airflow at least at some pitches (20). To our knowledge this is the first study that attempts acoustic analysis by calculating total acoustic energy during production of a nasal consonant and does not concentrate on formant frequencies of vowels or ‘nasal’ vowels. Our results show that indeed average nasal acoustic energy did increase after correcting septal deviation (Tables III and IV). It might be argued that changes were noticed because a patient simply phonated with increased vocal effort (i.e. pitch and loudness). However, all recordings were done in the same way, under the same conditions as a means to control different vocal effort (frequency and intensity). We measured

Table III. Means and differences in responses to nasality questionnaire at second testing.

| Item | Study group | Healthy group | ANOVA effect for group (not controlling for time 1, age, or gender) |
|------|-------------|---------------|-------------------------------------------------|
| 1 Do you think that when you speak it sounds like you have a blocked nose? | 1.333 | 0.421 | 13.983 1 32 0.001 |
| 2 Do you think that when you speak it sounds like a lot of sound is coming through your nose? | 1.067 | 0.421 | 6.365 1 32 0.017 |
| 3 Does your voice get tired during the day? | 0.467 | 0.526 | 0.052 1 32 0.822 |
| 4 Do you have a dry throat? | 1.133 | 0.632 | 2.399 1 32 0.131 |
| 5 Do you have tickling in your throat? | 1.067 | 0.474 | 2.978 1 32 0.094 |
| 6 Do you have phlegm? | 0.933 | 0.579 | 1.918 1 32 0.176 |
| 7 Do you find it uncomfortable to speak for a prolonged period of time? | 0.400 | 0.421 | 0.008 1 32 0.928 |
| 8 Do people have difficulty in understanding you because of your voice? | 0.667 | 0.211 | 3.018 1 32 0.092 |
| 9 Is your job affected by your voice? | 0.467 | 0.421 | 0.016 1 32 0.899 |
| 10 Does your voice affect you in social activities? | 0.667 | 0.316 | 0.932 1 32 0.342 |
| 11 Is your family, friends, or co-workers annoyed by your voice?* | 0.400 | 0.105 | 2.046 1 17.213 0.209 |
| 12 Are you worried about your voice?* | 0.333 | 0.158 | 1.050 1 21.888 0.343 |
| 13 Do you feel dissatisfied because of your voice?* | 0.400 | 0.263 | 0.378 1 32 0.543 |

*Brown–Forsythe F test.
Bold entries indicate the statistically significant scores.
Table IV. Examination if mean differences significantly differ from between groups (indicates significant change, reduction in phlegm in the study group, and significant increase in average total acoustic energy (ATAE) in dB for the study group).

| Item                                                                 | Mean change in scores | ANOVA effect for group (not controlling for time 1, age, or gender) |
|----------------------------------------------------------------------|-----------------------|---------------------------------------------------------------------|
|                                                                      | Study group           | Healthy group            | F     | df | P      |
| 1. Do you think that when you speak it sounds like you have a blocked nose? | -0.667 -0.105         |                        | 4.112  1 | 15.052 | 0.061 |
| 2. Do you think that when you speak it sounds like a lot of sound is coming through your nose? | -0.200 -0.105         |                        | 0.063  1 | 32  | 0.803 |
| 3. Does your voice get tired during the day?                        | -0.267 -0.211         |                        | 0.038  1 | 32  | 0.846 |
| 4. Do you have a dry throat?                                       | -0.400 -0.105         |                        | 1.202  1 | 32  | 0.281 |
| 5. Do you have tickling in your throat?                            | 0.067 -0.158          |                        | 0.493  1 | 32  | 0.488 |
| 6. Do you have phlegm?                                             | -0.867 0.053          |                        | 26.114 1 | 32  | 0.000 |
| 7. Do you find it uncomfortable to speak for a prolonged period of time? | -0.400 -0.211         |                        | 0.464 1 | 32  | 0.501 |
| 8. Do people have difficulty in understanding you because of your voice? | 0.067 -0.053          |                        | 0.649  1 | 32  | 0.426 |
| 9. Is your job affected by your voice?                              | 0.067 0.000           |                        | 0.242  1 | 32  | 0.626 |
| 10. Does your voice affect you in social activities?                | 0.000 0.105           |                        | 0.107  1 | 32  | 0.746 |
| 11. Is your family, friends or co-workers annoyed by your voice?    | 0.133 0.000           |                        | 1.277  1 | 32  | 0.267 |
| 12. Are you worried about your voice?                               | 0.133 -0.053          |                        | 1.150  1 | 16.850 | 0.299 |
| 13. Do you feel dissatisfied because of your voice?                 | 0.200 0.000           |                        | 1.101  1 | 19.335 | 0.307 |
| Average total acoustic energy (dB) (ATAE)                          | 2.705 0.513           |                        | 4.455  1 | 32  | 0.043 |

*Brown–Forsythe F test.
Bold entries indicate the statistically significant scores.

Differences in the overall energy pre- and postoperatively, and, as there is a consistent pattern across speakers, this is probably due to surgery. It would seem unlikely that all speakersphonated more loudly the second time. An extensive literature review has identified only four studies assessing acoustic features of resonance after septal surgery (4–7). In the first study (4) the researchers employed a variety of measurements; namely acoustic analysis with the Multi Dimensional Voice Program (MDVP), anterior rhinomanometry, nasalance based on the mirror-fogging test, and Voice Handicap Index (VHI) scores (21). For their acoustic analysis, the authors calculated fundamental frequency F0, jitter, shimmer, noise-to-harmonics ratio, voice turbulence index (VTI), soft phonation index (SPI), degree of voicelassness (DUV), degree of voice breaks (DVB), and peak amplitude variation (vAm). They report impressive and significant changes in all the above parameters. The authors claim that analysis with their model allows for a distinction between contributions of the supraglottic resonator. However, most of the parameters they measured (F0, Jitt, Shimm, VTI, SPI, DUV, DVB) are actually the effect of those portions of the vocal tract at laryngeal and supralaryngeal level, and there is no solid theoretical rationale why they would be affected by changes in nasal resonance. In the study by Celik et al. (5) the study group comprised patients who underwent septorhinoplasty with spreader grafts. Acoustic analysis of formant frequencies of nasализed vowels did not show changes that reached a statistically significant level, and the authors conclude that formant frequency does not seem to identify nasalance properly. Similar methodology and results are reported by Ozbal Koc et al. (6), whereas none of these two studies employed a control group. Kim et al. (7) recruited patients who underwent septorhinoplasty, endoscopic sinus surgery, or both, and performed acoustic analysis of nasализed vowels as well as nasalance measurements. Again regarding acoustic analysis no observed parameters showed statistically significant changes.

Regarding patient perception, a considerable number of our patients felt, upon direct questioning, that their resonance had changed for the better (Figures 1 and 2). However, statistical analysis of the questionnaire items related to perceived nasality did not show a significant change (questions 1 and 2). The discrepancy may be explained by the small sample size of our study. Repeat measurements were performed at four weeks postoperatively, and there might have been some residual nasal oedema. We feel in retrospect that it would have been beneficial to perform a further review three months postoperatively, which may have shown further benefit. It is of note that our participants reported a significant decrease in the presence of phlegm and dry throat, with both these features affecting vocal resonance. The reported decrease in phlegm and throat dryness is probably due to the establishment of improved nasal breathing after the operation. Question number 7 (‘Do you find it uncomfortable to speak for a prolonged period of time’) just missed significance.
### Table V. Examination if mean differences significantly differ from zero for each group. This table shows there were changes for the study group in dry throat, phlegm, and average total acoustic energy (ATAE) in dB; almost significant for Q7 (uncomfortable at prolonged speech); but nothing near significance for the healthy group.

| Study group       | Mean change | Standard deviation (SD) change | Mean | SD          | T    | df | Sig. |
|-------------------|-------------|--------------------------------|------|-------------|------|----|------|
| Healthy group     |             |                                 |      |             |      |    |      |
| 1. Do you think that when you speak it sounds like you have a blocked nose? | 0.667 | 1.447 | -1.764 | 14 | 0.096 | 0.105 | 0.315 | 1.455 | 18 | 0.163 |
| 2. Do you think that when you speak it sounds like a lot of sound is coming through your nose? | 0.200 | 1.320 | -0.622 | 14 | 0.567 | 0.105 | 0.160 | 0.075 | 1.314 | 18 | 0.194 |
| 3. Does your voice get tired during the day? | 0.587 | 1.260 | -0.311 | 14 | 0.364 | 0.105 | 0.160 | 0.075 | 1.714 | 18 | 0.087 |
| 4. Do you have a dry throat? | 0.867 | 1.110 | -0.105 | 14 | 0.567 | 0.105 | 0.160 | 0.075 | 1.314 | 18 | 0.194 |
| 5. Do you have tickling in your throat? | 0.939 | 1.110 | -0.353 | 14 | 0.364 | 0.105 | 0.160 | 0.075 | 1.714 | 18 | 0.087 |
| 6. Do you have phlegm? | 2.449 | 1.260 | -0.200 | 14 | 0.364 | 0.105 | 0.160 | 0.075 | 1.314 | 18 | 0.194 |
| 7. Do you find it uncomfortable to speak for a prolonged period of time? | 0.900 | 1.073 | -0.105 | 14 | 0.567 | 0.105 | 0.160 | 0.075 | 1.714 | 18 | 0.087 |
| 8. Do people have difficulty in understanding you because of your voice? | 0.053 | 1.000 | -0.353 | 14 | 0.364 | 0.105 | 0.160 | 0.075 | 1.714 | 18 | 0.087 |
| 9. Is your job affected by your voice? | 0.053 | 1.000 | -0.353 | 14 | 0.364 | 0.105 | 0.160 | 0.075 | 1.714 | 18 | 0.087 |
| 10. Does your voice affect you in social activities? | 0.053 | 1.000 | -0.353 | 14 | 0.364 | 0.105 | 0.160 | 0.075 | 1.714 | 18 | 0.087 |
| 11. Are your family, friends, or coworkers annoyed by your voice? | 0.053 | 1.000 | -0.353 | 14 | 0.364 | 0.105 | 0.160 | 0.075 | 1.714 | 18 | 0.087 |
| 12. Do you feel dissatisfied because of your voice? | 0.053 | 1.000 | -0.353 | 14 | 0.364 | 0.105 | 0.160 | 0.075 | 1.714 | 18 | 0.087 |
| 13. Do you have a more hydrated throat? | 0.587 | 1.110 | -0.105 | 14 | 0.160 | 0.160 | 0.160 | 0.160 | 1.000 | 18 | 0.105 |
| Average total acoustic energy (ATAE) (dB) | 0.524 | 1.000 | -0.211 | 14 | 0.364 | 0.105 | 0.160 | 0.075 | 1.714 | 18 | 0.087 |

*Bold entries indicate the statistically significant scores.*

### Study limitations

This study is a pilot study, therefore has certain limitations, such as the small sample size. A further study with a larger group, thus greater power, is planned in the future. We also utilized a non-validated questionnaire, which we aim to validate on a larger sample. One area not considered in this work was whether nasal obstruction objectively improved after septoplasty. We therefore relied on patient perception only to establish whether the operation was successful or not. All our patients reported satisfaction with the operative outcome. With hindsight it may have been better to include an objective measurement of nasal patency and/or resistance such as rhinomanometry or acoustic rhinometry. It would be very interesting to correlate changes in nasal volumes or resistance with spectrographic changes. This project could be expanded in the future to include such measurements.

### Conclusions

Hyponasality is a distinct vocal feature and the perceptual correlate of a blocked nose. When nasal obstruction is due to a deviated septum, then septoplasty is the treatment of choice. Patients frequently report that their voice sounds different after this procedure, i.e. less hyponasal. We wanted to investigate whether septoplasty causes measurable changes in vocal resonance or timbre. Potential postoperative modulations in one’s voice are significant to professional voice users and will certainly influence their decision to undergo surgery.

In this study it has been demonstrated that surgical correction of septal deviation results in significant spectrographic changes. In particular it can result in...
an increase in the average total acoustic energy during the production of the nasal consonant /m/. Our study failed to show significant change in patient perception postoperatively. However, a considerable number of our patients reported change in their vocal resonance for the better, and there was a statistically significant decrease in reports of phlegm and throat dryness. As with previous studies, we conclude that nasal resonance is difficult to quantify.

Acknowledgements

We are grateful to Dr Mark Huckvale, Senior Lecturer in Speech Sciences, Phonetics and Linguistics, University College London, for his invaluable contribution to the acoustic analysis of the voice samples.

Declaration of interest: The authors report no declaration of interest.

References

1. Chen MY, Metson R. Effects of sinus surgery on speech. Arch Otolaryngol Head Neck Surg. 1997;123:845–52.
2. Behrman A, Shikowitz MJ, Dailey S. The effect of upper airway surgery on voice. Otolaryngol Head Neck Surg. 2002;127:36–42.
3. Hosemann W, Gode U, Dunker JE, Eysholdt U. Influence of endoscopic sinus surgery on voice quality. Eur Arch Otorhinolaryngol. 1998;255:499–503.
4. Mora R, Jankowska B, Dellepiane M, Mora F, Crippa B, Salami A. Acoustic features of voice after septoplasty. Med Sci Monit. 2009;15:CR269–73.
5. Celik O, Boyaci Z, Yelken K, Atespere A, Celebi S, Koca O. Septorhinoplasty with spreader grafts enhances perceived voice quality without affecting acoustic characteristics. J Voice. 2012;26:493–5.
6. Ozbal Koc EA, Koc B, Erkan I, Kocak I, Tadihan E, Turgut S. Effects of septoplasty on speech and voice. J Voice. 2014;28:393.e11–5.
7. Kim YH, Lee SH, Park CW, Cho JH. Nasalance change after sinonasal surgery: analysis of voice after septoturbinateplasty and endoscopic sinus surgery. Am J Rhinol Allergy. 2013;27:67–70.
8. Stewart MG, Smith TL, Weaver EM, Witsell DL, Yueh B, Hanley MT, et al. Outcomes after nasal septoplasty: results from the Nasal Obstruction Septoplasty Effectiveness (NOSE) study. Otolaryngol Head Neck Surg. 2004;130:283–90.
9. Pirila T, Tikanto J. Unilateral and bilateral effects of nasal septum surgery demonstrated with acoustic rhinometry, rhinomanometry, and subjective assessment. Am J Rhinol. 2001;15:127–33.
10. Broms P, Jonson B, Malm L. Rhinomanometry. IV. A pre- and postoperative evaluation in functional septoplasty. Acta Otolaryngol. 1982;94:523–9.
11. Sipila J, Suonpaa J. A prospective study using rhinomanometry and patient clinical satisfaction to determine if objective measurements of nasal airway resistance can improve the quality of septoplasty. Eur Arch Otorhinolaryngol. 1997;254:387–90.
12. Ma EP, Yiu EM. Voice activity and participation profile: assessing the impact of voice disorders on daily activities. J Speech Lang Hear Res. 2001;44:511–24.
13. Fant G. Acoustic theory of speech production. The Hague: Mouton; 1960. p. 47–61.
14. Curtis JE. The acoustics of nasalized speech. Cleft Palate Journal 1970;7:480–96.
15. Fujimura O, Lindqvist J. Sweep tone measurements of vocal-tract characteristics. J Acoust Soc Am. 1971;49:541–58.
16. Chen MY. Acoustic correlates of English and French nasalized vowels. J Acoust Soc Am. 1997;102:2360–70.
17. Hong KH, Kwon SH, Jung SS. The assessment of nasality with a nasometer and sound spectrography in patients with nasal polyposis. Otolaryngol Head Neck Surg. 1997;117:343–8.
18. Soneghet R, Santos RP, Behlau M, Habermann W, Friedrich G, Stammberger H. Nasalance changes after functional endoscopic sinus surgery. J Voice. 2002;16:392–7.
19. Jiang RS, Huang HT. Changes in nasal resonance after functional endoscopic sinus surgery. Am J Rhinol. 2006;20:432–7.
20. Birch P, Gummes B, Stavad H, Prytz S, Bjorkner E, Sundberg J. Velum behavior in professional classic operatic singing. J Voice. 2002;16:61–71.
21. Jacobson B, Johnson A, Grywalski C, Silberglied A, Jacobson G, Benninger M, Newman C. The Voice Handicap Index (VHI): development and validation. Am J Speech Lang Pathol. 1997;6:66–70.
22. Sivansakar M, Fisher KV. Oral breathing increases Pth and vocal effort by superficial drying of vocal fold mucosa. J Voice. 2002;16:172–81.

Supplementary material available online

Supplementary Questionnaires to be found online at http://informahealthcare.com/doi/abs/10.3109/14015439.2015.1007160.