ORIGINAL RESEARCH

# Assessment of Acoustic and Nasalance Improvement in Maxillary Obturator Patients Using PRAAT Software: An *In Vivo* Study

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## Abstract

**Aim:** The purpose of this study was to evaluate the improvement in acoustic and nasalance in patients with maxillary obturators, using PRAAT software.

**Materials and methods:** The current study comprised a total of 16 patients who had acquired maxillary defects. Regardless of gender, the age range of these patients was 40–75 years old. The total number of patients were randomly divided into two groups (8 participants in each group) namely (A) Interim obturator group and (B) Definitive obturator group. Analysis was done using PRAAT software for two speech parameters namely nasalance and acoustic value. The first stage of speech analysis was completed without the use of an obturator, whereas the second stage involved inserting the obturator on the same day. The third stage occurred 2 months after the usage of the obturator. The data were recorded and statistically analyzed.

**Results:** In definitive obturator group, mean value for relative nasalance increases from before prosthesis (60.93 ± 3.34 db) to after 2 months of prosthesis (70.53 ± 2.24 db) while in interim group increased from 57.55 ± 4.31 db (before prosthesis) to 63.77 ± 3.66 db (after 2 months of prosthesis). This improvement was more marked with definitive obturator than interim obturator. The F2–F1 comparative mean value changed from before prosthesis to immediate after prosthesis in definitive group for /a/, /e/, and /u/ vowels was 9.77, 22, and 24.38, respectively. F2–F1 comparative mean changes from before prosthesis to after 2 months of prosthesis was 102, 75.75, and 87 for three vowels /a/, /e/, and /u/, respectively. Similarly, F2–F1 mean value in interim prosthesis group changes from before to after 2 months of prosthesis was 62.25, 27.62, and 1.75 for /a/, /e/, and /u/, respectively.

**Conclusion:** On conclusion, the definitive obturators were well-tolerated by patients with major defects and the results show that maxillary resection significantly impairs speech and definitive obturator rehabilitation is effective in regaining nasalance and acoustic speech components.

**Clinical significance:** Speech disorders in maxillectomy patients are a significant clinical issue since the surgery results in hypernasality, which impairs a person's ability to understand their own speech. Either surgical techniques or prosthetic rehabilitation are used to correct these abnormalities. Certain people require prosthetics to fix their speech even after surgery.


**Keywords:** Acoustic, Maxillary obturator, Nasalance, PRAAT software, Speech analysis.

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## Introduction

Maxillary carcinomas may arise as a primary tumor or may spread from adjacent areas. Hemimaxillectomy is typically used in management due to delayed diagnosis or late onset of symptoms. The resulting deficiency impacts the patient's psychological well-being, speaking, mastication, and facial appearance. For some people, rehabilitation may involve surgery or prosthetics.[1]

The quality of a person's life following surgery may be impacted by changes in appearance and psychological state. One of the major concerns in patients who undergo maxillectomy is impairment of speech intelligibility. Unwanted communication between the nasal and oral chambers lowers intraoral air pressure during speech production, which results in reduced vocal loudness, nasal air emission, articulatory imprecision, and hypernasal speech.[2]

One of two methods for treating the acquired maxillary palatal defect is through rehabilitation using a maxillary obturator or a free microvascularized flap. Every method has benefits and drawbacks of its own.[3] Maxillofacial prosthesis provides a non-invasive treatment modality for patients who are not fit to undergo complex microsurgical procedures. These individuals need to have their defects monitored or have major deformities, inadequate blood supply

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from radiation, advanced age, or poor health.[4] Reconstruction or obturation of the surgical defect improves speaking and swallowing abilities, which in turn improves quality of life by preventing food, drink, and air from escaping into the maxillary sinus and nasal cavities.[5]

In order to enhance the support, stability, and retention of an obturator, a good prosthetic design for functional repair of the maxillectomy defect makes use of the residual palate and dentition. A crucial factor to be taken into account while creating the obturator is the prosthetic bulb, which can be solid, open hollow, or closed hollow. It is important to assess the impact of prosthetic rehabilitation from several angles for patients with oral cancer. One of these is speech, which typically becomes incomprehensible following maxillary resection. Together, the respiratory, laryngeal, velopharyngeal, and articulatory systems perform the function of speech.[6]

A simple sound to examine and explain acoustically is the phonetic sound. The first and second formant frequencies (F1 and F2), which are a fairly basic set of acoustic descriptors, have frequently been used to describe them. Numerous past researches have demonstrated that maxillectomy patients' speech improves with an obturator prosthesis.[7,8] The majority of researches have studied the clinical improvement in speech with maxillary obturators by taking speech intelligibility into account. This study aimed to analyze different aspects of speech, such as nasalance and acoustic alterations, at three different stages of obturator management: before the prosthesis was inserted, on the day of the prosthesis implantation, and after 2 months.

## Materials and Methods

### Selection of Participants

The present *in vivo* study was conducted in the Department of Prosthodontics, SCB Dental College and Hospital, India, during the year of 2015–2016. Before the procedure started, ethical approval from the Institutional Ethical Committee was obtained. Sixteen patients with acquired maxillary defects, i.e., class I–IV (Aramany's classification of maxillary defect) reported to Institution were included in the present study. Regardless of gender, the age range of these patients was 40–75 years old. Patients with damaged vocal cords, hearing impairments, loose teeth, complete edentulous patients, patients with limited mouth opening, patients with neuromuscular disorders of any kind and patients who were unable to appear for additional analysis during speech recording were not included in this study.

Every participant had fluency in speaking Odia and showed no signs of cognitive impairment. Following a thorough examination, the patient had a detailed explanation of the treatment plan and complete history was obtained. The procedure was started only after obtaining the patient's consent. Patients who were reported to the Institution with acquired maxillary defects and underwent recent surgery were randomly divided into two groups (8 participants in each group) namely (A) Interim obturator group and (B) Definitive obturator group.

### Analysis of Speech

A speech pathologist assisted with the speech evaluation. The first stage of speech analysis was completed without the use of an obturator, whereas the second stage involved inserting the obturator on the same day. The third stage occurred 2 months after the usage of the obturator. Every patient group underwent three analyses at each stage to ensure that errors were eliminated.

Using PRAAT software, acoustic analysis and nasalance enhancement were examined (Paul Boersma and David Weenink, University of Amsterdam). A microphone was positioned five centimeters from the patient's lips during recording sessions in a calm, private room in order to collect data for spectrogram-based audio analysis. As model vowel sounds, the three Odia vowels /a/, /e/, and /u/ were employed. For three to four seconds, each person was asked to pronounce the three vowel sounds. Direct speech recording was done on a PC with Windows 7's 32-bit PRAAT programme. The same programme was used for the acoustic analysis, using a 44100 Hz sample rate. Formants represent the vocal tract's resonance frequency on a spectrogram. There may be any number of formants at any given time (much like with spectra), but the first three, suitably called F1, F2, and F3, are the most informative for speech. The software estimated the F2–F1 difference after determining the average formant frequencies, F1 and F2.

Improvement in nasalance was determined by intensity or loudness of vowel sound coming from mouth. This was analyzed by PRAAT software and loudness was interpreted in the form of decibel.

### Statistical Analysis

The SPSS software version 20 was used to analyze the data after it was entered into a Microsoft Excel spreadsheet. The Wilcoxon Signed Rank Test was used for a prospective analysis and $p = 0.05$ was chosen as the alpha level for all analysis.

## Results

The age-group of the included patients ranged from 40 to 75 years with a mean age of 59.5 years, out of 16 patients, 13 were males and 3 were females. In definitive obturator group, mean value for relative nasalance increases from before prosthesis (60.93 ± 3.34 db) to after 2 months of prosthesis (70.53 ± 2.24 db) while in interim group increased from 57.55 ± 4.31 db (before prosthesis) to 63.77 ± 3.66 db (after 2 months of prosthesis). The mean score of speech loudness in definitive obturator group was seen to increase after the use of prosthesis. Immediately after the use of obturator prosthesis, the mean score rose to more than 5 points than before. Similar difference was seen between the mean scores of immediate use and after 2 months use of the prosthesis. The difference in the scores was found to be significant ($p < 0.05$). More significant difference was observed after 2 months of the use of prosthesis. The mean score of loudness in interim prosthesis group was also seen to increase with the use of prosthesis. Immediately after the use of interim obturator prosthesis, the mean score value rose to 3 points than before. Similar difference was seen between the mean scores of immediate use and after 2 months use of the prosthesis. The difference in the score was found significant ($p < 0.05$). The overall nasalance was decreased with use of both definitive and interim prosthesis but values are more significant for definitive prosthesis in compare with interim prosthesis (Tables 1 and 2).

Acoustic analysis was done using PRAAT software. Average formant frequency F1 and F2 for vowel /a/, /e/, /u/ was recorded on spectrogram and F2–F1 value was calculated. Tables 3 to 6 showed the mean values for vowels /a/, /e/, /u/ for definitive and interim group, respectively. The F2–F1 comparative mean value changed from before prosthesis to immediate after prosthesis in definitive group for /a/, /e/, and /u/ vowels was 9.77, 22, and

**Table 1:** Definitive obturator (relative nasalance value) in term of intensity on spectrogram as db

| S. No. | Defect class | Before | After prosthesis | After 2 months |
|---|---|---|---|---|
| 1 | Class VI | 53.92 | 64.53 | 74.35 |
| 2 | Class III | 64.36 | 66.38 | 70.98 |
| 3 | Class IV | 60.14 | 63.01 | 74.22 |
| 4 | Class II | 60.43 | 68.28 | 69.29 |
| 5 | Class IV | 64.37 | 68.44 | 69.06 |
| 6 | Class IV | 60.3 | 66.9 | 72.33 |
| 7 | Class I | 63.05 | 64.05 | 67.69 |
| 8 | Class IV | 60.9 | 65.28 | 66.38 |
| Mean value for relative nasalance | | 60.93 (3.34) | 65.85 (1.97) | 70.53 (2.94) |
| Loudness before – Loudness after | | | 0.013* | |
| Loudness before – Loudness after 2 months | | | 0.015* | |
| Loudness after – Loudness after 2 months | | | 0.017* | |

*$p$-value < 0.05

**Table 2:** Interim obturator (relative nasalance value) in term of intensity on spectrogram as db

| S. No. | Defect class | Before | After prosthesis | After 2 months |
|---|---|---|---|---|
| 1 | Class II | 58.25 | 58.58 | 61.87 |
| 2 | Class II | 63.66 | 66.58 | 70.21 |
| 3 | Class I | 63.48 | 63.65 | 67.17 |
| 4 | Class II | 55.96 | 63.38 | 62.34 |
| 5 | Class II | 56.35 | 59.63 | 64.3 |
| 6 | Class II | 51.62 | 55.55 | 59.27 |
| 7 | Class II | 53.26 | 56.82 | 60.12 |
| 8 | Class I | 57.83 | 59.55 | 64.89 |
| Mean value for relative nasalance | | 57.55 (4.31) | 60.46 (3.75) | 63.77 (3.66) |
| Loudness before – Loudness after | | | 0.012* | |
| Loudness before – Loudness after 2 months | | | 0.012* | |
| Loudness after – Loudness after 2 months | | | 0.017* | |

*$p$-value < 0.05

24.38, respectively. F2–F1 comparative mean changes from before prosthesis to after 2 months of prosthesis was 102, 75.75, and 87 for three vowels /a/, /e/, and /u/, respectively. Similarly, F2–F1 mean value in interim prosthesis group changes from before to after prosthesis was 62.25, 27.62, and 1.75 for /a/, /e/, and /u/, respectively. Again F2–F1 mean value changes from before prosthesis to after 2 months of prosthesis was 116.12, 72.75, and 56.75 for /a/, /e/, and /u/, respectively, in interim group. The formant F2–F1 changes was statistically significant in definitive group except for vowel /a/ and /e/ where changes from before to immediate after prosthesis

**Table 3:** Comparative mean with SD for F2–F1 in definitive group

| | F2–F1 (Mean, SD) | | |
|---|---|---|---|
| | Before prosthesis | Immediate after prosthesis | After 2 months of prosthesis |
| Vowel a | 654.37 (75.70) | 644.62 (62.77) | 552.37 (65.75) |
| Vowel e | 1779.0 (105.97) | 1757.0 (100.68) | 1703.25 (93.03) |
| Vowel u | 592.5 (67.88) | 568.12 (76.87) | 505.50 (68.03) |

was not significant ($p$ = 0.441 and 0.068). In interim group, F2–F1 changes were significant except for vowel /u/ from before prosthesis to immediate after prosthesis ($p$ = 0.123).

The inference of the present study indicates that, the increase in loudness values were observed with the use of the prostheses an immediately and after 2 months use gradually. But this improvement was more marked with definitive obturator than interim obturator.

## Discussion

One of the recognized therapeutic options for acquired maxillary deformities is maxillary obturators. The obturator is constructed using a variety of materials. Introduced in the middle of the 1940s, silicone rubber is typically the material of choice due to its lightweight and attractive appearance, but in addition to being pricey, it has a short lifespan. Additionally, it is difficult to polish, has poor tear resistance, and is less retentive with traditional adhesives. It also encourages the growth of microorganisms in the presence of natural nasal secretions.[9]

Additionally, visible light-polymerized resin has been employed; however, the obturators' long-term endurance has not been evaluated. For the creation of these prostheses, heat-cured acrylic resin has shown to be one of the most resilient and tissue-compatible materials available. This substance allowed for the creation of a highly polished surface, which reduced the amount of bacteria that colonized.[10]

In this work, closed hollow bulb obturators were made in a single flask using heat-cured PMMA. An obturator's superior bulb should be closed since an open bulb gathers nasal secretions and adds weight to the prosthesis, which can cause bad hygiene and an offensive odor. The weight of the bulb is especially significant in patients with substantial maxillary abnormalities because it applies rotating and dislodging stresses to the abutment teeth. The hollow bulb obturator is more comfortable because of its small weight, which also solves one of the basic retention issues and enhances physiological processes.[11]

A nasometer can be used to measure nasalance directly. This is obtained by dividing the amount of nasal energy in speech by the nasal and oral sound pressure levels, which are measured independently. The ratio of nasal energy to nasal + oral acoustic energy is used to calculate nasalance.[12] The average vowel loudness was recorded using PRAAT software, which was developed by Paul Borsamac and David Weenink at the University of Amsterdam, in order to indirectly quantify nasalance in the current investigation. The information demonstrated that the values had changed significantly.

In both the definitive and interim obturator groups, using an obturator reduces nasalance overall. High nasalance scores are generally associated with sounds that have a high proportion of nasal sound pressure, such as nasal consonants like /m:/, /n:/, and /ng:/, according to research by Eckardt et al. and Kumar et al.[8,13]

**Table 4:** Comparative test of significance for F2–F1 in definitive group

| | *F2–F1* | | |
|---|---|---|---|
| | *Before vs immediate after prosthesis (p-value)* | *Immediate after prosthesis vs after 2 months of prosthesis (p-value)* | *Before vs after 2 months of prosthesis (p-value)* |
| Vowel a | 0.575** | 0.012 | 0.012 |
| Vowel e | 0.069** | 0.012 | 0.011 |
| Vowel u | 0.012 | 0.011 | 0.012 |

**Not significant at *p*-value > 0.05

**Table 5:** Comparative mean with SD for F2–F1 in interim group

| | *F2–F1 (Mean, SD)* | | |
|---|---|---|---|
| | *Before prosthesis* | *Immediate after prosthesis* | *After 2 months of prosthesis* |
| Vowel a | 683.87 (58.38) | 621.62 (69.25) | 567.75 (54.99) |
| Vowel e | 1831.12 (87.12) | 1803.5 (75.80) | 1758.37 (78.58) |
| Vowel u | 607.0 (18.01) | 605.25 (31.84) | 550.25 (21.56) |

**Table 6:** Comparative test of significance for F2–F1 in interim group

| | *F2–F1* | | |
|---|---|---|---|
| | *Before vs immediate after prosthesis (p-value)* | *Immediate after prosthesis vs after 2 months prosthesis (p-value)* | *Before vs after 2 months prosthesis (p-value)* |
| Vowel a | 0.012 | 0.017 | 0.012 |
| Vowel e | 0.017 | 0.012 | 0.012 |
| Vowel u | 0.123** | 0.012 | 0.012 |

**Not significant at *p*-value > 0.05

This indicates that the integrity of different resonant cavities affects the nasalance of voice. Resonance changes following maxillectomy and leads to hypernasality as air escapes through the defect, establishing oronasal communication. The obturator plate was used to seal the problem since enough oronasal separation is necessary for normal, understandable sound. A sufficient oronasal separation enhances resonance, therefore upon rehabilitation, nasalance in maxillectomy patients is nearly eradicated and may even be as low as in healthy individuals.

In the current investigation, the average formant values F1 and F2 on the spectrogram for the vowels /a/, /e/, and /u/ were recorded using PRAAT Software (Paul Borsamac and David Weenink, University of Amsterdam). The F2–F1 value was then determined. Vowel formant frequencies (F1, F2) are based on the vocal tract's shape, which is influenced by the tongue's location in relation to the throat and hard palate. Changes in tongue height mostly affect Formant 1, whereas changes in tongue advancement primarily affect F2.[14]

In general, high (/i/, /u/) and low (/e/, /a/) vowels have different F1 frequencies. The contraction of the vocal tract forming the back vowels (/u/, /a/, /o/) is what gives them their low F2 and usually minor F2–F1 difference. This result defied Shyammohan and Sreenivasulu in that it showed that front vowels (/i/, /e/), which are produced by constriction of the front cavity, have a considerable F2–F1 difference and a relatively greater F2 frequency.[15] All maxillectomy patients had significantly lower F2 than normal controls, according to Sumita et al.[14] The present research revealed that the F1 values for the three vowels, /a/, /e/, and /u/, increased following the use of a prosthesis. This was most likely due to a decrease in pharyngeal space as the tongue descended and took up some back space. The present study also discovered that, in both the definitive and interim groups, the F2–F1 value for every vowel drops following prosthesis use.

There are some limitations of the present study; speech recording was not done before maxillary resections. Therefore, it is not possible to compare the study's findings with the patient's non-resected status. Additionally, the study's sample size is modest. Expanding the scope of this research to include denture liner use, kinematic speech analysis, and a bigger sample size could ultimately lead to palatal defect voice improvement through maxillary obturator rehabilitation treatment.

# Conclusion

On conclusion, the definitive obturators were well-tolerated by patients with major defects and the results show that maxillary resection significantly impairs speech and definitive obturator rehabilitation is effective in regaining nasalance and acoustic speech components.

## Ethical Approval

The ethical approval from the Institutional Ethical Committee was obtained.

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