

Acoustic speech analysis of CAD/CAM and conventional Kennedy class IV removable partial dentures

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Background/aim

Phonetics is an important function of the oral cavity that can be affected by partial or total loss of teeth. This study aimed to examine the influence of the partial denture's construction technique (conventional and CAD/CAM) on speech quality through acoustic analysis of sound production of letters S, Sh, T, and D using sound analysis software.

Patients and methods

The study was conducted on 20 patients aged from 25 to 50 years having maxillary anterior teeth loss (Kennedy class IV classification). The patients were randomly categorized into two groups: group I received conventional removable partial dentures (RPDs), while group II received CAD/CAM RPDs. Acoustic speech analysis of the selected letters (S, Sh, T, and D) of the delivered RPDs was assessed and analyzed using ANSYS sound software and SIL speech Analyzer, 1 and 3 months after denture insertion. Statistical analysis was carried out using paired *t* test and independent *t* test.

Results

Group II showed significant difference ($P < 0.05$) in the acoustic pronunciation of the selected letters, in the follow-up period from denture insertion to 1 month after, while for the follow-up period from denture insertion to 3 months there was insignificant difference ($P > 0.05$) in the acoustic pronunciation of the S, Sh, and T sound compared to group I. Within group I and group II separately, they revealed significant difference for all the measured parameters except for VOT/(D) which was insignificantly different.

Conclusion

RPDs constructed by CAD/CAM technology have a more precise fit of the chrome–cobalt framework with a high quality of sound production even at the time of denture insertion.

Keywords:

CAD/CAM, Kennedy class IV, removable partial dentures, sound analysis

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Introduction

Partial edentulism is a condition in which one or more natural teeth are missing but not all of them [1]. The most common causes of loss of teeth are tooth decay and periodontal disorders [2].

The position and number of edentulous spaces, as well as their relationship to the existing tooth structure, were used to classify edentulous teeth positions [3]. The primary purpose of the partial edentulism classification system is to identify possible tooth configurations in the ridges and to facilitate communication among dental experts, students, and technicians [4].

The most common classifications are Kennedy's, Applegates, Avant, Skinner, Wild, Bailyn, Cumber, and Neurohr. Each classification has its own set of advantages and disadvantages. Kennedy's classification

is the most used by the majority of specialists worldwide, due to its immediate perception and ease of distinguishing [5]. Several studies have found that the treatment of patients with Kennedy's classification is largely dependent on their socioeconomic situation, such as income and educational level [6].

Although the prevalence of Kennedy class IV edentulism has decreased due to seat belt laws and growing awareness for oral protection in contact sports, it is still common. Kennedy class IV edentulous space can be short span (just lacking incisors) or long span (missing anterior teeth and some premolars). A fixed prosthesis would later result in an unsatisfactory

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cantilever effect, even if the abutments are periodontally sound [7].

Because of the intimate relationship between phonemes and their creation zones, even little alterations at these locations can affect them. The most significant relationship of partial or total teeth loss or dislocation, which causes a change in the oral cavity structure that will influence the resonance and the articulation of phonemes [8].

Teeth are thought to play a major role in the production of certain phonemes. Consequently, speech would be altered in a partial or complete edentulous state [9]. A prosthesis must meet the requirements for aesthetics, masticatory activity, phonation, and, most importantly, articulation. So that, to work properly, the teeth of the denture must be precisely associated with the tongue and other articulators. Once prosthesis is inserted, phonation, articulation, and resonance in the oral cavity may all change. Disarticulation of phonemes can be caused by articulator formation deficiencies, improper placement, and malfunction. The intimate relationship between phonemic parameters and intraoral structures emphasizes the relevance of prosthetic rehabilitation and the necessity for a prosthesis that improves phonemic articulation characteristics as well as aesthetic and masticatory roles [10].

Selective laser melting, selective laser sintering, and direct metal laser sintering are some of the terms used to describe laser-sintering technology. Fabricating removable partial denture (RPDs) with a laser-sintering approach rather than a casting technique could improve RPD quality while also making treatment less expensive and more accessible to a larger population. However, using the laser-sintering technique to make Co–Cr RPDs can change the mechanical, physical, and biocompatibility features of the materials, which can impair RPD clinical efficacy [11]. Differences in the fabrication process, such as laser beam power, scanning speed, metal particle size, and layer thickness, can affect the characteristics of laser-sintered alloys [12].

Speech has a major influence on patients' denture satisfaction that can affect their acceptance of dentures [13]. The insertion of RPDs can lead to speech variation. This variation may temporary but is still an origin of anxiety for patients [14].

During sound production, the tongue interacts with different portions of the teeth, the alveolar ridge, and

the hard and soft palates [15]. When some or part of these structures is covered or replaced by RPDs, proprioceptive feedback may be altered. Therefore, phonetics may be exaggerated by the presence of RPDs [16]. Most of the prior literatures on phonetics had been concerned with location of the artificial teeth and the vertical dimension of occlusion and there were few studies in the literatures assessing the role of partial denture construction on speech superiority.

Spectrograms are noninvasive voice quality research and evaluation methodologies. It is crucial to choose words that contain both consonants and vowels for the optimal examination of the phonetic spectral properties in the spectrogram. The acoustic changes of the phonemes may be due to the artificial teeth not being aligned correctly or the denture base of the prostheses being too thick [17].

There were few studies in the literature evaluating the effect of partial denture construction on speech quality. Therefore, this study aimed to examine the influence of the partial denture's construction technique on speech quality through the acoustic analysis of sound production of letters S, Sh, T, and D using sound analysis software.

Patients and methods

Patients

The study was conducted on 20 patients selected from the outpatient clinic of Misr University for Science and Technology, College of Oral and Dental Surgery, and Badr University in Cairo, Faculty of Oral and Dental Medicine.

The inclusion criteria: patients aged from 25 to 50 years having class IV Kennedy classification anterior space, with normal oral structures and normal hearing system. And having adequate interarch space, normal maxillary–mandibular relationship angle Class I, and good physical and mental health.

The exclusion criteria: patients having tongue-tie, uncontrolled diabetes, heavy smokers, a patient having recent radiation treatment, or having any signs of pathologic conditions such as osteoporosis, patients on corticosteroids, and bruxer patients.

Study design

The selected patients were randomly categorized into two groups:

Group I: patients who received RPDs constructed by the conventional (lost wax casting) technique.

Group II: patients who received RPDs constructed by the CAD/CAM laser-sintering technique.

The speech pronunciation of the selected letters S, Sh, T, and D of the delivered RPDs was assessed and analyzed using ANSYS Sound software (Sound Design and Quality, ANSYS Inc., Southpointe 2600 Ansyes Drive, Canonsburg, PA, USA) and SIL speech analyzer (SIL Technology, SIL International 2022), 1 and 3 months after denture insertion.

Ethical approval

The present study was conducted with the Code of Ethics of the World Medical Association, according to the principles expressed in the Declaration of Helsinki in 1975. This study was approved by the Medical Research Ethics Committee of the National Research Centre, Cairo, Egypt under approval number 0144052021. All patients were informed about the practical steps of this study and signed a written consent.

Methods

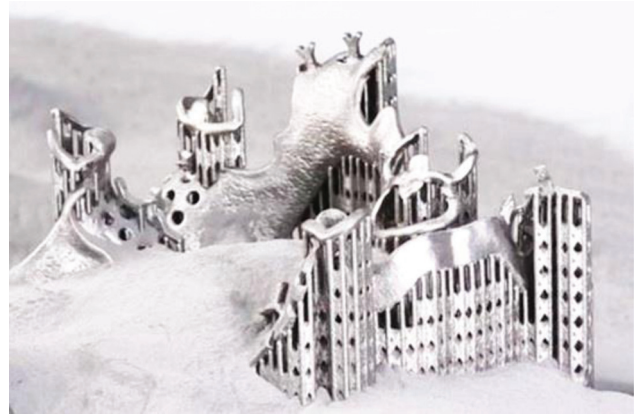
Removable partial denture fabrication

For each patient, impressions were made with an irreversible hydrocolloid material to obtain primary models; the partial denture design was planned after surveying the primary cast. Then mouth preparation was done carefully following the preplanned partial denture design, final impression was made. The final impressions were poured into an extra hard dental stone to get master models.

The models were sent to the dental laboratory to fabricate a cobalt–chromium metallic denture base using the conventional lost wax technique. While for group II the models were sent to the digital laboratory to be scanned (MEDIT T500, MEDIT Corp., Seoul, Korea) and obtain STL files, the preplanned design was drawn on the virtual casts on software (Medit Creator, MEDIT Corp.) and then printed using the metal additive printing machine (VULCANTECH VM120: Laser IPG Phototonics (IPG Photonics Corporation, 50 Old Webster Road, Oxford, MA), Germany); 3D printing of the cobalt–chromium metallic denture base (Fig. 1). Cobalt–chromium denture base was then finished and polished (Fig. 2).

The metal was tried inside the patient's mouth for minor modifications (if any); the jaw relation was recorded using a trial denture base and the final

Figure 1



Three-dimensional printing of the cobalt–chromium metallic denture base

Figure 2



Cobalt–chromium denture base after finishing and polishing.

try-in of the artificial teeth was done to check esthetics and phonetics.

The final dentures were checked in the patient's mouth, and any occlusion adjustments were done if needed. Then, the patients were recalled for follow-up and speech assessment (Fig. 3).

Speech acoustic analysis

Speech acoustic analysis was done in a soundproof air-conditioned room. The patient was seated comfortably on a chair. A microphone was positioned 4–6 inches away from the patient, which was connected to a computer in which ANSYS sound software and LIS technology were installed (Fig. 4). A list of words containing the selected letters were given to each patient. These words were read at an interval of 3

seconds from a group of words, particular words, and consonants to be studied were isolated. The computerized data of various acoustic parameters were obtained (Fig. 5). The speech acoustic analysis was done through the listed parameters mentioned in Table 1.

Sample size calculation

The study was planned with a continuous response variable from independent control and experimental subjects with one control(s) per experimental subject.

Figure 3



Final maxillary partial denture inside the patient's mouth.

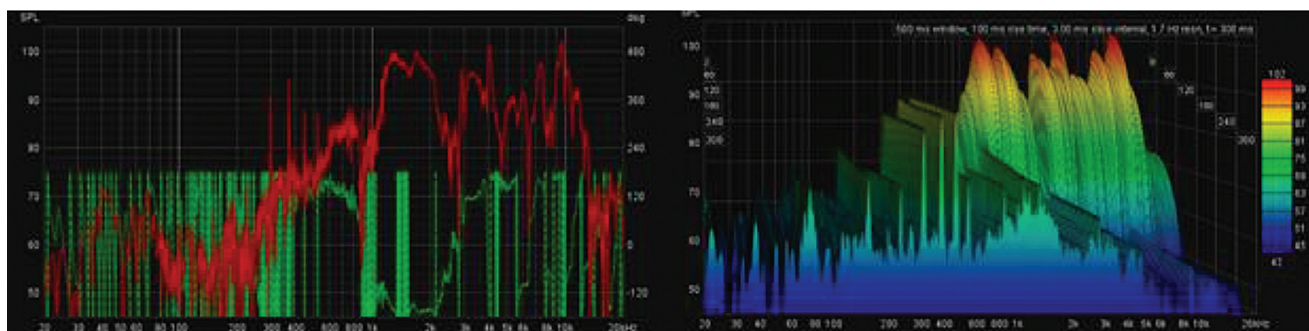
In a previous study [18], the response within each subject group was normally distributed with a SD of 46.4. If the true difference in the experimental and control means is 61, we need to study 10 experimental subjects and 10 control subjects to be able to reject the

Figure 4



Speech analysis using sound design and quality.

Figure 5



Screenshot of the sound analysis using sound design and quality (ANSYS Inc.).

Table 1 Parameters of speech analysis*

Parameters used	Abbreviation	Role
Frequency peak noise energy	FPNE	FPNE plays a more vital role in the differentiation of /s from /sh, thus it depends on the way the tongue articulates with the palate. Normal values for dentate persons are (/sh from 2500 to 4500 Hz) and /s from 4000 to 8000 Hz
Frequency proximity of burst	FPB	Phonetic identification of noise burst depends on vowel context
Voice Onset Time	VOT	VOT provides information regarding the interval between the articulatory release of stop and the onset of vocal fold vibration. It is a measure of time between supraglottic event and onset of voicing. For stops, VOT is the interval between the release of the stop and the appearance of periodic modulation for the following sound. The relatively late voicing onset for velars indicates that VOT varies with the place of stop articulation. The general rule is that bilabials have the shortest VOTs, alveolars have intermediate VOTs, and velars have the longest VOTs

*Cited from Adaki *et al.* [20].

null hypothesis that the population means of the experimental and control groups are equal with a probability (power) of 0.8. The type I error probability associated with this test of this null hypothesis is 0.05.

Statistical analysis

Statistical analysis of the given data was performed using IBM SPSS software package, version 24.0. (IBM Corp., Armonk, New York, USA) and GraphPad Prism. Performing speech analysis for each group depends on the amount of change for each speech parameter in percentages (%) at baseline, after 1 month, and 3 months according to the following formula [19]:

$$C \% = (X_2 - X_1) / X_1 \%$$

where C% is the change percentage, X1 the old value, and X2 is the new value.

Data revealed as means and SDs for different speech parameters for each letter sound and comparison between different time intervals for each group performed by paired *t* test and comparison between both groups performed using independent *t* test.

Results

Regarding, frequency peak noise energy for (S) sound: there was a significant elevation of the follow-up period

(RPD-0#RPD-1) by 45 and 59% for groups I and II, respectively. For the follow-up period from RPD-0#RPD-3, there was insignificant elevation by the two groups by 70 and 75%, respectively (Table 2). For Sh sound, there was a significant reduction at RPD-0#RPD-1 by 33 and 49% for groups I and II, respectively, while there was an insignificant reduction in the follow-up period (RPD-0#RPD-3) by 63 and 67% for groups I and II, respectively (Table 2).

For frequency proximity of burst, the T and D sounds showed a significant reduction in the follow-up period (RPD-0#RPD-1); for T sounds the values were 39 and 53% for groups I and II, respectively, and the values for D sound were 43 and 57% for groups I and II, respectively. After 3 months, the T and D sounds showed an insignificant reduction (RPD-0#RPD-3). The values of T sound were 79 and 82% and for D sound were 70 and 73% for groups I and II, respectively (Table 2).

For voice onset time of the T sound, initially, there was a significant reduction of RPD-0#RPD-1 by 34 and 50% for groups I and II, respectively. Later there was an insignificant reduction at RPD-0#RPD-3 by 60 and 62% for groups I and II, respectively (Table 2), while the D sound showed an insignificant reduction in all follow-up periods. The values were 39 and 38% for RPD-0#RPD-1 for groups I and II, respectively, and for RPD-0#RPD-3 it was 40% for both groups (Table 2).

Table 2 Comparison of speech analysis parameters between group I and group II during the 3 months follow-up

Parameter/sound	Follow-up	Group I	Group II	P value
FPNE/(S)	RPD-0#RPD-1	(+) 44.61±5.81	(+) 59.28±6.59	0.0001*
	RPD-0#RPD-3	(+) 69.67±4.4	(+) 74.46±6.28	0.0638
	P value	0.0001**	0.0001**	
FPNE/(SH)	RPD-0#RPD-1	(-) 32.51±1.89	(-) 48.67±2.09	0.0001*
	RPD-0#RPD-3	(-) 62.84±6.54	(-) 66.49±9.27	0.3224
	P value	0.0001**	0.0001**	
FPB/(T)	RPD-0#RPD-1	(-) 38.74±2.08	(-) 52.63±3.67	0.0001*
	RPD-0#RPD-3	(-) 78.54±5.29	(-) 81.49±2.87	0.1385
	P value	0.0001**	0.0001**	
FPB/(D)	RPD-0#RPD-1	(-) 42.58±4.09	(-) 57.21±5.79	0.0001*
	RPD-0#RPD-3	(-) 69.58±3.67	(-) 72.81±5.19	0.1255
	P value	0.0001**	0.0001**	
VOT/(T)	RPD-0#RPD-1	(-) 34.28±1.94	(-) 49.61±2.06	0.0001*
	RPD-0#RPD-3	(-) 59.84±6.77	(-) 62.38±7.92	0.4508
	P value	0.0001**	0.0001**	
VOT/(D)	RPD-0#RPD-1	(-) 38.65±5.92	(-) 37.54±4.27	0.6364
	RPD-0#RPD-3	(-) 39.81±7.82	(-) 40.13±8.17	0.9297
	P value	0.7128	0.3860	

All data are expressed as mean%±SD. FPB, frequency proximity of burst; FPNE, frequency peak noise energy; RPD, removable partial denture; VOT, voice-onset time. RPD-0; baseline, RPD-1; 1 month, RPD-3; 3 months. *Significant difference between groups I and II at P value less than or equal to 0.05, using independent *t* test. **Significant difference between different time intervals for each group at P value less than or equal to 0.05, using paired *t* test.

Using paired *t*-test for significance comparison between different follow up for each parameter in each group, it revealed significant difference ($P < 0.05$) except for voice onset time of VOT/(D) which was insignificant (Table 2).

Discussion

Speech problems are common after the placement of a removable prosthesis, especially if anterior teeth were lost, as this has a direct impact on consonants, particularly lingopalatal sounds [19]. The effect of different analyzed spectrograms software (ANSYS and LIS technology) on lingopalatal sounds were analyzed in this study using different analyzed spectrogram software (ANSYS and LIS technology), which analyze the frequency of emitted sound in Hz or m/s concerning denture changes and oral resonance cavity [21]. Because it is impossible to check all the letters, specific letters were selected. Some sounds such as S, T, Sh, and D are more perceptible and more often impaired, according to previous articles, due to alterations in oral structures and the necessity for more accurate articulation movements. As a result, the sounds of S, Sh, T, and D were investigated [22].

FPNE plays a major role in the differentiation of S from Sh; thus, it depends on the way the tongue articulates with the palate. In this study, FPNE when compared with normal dentate values the sound S showed elevation values in both groups in all follow-up periods. This increase was only significant 1 month following denture placement. In all follow-up periods, the Sh sound exhibited lower values in both groups, with these reductions being significant only in the 1-month follow-up period following denture placement. This shows that the pronunciation of S and Sh were well differentiated in both constructed types of RPDs [20].

The reduction values of frequency proximity of burst and voice onset time of T and D sounds were significant only in the follow-up period from denture insertion (after 1 month) and insignificant in the follow-up period from denture insertion (after 3 months). These reduction values of the T and D sounds were results of more posterior articulation of both sounds consequences; the pronunciation of the letter D was improved in both groups [23].

These findings demonstrated that PRPs manufactured using the CAD/CAM technology outperformed RPDs made with the lost wax technique in the early stages of denture placement. This could be because

RPDs designed with CAD/CAM technology have a thin framework that fits the mouth precisely with little initial modifications.

The framework of RPDs fabricated using the lost wax technique is made of high-shrinkage alloys, leading to a less precise mouth fit [24]. As a result, CAD/CAM technologies enable more exact and systematic modelling, potentially reducing the time-consuming procedures of both chairside and laboratory work, while also is providing RPDs with high-quality sound production even during denture placement [25].

Other authors [8,26] believe that speech is a learnt, habitual neuromuscular pattern, and in younger patients, adaptation is easier and after 1 week of partial denture use; issues with articulation of some letters were alleviated, this can explain our findings that after 3 months of RPD placement, there was no significant difference between the two groups.

Conclusion

Within the limitation of this study, it could be concluded that RPD constructed by the CAD/CAM technology has a more precise fit of the chrome-cobalt framework with a high-quality of sound production even at the time of denture insertion.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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