Effect of Septoplasty on Cepstral Analysis of Voice

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Received: 6 April 2015 / Accepted: 16 May 2015 / Published online: 29 May 2015
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Abstract Resonance change is a common clinical symptom in individuals with deviated nasal septum. Often this anatomical deficit is surgically treated by septoplasty. Therefore monitoring resonance changes using acoustical tools is vital. Hence, the study investigated cepstral measure differences in subjects with deviated nasal septum compared to normals. A case–control study design involving 20 subjects within 18–40 years divided into Group I of 10 subjects with deviated nasal septum (DNS) and Group II of 10 normal subjects participated. All the subjects sustained nasalized vowel /ã/ at 10 cm mouth–microphone distance for minimum of 5 seconds. For Group I, voice sample was recorded in 2 conditions, 2 days pre-septoplasty and 1 month post-septoplasty. Cepstral peak prominence (CPP) and smooth cepstral peak prominence (CPPS) values were extracted using the Hillenbrand algorithm. Mean values revealed increased CPP and CPPS measure post-septoplasty when compared to pre-septoplasty. ANOVA showed statistically significant difference only for CPPS at $p = 0.00$. The higher cepstral values of post-septoplasty is due to widened nasal passage that leads to increased nasal volume, decreased acoustic damping and increased nasal patency. These changes in supraglottic chambers will result in a better acoustic space for good resonance. However, the CPPS values were not similar to normal subjects because of

scarring or incomplete recovery of the outer mucosal layer of the nasal tract. Thus, we can conclude that cepstral analysis is a sensitive tool to detect resonance changes in the nasal patency.

Keywords Cepstral analysis · Deviated nasal septum · Septoplasty · Voice

Introduction

Nasal cavity is a mucosal lined supra-glottic structure that is divided by the nasal septum. Many a time nasal obstruction is caused commonly due to DNS. This medical condition has a negative consequence on the nasal patency by decreasing the transfer action of nasal sounds in the nasal tract [1]. Nasal obstructions as a consequence of severe septum deviations also lead to chronic sinusitis, otitis media, pharyngitis and vestibular dysfunction [2]. Generally, the first line of treatment for nasal obstruction involves prescription of decongestants. Contrastingly in cases with anatomical deficits like DNS, it is straightened by septoplasty [3]. This minor surgical procedure is performed to widen the nasal passage, which in turn alters the resonance characteristics of the vocal tract [4]. These changes highlight the importance of monitoring resonance changes in individuals with DNS.

According to classical resonance theory of hearing, our human ear performs a Fourier analysis to all the incoming sounds, and it tunes to the frequency corresponding to the incoming sounds frequency [5]. This suggests that a powerful acoustical analysis of an individual's voice should be able to mimic its spectral properties. Considering this viewpoint, literature suggests that acoustic analysis programs have the potential to quantify and compare transfer

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action of the vocal tract [6]. Few of the acoustic programs sensitive to capture transfer action are formant frequency [7], amplitude difference [8] and voice low tone to high tone ratio [9].

Over the years few of the acoustical tools have been used by researchers with the focus of monitoring resonance changes before and after septoplasty. One such acoustical study was conducted on 20 adults diagnosed with DNS. The authors reported significant improvement in fundamental frequency, amplitude perturbation and frequency perturbation measures after 1 month of recovery from septoplasty [7]. Similarly, Konior and colleagues reported that post-septoplasty there was increased nasal airflow and enhanced perceptual quality of the voice for/n/phoneme [10]. These evidences collectively support there are changes in resonance after surgical management. But the main drawback of these routinely used time based measures are that it relies on voice production to be periodic in nature, whereas in fact abnormal voices are produced aperiodically [11]. Hence, in dysphonic voices the reliability of these measures is questionable [12–14]. Therefore, in order to cutback these limitations, a new tool named cepstral analysis was proposed.

Cepstrum is an acoustical tool that performs a Fast Fourier transform (FFT) on the spectrum of the speech signal. In addition, cepstral tool performs acoustical analysis without depending upon changes in fundamental frequency [11]. Therefore, it has the potential to accurately note and quantify harmonic organization of voice [15]. A normal voice is characterized with a good harmonic organization whereas vocal pathology cases consist of poor harmonics [16]. Based on this viewpoint, experimental evidences suggest cepstral measure to successfully predict several voice dysfunctions [17–19]. Therefore in our study we hypothesise that, in individuals with DNS who undergo septoplasty cepstral measure can provide a better picture of the resonance characteristics by an increase in the values of the cepstral measures after the surgery. On the continuum, cepstral analysis tool was not previously used to monitor resonance changes and there is scarcity of evidence reporting the use of cepstral analysis to quantify resonance changes before and after septoplasty. Hence, the present study was undertaken to observe cepstral measure differences in individuals with DNS before and after septoplasty.

Method

For the study a case–control study design was adopted. Total of 20 subjects within the age range of 18–40 years participated in the study. They were divided into two

groups. Group I consisted of 10 subjects (mean age of 27.2 years) diagnosed with DNS and Group II consisted of 10 gender matched normal subjects (mean age of 29.4 years). The subjects were included in Group I only if anterior rhinoscopic examination performed by an Otorhinolaryngologist with minimum of 5 years of experience showed DNS. Assessment and treatment on all the subjects was performed by the same Oto-rhinolaryngologist, pre-operatively and post-operatively. None of the subjects were under any decongestant or medical treatment during the course of the study. Subjects with history of smoking, alcohol consumption, vocal abuse, recurrent laryngitis were excluded from the study. Medical history of the subjects did not report any neurological problems or surgery done to the oro-pharyngeal apparatus. Further, subjects who signed the Informed Consent Form were only included.

The speech samples were recorded in Speech Science Laboratory of a hospital setup. A dynamic microphone was held at maximum of 15 cm mouth to microphone distance throughout the voice recording. This was fed directly into Speech Tool 1.65 software digitally at 44 KHz sampling rate. Hillenbrand algorithm was applied to the speech samples at 150 frames averaging window size and 10 bins size of the averaging window to extract the cepstral parameters. The subjects were seated upright in their comfortable position in a relatively low noise environment. All the subjects were instructed to sustain nasalized vowel /ã/ for a minimum duration of 5 seconds at their comfortable pitch and loudness level across two trials. The task was modelled to all the subjects and repeated whenever necessary. For Group I subjects, the phonation sample was recorded in two conditions, 2 days before the subject underwent septoplasty (pre-operative) and after 1 month recovery from surgery (post-operative). The criteria for the recording the voice samples before and after septoplasty was based on previous investigations cited in literature [7]. Among the samples recorded, only the middle stable segment of minimum 5 seconds was subjected to further acoustical analysis. The voice spectra were derived using FFT to convert the signal from time domain to frequency domain. This spectrum was once again subjected to another series of FFT to obtain a cepstrum. Following this, two parameters were calculated, CPP and CPPS. Each recording session lasted for 5 minutes.

Total of 30 tokens [(10 subjects $\times$ 1 phonation $\times$ 1 condition) + (10 subjects $\times$ 1 phonation $\times$ 2 conditions)] was collected and subjected to further statistical analysis. The results were tabulated and calculated for mean and standard deviation. ANOVA was performed to observe for any statistical difference using SPSS (Version 17).

Results

Post surgically none of the subjects had oozing of blood from nose or had any other medical complication during the recordings. No subject reported of any pain in the surgically treated area. Descriptive statistics revealed that there was improvement in both CPP and CPPS measures post-septoplasty in comparison to pre-septoplasty condition, as seen in Table 1. Hence, the results established in the study thereby prove our hypothesis of increased cepstral measures after septoplasty treatment (Figs. 1, 2).

It is evident from Table 1 that the values obtained for CPP measure post-septoplasty was similar to the value obtained by normal subjects. Contrastingly, in the second parameter of CPPS measures, values were not at par with that of the normal subjects. ANOVA results reviewed statistically significant difference only for CPPS parameter [F (11.667) df = 2; $p = 0.000$]. However no significant difference was noted for CPP parameter [F (1.169) df = 2; $p = 0.324$]. Post-hoc analysis was performed using Bonferroni test, on which results was indicative of no significant difference at 95 % confidence level. Figure 3 represents CPPS waveform extracted from the voice samples of the subjects. It is very clear from Fig. 3 that reduced amplitude waveform with limited number of peaks are of pre-septoplasty condition, which concludes to have decreased harmonic organization. On the other hand, results of post-septoplasty reveal enhanced amplitude with multiple peaks, indicating better resonance therefore having a better degree of harmonic organization. However, the waveform is not prominently smooth with higher amplitude as observed and depicted for normal subjects.

Discussion

The changes noted in cepstral parameters are attributed to the structural changes resulting from septoplasty. Studies quote presence of increased nasal resistance at the region of upper lateral cartilage and nasal septum [7]. Hence a good surgical procedure, like septoplasty, must be able to cut back the increased nasal resistance that is caused by the nasal obstruction. Supporting this view in the present study, post operatively the structural changes would have resulted

Table 1 Descriptive statistics of CPP and CPPS measures across normal, pre-septoplasty and post-septoplasty conditions

	Normal	Septoplasty	
		Pre-operative	Post-operative
CPP	19.49 (± 1.85)	18.21 (± 2.73)	19.17 (± 1.55)
CPPS (dB)	8.86 (± 1.09)	6.91 (± 1.16)	7.44 (± 0.66)

Fig. 1 Mean and SD of CPP values across pre-septoplasty, post-septoplasty and normal subjects

Fig. 2 Mean and SD in dB of CPPS values across pre-septoplasty, post-septoplasty and normal subjects

Fig. 3 CPPS waveform extracted from /a/ phonation of pre-septoplasty, post-septoplasty and normal subjects

in decreased nasal resistance which is effectively reflected by means of increased CPP and CPPS values. It can also be said that after septoplasty has been performed there is decreased tissue surface area and widened nasal cavity. Consequently, this in turn will result in changes in the vocal tract like increased nasal volume, decreased acoustic damping and increased nasal patency, thereby providing better acoustic space for good resonance [4, 20].

The findings of the present study are in consonance with literature [7, 10]. However, the findings are contrasting

with the results obtained by researchers who did not obtain acoustical changes post-septoplasty [4, 21]. The dissonance in results is attributed to the type of surgery performed to correct the nasal septum. As each of their study subjects underwent more than one type of surgery the authors reported that they could not establish any specific relationship between the surgical procedure and acoustical changes [4, 21]. This validates the opinion and sheds light that the type of surgery can play a vital role in predicting successful voice outcomes in individuals with DNS. This however did not influence our study results as all the subjects underwent one type of surgical procedure. Furthermore, several authors strongly point to quantify the subjects symptoms using objective measures, as there exists a large discrepancy using subjective measures [22]. Acoustic techniques using vocalizations or phonation tasks offer very good scope clinically, as little training is required to optimally record the speech samples in addition to easily obtaining repeated voice samples.

Literature on experimental evidence report DNS to be the root cause for cul-de-sac resonance [23]. Therefore the primary goal of septoplasty must converge to enhance nasal patency that can promote smooth transfer of harmonics, an important parameter of a good resonator. In addition, post surgically the para-nasal sinus has increased acoustic coupling that leads to increased amplitude of the voice [4]. Over all the surgical correction will result in an unobstructed nasal cavity, which tends to decrease the cul-de-sac resonance thereby leading to increased harmonic organization in the nasal tract. This is evidenced as increased CPP and CPPS values of the study. These views can hold more concreteness, if supported by perceptual analysis, which was not performed in the current study.

In addition, though literature suggests that traditional techniques like fundamental frequency have successfully reported to note differences before and after surgery, it does not take supra-glottic structures into account [24]. Hence, inclusion of an acoustical program, like cepstral analysis, that focuses upon harmonics observed in the supra-glottic structures can provide a better picture of the resonatory system. Also, advancement in computer technology has enabled researchers to develop algorithms that can be effectively used to readily assess resonatory system via non-invasive techniques [20]. Therefore, the study took into account of using cepstral analysis via hillenbrand algorithm available in Speech Tool software.

Despite statistically significant changes, the values obtained for CPPS measure post-surgically were not similar to that of normal subjects. This could be because of scarring or partial recovery of the outer mucosal layer of the nasal tract, which is vital for smooth transfer of acoustic energy. Since the present study performed acoustical analysis only after 1 month of follow up we do not know if the cepstral

measures would have been within normal range, perhaps if a late follow up after 3 months was also included. This would have given better picture of the concept being investigated. Poor follow up and high dropout rate prevented the study from performing acoustical analysis after 3 months. In addition, literature suggests no statistically significant change in acoustical analysis even after 3 months post-septoplasty [25]. On the continuum, literature using questionnaires evidences that individual with DNS to commonly report reduced respiratory control [26]. Having such respiratory deficit contributes to automatic changes in the laryngeal and supra-glottic resonatory system [25]. Such physiological changes are expected to have variations in the fundamental frequency which indirectly can alter the harmonics of the voice leading to decreased cepstral values [27]. However, this view cannot be fully supported as the methodology did not objectively measure respiratory or laryngeal system.

Summary and Conclusion

The present study was undertaken to note cepstral changes in individuals with DNS undergoing septoplasty. Results of descriptive statistics revealed increased CPP and CPPS values post-septoplasty comparatively. The data of higher cepstral values is due to increased nasal patency that is achieved post-septoplasty. In summary, we can conclude that cepstral analysis is a sensitive tool to successfully detect acoustic changes in the nasal patency. These measures are also useful in counselling resonance changes among professional voice users, who particularly are sensitive to voice abnormalities. Successful outcomes of different surgical techniques can also be monitored when voice analysis techniques are used aptly. Further studies are warranted considering conversational speech as the stimuli on a larger population. The statement should be also supplemented by perceptual analysis.

Conflict of interest We authors declare no conflict of interest.

Ethical Standard All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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