Devising an Objective Nasal Vibration Test for Nasal Resonatory Disorders

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ABSTRACT

The present study investigates the clinical applicability of a new device which objectively measures nasal resonating vibration via piezoelectric vibratory sensor from 10 normal volunteers, 10 patients with definite hypernasality and 10 nasal polyposis patients.

For the assessment of the hypernasality, the ratio of 'ng' to 'a' as well as that of 'mama' to 'papa' passages were used. For the evaluation of hyponasality, the ratio of nasal vibration post- to pre-induced cul-de-sac resonation was calculated.

In the control group, the ratio of ng/a and mama/papa passages was larger than 8, while in the hypernasality group, the ratio was markedly lower. The vibratory signals of 'a' and 'ng' increased markedly in the control group and the hypernasality group after inducing cul-de-sac resonation, while in the hyponasality group, the change was minimal.

Keywords: Piezoelectric vibratory sensor, Nasal vibration, Cul-de-sac resonation Hyponasality, Hypernasality,

1. INTRODUCTION

For those patients with velopharyngeal incompetence either by cleft palate or the paralysis of the velopharynx, the severe functional disturbance of the soft palate may result in the regurgitation of foods into the nasal cavity during the swallowing process and excessive nasal resonance during phonation. The medical term for the latter condition is hypernasality or *rhinolalia aperta* [1,2]. Conversely, an obstruction of the nasal cavity by nasal polyps or various tumors such as inverted papilloma or carcinoma, or an obstruction of the nasopharyngeal cavity by the adenoid enlargement or angiofibroma may havw severely reduced nasal resonance, in which case the condition is termed hyponasality or *rhinolalia clausa* [3].

For the phonating disturbances from abnormal nasal resonance, it may be difficult even for trained ENT specialists to differentiate hypernasality from hyponasality just by listening to the diction. In most cases, the observation may be limited to such a statement as

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'abnormaly pronounced nasal sound.' Therefore, proper differentiation may require an anatomical assessment of the soft palate, movement of the soft palate on phonation and evaluation of the nasal cavity for any abnormalities [4]. The speech pathologist or speech therapist should look for the presence of any faulty pronunciation of consonants through a reading test as well as hyperresonance during vowel phonation.

When a speech disorder caused by nasal resonance disturbances is treated by surgical procedures or speech therapy, an objective means to determine improvements made by the treatment may be needed. Some of the conventional semi-objective methods include the mirror clouding test, the nasal vibration test and the nares occlusion test of exhalatory efficiency [4].

In the mirror clouding test [4], the subject reads sentences containing many nasal consonants and sentences with no consonants while holding a cold metal mirror in front of the nasal aperture. Unusually heavy clouding while reading the sentences without nasal consonants constitutes heavy nasal emission, therefore hypernasality. If unusually little clouding occurs while reading the sentences with many nasal consonants, an obstruction of the nasal passage and hyponasality may be suspected. Although the extent of the clouding may be used to quantitatively estimate the severity of the condition to a certain extent, objective measuring may be difficult.

Nasal vibration test [4] involves the examiner's finger being placed on the subject's *ala nasi* to detect the vibration while the subject is reading various sentences and words with or without nasal consonants. Again, objectivity may be lacking in this test as well.

Nares occlusion test of exhalatory efficiency [4] evaluates how long a subject can count numbers out aloud after one deep inhalation. The subject does the procedure normally at first and then repeats the procedure while obstructing the nasal passages with fingers. Comparison of the results between the two session allows some quantitative estimation of nasal emission, although the test is less than ideal.

More objective tests have been developed. Warren [5] used several kinds of sensors to detect air pressure and currents within the nasal and oral cavities and reported a method which could indirectly estimate the area of velopharyngeal orifice. Fletcher [6] measured the sound levels eminating from the nasal and oral cavities and used the ratio of the two values to calculate the nasal resonance. This method showed high correlation with the judgement of nasal resonance disorders by phoniatrical specialists [7]. Currently, the measuring device is marketed under the brand name Nasometer.

For the present study, the authors tried to enhance the nasal vibration test with better objectivity and quantitative potential using a piezoelectric sensor. The device was clinically applied to three groups of subjects with either normal resonance, hypernasality or hyponasality in order to test the efficacy of the procedure and the device.

2. MATERIALS & METHODS

The detection device

A vibratory sensor of piezoelectric type commonly used in a telephone (PKD20EW-01R) was prepared. In order to minimize the effects from the oral cavity, a modification was made by covering the sensor with duralumin except for the receiving area where a metal tube 30mm in length and 5mm in diameter was attached (Fig 1).

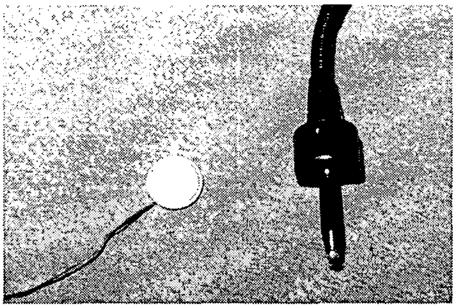
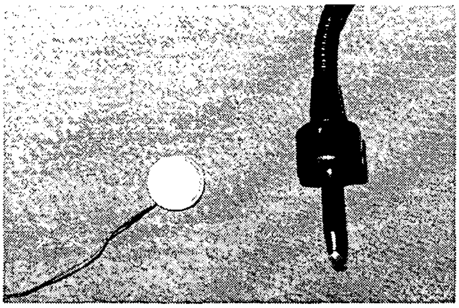


Fig. 1. Nasal vibratory sensor: A piezoelectric receiver for telephone (PKD20EW-01R), left, and a modification by coating with duralumin and a small hollow tube tip.



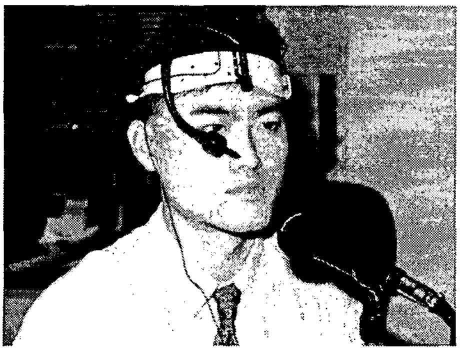


Fig. 2. Application of the nasal sensor on the ala nasi

The other end of the tube was to make a contact flush to the *ala nasi* of a subject, preventing any changes in the sound pressure through the air affecting the sensor. The whole sensor unit was attached to a head band commonly used for ENT examinations. (Fig 2)

A preamplifier, a power supply, a filter and an isolation part were prepared and assembled by medical engineers. The input was digitized with a 12-bit A/D board (DT2821) and analyzed using computer software (CSpeech 3.1). Three channels within the software were used; the first channel for acoustic wave forms from the microphone, the second channel for the signals from the vibratory sensor, and the third channel just for the envelops of the vibratory signals in order to enhance the measurement. (Fig 3)

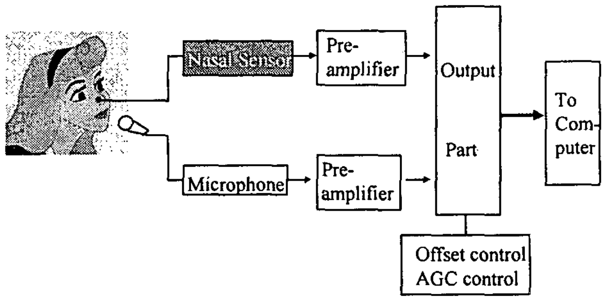


Fig. 3. Block diagram of the system

Measurement of nasal resonating vibration

The sensor was attached to the *ala nasi* following a gentle rubbing with alcohol. A microphone was placed 15cm in front of the mouth to pick up acoustic signals. The subjects were asked to pronounce the vowel 'a' and the nasal consonant 'ng' as well as the sentences containing mainly nasal consonants ('mama' passages in Korean) and the sentences with no nasal consonants ('papa' passages in Korean).

Instead of using the absolute values of the vibration, the ratio of the 'ng' values to the 'a' values were calculated and used for detection and differentiation of hypernasality, since the contact status between the ala nasi and the sensor may affect the results. The ratio of signals from the 'mama' passages to signals from the 'papa' passages were used for a similar reason. The signal strength was calculated from the envelops and the baseline values from Channel 3 using computer software (ImagePro II). aiding in the calculation of the areas between the two (Table. 1).

The extent of nasal obstruction was measured by the ratio of signals from 'a' with the cul-de-sac resonation induced by obstructing the nose with a finger to the same pronunciation without the obstruction. The same procedure was repeated with the nasal consonant 'ng'(Fig 4, Table 1).

Fig. 4. Measurement of the nasal vibration with occlusion by a finger in order to induce 'Cul-de-sac resonation'

Table 1. Calculation and analysis of the nasal vibration:

A. Measurement for hypernasality

1) vowel /a/, and nasal consonant /ng/;

$$\text{ratio of } \frac{/ng/}{/a/}$$

2) /mama/ passage (8 syllable phrase which contains 8 nasal consonants), and /papa/ passage (8 syllable phrase which contains no nasal consonant);

$$\text{ratio of } \frac{/mama/passage}{/papa/\ passage}$$

B. Measurement for hyponasality

1) vowel /a/, and vowel /a/ with occlusion;

$$\text{ratio of } \frac{occ/a/}{/a/}$$

2) nasal consonant /ng/, and nasal consonant /ng/ with occlusion;

$$\text{ratio of } \frac{occ/ng/}{/ng/}$$

Clinical applications

The measuring procedure was applied to three groups: 1) Control group with 10 normal subjects (5 males, 5 females, mean age 32); 2) Hypernasality group with 10 subjects with either congenital cleft palate or a functional velopharyngeal incompetence (6 males, 4 females, mean age 34); 3) Hyponasality group with 10 subjects with nasal polyposis (5 males, 5 females, mean age 33). The ratio of 'ng' to 'a' and 'mama' to 'papa' passages were calculated as well as the ratio of 'a' and 'ng' with cul-de-sac resonation to that with no obstruction.

Statistical analysis

A paired t-test was used to compare between the groups ($p<0.05$).

3. RESULTS

The mean ratio of 'ng' to 'a' in the normal group (Fig 5,6) is 8.2(±2.1) and the mean ratio of 'mama' passages to 'papa' passages is 10.0(±2.1)(Fig 10). In the hypernasality group (Fig 7,8), the ratio is 2.5(±0.4) and 2.2(±0.3) respectively, while in the hyponasality group, the ratio is 6.7(±1.6) and 7.0(±1.7) respectively (Fig 10). Compared to the normal group, the hypernasality group showed statistically significant difference ($p<0.05$) while the hyponasality group showed no significant difference. The difference between the hypernasality group and the hyponasality group was also significant ($p<0.05$).

The mean ratio of increase when cul-de-sac resonation was induced is 2.6(±0.2) in the normal group (Fig 9) and 2.8(±0.2) in the hypernasality group, while in the hyponasality group, the increase was minimal at 1.2(±0.1) (Fig 11). Statistically significant differences were noted between the normal group and the hyponasality group, and between the hypernasality group and the hyponasality group ($p<0.05$).

When the cul-de-sac resonation was induced during the pronunciation of 'ng' as compared to 'a', the signals increased by 3.0(±0.4) in the normal group and 3.2(±0.3) in the hypernasality group, while in the hyponasality group, the increase was minimal at 1.2(±0.1) (Fig 12).

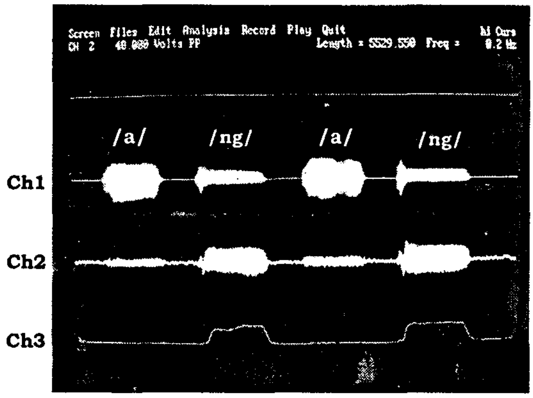


Fig. 5. A case of normal nasal resonance:
- phonation of /a/, /ng/, /a/, /ng/
- Ch 1: acoustic waveform from microphone

Ch 2: vibration from nasal sensor Ch 3: envelope of Ch2

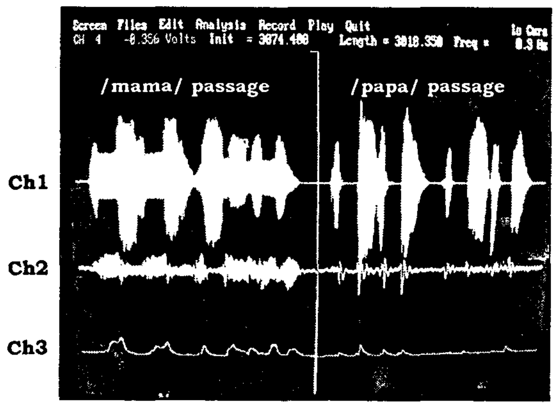


Fig. 6. A case of normal nasal resonance:
- phonation of /mama/ passage, /papa/ passage
- Ch 1: acoustic waveform from microphone

Ch 2: vibration from nasal sensor Ch 3: envelope of Ch2

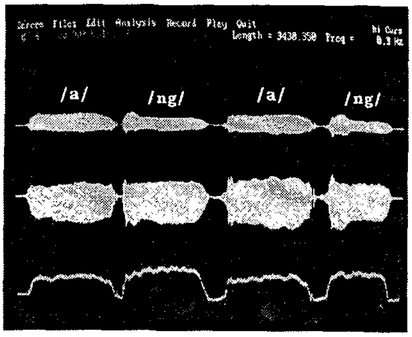


Fig. 7. A case of hypernasality (cleft palate):
- phonation of /a/, /ng/, /a/, /ng/
- Ch 1: acoustic w aveform from microphone
  Ch 2: vibration from nasal sensor
  Ch 3: envelope of Ch2

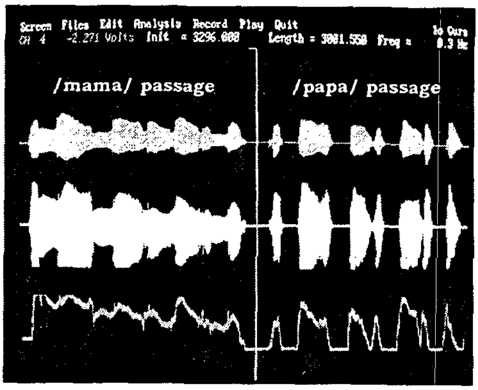


Fig. 8. A case of hypernasality (cleft palate):
- phonation of /mama/ passage, /papa/ passage
- Ch 1: acoustic waveform from micropho
  Ch 2: vibration from nasal sensor
  Ch 3: envelope of Ch2

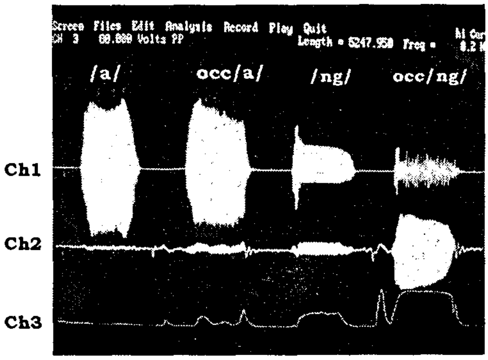


Fig. 9. Induced 'Cul-de sac' resonation by occluding one nostril by \a finger in a nomal nasal resonance:
- phonation of /a/, /a/ with occlusion, /ng/, /ng/ with occlusion
- Ch 1: acoustic waveform from microphone
  Ch 2: vibration from nasal sensor
  Ch 3: envelope of Ch2

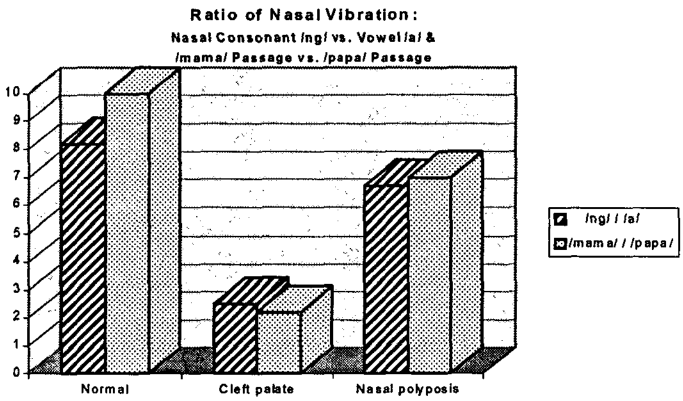


Fig. 10. Comparison of ratio of $\frac{/ng/}{/a/}$ and ratio of $\frac{/mama/ \text{ passag}}{/papa/ \text{ passage}}$ among normal control, hypernasality, and hyponasality.

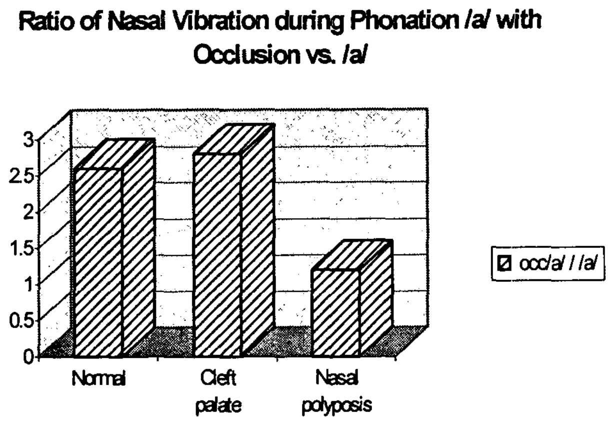


Fig. 11. Comparison of ratio of $\frac{/a/\text{ with occlusion}}{/a/}$ among normal control, hypernasality, and hyponasality.

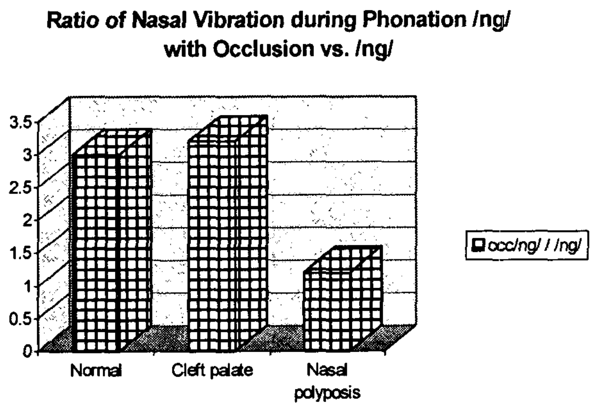


Fig. 12. Comparison of ratio of $\frac{/ng/\text{ with occlusion}}{/ng/}$ among normal control, hypernasality, and hyponasality.

4. DISCUSSION

The nasal resonance disorders can be grouped into either hypernasality with nasal emission or hyponasality. Some of the conditions that can cause hypernasality include organic disorders such as cleft palate, submucous cleft palate and traumatic palatal defect as well as the secondary slowing of the soft palate movements caused by either neurological or psychological reasons. Hyponasal conditions may be caused by rhinosinusitis, allergic rhinitis, nasal polyposis, adenoid vegetation and tumors in the nasopharynx [4].

Hypernasality is frequently related to anatomical or functional disturbances in the soft palate. The soft palate consists of 5 muscles (tensor veli palatini, levator veli palatini, palato-pharyngeus, palato-glossus and uvular) and during normal nasal breathing, these muscles do not contract, leaving the velopharyngeal isthmus open widely. However, in the second stage of swallowing (pharyngeal phase), these muscles do contract, occluding the velopharyngeal isthmus and preventing the regurgitation of food or saliva. Normally, the pronunciations of all vowels and consonants excluding the nasal consonants lead to the occlusion of the velopharyngeal isthmus precluding hypernasality. For the nasal consonants, the exhalatory air is channeled to the nasal cavity resulting in the nasal resonance [8-10].

Some of the phonating or linguistic disorders caused by the functional disturbance of the soft palate are as follows; excessive hypernasality during the pronunciation of vowels or voiced consonants, a nasal emission during the pronunciation of power consonants, a compensatory articulation, a retardation of the speech and linguistic development in children and phonation disturbances caused by auditory disorders, etc [4].

For evaluation of the soft palate function, a flexible nasopharyngoscope may be effective, and by attaching a camera, a video-endoscopic examination is possible and useful in the objective evaluation of the results of surgery or speech therapy. Through the endoscope, the examiner can observe the soft palate movement during the pronunciation of vowels and can record the movement of not only the posterior pharyngeal wall but also the lateral pharyngeal walls. Other available methods include the video fluoroscopic studies and EMG [8-11].

For the evaluation of nasal resonance, the sound spectrographic analysis of the recorded sound is commonly used. A normal nasal consonant sound registers the 1st formant at 250Hz, which is much lower than the frequency from a normal vowel. The 2nd formant is at 2500Hz, much higher than that of a vowel [12-15]. Therefore, in a hypernasal condition, the pronunciation of a vowel accompanies a nasal resonance, greatly affecting the usual formant frequency. In a hyponasal condition, the intensity of the resonance frequencies F1 and F2 is markedly reduced. However, the sound spectrographic analysis alone may not be sufficient to differentiate nasal resonance from oral resonance.

As stated earlier, some of the traditional, semi-objective methods to evaluate nasal resonance include the mirror clouding test, the nares occlusion test of exhalatory eifficiency and the nasal vibration test. These methods showed limitations in quantitatively and objectively evaluating the nasal resonance [4].

The pressure/flow technique reported by Warren [5] used the pressure and current in the nasal and oral cavity to calculate the area of the nasopharyngeal passage. This method is costly since it requires many sophisticated devices.

Recently, some of the methods that can objectively evaluate nasal resonance have been reported. One such method, using a tonar that can express the ratio of sonic resonations in oral and nasal cavities showed 0.8 correlation with the subjective judgement of examiners [6,7].

A modification of this method led to the development of a computerized measuring device (Nasometer, Kay Elemetrics Co.) which detected the acoustic energy from the nasal and oral cavities using microphones. It is the most popular method currently used in many institutions [16].

The device used in the present study is a modification of the nasal vibration test. The sensor used in the device is relatively inexpensive, and once the control portion is made, a personal computer and the multi-purpose sound analysis software (CSpeech) can be used, making it a practical, low cost procedure. Furthermore, the test uses the ratio between the vowel and the nasal consonant instead of any absolute values to reduce procedural errors and aid in the differentiation of normal and hypernasal conditions. When cul-de-sac resonation is induced, the hyponasal condition can be differentiated from the normal or hypernasal conditions by its lack of change in vibrations.

For more definite evaluation of the efficacy of the device and the test, further studies may be needed on patients with congenital cleft palate, chronic rhinosinusitis and soft palate paralysis whose pre-treatment and post-treatment changes in nasal resonance can be measured with the device.

5. CONCLUSION

A new nasal vibration testing device which can objectively measure the nasal resonance was developed using a piezoelectric sensor. The new device can be an objective, cost-effective means to detect nasal resonatory disorders and to readily differentiate hypernasality and hyponasality.

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Received : Jan. 20, 2000
Accepted : Feb. 5, 2000

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