

Original Research Article

A study on changes in phonetics in completely edentulous patients before and after rehabilitation with conventional and customized complete dentures

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ABSTRACT

Background: A realistic approach to the phonetic aspect in complete denture construction is most often subdued by various factors. The palatal rugae, an important landmark in speech orderliness, are frequently affected due to lack of proper texture on a complete denture. Establishing a correlation between customized palatal surfaces of complete dentures and speech improvement will help to ameliorate post insertion appointments of articulation deficiencies.

Methods: Ten completely edentulous subjects of either sex with a mean age range of 50-70 years, fulfilling the inclusion criteria were included in this study. All the participants received three sets of dentures, followed by assessment of speech using photo articulation test, speech intelligibility and acoustic analysis in edentulous state and subsequently after insertion of conventional denture, denture with customized rugae, and denture with customized metallic base.

Results: The data collected was subjected to statistical analysis using SPSS 24.0 version and GraphPad Prism version 5. The statistical analysis was carried using ANOVA and student t-test. On evaluating the error patterns, distortion was maximum followed by substitutions. These errors were maximum in edentulous state and decreased subsequently, with the least errors in customized rugae dentures. A statistically significant positive correlation ($p < 0.0001$) was found.

Conclusions: Apart from retention, stability and support, equal amount of emphasis has to be laid down on phonetical aspects to improve the overall psychological well-being and social upliftment for patients. The improvement in verbal proficiency for completely edentulous patients can be minimized considerably by customizing the palatal portions.

Keywords: Customizations, Acoustic analysis, Intelligibility, Photo articulation

INTRODUCTION

Speech articulation is defined in the glossary of prosthodontic terms as the phonation of sounds in connected discourse; the movement and placement during speech of the organs that serve to interrupt or modify the voiced or unvoiced air stream into meaningful sounds.¹ The evolution of sound into audible and intelligible

speech was one of the key milestones which enabled human beings to be superior in all aspects than others. Its production involves neural, muscular, mechanical, aerodynamic, acoustic and auditory factors.² Based on combination of phonation and articulation, speech was divided into five components: respiration, phonation, resonance, articulation and neural integration, with the sixth component being audition or the ability to hear

sounds, that was added later.³ Hearing regularizes and monitors speech outputs and strike a balance with the higher centers and normalize the speech patterns. Thus, a compromised hearing impedes the feedback mechanism and hence, influences speech. Speech is the elixir of life to maintain social well-being, and it places the responsibility on the part of prosthodontist to not only rehabilitate what's lost, but at the same time to undertake a holistic approach such that an edentulous patient rehabilitated with a complete denture enjoys a hassle-free life in terms of speaking or communicating.

In prosthodontic rehabilitation of completely edentulous subjects with complete dentures, often there remains a complain regarding difficulty of pronouncing few words or phonemes, which is frequently attributed to the insufficient replication of the patient's own rugae form and palatal contours correctly in the prosthesis. Failure to simulate inconspicuous palatal contours in denture wearers may often lead to discernible changes in phonation. Most of the literature on this aforesaid arena of complete dentures relates to western context and a thorough search of the literature revealed studies with similar structural design have been attempted earlier. Researches in the past though have scuttled its way in achieving means to modify the palatal portion of the complete dentures, but often had confronted difficulties in analyzing and interpreting degrees of improvement in speech on a punctilious standpoint from a prosthodontic perspective.

This study aimed to make a comparative evaluation of speech as a transition from the edentulous state to a customized palatal surface and to appraise the improvement in completely edentulous subjects rehabilitated with a conventional denture, Customized rugae fabricated denture (CRD) and a denture with customized metallic base (CMD). The study was based on a null hypothesis that no association would exist between improvement of speech and rehabilitation with conventional or customized complete dentures.

METHODS

A quasi experimental study design was undertaken. Since a quasi-experimental design aims to establish a cause-and-effect relationship between an independent and dependent variable, like a true experiment. However, unlike a true experiment, as a quasi-experiment does not rely on random assignment, the subjects are assigned to groups based on non-random criteria. The study was performed on completely edentulous subjects, within the age range of 50 to 70 years, reporting to the department of prosthodontics and Crown & Bridge; Ali Yavar Jung National institute of speech and hearing disabilities, regional center (AYJNISHD), Kolkata. For the present study, purposive sampling was followed and based on the limited evidence of interrelationship of acoustic analysis and efficacy of complete dentures, the under designed formula for continuous data considering $\alpha=0.05$, power:

90%, β : 0.1, Confidence interval: 95% and Coefficient of variation (CV%): 17.5; was computed to determine the sample size (n).

$$n = 2x(Z(1 - \alpha/2) + Z\beta)2x \sigma^2 \div \Delta^2$$

Where Δ =size of difference, α =significance level, β =power or probability of detecting a significant result, and σ =SD of data and Z_p =points on normal distribution to give required power and significance.

The subjects (5 male and 5 females, each further sub assigned into groups viz M0, M1, M2 & M3), fulfilling the inclusion criteria i.e. completely edentulous with a Class 1 ridge relationship was duly included for the study purpose. Previous denture wearers, patients with less than adequate interarch space, less than average ridge height, patients with auditory defects, poor neuromuscular control, presence of tori, flabby tissue and severe undercuts were excluded. Informed written consent was taken from each subject after explaining the need of the study. For each individual 3 sets of dentures were fabricated viz conventional complete denture, CRDs and CMDs, following which they were subjected to various speech analysis parameters, and compared through photo articulation (PAT), speech intelligibility (SI) and acoustic analysis within the time interval of 10-14 days for each of them, the study was conducted over a duration of 14-16 months from 01 February 2017 to 15 April 2018, which included implementation of study design, selection of subjects, data acquisition and statistical outlining.

History taking and detailed clinical examination was done, followed by fabrication of conventional complete dentures in conventional fashion. At the time of delivery of the prosthesis, occlusal equilibrations and minor adjustments were performed and the subject was requested to report back after a gap of a week for speech tests. Subsequently, fabrication of CRDs was done with marking of rugae patterns in definitive maxillary cast using a permanent marker, ensuring to block out all unfavorable undercuts. Auto-polymerizing resin (clear) by the sprinkle-on method was added on the rugae portion in the cast such that the markings appeared through the transparent resin. Then, auto-polymerizing resin (pink) was added by the same method on the rest of the definitive maxillary cast and the record base was fabricated in the usual manner. Trial denture verification was accomplished. Dental floss (waxed interdental floss,) was cut as per the required lengths and was luted over the rugae marking seen through the record base using inlay casting wax as seen in (Figure 1).

Fabrication of CMD was commenced by scribing the outline on the definitive cast. Block out was performed in two stages. The definitive casts were placed in slurry water and pre-heated for accurate duplication. A metal duplicating flask was used for the procedure and duplicating media was reversible hydrocolloid. After the final gelation time had elapsed, the cast was pried out

carefully and the mould was ready for pouring of the refractory material.



Figure 1: Fabrication of customized rugae maxillary complete dentures.

Tacky liquid was painted within the confines of the proposed base. Retention meshwork wax pattern was adapted over the facial ridges along the confines and a stippled casting wax was adapted in the center of the palate. The excess was trimmed down with a No. 11 Bard Parker knife, the borders and the joint between the mesh and the palatal stippled surface were sealed with blue inlay wax. The cast was sprued and invested. Finally, the conversion of cast to record base was done by addition of polymerizing resin and the denture was flaked and processed further in conventional fashion as depicted in (Figure 2).



Figure 2: Fabrication of customized metallic base maxillary complete dentures.

Edentulous status of each patient was recorded. All the subjects received three sets of dentures followed by assessment of speech which was done through photo articulation test, speech intelligibility and acoustic analysis in edentulous state. Subsequently, speech was also analyzed after insertion of conventional denture, denture with customized rugae and denture with customized metallic base. Speech assessment was carried out in four stages. First stage was carried out in subjects in edentulous state which was designated as M0; second stage with the conventional maxillary dentures designated as M1; third stage speech assessment was done with the customized rugae maxillary dentures noted as M2 and fourth stage with the customized metallic base dentures denoted as M3 respectively. Each subject was assessed for all above mentioned parameters for each designated

stage at an interval of 10-14 days. The subjects were analyzed twice in each stage of recording to minimize the degree of errors, if any.

PAT was done with the help of the Bangla articulation test (BAT) developed by AYNISHD, Bonhoogly, Kolkata that consisted of 76 test words having all vowels and consonants. The vowels and consonants were evaluated at initial, middle, and final word positions. Articulatory errors i.e. substitution, omission, distortion, and addition of words were analyzed and data was recorded. SI was evaluated using intelligibility rating Scale as provided by the department of speech and hearing disabilities, Kolkata. The printed sheet was explained to the subjects and they were asked to readout a list of words provided at an interval of few seconds to maintain uniform space and later they were engaged in a conversation for a short period of time. The scoring was based on a seven-point scale by two observers and data was recorded. Acoustic analysis was performed through PRAAT software (Paul Borsamac and David Weenink, University of Amsterdam).⁴⁻⁶ Recordings were made in a quiet sound proof, isolated room with the subject seated comfortably and a microphone was positioned 6 inches (15 cm) away from the subject as seen in (Figure 3,4). Each subject was asked to pronounce the vowels, consonants, and blends for a period of 3-4 seconds as clearly as possible. Speech was recorded directly on a computer using PRAAT software (32 bit) Window 7. The analysis was performed at a sampling rate of 44100 Hz. The data was isolated and computerized data of various acoustic parameters were obtained. The data collected was subjected to statistical analysis using SPSS 24.0 version and GraphPad Prism version 5.



Figure 3: Acoustic analysis performed using PRAAT.

RESULTS

Data had been summarized as mean and standard deviation for numerical variables and percentages for categorical variables. According to Shapiro and Wiilk test, the data distribution was normal. Hence parametric statistics have been followed. One-way analysis of variance and student t-test was used to compare means for numerical data, with the level of significance at

p=0.05. If the calculated p value was found insignificant, then the null hypothesis was rejected in favor of the alternative hypothesis. Scores of photo articulation test for M0 (edentulous state), M1 (conventional denture), M2 (customized rugae denture) and M3 (customized metallic base denture) were determined for all the study subjects. The level of significance was found to be significantly correlated between M0 and M1; M0 and M2; M0 and M3; and between all these four groups (p<0.0001), (Table 1). Scores of speech intelligibility for M0, M1, M2 and M3 were determined and statistically it was found to be significant (p<0.0001), (Table 2). Acoustic analysis was done using the first and second formant frequencies (F1 and F2) for all the four stages. It was found that formant frequencies fall within the normal range for M0, M1, M2, and M3 but with the upper limit of the range for M2, suggesting that articulation was better with customized rugae dentures. Voice onset time for “d” was least with customized rugae dentures and increased for M0 and M1, which indicated better articulation and pronunciation with customized rugae dentures. The burst duration was on the very higher side

without dentures and subsequently decreased, with the least with CRDs as depicted in (Figure 3). A strong positive correlation between improvement of speech and various customizations of complete dentures was observed using Pearson correlation coefficient (Table 3).

DISCUSSION

The insertion of complete dentures often leads to speech alteration. Although many of the alterations are temporary in nature, but they often create a sense of worry for patients. From a broad prosthodontic point of view, there is a definite lacuna of guidelines for designing dentures with the best phonetic success. The study includes completely edentulous subjects of either sex, as differences in palatal morphology often creates a differential response to change in the oral cavity geometry, created by maxillary prostheses.⁷ A plausible explanation is that, the mean fundamental frequency which is associated with the perceptual notion of pitch is commonly considered as the major difference between adult male and female voices.

Table 1: Distribution of mean photo articulation test among four groups.

Parameters	Group	N	Mean	SD	Minimum	Maximum	Median	P value
Photo articulation test	M0	10	60.4000	3.1693	56.0000	67.0000	60.0000	<0.0001
	M1	10	53.8000	5.2873	47.0000	63.0000	52.5000	
	M2	10	41.6000	5.7774	32.0000	51.0000	40.5000	
	M3	10	44.6000	5.0155	39.0000	54.0000	43.5000	

Table 2: Distribution of mean intelligibility test among four groups.

Parameters	Group	N	Mean	SD	Minimum	Maximum	Median	P value
Intelligibility test	M0	10	2.1000	0.5676	1.0000	3.0000	2.0000	<0.0001
	M1	10	1.5000	0.5270	1.0000	2.0000	1.5000	
	M2	10	0.4000	0.5164	0.0000	1.0000	0.0000	
	M3	10	0.8000	0.4216	0.0000	1.0000	1.0000	

Table 3: Strong positive correlation between improvement of speech and various customizations of complete dentures.

Correlations				
Parameters	M0	M1	M2	M3
Pearson correlation coefficient (r)	0.187	0.204	0.928**	0.897**
P value	-	0.572	0.332	0.047
Number	10	10	10	10
Pearson correlation coefficient (r)	0.204	-0.765	0.816**	0.229
P value	0.572	-	0.066	0.525
Number	10	10	10	10
Pearson correlation coefficient (r)	0.033	-0.601	1**	-0.543
P value	0.928	0.066	-	0.105
Number	10	10	10	10
Pearson correlation coefficient (r)	-0.047	0.229	-0.843	1**
P value	0.897	0.525	0.105	-
Number	10	10	10	10

**Correlation is significant at the 0.01 level (2-tailed).

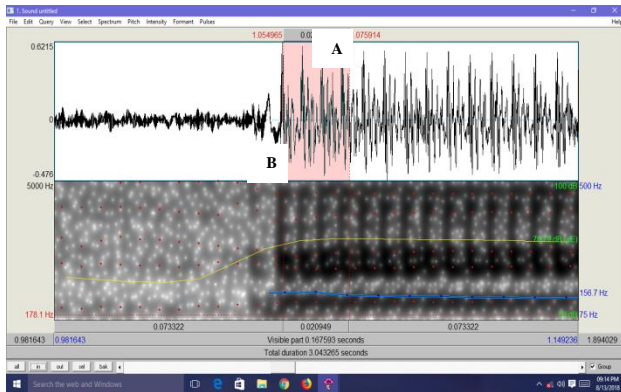


Figure 4: The spectrograph shows the (A) voice onset time measured in milliseconds and (B) identifying the burst and duration using the stimulus word “PAT” and “DIE”, expressed in local linguistics.

Cross-gender acoustic variations can mainly be accounted by anatomical and physiological differences that arise during puberty. Vocal folds become longer and thicker in males that explain why they tend to vibrate more slowly than those of women. A second important anatomical issue is the vocal tract length, that is, the distance from the vocal folds to the lips: all things being equal, the longer the vocal tract, the lower the resonant frequencies. According to the studies, the average length of the adult female vocal tract is about 14.5 cm, while that of a male individual is about 17 to 18 cm long.⁸⁻⁹ These results would account, at least in part, for cross-gender differences observed in vowel formants and consonant noise, which is evident in the present study in terms of quantification in improvement of various speech parameters for both male as well as female subjects. A study substantiated the finding by advocating that when investigating the impact of prosthesis on speech, it is wise to consider the role of both palatal morphology and gender, because men and women have different speech sound amplification, because of their different oral cavity volume.¹⁰ Thus, in the present study both the parameters were considered and evaluated.

In the present study, first a conventional complete denture was fabricated for the subjects, which was worn for a period of 8-10 days, following which the individual was subjected to speech analysis. Taking this period into account is very essential and this consideration is in accordance with the study performed by authors who advocated similar findings that the process of adaptation of the prosthesis seems to be acquired through a “feedback mechanism” (orosensorial reflex) concerned with speech motor programming.¹⁰⁻¹² In the present study, this fact can explain the aspect of improvement of speech in subjects at the stages of customizations, because the same subject when analyzed for speech tests had already been subjected to a period of adaption for more than two weeks.

The thickness of dental floss used in CRDs, was restricted to less than a millimeter. Two or three floss threads were luted together for duplicating variations in the thickness of rugae as required. Similar method of customizing rugae of a maxillary complete denture using waxed dental floss and standardizing the thickness of the dental floss to less than a millimeter was carried out by authors.¹³⁻¹⁴

The results obtained from the present study for PAT, showed the least amount of articulatory errors in terms of percentage with the customized rugae dentures. The distortions were maximum, followed by substitutions which were mainly for dentoalveolar and fricatives, influenced by the position of tongue, tooth and surface of the anterior portion of hard palate. The articulatory errors that took place for the subjects in the initial and consecutive stages of assessment could be explained on the basis of “speech production” model.¹⁵ Phonetic implementation does not “know whether the input sequence of phonological segments contain errors in serial order or not; and whether segments are implemented appropriately to their actual position.” The author further stated that, “nothing in errors suggests that the units erroneously shifted in their serial order have spatiotemporal specifications.”

The results of our study were in accordance to a study, common errors in articulation with conventional denture and without dentures were substitution of ‘sh by s’, ‘t by ta’, ‘c by ch’, ‘ja by da’ and speech was clearer with customized rugae dentures.¹⁶ This could be due to the fact that customized rugae dentures yielded least articulatory errors because of the elevations created by the dental floss, which guided the tongue to accurately locate the anatomical “cues”. This prevented the jet of air emitted by the tongue from escaping towards the vault.

An investigation by author analyzed the intelligibility results in terms of word accuracy and found out that it was significantly lower when not wearing a complete denture compared to after denture insertion, and also found a significant improvement in the speech.¹⁷ The results were in accordance with the findings of the present study, but contrasting to the fact that the speech intelligibility was computed based on the word accuracy by means of an automated speech recognition system, unlike the subjective way of intelligibility. A study by author supports the evidence of this present study, by advocating that there might be some evidence that overall speaking rate varies with paralinguistic characteristics such as speaker’s gender and dialect.¹⁸ Although the speaking rate can be associated with a reduced conversational speaking style, but a direct link between speaking rate and intelligibility remains unclear.

It was found that articulation was better with customized rugae dentures. Apart from the better anatomical and tactile localization of the tongue with specific areas on the anterior portion of the palatal surfaces of the

customized dentures, other factor which might have influenced positive results was that the study population was gauged on a basis of local dialect (Bengali) in form of stimulus sentences or words or syllables. There is always an aerodynamic constraint on vocal cord vibration in pronouncing the obstruent. Articulatory errors were prevalent among these plosives in the present study and decreased as transiting from edentulous to customized states. A probable explanation for such an occurrence could be due to smaller oral cavity volume as a sequel of complete edentulism. An author in his revision of a paper had stated that for the vibrations of vocal cords, it requires that air should flow through the glottis.¹⁹ When an obstruent is pronounced, air builds up in the oral cavity and the pressure gradually rises, but if the oral pressure is same or equal to the sub-glottal pressure, flow will fall below the required amount necessary to maintain vocal vibration. This constraint can be overcome by expanding the oral cavity volume to absorb the accumulating air. Such expansion may be done passively, due to the natural compliance of the vocal tract walls to the impinging pressure, or actively by lowering the tongue and jaw, to an extent substantiates the reasoning for the present study. The results of this study would enable to improve speech difficulties encountered in edentulous subjects and would provide a guideline for specific customizations of complete dentures.

Limitations

Limitations of present study included subjective evaluations that could have varied among different observers. Improvement could have been compared over a longer span of time after initial adaptation of both conventional and customized dentures. The reasons for no absolute improvement in parameters and certain articulatory errors persisting even after rehabilitation with customized dentures were deciphered and explained but for a more conclusive understanding, further studies with a similar structural design needs to be done to unravel this finding.

CONCLUSION

Apart from retention, stability and support of the prosthesis, an equal amount of emphasis has to be laid down on phonetical aspects to improve the overall psychological well-being and social upliftment for patients. In edentulous individuals whose profession demands fluency and clarity in speech, the maxillary dentures should be customized either at rugae area or the anterior portion of palate or both, to enhance better tactile location of the tongue for speech enhancement. An absolute eradication of all articulatory errors though may not be feasible, but gross errors can be identified and corrected through customizations to a certain degree. This study was not without limitations. Many different factors, such as the patient turnover and the limits of resources, affect voice analysis. To reduce an inter-subjective and intra-subjective effect on analysis quality, study

undertaken should be lucid in terms of data acquisition, for better identification and quantification.

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