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Influence of the Partial Denture on the Articulation of Dental and Postalveolar Sounds

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ABSTRACT

Dental prosthesis is a foreign body in oral cavity and thus necessarily interferes with speech articulation. The purpose of this study was to examine influence of partial denture on speech quality and to show eventual differences in pronunciation of dental sounds c [ts], z [z], s [s] and postalveolar sounds č [tʃ], ž [ʒ] and š [ʃ]. We have examined differences in pronunciation between subjects with removable partial dentures, the same group without partial dentures and a control group. The study was performed on 30 subjects with removable partial dentures and 30 subjects with complete dental arch. All subjects were recorded while reading six Croatian words containing the examined sounds. Recordings were analyzed with Multispeech Program (Kay Elemetrics Inc.). Acoustic analysis – LPC (linear prediction coding) provided formant peaks (Hz) for each examined sound, its intensity (dB) and formant bandwidths (Hz). Results showed that subjects with partial dentures had 50% less distorted variables and that prostheses did not completely restore articulation of postalveolar sounds. Groups with and without prostheses had lower formant peaks intensities and wider formant bandwidths in comparison to the control group. Partial dentures have not significantly interfered with resonance frequency. At the same time, pronunciation of the examined sounds was significantly improved. However, precision of the articulation movements has deteriorated.

Key words: *partial denture, speech, consonant articulation, formant, acoustic analysis*

Introduction

Speech is a medium for verbal communication between people and one of the most complex human activities[1,2]. Research in the acoustic theory of speech

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shows that changes in vocal tract shape lead to changes in speech[3,4]. According to Jacobs et al., clinical assessment of speech therapists is that 84% of patients with dentures in at least one jaw have distortion of speech articulation. However, different shapes of the vocal tract and different articulator movements can attain same acoustic and perceptive results[6]. This phenomenon can be explained by flexibility and adaptability of the articulation system.

Patient satisfaction with removable partial denture depends on his chewing ability, aesthetics of the denture and phonation[7]. Therefore, prostheses should enable successful speech (considering the communication demands)[8].

Primary influence of the dentures is on articulation and resonance, but there are signs of an influence on phonation as well[4]. A dentist is directly interested in articulation distortion caused by lips, tongue, teeth, hard palate, soft palate and alveolar ridge deformities because he restores and changes these tissues during prosthetic treatment. As a result, the dentist must be acquainted with speech principles, especially with the position of consonant articulation, formation of which depends on previously mentioned structures.

Consonants have characteristics of noise sound – they are complex sounds containing a range of frequencies with no simple mathematical relation[9].

Shape of a consonants spectrum is a result of interaction between the primary sound source spectrum and the frequency characteristics of the vocal tract functioning as a filter and intensifying or suppressing certain frequencies[9]. The final voice sound has peaked spectral form where spectral parts called the formants (F1, F2, F3…) correspond to peaks[11].

Generation of air turbulence with obstacles to the air stream flow in the areas of vocal tract constriction produces fricatives and affricates. For example, upper and lower teeth and upper lip are obstacles to the air stream flow during the pronunciation of sounds *s* [s] and *š* [ʃ]. Source of the sound is in the frontal cavity resulting in the dependency of the sound filtration to the resonance characteristics of the frontal cavity. When the constriction of the vocal tract moves forward it decrease the length and volume of the resonator (frontal cavity) resulting in higher resonant frequencies.

Rounding of the lips is another factor contributing to the vocal tract extension resulting in the decreased resonance frequencies. Formation of sublingual cavity has same effect. According to the formula $Fn = (2n-1)c / 4l^*$ sound *s* [s] will have formants around 8 kHz and sound *š* [ʃ]. around 3.5 kHz. This effect is result of rounded lips and formation of the sublingual cavity that makes frontal cavity longer and decreases resonance frequencies of vocal tract in more distal pronunciation of sound *š* when compared to the pronunciation of sound *s*[12].

Sounds are different because of the formant frequencies depending on the vocal tract shape and length[13]. That is the reason we took formant values as assessment criteria of speech quality.

Former studies showed differences in pronunciation of almost all consonants between the patients wearing prostheses and people with complete dental arch[14]. However, some sounds, like c [ts], *z* [z], *s* [s], *č* [tʃ], *ž* [ʒ] and *š* [ʃ] are more sensible and more often compromised due to the changes of oral structures and because of the demand for more precise articulation movements. This is the main reason why we have focused our study on these sounds[6].

The aim of this study was:

1. to examine the influence of the partial dentures on speech quality;
2. to show eventual differences in articulation of the sounds c [ts], *z* [z], *s* [s], *č*

[tʃ], *ž* [ʒ] and *š* [ʃ] between subjects with their own natural teeth and subjects with partial teeth loss and the same group with partial dentures.

Subjects and Methods

The present study was carried out on 60 subjects divided in two groups. The experimental group consisted of patients with removable partial dentures in at least one jaw (average age: 60 years). Control group consisted of subjects with complete and continuous dental arch without visible jaw discrepancy and diagnosed articulation distortion (average age: 21 years). None of the examinees had impaired hearing during speech learning stage in the childhood. Croatian was native language to all of them. All examinees of the experimental group were treated in the Department of Prosthodontic, School of Dental Medicine in Zagreb. All dentures were new (aprox. 20 days old) and in accordance with the professional standards in terms of aesthetics, function, stability, retention, construction, materials and load invoked on remaining teeth. Age difference between experimental group and control group existed because it was difficult to find subjects in their sixties with a complete dental arch. The age difference probably caused some differences between the results of these two groups.

We have recorded the pronunciation of six Croatian words: *sisak, šišati, čaša, policajac, zazidati* and *žezlo* pronounced with normal speech intensity and speed. The control group was recorded once and the experimental group was recorded twice – with and without prostheses. Speech was captured with microphone (Profipower, MD 431, Sennheiser) recorded on minidisk (Sony, MD, MZ-1) and analyzed with Multispeech Program (Kay Elemetrics, Inc.) using LPC analysis (Linear Predictive Coding). Minidisk sampling frequency was 44.1 kHz. This sampling frequency was high enough to provide high fidelity of recorded sounds from 20–20,000 Hz, enough for acoustical analysis of human speech frequency ranges from 100–13,000 Hz.

LPC is an acoustic spectral analysis that provides central formant frequencies (in Hz), formant bandwidths (in Hz) and formant intensities (in dB) using autocoeficients (Figure 1). These values provide information about filtering function of the vocal tract that primary depends on its length and shape during the articulation of each sound[12,14].

We analyzed sound *s* [s] in word **s**isak, *š* [ʃ] in **š**išati, *č* [tʃ] in **č**aša, *c* [ts] in poli**c**ajac, *z* [z] in **z**azidati and *ž č* [ʒ] in **ž**ezlo. Sounds c, z and *s* are dental sounds and formed when tongue blade touches upper teeth, while sounds *č, ž* and *š* are postalveolar sounds formed when with tongue tip touches frontal part of hard palate.

We have used LPC analysis to calculate five central formant frequencies, formant bandwidths and formant intensities for each examined sound. We have included only those values for each sound in statistical data processing that were

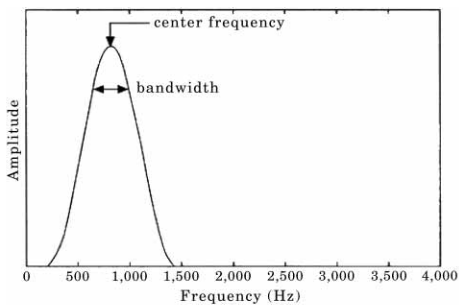

Fig. 1. Graphic illustration of central formant frequencies, its intensities and bandwidths.

significant according to their acoustic energy. These values are:

- Central frequencies of F4 and F5, their bandwidths and intensities of sounds *c, z* and *s*
- Central frequencies of F1 and F2, their bandwidths and intensities of sounds *č, ž* and *š*

We have used Statistics for Windows (Release 4.5 A, Stat Soft Inc., 1993) for statistical analysis and t – test to determine the differences between two groups.

Results

We have obtained the following results when we compared control group with group consisting of subjects without prostheses and same subjects with prostheses (value of significance: $p<0.05$).

Table 1 shows statistically significant differences obtained with t-test between control group and experimental group without prostheses. Twelve variables showed statistically significant differences (Figure 2). The experimental group had:

- lower central formant frequency intensities of sounds *c, s, š* and *č*
- wider formant bandwidths of sounds *š* and *ž*

Table 2 shows statistically significant differences obtained with t-test between control group and experimental group with prostheses. Five variables showed

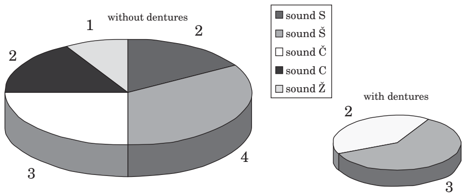

Fig. 2. Number and proportion of variables in experimental group with and without dentures which shows statistically significant differences.

TABLE 1
STATISTICALLY SIGNIFICANT VARIABLES (T-TEST; p<0.05) BETWEEN CONTROL GROUP AND EXPERIMENTAL GROUP WITHOUT DENTURES (N=30)

Examined variables**	Experimental group		Value of significance (p<0.05)	Control group	
	Arithmetic mean	Standard deviation		Arithmetic mean	Standard deviation
S/ i-cf F4	16.23	11.310	0.000283	29.30	14.66
S/ i-cf F5	15.18	7.650	0.000046	26.57	11.24
Š/ bw F1	421.93	552.863	0.034169	194.97	150.78
Š/ bw F2	821.77	448.674	0.000056	439.57	174.18
Š/ i-cf F1	12.33	17.703	0.000039	27.83	7.06
Š/ i-cf F2	5.27	16.809	0.000001	23.30	5.63
Č/ bw F2	995.33	490.570	0.000421	570.97	381.08
Č/ i-cf F1	11.90	16.816	0.031095	20.07	11.27
Č/ i-cf F2	3.63	17.738	0.001264	15.83	8.60
C/ i-cf F4	7.47	18.482	0.024602	18.13	17.30
C/ i-cf F5	7.00	12.544	0.000555	18.96	10.43
Ž/ bw F2	1215.80	747.377	0.001919	685.30	490.33

TABLE 2
STATISTICALLY SIGNIFICANT VARIABLES (T-TEST; p<0.05) BETWEEN CONTROL GROUP AND EXPERIMENTAL GROUP WITHOUT DENTURES (N=30)

Examined variables**	Experimental group		Value of significance p(<0.05)	Control group	
	Arithmetic mean	Standard deviation		Arithmetic mean	Standard deviation
Š/ bw F2	586.83	339.398	0.038789	439.57	174.18
Š/ i-cf F1	23.73	6.817	0.025759	27.83	7.06
Š/ i-cf F2	19.27	6.085	0.009980	23.30	5.63
Č/ cf F1	3076.90	543.964	0.020225	3387.17	458.91
Č/ cf F2	5358.70	602.306	0.031138	5680.70	524.09

Explanation of abbreviations used in Tables 1 and 2

S/ i-cf F4 – central F4 frequency intensity of sound *s*
S/ i-cf F5 – central F5 frequency intensity of sound *s*
Š/ bw F1 – F1 bandwidth of sound *š*
Š/ bw F2 – F2 bandwidth of sound *š*
Š/ i-cf F1 – central F1 frequency intensity of sound *š*
Š/ i-cf F2 – central F2 frequency intensity of sound *š*
Č/ cf F1 – central frequency F1 of sound *č*
Č/ cf F2 – central frequency F2 of sound *č*
Č/ bw F1 – F1 bandwidth of sound *č*
Č/ i-cf F1 – central F1 frequency intensity of sound *č*
Č/ i-cf F2 – central F2 frequency intensity of sound *č*
C/ i-cf F4 – central F4 frequency intensity of sound *c*
C/ i-cf F5 – central F5 frequency intensity of sound *c*
Z/ bw F5 – F5 bandwidth of sound *z*

statistically significant values (Figure 2). The experimental group had:

- lower central frequency intensities of F1 and F2 of sound *š*
- wider F2 bandwidth of sound *š*
- lower central frequency of F1 and F2 of sound *č*

Central formant frequency intensities vary more then central formant frequency, both in conditions with and without prostheses. The experimental group had lower central frequency intensities and wider formant bandwidths in comparison to the control group (Figures 3–6). In addition, central formant frequency values varied less without clearly distinctive manner; sometimes it was higher sometimes lower when compared to the control group.

Discussion

Partial teeth loss changes anatomical and functional characteristics of the oral cavity and can consequently influence speech quality[4]. Results of this study clearly showed that partial dentures significantly improve articulation of examined sounds (*c, z, s, č, ž, š*). Consequently,

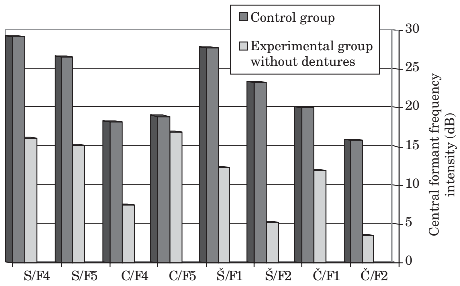

Fig. 3. Central formant frequency intensities of sounds which showed statistically significant differences between control group and experimental group without dentures.

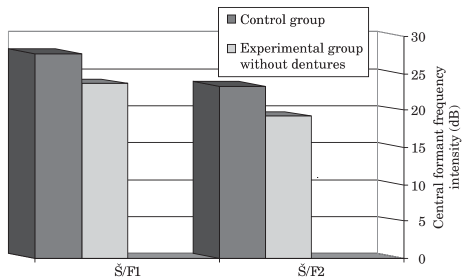

Fig. 4. Central formant frequency intensities of sounds which showed statistically significant differences between control group and experimental group with dentures.

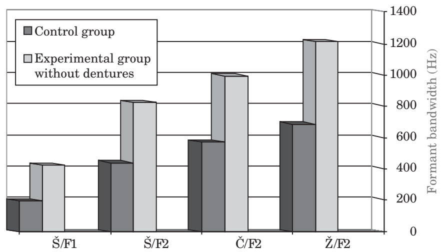

Fig. 5. Formant bandwidth of sounds which showed statistically significant differences between control group and experimental group without dentures.

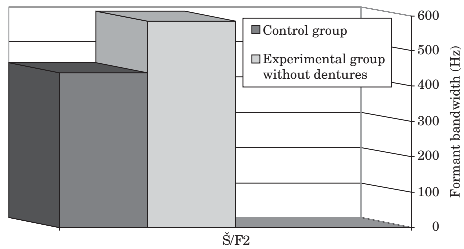

Fig. 6. Formant intensities of sounds which showed statistically significant differences between control group and experimental group with dentures.

Explanation of abbreviations used in figures 3–6:

S/F4 – F4 of sound *s*
S/F5 – F5 of sound *s*
C/F4 – F4 of sound *c*
C/F5 – F5 of sound *c*
Š/1F – F1 of sound *š*
Š/2F – F2 of sound *š*
Č/1F – F1 of sound *č*
Č/2F – F2 of sound *č*
Ž/F2 – F2 of sound *ž*

the number of statistically significant differences in examined variables decreased 50% in the group with prostheses when compared to the group without prostheses. There were 12 significantly differing variables in the group without prostheses, and only 6 significantly differing variables in the group with prostheses.

When we compared variable values of experimental group, it was obvious that central formant frequency intensities and formant bandwidths differed more then central formant frequency. Experimental group had lower intensities of central frequency and wider formant bandwidths due to imprecise articulation. If we imagine a vocal tract as a tube opened on one side then it is clear that tooth loss or foreign bodies like prostheses inadequately define and actually change the dimensions of the vocal tract. This results in dissemination of a part of acoustic energy, consequently decreases central formant frequency intensities and increases formant bandwidths.

Central formant frequency differed without clearly distinctive manner; sometimes it was higher, sometimes lower.

On the other hand, partial tooth loss and prostheses have no influence on filtering function of the vocal tract and on its resonance characteristics during pronunciation of examined sounds. Dental sounds (c, z, s) and postalveolar sounds (*č, ž, š*) were distorted in conditions without prostheses, while only postalveolar sounds remained distorted with prostheses. Prostheses substitute lost teeth and result in restored pronunciation of dental sounds normally articulated by rising tongue blade to the palatal surfaces of the upper teeth and alveolar ridge. Dental base does not substitute any structure but is necessary for the retention. It changes anatomical relations in palatal region, which compromises pronunciation of postalveolar sounds articulated by rising tongue blade to the postalveolar region of the hard palate. Thickness and contours of the denture base strongly influence correct pronuntination[17]. According to Petrović, 1 mm increase in thickness of palatal base causes 60% speech distortion[3].

The dentures in this study had good arrangement of the upper frontal teeth and contours of the palate base. This conclusion is based on the fact that dental sounds did not differ at all. Distorted dental sounds pronunciation is mainly caused by irregular frontal teeth arrangement and/or irregular thickness and contour of the denture base covering alveolar ridge. Petrović's study clearly showed how small changes in teeth placement in antero – posterior direction have significant impact on sound articulation[3]. Two mm change in the upper teeth labial position caused of 80% distortion in the articulation of sound when compared to the normal speech.

Runte and al. noticed that changing inclination of central incisivus, especially in labial direction in upper denture decreases spectral frequency range of sound *s*[15].

Although there is strong evidence of significant improvement in articulation with prostheses, results of this study did not show complete restoration in articulation of postalveolar sounds. Probable explanation of this phenomenon is that 26 of 30 subjects had 30 days old dentures in the time of examination – period too short for complete adaptation to the new dentures.

Horga claims that subjects with interferences in vocal tract can produce sounds *s* and *š* significantly closer to values of speech in natural conditions after the time of practice[6]. According to Petrović, first 30 days are the most important for adaptation process. Patients motivated to accept new dentures will try to adapt to the new intraoral dimensions. However, if the dentures were not adequate, adaptation might not appear even after 8 months. It might be necessary to make required corrections or to make new prostheses in case of inadequate dentures[3].

Our opinion is that sound articulation will give better results if subjects had prostheses for a longer period. Further studies should define criteria for denture manufacturing process considering the quality of pronunciation of examined sounds. In addition, further studies should identify factors with the highest influence on the adaptation capacity.

From our point of view, existence of dentures is the major cause of difference in formant characteristics between experimental and control group. The age difference has minor effect because adult vocal tract anatomic characteristics are pretty much the same regardless of age. However, stronger air pressure noticed in younger persons could explain higher intensities of format frequencies in control group

Conclusions

1. The partial dentures significantly improve pronunciation of examined sounds (*c, z, s, č, ž, š*). Number of significantly differing variables decreases for 50 % in conditions with prostheses when compared to the conditions without prostheses.
2. Central formant frequency intensities with and without prostheses and formant bandwidths differed more then central formant frequency. Partial teeth loss or existence of dentures causes imprecise articulation movements and dissemination of a part of acoustic energy, which in return results in decreasing formant intensity and increasing formant band-widths.
3. Partial dentures completely correct pronunciation of dental sounds *c, z* and *s,* restoring lost oral structures, while only partially correcting the pronunciation of prepalatal sounds *č, ž* and *š*. This effect is result of denture base covering palate and alveolar ridge and thus changing anatomical relations in this area. Another cause for this effect is short period used for adaptation to new devices.

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UTJECAJ DJELOMIČNE PROTEZE NA IZGOVOR DENTALA I PALATALA

S A Ž E T A K

Proteza, kao strano tijelo u usnoj šupljini, neizbježno interferira s govorom. Svrha ovog istraživanja bila je ispitati utjecaj djelomične proteze na kvalitetu izgovora te prikazati eventualne razlike u artikulaciji sibilanata *c, z* i *s* te prepalatala *č, ž* i *š* između nositelja djelomičnih protetskih radova, istih ispitanika bez proteza i kontrolne skupine koju su činile osobe s kontinuiranim zubnim lukom. Ispitivanje je provedeno na 30 ispitanika nositelja djelomične proteze barem u jednoj čeljusti i 30 ispitanika kontrolne skupine. Ispitanici su čitali pojedinačne riječi s ispitivanim glasnicima. Glasnici su analizirani kompjutorskim programom – Multispeech Program (Kay Elemetrics Inc.). Akustičkom analizom – LPC analiza (linear prediction coding) – dobivene su centralne frekvencije formanata (Hz) za svaki ispitivani glasnik, širine formanata (Hz) te intenziteti centralnih frekvencija (dB). Rezultati su pokazali da ispitanici s protezom imaju 50% manje odstupajućih varijabli te da proteza nije omogućila potpunu rehabilitaciju artikulacije prepalatala. I sa i bez proteze manji su intenziteti centralnih frekvencija i veći formantski rasponi u odnosu na kontrolnu skupinu. Djelomična proteza bitno poboljšava izgovor ispitivanih glasnika, ne utječe bitnije na rezonantne frekvencije govornog prolaza pri izgovoru ispitivanih glasnika, već na preciznost artikulacijskih pokreta. Zbog prekratkog perioda adaptacije nije došlo do potpune rehabilitacije artikulacije palatala.