Spectral Characteristics and Nasalance Scores of Hypernasality in Patient with Cleft Palate

Byung-Soo Soh* · Hyo-Keun Shin · Hyun-Gi Kim*****

ABSTRACTS

Differential instrumentation for the diagnoses of individuals with Cleft palate has been used to objectively measure speech problems. The Cepstrum Method was used to study the vocal tract transfer function. The vocal tract transfer function and the source spectrum should be considered in the evaluation of nasal resonance. The aim of this study was to collect quantitative data on the acoustic Instrumentation used for evaluating hypernasality. Normal subjects (9 male, 21 female ; 37 male children, 20 female children) and individuals with VPI (13 male, 8 female; 16 male children, 9 female) participated in this study. The vowel /i/ was selected to gauge the severances of hypernasality Spectral and Cepstral studies using CSL was used to identify the acoustic characteristics. Cepstrum analysis shows significant differences in quefrency and amplitude. The quefrency of normal groups was shorter than that of the VPI groups, while the amplitude of normal groups was lower than that of the VPI groups. This may have significance in the evaluation of nasal resonance.

Keywords: VPI, Hypernasality, Cepstrum

I. Introduction

Speech problems in children with cleft palate are caused by velopharyngeal incompetence (VPI) after surgical closure of the cleft. However, VPI has been a much-debated problem in the past few decades. It is a problem of importance and topical interest not only because it touches upon a number of disciplines, but also because several particulars have yet to be clarified.

The most important factors that influence speech problems for cleft palate speakers are resonance disorders and articulation disorders. These disorders are related to the quality

* Dept. of Oral and Maxillofacial Surgery, School of Dentistry, Chonbuk National University.

** Dept. of Oral and Maxillofacial Surgery, School of Dentistry, Chonbuk National University.

*** Research Institute of Speech Science CNU.

and intelligibility of speech. After surgery, most children with cleft palate will develop normal and intelligible speech depending on their ability to achieve adequate velopharyngeal closure.

The inability to achieve velopharyngeal closure has a direct Impact on speech intelligibility and language learning. Moreover, VPI can also have indirect implications for voice disorders and hearing impairement.

Diagnoses of resonance and articulation disorders in children with cleft palate have required the understanding of oro-pharyngeal physiology. The evaluations performance of children with cleft palate can be used to examine any child's speech error patterns. It is assumed that the primary goal for the evaluation of children with cleft palate is identifying and treating the speech problems associated with VPI.

Differential instrumentation for the diagnoses of individuals with Cleft palate has been used to objectively measure speech problems.

Spectral analysis of individuals with cleft palate can also provide valuable information on speech production. Many researchers reported that spectral distortion associated with nasality is increased in the first formant and bandwidth along with a reduction in the intensity of the first formant. Other researchers also noted that the third formant widens in quantifying the spectrographic characteristics of nasality. The Cepstrum Method was used to study the vocal tract transfer function. However, the Cepstrum Method does not account for the effect that the source spectrum has on severe hypernasality, or for how the amount of pitch variation influences the degree of nasalization on synthesized vowels . Both the vocal tract transfer function and the source spectrum should be considered in the evaluation of nasal resonance.

The primary aim of this study was to collect quantitative data on the acoustic instrumentation used for evaluating hypernasality. This data can make a secondary contribution to establishing a database on speech synthesis while increasing awareness of those disabled by speech problems.

II. Method

II.1. Subjects

Normal subjects (9 male, 21 female; 37 male children, 20 female children) and individuals with VPI (13 male, 8 female; 16 male children, 9 female) participated in this study. The mean age was 24.5 (SD, 4.7) years, with a range of 19 to 37 years for adults and 11.9 (SD, 0.9) years with a range of 10 to 13 years for children. Each subject had a diagnoses of cleft palate or velopharyngeal incompetence. The mean age of the patient group was 24.2 (SD, 2.1) years with a range of 20 to 28 years for VPI adults and 11.8 (SD, 4.7) years with a range of 4 to 18 years for VPI children.

Table 1. Subjects.

	Male		Female	
	Adults	**children**	**Adults**	**Children**
Nr. sub	9	37	21	20
VPI	13	16	8	9

II.2. Speech Sample

The speech sample was composed of five simple vowels /a, e, i, o, u/ Among the five simple vowels and diphthong vowels, the vowel /i/ was selected to gauge the severeness of hypernasality. Because the high vowel /i/ is considered to be a general speech sample, it is suitable for evaluating cepstrum characteristics and nasalance. The oral construction of this vowel is appreciable even in small degrees of nasal coupling that may occur when nasal sound is transmited through the oral cavity.

II.3. Acoustic Analysis

The computer-implemented speech analysis system, CSL, was used to identify the acoustic characteristics of hypernasality. Cepstrum is the inverse spectrum calculated by taking an FFT of the log magnitude values of the original spectrum. FFT was obtained from a waveform of the target sampling rate 11025 data. A 1024 point FFT was used for data sampled at rates between 20 K and 25.6 K per second, representing a frame duration of 40 to 50 msec. The preemphasized value was 0.9 with hamming window. Cepstrum was displayed on a time axis with normalize and is set to approximately -10 dB and. 10 dB with 0.1 to 12.0 msec.

A dynamic microphone Shure SM48 was palced on approximately 19 cm from the subjects lips. Each speech sample was recorded on a Sony Tape recorder TC D-10 which stored each sampling rate 11015 on CSL.

Fig.1. shows a sample of the FFT power spectrum. A 20ms Hamming window was applied to a steady-state portion of the waveform and multiplied using the FFT Power Spectrum and Cepstrum analysis

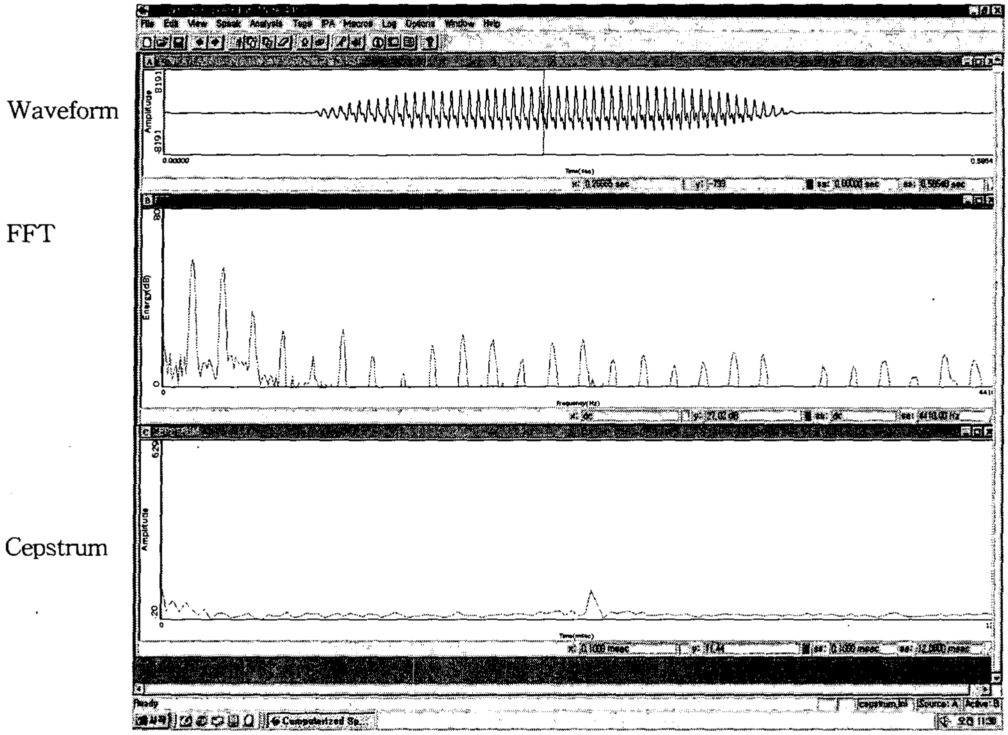

Fig. 1. FFT Power Spectrum and Cepstrum display using CSL model 4300-B

III. Results

Table 2 shows the fundamental frequency (ffo) and energy in the FFT Power Spectrum of NA males and females and VPI males and females. The fundamental frequency values of the VPI group (males: 176 Hz, SD: 60 Hz, females: 234 Hz, SD: 17 Hz) were higher than those of the NA group (males: 112 Hz, SD: 14.9 Hz, females: 210 Hz, SD: 18 Hz). The energy of vowels in the VPI group (males:47.0 dB, SD: 8.0 dB, females: 44.8 dB, SD: 6.8 dB) was also higher than that of the NA group (males: 33.5 dB, SD: 6.7 dB, females: 37.0 dB, SD: 4.0 dB)

The Quefrency of VPI group (males: 6.0 ms, SD: 1.9 ms, females: 4.1 ms, SD: 0.3 ms) was shorter than that of the NA group (males: 8.6 ms, SD: 1.0 ms, females: 4.9 ms, SD: 1.1 ms). However, the amplitude of the VPI group (males: 55.0 dB, SD: 19.0 dB, females: 51.7 dB, SD: 15.1 dB) was higher than those of the NC group (males: 51.7 dB, SD: 15.7 dB, females: 42.7 dB, SD: 17.7 dB).

Table 2. FFT Power Spectrum data and Cepstrum data in Normal group and VPI group.

	FFT				**Cepstrum**			
	ffo		**energy**		**quefrency**		**amplitude**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
m. VPI	176	60	47.0	8.0	6.0	1.9	55.0	19.0
f. VPI	234	17	44.8	6.8	4.1	0.3	51.7	15.1
m. Nr	112	14.9	33.5	6.7	8.6	1.0	51.7	15.7
f. Nr	210	18	37.0	4.0	4.9	1.1	42.7	17.7

Table 3. Vowel formant value (F1, F2, F3) in Normal group and VPI group.

	F1		F2		F3	
	Mean	SD	Mean	SD	Mean	SD
m.VPI	432	134	2646	547	3652	276
f. VPI	417	110	2289	409	3445	299
m. Nr	270	37	2106	152	3114	200
f. Nr	322	48	2670	175	3511	1936

Table 4. Formant Bandwidth (BW1, BW2, BW3) in Normal group and VPI group.

	BW1		BW2		BW3	
	Mean	SD	mean	SD	mean	SD
m.VPI	138	46	273	58	276	46
f. VPI	153	56	300	65	290	30
m. Nr	72	38	146	39	179	462
f. Nr	78	10	384	81	139	15

Table 3 shows the vowel formant (F1, F2, F3) in the NC group and the VPI group. Table 4. shows the formant bandwidth in the NC group and the VPI group.

The spectrogram (fig. 3) shows that acoustic energy of the high frequency region in the VPI group is reduced in comparison with the NC group. The formant frequency (F1, F2, F3) of the VPI group is higher than that of the NC group. The bandwidth of the VPI group is higher than that of the NC group except for the BW2 of female.

Wave form

LPC

Spect rogram

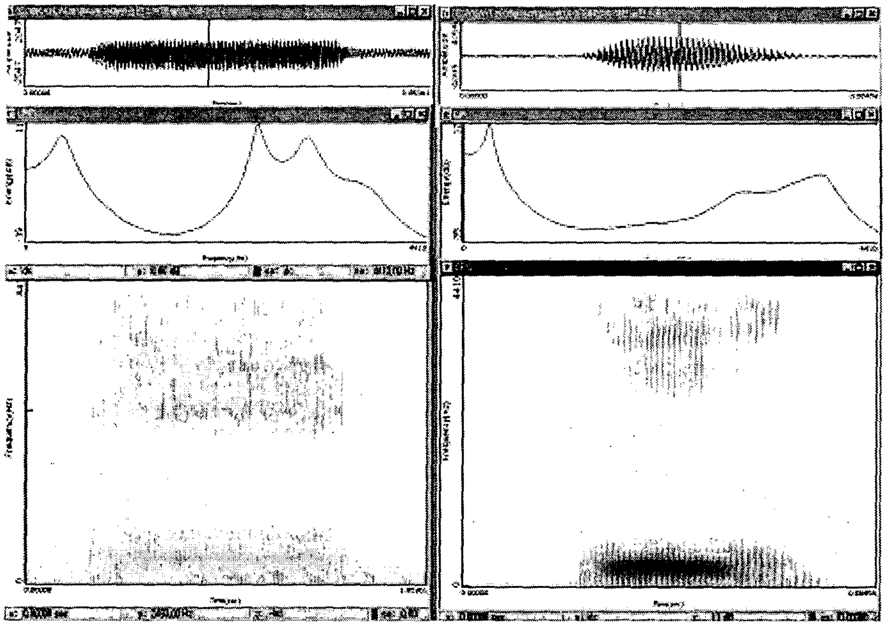

Fig. 3. Comparison of the vowel formant in the NC group with the VPI group. Left: Normal group. Right: VPI group.

IV. Discussion

The advancements of instruments have proven clinical value in evaluating velopharyngeal incompetence. Spectrography continues to play an important role in basic research and may help clinicians understand the nature of nasalized speech. However, its use as a routine clinical tool is not widespread, despite the work of many researchers which recommended the use of spectrographic analysis in evaluating speech therapy for velopharyngeal dysfunction. Moreover, acoustic correlates of nasalization appear to be a far more formidable and perhaps questionable task than was first suspected.

Spectral and Cepstral studies using computer-implemented speech analysis systems are useful in distinguishing between the speech of hypernasal and non-hypernasal people18). Particularly, Cepstrum was used to represent the vocal tract transfer function. It can show the amount of influence that pitch variation has on synthesized vowels. Both the vocal tract transfer function and the source spectrum should be considered when evaluating nasal resonance 19). Analysis of the one-third-octave power spectra showed that significant differences are found in the region of the first and second formant. This suggests that this region may have significance in the evaluation of nasality. This new approach provides an assessment of the severity of hypernasality, regardless of age, sex, or loudness level. Each one-third-octave spectrum was normalized to the amplitude and frequency of the band containing the fundamental frequency.

Fig 5 shows a FFT power spectrum and Cepstrum for a sample of normal speech and of hypernasl speech. Cepstrum showed a significant difference between the NC group and the VPI group. The Quefrency of the VPI group was shorter than that of the NC group. The amplitude of the VPI group, however, was higher than that of the NC group. A reduction in the over all intensity level of speech is characteristic of hypernasality . The first three formants of vowels for the VPI group are higher than those of the NC group 23). The first three bandwidths of vowels for the VPI group were also wider than those of the NC group.

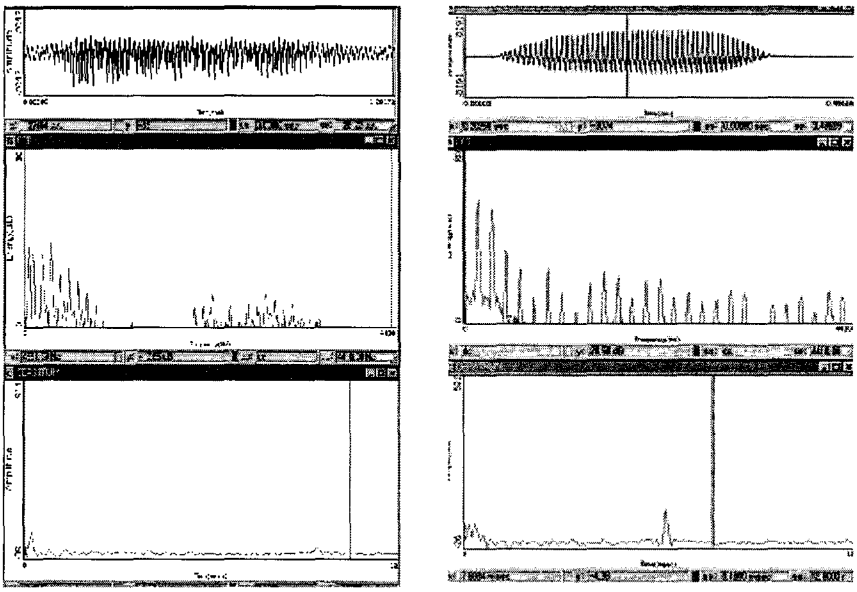

Fig. 5. FFT power spectrum and Cepstrum for a speech sample of hypernaslaity between the normal (left) and the VPI (right). Arrow shows the peak of the fundamental frequency.

These features showed that the acoustic correlates of nasalization might be appeared in spectrogram of nasalized high vowels.

V. Results

The results of this study are as follows:

1. Cepstrum analysis shows significant differences in quefrency and amplitude. The

Quefrency of normal groups was shorter than that of the VPI groups, while the amplitude of normal groups was lower than that of the VPI groups. This may have significance in the evaluation of nasal resonance.

2. The first three formant frequencies of the VPI groups are higher than those of the NC groups and the first three formant bandwidths of the VPI groups are wider than those of the NC group.

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received: January 30, 2005
accepted: February 30, 2005

▲ Byung-Soo, Soh D.D.S., Ph.D.
Dept. of Oral and Maxillofacial Surgery,
School of Dentistry, Research Institute of Speech Science
Chonbuk National. University.
Dukji-Gu Keumam-dong San 560-756, Jeonju city
Tel: +82-63-270-2113

▲ Hyo-Keun Shin. D.D.S., Ph.D.
Dept. of Oral and Maxillofacial Surgery,
School of Dentistry, Research Institute of Speech Science
Chonbuk National. University.
Dukji-Gu Keumam-dong San 560-756, Jeonju city
Tel: +82-63-270-2014
E-mail: hkshin@chonbuk.ac.kr

▲ Hyun-Gi Kim
Research Institute of Speech Science
Chonbuk Natl. University.
Dukji-Gu Keumam-dong San 560-756, Jeonju city
Tel: +82+63+270-4325/3888
E-mail: hyungk@chonbuk.ac.kr