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Effect of Prosthodontic Rehabilitation of Maxillary Defects on Hypernasality of Speech

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Keywords
Hypernasality; maxillary obturator; speech intelligibility.

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The authors deny any conflicts of interest.

Accepted January 1, 2015

doi: 10.1111/jopr.12309

Abstract

Purpose: To establish a correlation between the effective internal diameter of the maxillary defect, the resonating frequency, and the effectiveness of the definitive obturator in reducing the percentage nasality.
Materials and Methods: Twenty-nine patients who underwent maxillectomy confined only to the hard palate (Aramany's class I and class II defect) and were wearing a definitive obturator for at least 3 months were included. The percentage nasality and resonating frequency were calculated with the help of Praat software. The patients were asked to read out a "Rainbow" passage and also to phonate and articulate vowels. Both parameters were assessed with and without the obturator prosthesis.
Results: Following obturator use, a mean change of 1.07 ± 0.83 kHz was observed in the resonating frequency ($p < 0.001$). The percentage change in resonating frequency was found to be $27.48 \pm 4.99\%$ following obturator use ($p < 0.001$). The effective internal diameter of the maxillary defect was calculated with the help of a Vernier caliper. The correlation between absolute and percentage values of resonating frequency and nasality before and after obturator use was found to be negative.
Conclusion: This study found that efficacy of the obturator prosthesis in reducing nasality was greater in smaller defects than in large defects.

An undesirable consequence of maxillectomy is the impairment of speech intelligibility. The communion between the oral and nasal cavities produced by resection of the palate reduces intraoral air pressure during speech production, causing articulatory imprecision, hypernasal speech, nasal air emission, and reduced vocal loudness. Defects created by maxillectomy can be reconstructed successfully using free and microsurgical transplants, grafts, and distant or regional flaps.[1,2] However, prosthetic rehabilitation is a better option after maxillary resections due to short treatment time, low cost, and the possibility of modification according to the patient needs.[3-5] Additionally, the surgical site is always accessible for a check for disease recurrence.[4] The aim of the obturator prosthesis is to block the undesired communication between the oral and nasal cavities created by tumor resection surgery and to improve speech intelligibility and swallowing.

Different types of obturator prostheses have been used in the past to evaluate their effect on speech nasality and articulation. Both objective and subjective methods have been used to determine the acoustics of the maxillary defect,[6-12,14-19] but the literature lacks evidence on a relationship of the effective internal diameter of surgical resection and the percentage nasality of speech.

The aim of this study was to establish a correlation between the effective internal diameter of the maxillary defect and the resonating frequency and the efficiency of the definitive obturator in reducing the percentage nasality.

Materials and methods

The records of all the patients who underwent maxillectomy between 2010 and 2013 were reviewed. A total of 79 patients were identified and invited by telephone. Twenty-one did not respond to the invitation, five had medical problems like neuromuscular disorders, damaged vocal cords, or hearing defect, twelve were completely edentulous, seven had resections involving the soft palate, and five did not wish to participate in the study. The remaining 29 patients who underwent maxillectomy confined only to the hard palate (Aramany's class I and class II defect) and were wearing a closed bulb hollow definitive obturator (the bulb portion of the prosthesis was completely enclosed, with the inner portion of the bulb being hollow) for at least 3 months, were included in the study. Thus the sample size constituted 29 patients aged between 28 and 60 years (17 men, 12 women). The study was approved by the

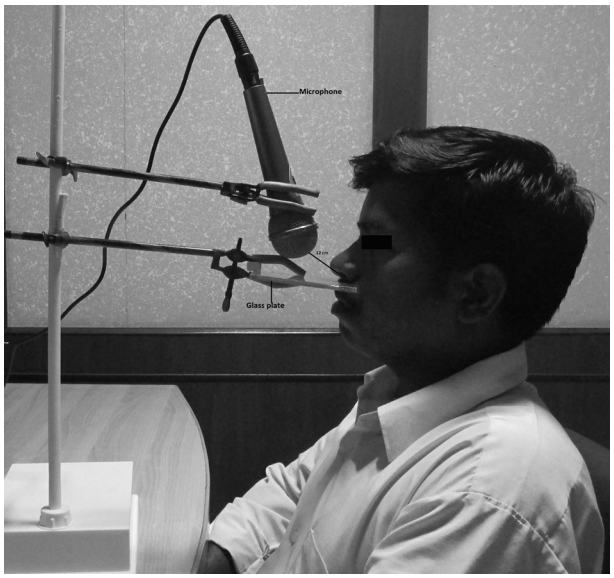

Figure 1 Position of patient, microphone, and the glass plate.

institutional human ethical committee of Saraswati Dental College and Hospital, Lucknow, India.

Estimating the effective internal diameter of the palatal defect

The definitive obturator was relined with soft liner (GC soft liner; GC Corporation, Tokyo, Japan) and placed in the patient's mouth. After the bulb had been molded, the obturator was taken out, and the maximum diameter of the obturator bulb was measured in the anterio-posterior dimension with the help of a Vernier caliper (Mitutoyo, Kawasaki, Japan). This was recorded as the effective internal diameter of the defect.

Calculating the resonating frequency and percentage nasality

The patient was made to sit upright on a chair in a soundproof room (Fig 1). An arrangement was placed in front, such that a clamped glass plate was positioned between the nose and mouth of the patient. A microphone (SBCMD110; Philips, Amsterdam, The Netherlands) was placed above the glass plate, 12 cm in front of the external nares.[7,21] The patient was asked to read aloud a "Rainbow passage"[20,22,23] and phonate the vowels "i" and "u." All patients participating in this study had had at least secondary level (grade 12) education with basic reading and writing proficiency in English. Hence they were assigned to read the Rainbow passage.

The sound was recorded and analyzed using Praat software (Institute of Phonetics Sciences, University of Amsterdam, The Netherlands) at a default frequency of 44,100 Hz, which is the finest frequency used for recording most sounds. A click on the icon "view and edit" in the editor window opened the Praat editor window showing the spectrogram of the recorded sound. The spectrogram had a broadband frequency range of 0 to 5000 Hz, which was sufficient to analyze the normal and hypernasal sound. The *x*-axis of the spectrogram showed the frequency and the *y*-axis, the amplitude. The resonating frequency was calculated by subtracting P0 from A1 (A1-P0) where A1 was the highest harmonic near the frequency of the first formant F_1, and P0 was a specific harmonic peak reinforced by resonances within the nasal passages. There are two methods to find the frequency of the first formant F_1. The first is to find the first highest peak on the spectrogram, but this method can incorporate operator bias in locating the first highest peak. The second and the most reliable method is by using the formant tool in the editor window. The cursor was pointed on the F_1, to get the amplitude of A1 on the *y*-axis and frequency of F_1 on the *x*-axis of the spectrogram. The amplitude of A1 did not vary with the vowel quality. The next highest peak near the A1 represented the P0. P0 was subtracted from the A1 to calculate the resonating frequency.

The percentage nasality was calculated from the formula $\{[(N)/(N + O)] \times 100\}$, where N was the nasal acoustic energy and O the oral acoustic energy. The nasal acoustic energy was obtained from the software by clicking the icon "info" in the Praat object window. The oral acoustic energy was obtained by placing the microphone on the underside of the glass plate, recording the sound as stated earlier and then clicking on the icon "info" in the Praat object window. All recordings were evaluated with and without the obturator in place.

Data were analyzed using SPSS v15.0 (SPSS Inc., Chicago, IL). Values have been represented as mean ± SD. Normality of the distributions was checked using Kolomogorov Smirnov test. All three distributions (i.e., resonating frequency before use of obturator, resonating frequency after use of obturator, and effective internal diameter of defect) were normal; hence a parametric evaluation plan was adopted. Change in resonating frequency was assessed using paired "*t*"-test. Resonating frequencies with and without obturator use and that of maxillary defect dimensions with resonating frequencies were correlated using the Pearson correlation coefficient.

Results

The mean effective internal diameter of the defect was 27.77 ± 3.75 mm. The quantitative values of the effective internal diameter of the defect are shown in Figure 2.

A mean resonating frequency of 1.16 ± 0.53 kHz was observed without obturator use and 0.09 ± 0.07 kHz with obturator use. A mean change of 1.07 ± 0.83 kHz was observed in the resonating frequency following obturator use. Statistically, this change was significant ($p < 0.001$), indicating that the change in frequency followed a systematic pattern. On evaluating the correlation between pre- and postobturator use for resonating frequency, the correlation was found to be negative (i.e., with obturator use, there was a decrease in resonating frequency, and this decrease was of a moderate nature [r = –0.586]) (Table 1).

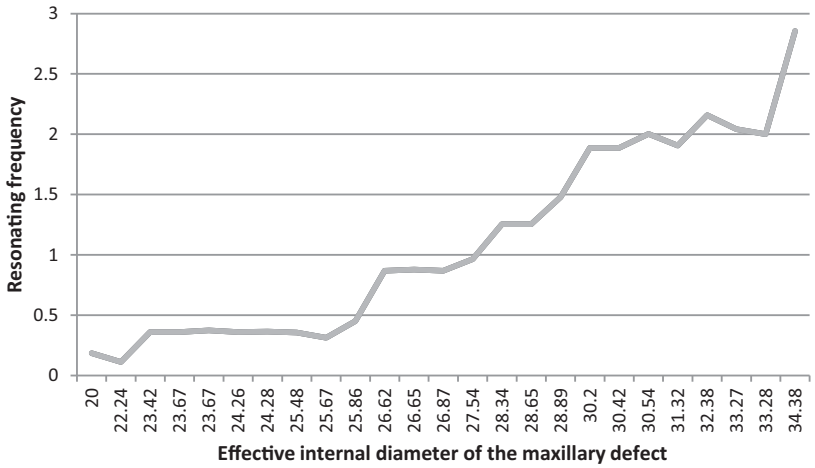

Figure 2 Resonating frequency without obturator use.

Table 1 Mean change in resonating frequency following obturator use

	Mean (kHz)	Std. deviation
Without obturator	1.16	0.53
With obturator	0.09	0.07
Mean change	1.07	0.83
Significance (Paired "*t*"- test)	$t = 6.725$; $p < 0.001$	
Correlation between pre- and postobturator use values	r = –0.586	

Table 2 Mean change in percentage nasality following obturator use

	Mean (%)	Std. deviation
Without obturator	38.96	4.25
With obturator	11.48	1.34
Mean change	27.48	4.99
Significance (Paired "*t*"- test)	$t = 28.631$; $p < 0.001$	
Correlation between pre- and postobturator use values	r = –0.443	

In terms of percentage resonating frequency, a mean change of 27.48% was observed following obturator use. Statistically, this change was significant ($p < 0.001$). The correlation was also found to be negative (r = –0.443) (Table 2).

There was strong positive correlation between effective internal diameter of the defect and resonating frequency (r > 0.9; $p < 0.001$) for both absolute as well as percentage values before obturator use, indicating that the resonance consistently increased with an increase in the diameter of the defect. Following obturator use, the resonating frequency showed a moderate decrease, with an increase in the effective diameter of the defect (r = –0.598; Table 3); however, for the percentage of resonating frequency, the correlation was still found to be positive (r = 0.888; $p < 0.001$). Also, there was a significant reduction in hypernasality on obturation of maxillary defects up to an effective internal diameter of 28.50 mm (Fig 3).

Table 3 Correlation of effective internal diameter of defect with resonating frequency and percentage nasality with and without obturator

Parameter	Before obturator use	After obturator use	Change in frequency
Absolute values			
Effective internal diameter of defect	r = 0.957[a]	r = –0.598[b]	r = 0.958[a]
% values			
Effective internal diameter of defect	r = 0.915[a]	r = 0.888[a]	r = 0.888[a]

[a]$p < 0.001$; [b]$p = 0.001$

Discussion

Nasalance of voice depends on the integrity of various resonating cavities. Once the integrity is lost after surgery, resonance of the voice is adversely affected. Maxillectomy causes hypernasality of voice as the air escapes through the nasal cavity and the maxillary defect. Oronasal separation is required for intelligible phonation and articulation, which is achieved to a great extent by prosthetic obturation of the hard palate defect; however, its efficacy in the large defect is still unknown. Hence this study was planned to establish a correlation between the effective internal diameter of the maxillary defect and the effectiveness of the definitive obturator in reducing the percentage nasality.

The definitive prosthesis used in this study was a closed bulb hollow obturator. The hollow obturator has the advantage of being lightweight, providing for greater patient comfort, less pressure to the surrounding tissue, and more efficiency compared to the solid bulb obturator. Closing the obturator bulb reduced the air space in the defect. The correlation was found to be negative both in terms of resonating frequency (r = –0.586) and % resonance (r = –0.443) (i.e., the efficacy of obturator prosthesis was lower in larger than in smaller defects).

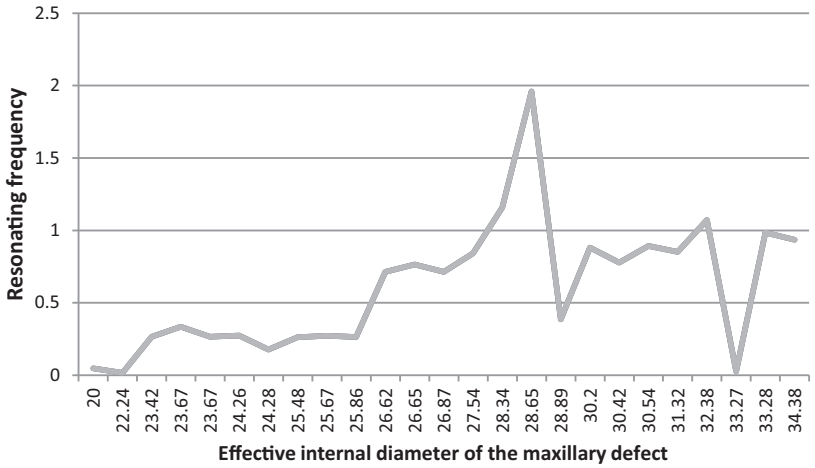

Figure 3 Efficacy of obturator prosthesis in reducing hypernasality.

The mean percentage nasalance without obturator (38.96) was not as high as that reported by Rieger et al,[7] possibly because the maxillary defect taken for this study was confined only to the hard palate; however, postoperative results after wearing the obturator were almost similar. Pauloski et al[5] showed that speech function was mild to moderately negatively correlated with most surgical resection variables, indicating that larger amounts of resected tissue were associated with worse speech function. They measured the speech outcome in terms of percent correct consonant phonemes and percent conversational understandability and not in terms of nasality. Kumar et al,[6] in a study on ten maxillectomy patients rehabilitated with hollow bulb obturators of varying height, showed that articulation and nasality improved after providing an obturator; however, no statistically significant correlation was established for different obturator bulb height.

Our results show that hypernasality of speech improves more effectively on obturation of smaller palatal defects than larger defects. Small defects usually present with fewer soft tissue undercuts, while the converse is true for large defects. Such undercuts are left alone to facilitate an easy path of insertion and removal of the obturator bulb. Thus the effective internal diameter of the defect is actually less in such instances. Also the unobturated part of the defect can act as an air column to heighten nasality. Defects with larger diameters (diameter $>$ 28.50 mm) when obturated did not show a similarly effective trend in reduction of nasality. The results, however, did support the views of Reiger et al,[7] Pauloski et al,[5] and Kumar et al[6] in that the hypernasality and intelligibility of speech worsened with an increase in the defect dimensions. We have evaluated the defect size in the antero-posterior axis and used software other than the one previously used to objectively evaluate hypernasality.

Conclusion

This study found that efficacy of the obturator prosthesis in reducing nasality was greater in smaller defects than in larger defects. Prosthetic obturation of palatal defects efficiently serves to block the oronasal communication created by tumor resection and facilitates early oral feeding; however, the issue of hypernasality and speech intelligibility may not be entirely addressed, especially in large diameter defects.

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