

Role of Palatal Rugae in Speech Rehabilitation of Complete Denture Patients: A Comparative Spectrographic Study

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ABSTRACT

Background:

Speech performance is an important determinant of functional success and patient satisfaction following complete denture rehabilitation. Palatal rugae present in natural dentition serve as tactile and positional guides for the tongue placement during articulation of linguopalatal sounds. Conventional dentures often lack this anatomical reference, potentially impairing phonetics. Incorporation of reproduced palatal rugae into complete dentures may improve phonetic performance and speech adaptation.

Aim:

To evaluate and compare phonetic performance in completely edentulous patients wearing dentures with and without palatal rugae using spectrographic analysis and subjective assessment.

Materials and Methods:

This prospective clinical study was conducted on 21 completely edentulous patients rehabilitated with complete dentures. Each participant was evaluated under three conditions: (1) no denture, (2) complete denture with characterized palatal rugae, and (3) complete denture without rugae. Speech recordings were obtained in a controlled environment using a standardized microphone setup (44.1 kHz, 16-bit). Phonetic stimuli were derived from a validated Hindi articulation test, and linguopalatal phonemes /t/ and /d/ were assessed in different word positions. Acoustic analysis was performed using Praat software to evaluate spectrographic clarity and articulation duration. Additionally, perceptual speech assessment was conducted by two independent speech-language pathologists blinded to the study conditions. Subjective evaluation was also performed using a visual analogue scale (VAS) for speech clarity, ease, and satisfaction.

Results:

Dentures incorporating palatal rugae demonstrated significantly improved phonetic outcomes. Spectrographic clarity increased from 68 ± 12 to 92 ± 10 for /t/ and from 71 ± 14 to 95 ± 12 for /d/ ($p < 0.001$). Articulation duration was significantly reduced, and patient-reported speech outcomes were significantly improved. Perceptual evaluation revealed enhanced articulation accuracy and reduced slurring in the rugae group. VAS scores for speech clarity, ease, and overall satisfaction were also highest with rugae-incorporated dentures.

Conclusion:

Incorporation of palatal rugae in maxillary complete dentures was associated with improved phonetic outcomes, enhanced clarity and ease of speech, reduced slurring, and improved patient satisfaction. This simple modification should be considered an important adjunct in denture design to optimize speech performance.

Keywords: Complete denture, palatal rugae, speech analysis, phonetics, spectrography, edentulous patients, linguopalatal phonemes.

INTRODUCTION

Complete edentulism continues to be a significant oral health challenge worldwide, with high prevalence among the elderly population. Prosthetic rehabilitation through complete dentures remains most widely accepted treatment modality for restoring oral functions such as mastication, phonation, and esthetics in completely edentulous patients.¹ While conventional complete dentures restore many oral functions adequately, limitations exist in their ability to reproduce natural phonetics due to the absence of anatomical reference structures such as palatal rugae.² Palatal rugae are anatomical folds or ridges of the palatal mucosa situated on the anterior third of the palate, posterior to the incisive papilla. These structures play an essential role in speech articulation, tongue placement, and tactile sensation.³ Speech production is a complex process that involves coordinated interaction between respiratory, phonatory, and articulatory systems. In the natural dentition, the rugae provide a surface against which the tongue makes contact during the articulation of certain linguopalatal sounds, including alveolar and retroflex phonemes. It contributes significantly to the articulation of consonant sounds such as /t/ and /d/, which require precise tongue-palate contact.⁴ The lack of palatal rugae in complete denture bases has been reported to negatively influence the clarity of these sounds leading to phonetic inaccuracies, impaired articulation, and reduced patient satisfaction.⁵ To

address this limitation, characterization of complete dentures with added palatal rugae has been proposed as means of improving speech performance and patient adaptation.⁶

Speech assessment in complete denture wearers can be carried out using multiple approaches, including perceptual evaluation by trained clinicians, patient-reported outcome measures, and objective instrumental techniques such as acoustic and spectrographic analysis.^{7,8} Perceptual assessment, although clinically valuable, is inherently subjective and may be influenced by inter-examiner variability.⁷ Similarly, patient-reported measures provide insight into functional adaptation and satisfaction but lack precise quantitative assessment.⁸ In contrast, instrumental methods, particularly acoustic and spectrographic analysis, offer objective, reproducible, and quantifiable evaluation of speech characteristics.⁹ By analyzing acoustic parameters of speech sounds, spectrography provides valuable insight into articulatory patterns, enabling quantification of the effects of prosthetic modifications on phonation.

Previous investigations have demonstrated that modifications of the palatal contour can significantly influence phonetic function and speech intelligibility in complete denture wearers. Appropriate reproduction of palatal anatomy has been associated with improved articulation accuracy and more natural tongue–palate contact during speech production.¹⁰ Given that speech plays a central role in social interactions and overall quality of life, evaluating modifications that may improve phonetics in denture wearers is clinically significant. However, limited research has been conducted to systematically evaluate the role of palatal rugae incorporation in complete dentures using spectrographic methods in the Indian population.

This study, therefore, was undertaken to perform a spectrographic analysis comparing conventional complete dentures, dentures with characterized palatal rugae, and polished complete dentures to determine their effect on phonetic quality and articulation of linguopalatal phonemes in edentulous patients.

Hypothesis

Null Hypothesis (H0):

There is no significant difference in spectrographic speech outcomes, perceptual speech assessment scores, patient-reported speech satisfaction, or adaptation outcomes among completely edentulous patients evaluated without dentures, with complete dentures incorporating palatal rugae, and with complete dentures without palatal rugae.

Alternative Hypothesis (H1):

Incorporation of palatal rugae into complete dentures results in significant improvements in spectrographic speech parameters, perceptual speech assessment scores, patient-reported speech satisfaction, and adaptation outcomes compared with dentures without palatal rugae and the edentulous condition.

MATERIALS AND METHODS

Study Design and Setting

This prospective crossover study was conducted in the Department of Prosthodontics at Seema Dental College and Hospital, Rishikesh, over a period of six months. The study aimed to evaluate variations in phonetic performance among completely edentulous patients under different prosthetic conditions. The study protocol received approval from the Institutional Ethics Committee of Seema Dental College and Hospital, Rishikesh. Before participation, all subjects provided written informed consent, including consent for audio recording, in accordance with ethical research standards.

Study Population

The sample size was determined using G*Power software version 3.1.9.4 with $\alpha = 0.05$, $\beta = 0.20$, power = 80%, and effect size = 0.65. The calculation yielded 21 participants. Patients were recruited from the outpatient department of Prosthodontics according to the following criteria.

Inclusion and Exclusion Criteria

Patients were selected according to predefined inclusion and exclusion criteria. The inclusion criteria comprised completely edentulous patients seeking new complete dentures, either for the first time or as replacements, aged 45–80 years. Only patients who were fluent speakers of the native language and free from severe systemic or neuromuscular disorders, auditory impairments, oral pathology, xerostomia, or tongue-tie were included in the study. Patients presenting with congenital anomalies or maxillofacial deformities affecting phonation, a history of maxillofacial trauma or surgery altering palatal anatomy, or those unwilling or unable to cooperate during speech recording procedures were excluded from the study.

Prosthetic Intervention and Study Conditions

All participants received maxillary and mandibular complete dentures fabricated using standardized clinical and laboratory procedures. Phonetic evaluation was conducted under three distinct conditions:

1. Edentulous state (without denture)
2. Denture with incorporated palatal rugae

3. Denture with a smooth, polished palatal surface

Denture Fabrication Protocol

Each participant was rehabilitated with two sets of maxillary and mandibular complete dentures fabricated using standard clinical and laboratory procedures. To create dentures with palatal rugae, a modification of Neelakanthan's method was employed.¹¹ Initially, primary impressions were made using impression compound in stock trays, and casts were poured. A putty index was then adapted over the rugae region of the maxillary cast to accurately duplicate the natural palatal rugae pattern (Figure 1). Molten baseplate wax was poured into the putty index, enabling the transfer of the rugae pattern onto the trial denture base. During denture processing, the waxed rugae pattern was carefully preserved and incorporated into the palatal surface of the definitive denture base (Figure 2A). The completed maxillary denture demonstrated clear duplication of the palatal rugae after final finishing and polishing (Figure 2B).

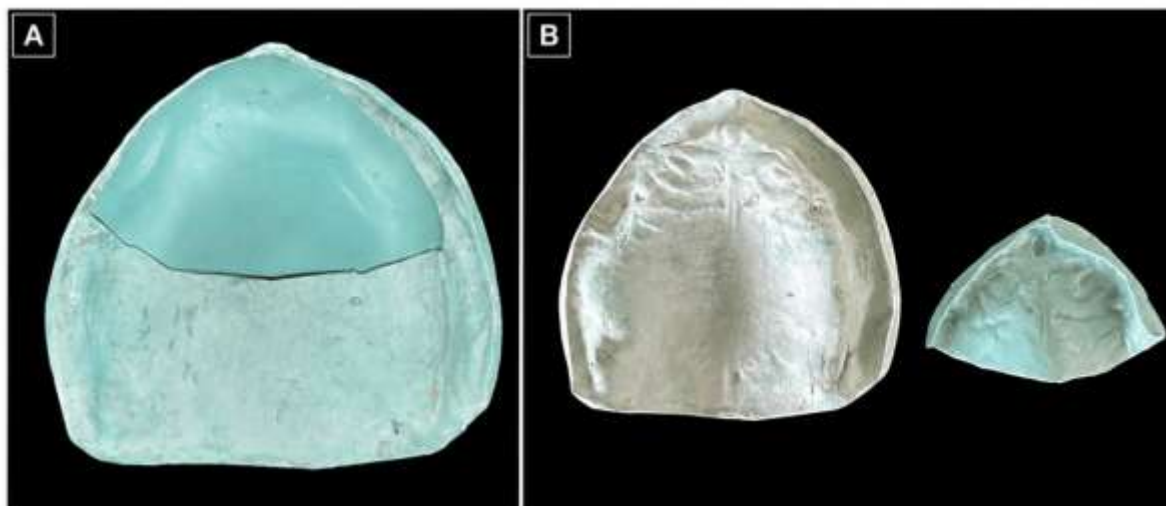


Figure 1: Putty index adaptation on the maxillary cast for duplication of palatal rugae during complete denture fabrication.

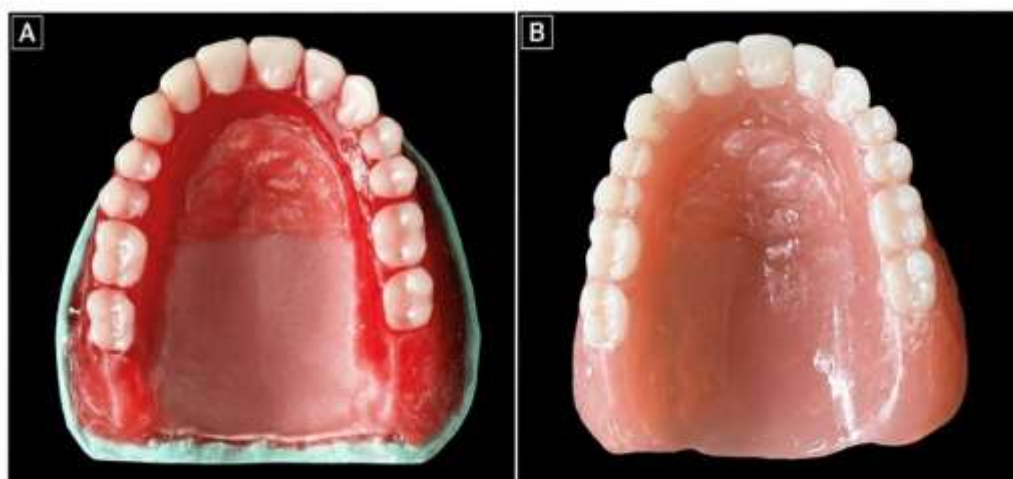


Figure 2: Maxillary complete denture demonstrating palatal rugae duplication. (A) Wax-up; (B) Final processed denture after polishing.

Speech Stimuli and Phonetic Assessment

Speech stimuli were derived from a standardized Hindi articulation test developed by the Helen Keller Institute of Research and Rehabilitation for the Disabled Children.¹²

To evaluate phoneme production across different articulatory contexts, words containing the target phonemes in initial (I), medial (M), and final (F) positions were selected.

Participants were instructed to articulate each word clearly at a comfortable speaking pace and intensity. Each stimulus was repeated three times, and the most consistent recording was selected for further acoustic analysis. All

speech samples were recorded under standardized conditions and subsequently analyzed using Praat software for spectrographic evaluation.

Table 1: Standardized Hindi words containing the linguopalatal phonemes /t/ and /d/ in initial (I), medial (M), and final (F) positions, along with their IPA transcriptions, used for phonetic and spectrographic analysis.

S.No.	Phoneme	Position	Word (Hindi)	IPA Transcription
1	/t/	Initial (I)	टीबी	/ti:bi:/
2	/t/	Medial (M)	बटन	/bətən/
3	/t/	Final (F)	ऊँट	/u:nt/
4	/d/	Initial (I)	डिब्बा	/dɪb:a/
5	/d/	Medial (M)	लड्डू	/ləd̪:u:/

Speech Sample Recording Protocol

Patients were recalled after 2 weeks of denture insertion for phonetic assessment as speech adaptation to new complete denture normally takes between 2-4 weeks after insertion.¹² Each patient underwent phonetic evaluation at three stages:

1. Stage 1 – Without denture (baseline).
2. Stage 2 – Characterized denture with palatal rugae.
3. Stage 3 – Denture without palatal rugae.

All recordings were conducted in a quiet room using a multimedia microphone positioned 10 cm from the participant's mouth, with sampling at 44.1 kHz and 16-bit resolution. Speech tasks involved articulation of the linguopalatal phonemes /t/ and /d/. Each sample was digitized and stored for spectrographic analysis. The phonetic assessment and recordings were conducted with the assistance of two experienced speech-language pathologists to ensure accuracy and reliability of the data.



Figure 3: Speech recording setup used for phonetic evaluation and acoustic analysis in completely edentulous patients. (A) Without denture; (B) Denture with incorporated palatal rugae.

Acoustic Analysis

Spectrographic clarity was assessed using Praat software version 6.4.48 (Paul Boersma and David Weenink, University of Amsterdam, The Netherlands). The clarity of each target phoneme was evaluated based on the visual and acoustic distinctness of consonant release bursts, formant transitions, and signal definition observed on the spectrogram. As no universally accepted spectrographic clarity scale exists for complete denture speech analysis, a structured semi-quantitative scoring system was developed for this study. A semi-quantitative clarity score ranging from 0 to 100 was assigned independently by two experienced speech-language pathologists blinded to the study condition.

Scores were assigned according to the following criteria:

- 0–25: Poor clarity with indistinct consonant release and marked speech distortion.
- 26–50: Fair clarity with reduced acoustic definition and inconsistent articulation.
- 51–75: Good clarity with recognizable consonant production and moderate acoustic definition.
- 76–100: Excellent clarity with distinct release burst, clear formant transition, and precise articulation.

The final clarity score for each phoneme was obtained by averaging the scores of both evaluators. Inter-rater reliability was assessed using the Intraclass Correlation Coefficient (ICC).

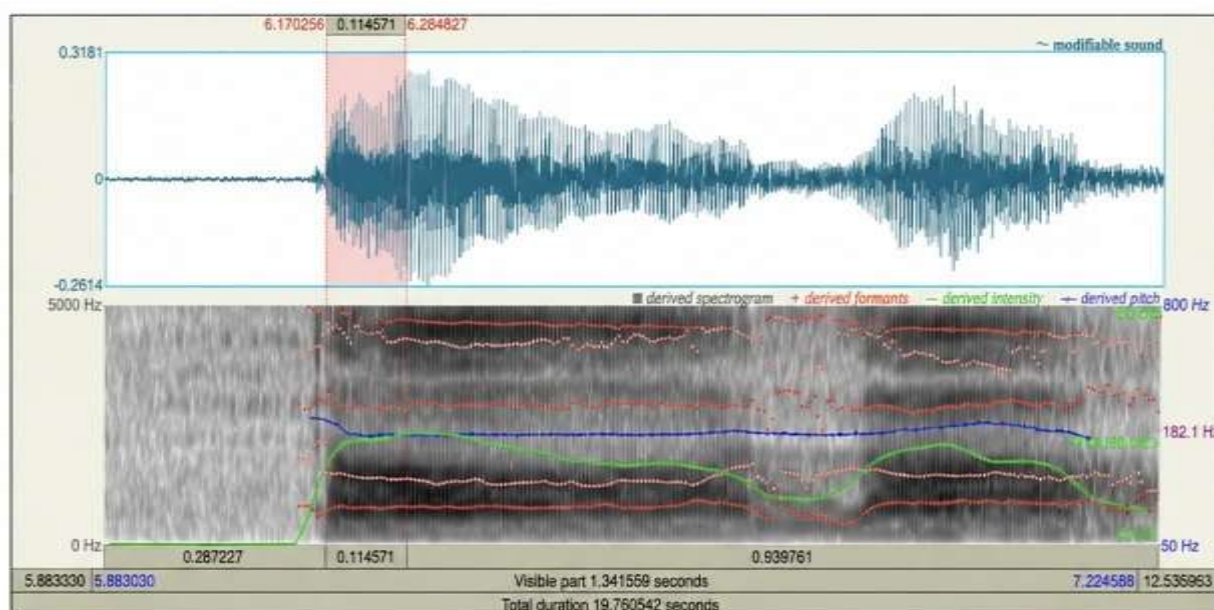


Figure 4: Representative Praat spectrogram showing consonant release burst and formant transitions of the /t/ phoneme.

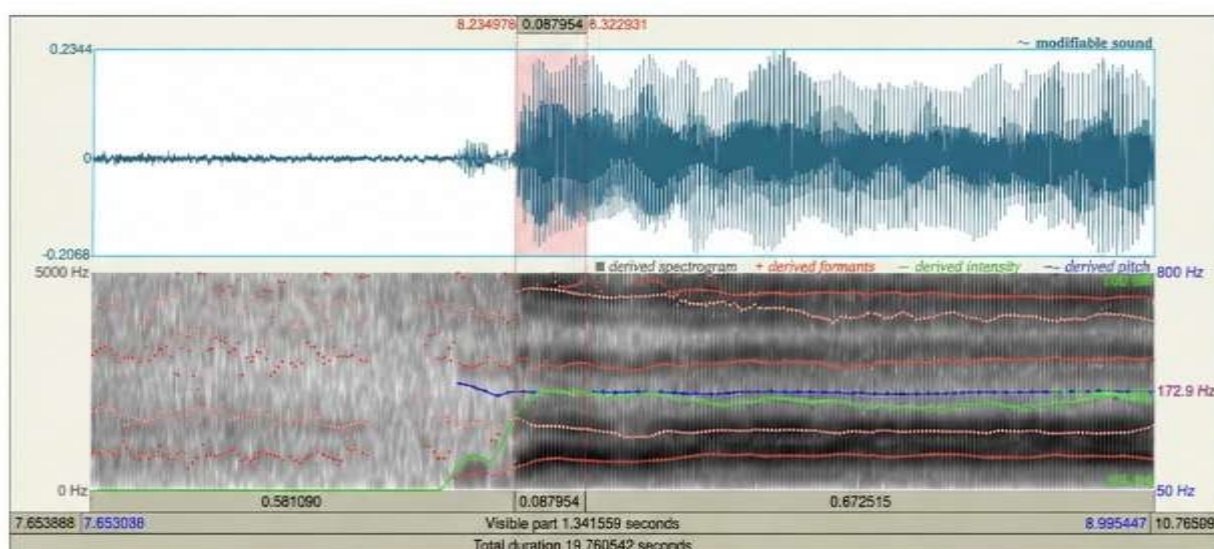


Figure 5: Representative Praat spectrogram showing consonant release burst and formant transitions of the /d/ phoneme.

Perceptual Evaluation of Speech

In addition to instrumental analysis, speech samples were assessed perceptually by two independent and experienced speech-language pathologists. The evaluators were blinded to the experimental conditions. They independently analyzed the recordings for clarity, accuracy of articulation, and presence of speech distortions such as slurring. The average of their scores was used for statistical analysis. Intra-observer reliability was evaluated to ensure reliability of the perceptual findings.

Patient-Reported Outcomes

Participants' subjective experience was assessed using a 10-point visual analogue scale (VAS). The parameters evaluated included ease of speaking, clarity of pronunciation and overall satisfaction of the patient. Additional feedback regarding speech difficulties and tongue–palate coordination was also recorded.

Outcome Measures

1. Spectrographic analysis
 - Spectrographic Clarity Score
 - Duration of articulation (ms).
2. Subjective assessment
 - Visual analogue scale (VAS, 0–10) for ease of speech, clarity, and satisfaction.
 - Reports of slurring or tongue–palate miscoordination.
 - Perceptual Speech Evaluation.
3. Adaptation outcomes
 - Patient-reported comfort with each condition.

Statistical Analysis

The statistical analysis was performed to test the null hypothesis that incorporation of palatal rugae in complete dentures does not significantly influence phonetic performance, perceptual speech outcomes, patient satisfaction, or adaptation compared with dentures without palatal rugae and the edentulous condition.

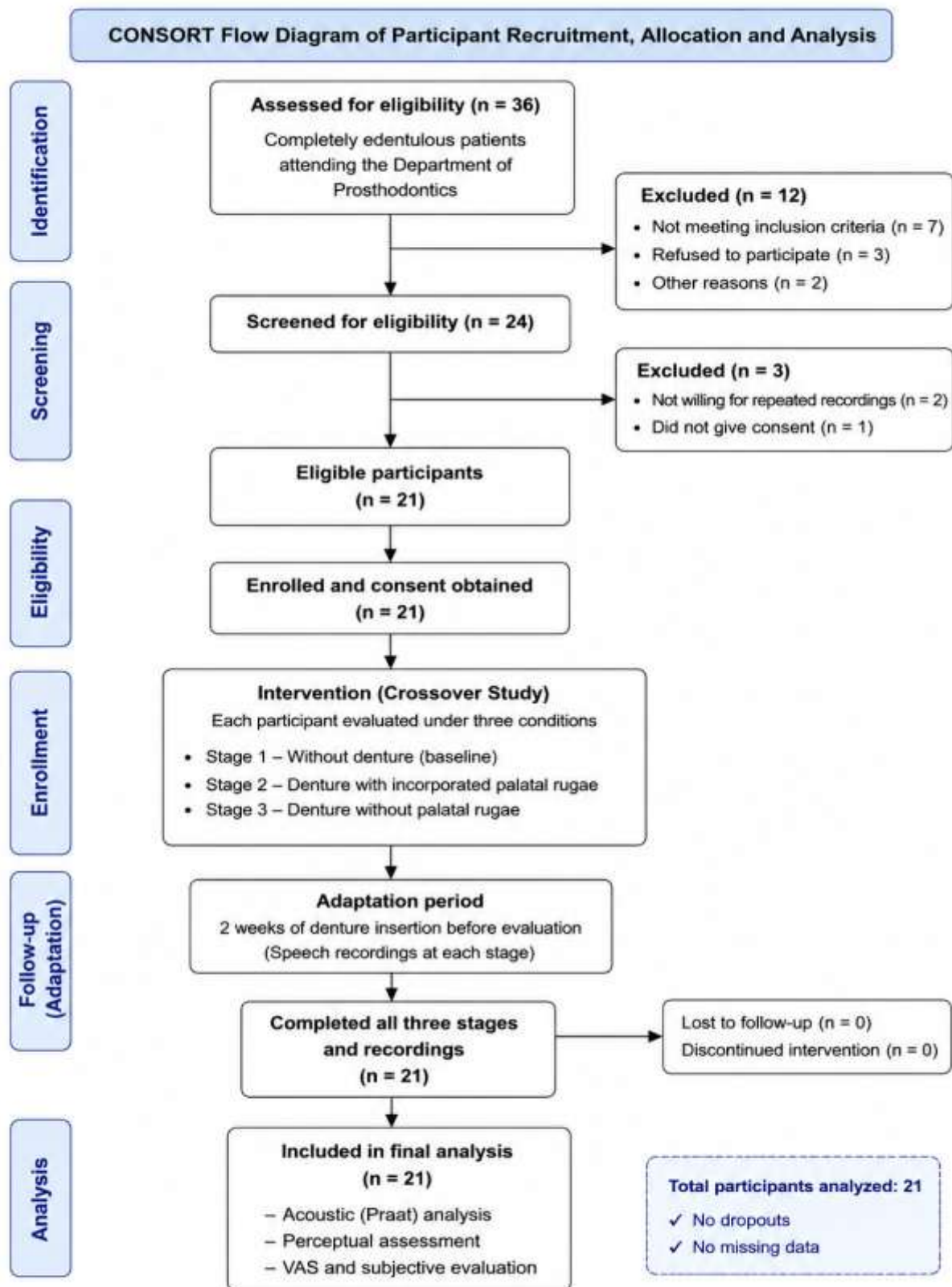
All data were tabulated and analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY). Quantitative variables were expressed as mean $\pm$ SD and analyzed using repeated-measures ANOVA for normally distributed data or Friedman's test for non-parametric variables. Post-hoc pairwise comparisons were adjusted with Bonferroni correction. Categorical data such as slurring were analyzed using Cochran's Q test. Inter-rater reliability for perceptual assessment was determined using the intraclass correlation coefficient (ICC). A p-value < 0.05 was considered statistically significant. In addition to statistical significance testing, effect sizes were calculated to determine the magnitude of differences among study conditions. Partial eta squared (η^2p) was reported for repeated-measures ANOVA analyses and interpreted as small (0.01), moderate (0.06), or large (0.14) effects.

Inter-rater reliability for perceptual speech assessment was evaluated using the Intraclass Correlation Coefficient (ICC) based on a two-way random effects model with absolute agreement. ICC values were interpreted as poor (<0.50), moderate (0.50–0.75), good (0.75–0.90), and excellent (>0.90). A p-value < 0.05 was considered statistically significant.

RESULTS

Participant Recruitment and Flow

A total of 36 completely edentulous patients were assessed for eligibility. Twelve patients were excluded due to failure to meet inclusion criteria, refusal to participate, or other reasons. Twenty-one participants fulfilled the eligibility criteria, provided informed consent, and were enrolled in the study. All participants completed the three study conditions and were included in the final analysis. No participant was lost to follow-up and no data were missing (Figure 6).



* All recordings were analyzed by two blinded speech-language pathologists and acoustic analysis was performed using Praat software.

Figure 6: CONSORT flow diagram of participant recruitment and analysis.

The mean age of participants was 61.8 ± 7.2 years, with a male-to-female ratio of 12:9. The mean duration of edentulism was 5.4 ± 2.1 years. All patients were fluent speakers of the native language and completed the study

protocol without dropouts. Baseline demographic characteristics were homogenous, ensuring comparability of outcomes across the three test conditions: no denture, denture with palatal rugae, and denture without rugae.

Table 2 presents the spectrographic outcomes for the linguopalatal phonemes /t/ and /d/. Dentures incorporating palatal rugae demonstrated significantly higher spectrographic clarity scores (92 ± 10 for /t/ and 95 ± 12 for /d/) compared with both the denture without palatal rugae and the no-denture condition ($p < 0.001$). Similarly, articulation duration was shortest in the rugae group (162 ± 18 ms for /t/ and 167 ± 17 ms for /d/), indicating faster and more precise phoneme production. These findings suggest that incorporation of palatal rugae may enhance speech production by improving acoustic definition and reducing articulatory latency.

Repeated-measures analysis demonstrated a significant effect of denture condition on spectrographic clarity scores for both /t/ and /d/ phonemes ($p < 0.001$). The observed effect size was large (partial $\eta^2 = 0.42$). The magnitude of this effect suggests that incorporation of palatal rugae has clinically meaningful benefits in speech rehabilitation beyond statistical significance alone.

Table 2: Spectrographic outcomes of /t/ and /d/ phonemes under three test conditions

Phoneme	Parameter	No Denture	With Palatal Rugae	Without Palatal Rugae	p-value
/t/	Spectrographic Clarity Score	68 ± 12	92 ± 10	81 ± 11	$<0.001^*$
/t/	Duration of articulation (ms)	184 ± 22	162 ± 18	175 ± 20	0.002^*
/d/	Spectrographic Clarity Score	71 ± 14	95 ± 12	82 ± 13	$<0.001^*$
/d/	Duration of articulation (ms)	190 ± 21	167 ± 17	178 ± 19	0.004^*

*Statistically significant ($p < 0.05$)

Table 3 highlights the subjective speech ratings using a 10-point visual analogue scale (VAS). Patients reported the highest scores for ease of speech (8.6 ± 1.0), clarity of pronunciation (8.9 ± 0.9), and overall satisfaction (9.1 ± 0.8) when using dentures with palatal rugae. Scores for the denture without palatal rugae group were intermediate, whereas the no-denture condition consistently yielded the lowest ratings. The differences between groups were statistically significant ($p < 0.001$), confirming that objective acoustic benefits observed with rugae incorporation translated into improved patient-perceived outcomes.

Inter-rater reliability analysis demonstrated good agreement between the two blinded speech-language pathologists for perceptual speech assessment (ICC = 0.87, 95% CI: 0.79–0.93), indicating acceptable consistency of scoring across study conditions.

Table 3: Subjective speech ratings (VAS 0–10)

Variable	No Denture	With Palatal Rugae	Without Palatal Rugae	p-value
Ease of speech	4.9 ± 1.2	8.6 ± 1.0	7.2 ± 1.1	$<0.001^*$
Clarity of pronunciation	5.2 ± 1.3	8.9 ± 0.9	7.5 ± 1.2	$<0.001^*$
Overall satisfaction	5.5 ± 1.4	9.1 ± 0.8	7.8 ± 1.1	$<0.001^*$

*Statistically significant ($p < 0.05$)

Table 4 summarizes patient-reported comfort and adaptation. Slurring was most frequent in the no-denture condition (71%) and decreased markedly with palatal rugae (14%), compared to polished dentures (32%) ($p = 0.006$). Likewise, tongue–palate coordination was rated “good/excellent” by 85% of patients in the rugae group, compared to 65% in the denture without rugae group. These findings underscore the role of palatal rugae in facilitating neuromuscular coordination during speech and minimizing articulation errors.

Table 4: Comfort and adaptation outcomes

Outcome	No Denture	With Palatal Rugae	Without Palatal Rugae	p-value
Slurring reported (%)	71%	14%	32%	0.006*
Tongue–palate coordination rated “good/excellent” (%)	—	85%	65%	0.04*

*Statistically significant ($p < 0.05$)

Overall, the results demonstrate that complete dentures characterized with palatal rugae provided superior phonetic performance, higher patient satisfaction, and better adaptation in comparison with the other two groups.

DISCUSSION

Based on the statistically significant improvements observed in spectrographic clarity, articulation duration, subjective speech ratings, and adaptation outcomes, the null hypothesis was rejected.

The rehabilitation of completely edentulous patients encompasses not only the restoration of mastication and esthetics but also the re-establishment of efficient phonatory function. Speech plays a pivotal role in determining patient satisfaction and overall quality of life, and even minor alterations in phoneme articulation may adversely affect communication and social confidence. In the present study, incorporation of palatal rugae into the maxillary complete denture resulted in significant improvement in phonetic performance, particularly for linguopalatal phonemes such as /t/ and /d/. These improvements were demonstrated objectively through spectrographic analysis and subjectively through enhanced patient-reported speech outcomes.

The findings of this study are consistent with previous investigations emphasizing the role of palatal rugae in speech articulation. Palatal rugae serve as tactile and positional guides for the tongue during phoneme production, and their absence in conventional dentures may interfere with consonants requiring precise tongue–palate contact. By reproducing these anatomical structures, characterized dentures restore a more natural oral topography, facilitating improved tongue positioning and reducing phonetic errors.⁸ Similar findings have been reported by Adaki et al. and Mahross and Baroudi, who demonstrated that palatal surface modifications can positively influence speech intelligibility and acoustic characteristics in complete denture wearers.^{13,14}

Spectrographic analysis in the present study demonstrated significantly greater clarity and shorter articulation duration for both /t/ and /d/ phonemes in dentures incorporating palatal rugae. These findings suggest that restoration of palatal morphology contributes to improved articulatory precision and more efficient speech production. Similar observations have been reported in previous acoustic investigations evaluating palatal contour modifications in complete dentures.^{13,14}

The beneficial effect of palatal rugae may be explained by enhanced oral stereognostic perception and improved sensorimotor feedback. Palatal rugae act as anatomical landmarks that facilitate accurate tongue positioning during speech production. Restoration of these structures within complete dentures may improve neuromuscular coordination, resulting in greater articulatory precision and reduced speech distortion. This mechanism is particularly relevant for linguopalatal consonants that require precise tongue–palate contact.^{15,16}

Patient-reported outcomes in the present study mirrored the objective acoustic findings. Participants wearing dentures with incorporated palatal rugae reported significantly greater ease of speech, improved clarity of pronunciation, and higher overall satisfaction. These findings are consistent with reports demonstrating that improved phonetic performance contributes substantially to patient confidence, social interaction, and oral health-related quality of life.^{6,7,17,18} These findings are also in agreement with Abu-Awwad et al., who reported improved patient satisfaction and oral health-related quality of life following incorporation of palatal rugae into complete dentures.⁶ Reduced slurring and improved tongue–palate coordination observed in present investigation further support the role of palatal rugae as functional reference points during speech production.

From a clinical perspective, incorporation of palatal rugae represents a simple and inexpensive modification that can be implemented during conventional denture fabrication without increasing treatment complexity. Given the importance of speech for social interaction and quality of life, particularly among elderly edentulous individuals, even modest improvements in phonetic performance may have meaningful clinical benefits.^{6,18}

Objective acoustic assessment has become increasingly valuable tool in evaluating prosthodontic interventions affecting speech. Unlike perceptual assessment alone, spectrographic analysis provides measurable and reproducible information regarding articulation quality and speech timing. The use of Praat-based acoustic analysis in the present investigation strengthens the validity of the findings by providing objective evidence supporting the phonetic benefits of palatal rugae incorporation.⁹ Furthermore, emerging digital technologies have increasingly

recognized the importance of reproducing patient-specific palatal anatomy to optimize speech rehabilitation outcomes.¹⁹

Future investigations should incorporate larger multicenter patient populations, randomized crossover study designs, and extended follow-up periods to better evaluate the long-term influence of palatal rugae incorporation on speech rehabilitation. The application of advanced assessment techniques, including objective tongue-tracking systems, electropalatography, and detailed acoustic parameters such as voice onset time and spectral moment analysis, may provide deeper insight into the mechanisms underlying phonetic adaptation. Furthermore, recent advances in CAD/CAM and additive manufacturing technologies have enabled precise customization of denture base morphology,^{20,21} creating opportunities for the digital reproduction of patient-specific palatal anatomy.²² Evaluation of digitally fabricated complete dentures with customized palatal rugae may further enhance our understanding of speech rehabilitation and contribute to the development of evidence-based prosthodontic protocols aimed at optimizing phonetic outcomes in edentulous patients.^{19,20}

Although the present findings are encouraging, caution should be exercised when extrapolating the results to other languages and phonetic systems because speech production patterns vary across linguistic populations.

Notwithstanding the encouraging outcomes of present investigation, certain limitations must be considered while interpreting the findings. The relatively limited sample size ($n = 21$) may restrict the generalizability of the results to broader edentulous populations. Furthermore, speech evaluation was conducted at a single postoperative interval without longitudinal assessment, thereby precluding comprehensive analysis of progressive neuromuscular adaptation associated with prolonged denture usage. Additionally, the crossover sequence was not randomized and no washout period was incorporated between study conditions, which may have introduced order effects. Also, phonetic evaluation was restricted to selected Hindi linguopalatal phonemes (/t/ and /d/), limiting extrapolation to broader linguistic contexts. Variability in acoustic interpretation and the inability to blind participants may also have contributed to measurement and response bias. Nevertheless, the findings provide preliminary clinical evidence supporting the functional significance of palatal rugae reproduction in complete denture therapy. Future well-designed randomized longitudinal studies are warranted to strengthen the evidence base.

CONCLUSION

This study reinforces the functional significance of palatal rugae in complete denture design. Their incorporation was associated with enhanced phonetic quality, reduced speech errors, accelerated patient adaptation, and improved overall satisfaction among complete denture wearers. Prosthodontists may therefore consider denture characterization with palatal rugae as a valuable adjunct to conventional denture fabrication for optimizing speech outcomes and functional rehabilitation. However, further well-designed longitudinal studies with larger sample sizes and broader phonetic evaluation are required to substantiate these findings and establish definitive clinical guidelines.

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