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RESEARCH ARTICLE

ACOUSTIC CHARACTERISTICS OF CONSONANTS IN THE SPECTROGRAM FOR SPEECH ANALYSIS WITH DENTURE PROSTHESIS

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ABSTRACT

Purpose: The Purpos of the article is to asses the improvement on speech quality analysis with spectrogram by modified maxillary denture. We should gain familiarity with acoustic cue features of consonants with spectrographic representations of sounds.
Background: "Speech is a brief, physiologically generated and socially conditioned vibratory impact on the human organism upon the atmosphere". The sound is characterized by phonation or articulation, or both plus resonances.
Results: The acoustic cues for consonants like stop gap, release burst, VOT, Friction noise, Formants transition, formant durations, voice bar and formant frequencies are to be analyse perceptually and objectively. We need to appreciate the differences between narrow-band and wide-band spectrograms, by learning how features of speech sounds appear on spectrograms and how the spectrogram can lead to a quantitative analysis of the source and filter aspects of speech sounds.
Conclusion: One of the main aspects of prosthodontic treatment for the management foredentulism depends on acoustic quality of speech. Maxillary palatal surface is significant in producing speech sounds particularly for consonants.

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INTRODUCTION

In basic acoustics, when an object is vibrating, we hear the sound waves that is transmitted to our ear through medium of air molecules (https://www.kul.pl/files/30/phonobabble/ Basic _acoustis_and_audition.pdf). This is caused by air molecules by the interplay of elasticity and inertia of air molecules and the air pressure in alternating regions of compression and rarefaction moving away from the source as time proceeds called pressure wave (the sound). The properties of sound waves are the amplitude which is the peak deviation from air pressure fluctuation and the frequency which is the air molecules that are vibrating at a rate per unit of time (cycles per second) 100cps = 100Hz (hertz). (https://www.kul.pl/files/ 30/phonobabble/Basic_acoustis_and_audition.pdf) A sound wave which has only one frequency is called a pure tone. But most sound waves which have only one frequency is often composed of more frequencies called complex tone. This complex tone can be periodic or aperiodic.

A) Periodic pattern of vibrations repeats itself (e.g. Vowels)
B) Aperiodic pattern (noise) vibrations have no repeated patterns (e.g. fricative).

In this aperiodic sounds (noise) Transient noise is produced by a burst of noise of short duration e.g. stop consonants. Continuous noise is produced by turbulent air passing through a narrow constriction e.g. fricatives. A graph (Fig.1) showing the amplitude of an air molecule movement towards a time course is called wave form. (Amplitudein" Y" axis and Time in "X") but a graph shows amplitude by frequencies is a spectrum (power spectrum) (https://www.kul.pl/files/30/ phonobabble/Basic _acoustis_and_audition.pdf). The purpose of this article is to familiarize with acoustic cue features of consonants with spectrographic representations of sounds on analyzing speech with denture prosthesis.

Background

Speech Mechanism: - In speech, the larynx is the sound source and vocal tract is a system of acoustics filters. The vehicle for

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speech wave (carrier) is glottal wave that composed of fundamental frequency (F_0) which varies from 60-500 Hz. The vocal fold plays by vibrating activity (on and off) and leads to a speech function connected to phonemic difference (voice. Voiceless) (https://www.kul.pl/files/30/phonobabble/Basic_acoustis_and_audition.pdf). In prosthodontics, patients treated with removable Prosthesis, resonant system of vocal tract (VT) (Fig.2) is affected especially in the oval cavity.

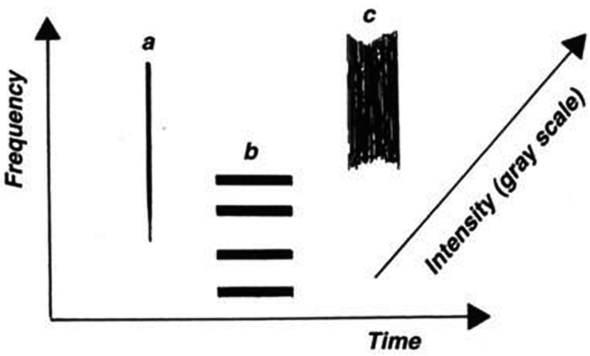

Fig.1. Diagram showing the dimension of a spectrogram: time on the horizontal axis, frequency on the gray (darkness) scale, stylized spectrographic patterns are shown for (a) a burst of noise, (b) a vowel with four formants, and (c) a nose with high-frequency energy

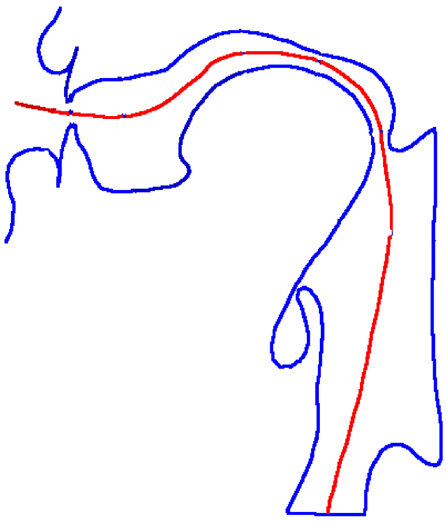

Fig.2. Vocal Tract

The speech mechanism makes extensive use of their filtering function of resonators. This acoustic filter transmits the glottal wave by reducing the amplitude of certain range of frequency while allowing other frequencies band to pass out through oral cavity, with response of the vocal tract together with tongue that impose a pattern of certain natural frequency regions in the length of 17cm vocal tract (e.g. 500Hz,1500Hz,2500Hz). These respective peaks of energy (formants – F_1 ,F_2,F_3), the output of the resonance system which always has the glottal wave as (F_0) and the formants (F_1,F_2,F_3……) which are imposed by vocal tract (Fig.3). Any further modification of these formants structures can be obtained by altering the tongue and lip positions, so there is a relation between articulation and the format structure (https://www.kul.pl/ files/30/phonobabble/ Basic_acoustis_and_audition.pdf).

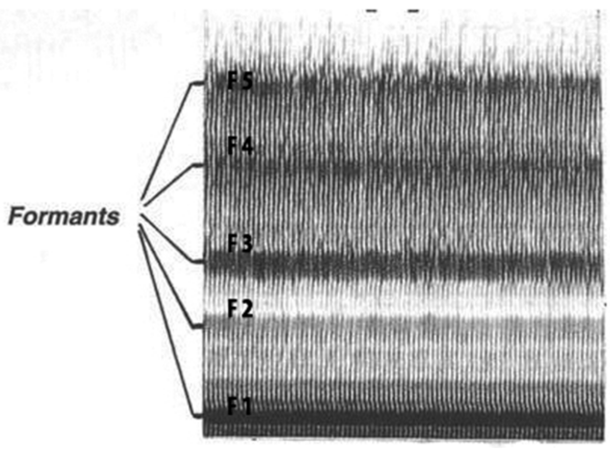

Fig. 3. Formants in Spectrogram

Acoustic Characteristics of Consonants

In the study of resonance properties of tubes, representing a simplified model of the vocal tract, the fundamental of the speech acoustics are resonances because most difference in phonetic quality stem from difference in resonance patterns of VT as it changes shape (https://www.kul.pl/files/30/ phonobabble/Basic_acoustis_and_audition.pdf). This change is shape of volume occurs as at least one constriction along the length of VT. Different constrictions occurs to different level (manner of speech) of articulation in VT and primarily by stretching the length of the vocal folds (voicing) gives acoustic characteristics of the vowels and consonants sounds in speech production (https://www.kul.pl/files/30/phonobabble/Basic_acoustis_and_audition.pdf). When removable prosthetics particularly maxillary prosthesis occupies the VT space at the level of oral cavity, the articulation and resonance is mainly affected. The most common speech sounds are the consonants (https://www.phon.ox.ac.uk/jcoleman/consonant_acoustics.htm).

The acoustic characteristics of consonants are divided by voicing: -

1.Voiced 2. Voiceless

Manner of articulation

Voiced → ← **voiceless**

Stops
Fricative
Affricative
Nasal
Laterals
Approximates

Place of articulation

1) Labial
2) Labiodental
3) Dental
4) Alveolar
5) Palatal
6) Velar
7) Vocal fold

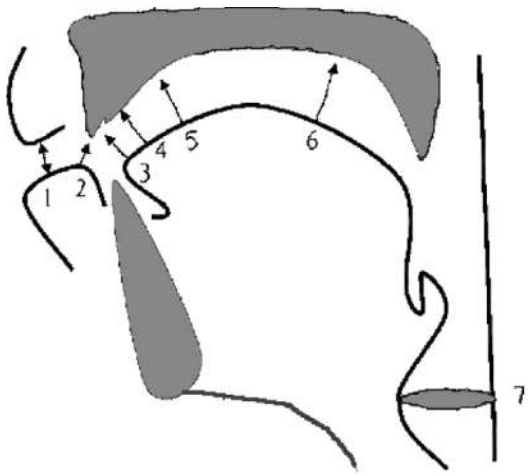

Fig. 4. Place of Articulation

RESULTS

In spectrogram the voicing, manner of articulation and place of articulation for consonants are given by cues, frequency, bands, gap and noise of aspiration, friction, duration cues and periodicity. The Periodic laryngeal sound source (voiced) stops, fricative and affricatives have two sound sources (https://www.phon.ox.ac.uk/jcoleman/consonant_acoustics.htm). This periodic laryngeal sound source is combined with aperiodic VT sound source.

Acoustic cues for consonants

Aperiodic sound source is produced by two different types of disturbances

1. Sudden release of air built-up behind closure. e.g. stops
2. Turbulence in the air rushes through a narrow constriction. e.g. Fricative

Stop consonants

Stop consonants are characterized by a complete closure somewhere in the vocal tract having three phase closure, release and transition and for the postvocalic stop reverse the steps (2). Stop gap corresponds to the complete closure of the vocal tract with minimally radiated acoustic energy and there is a silence for voiceless stops and voice bar for voiced stops in spectrogram with range of duration 50 - 150 ms[2]. (Fig.5)

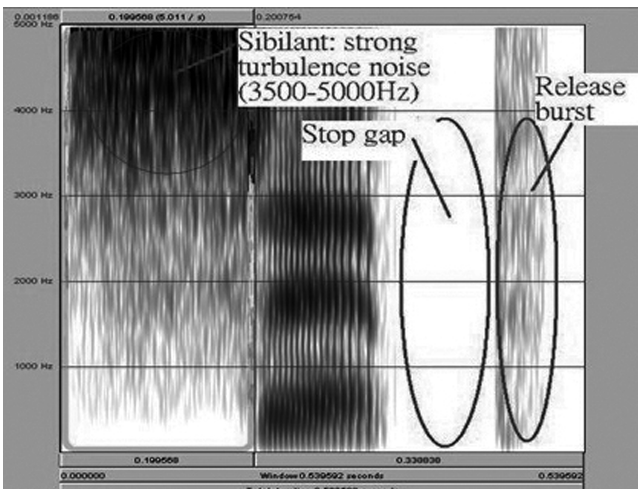

Fig. 5. Stop gap and Release Burst in spectrogram

Stop release (burst) gives rise to pressure and has been rising behind the obstruction and rapid release produces a transient minimal duration of 20 - 30 ms, thus, suitable temporal resolution is needed (Diehl, 2008). In voiceless stops following the burst with frication a noise is generated at the place of articulation of low frequency for /p/ (500 - 1500 Hz) (falling spectrum), high frequency for /t/ (above 4 kHz) (rising spectrum) and mid-frequency for /k/ (1.5 - 4 kHz) (peaked spectrum) (Diehl, 2008).

Cues for voicing

Voiceless consonants like /p t k/ are phonetically distinguished from /b d g/ by voicing. VOT is the interval between the release of the stop and the onset of vocal fold vibration (Brinca *et al*., 2016). For /p t k/ VOT may range from 25 to 80 ms with a mean of 45 ms and for /b d g/ VOT may range -20 to +20 ms with a mean of 10 ms and with a voice bar for intervocalic stops. (Brinca *et al*., 2016) Formant transitions (Fig.6) is an articulatory movement from stop to vowel and involves a formant movement as the resonating chamber of the vocal tract changes, the formant frequencies change. These formant transitions are important for perception that is approximately 50 ms in duration (https://www.phon.ox.ac.uk/jcoleman/consonant_acoustics.htm). Formant transitions in spectrogram shows F1 usually raises for the stop consonants F2 and F3 are not so simple.

for /p b/ F2 and F3 rise slightly
for /t d/ F2 falls and F3 rises slightly.
for /k g/ F2 and F3 separate steeply and rapidly, However, a given stop is associated with a variety of transitions and there is no fixed transition pattern for perception (https://www.phon.ox.ac.uk/jcoleman/consonant_acoustics.htm).

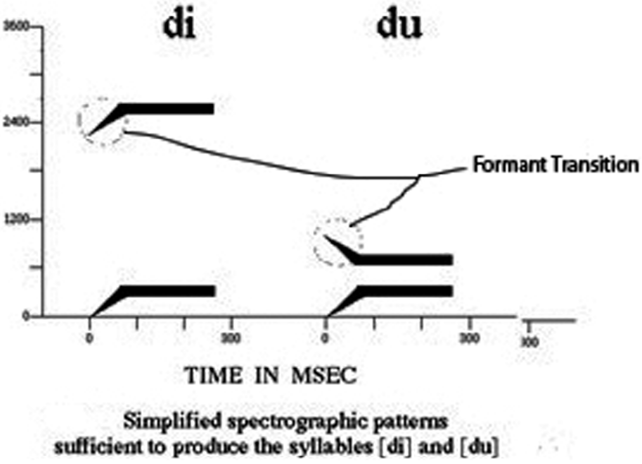

Fig. 6. Formant Transition

Fricatives

Articulation which have narrow constriction in the vocal tract and when air flow rate is high, complex turbulence results with unpredictable Turbulent air that perceived as turbulent noise (https://www.phon.ox.ac.uk/jcoleman/consonant_acoustics.htm). (Shown in Figure.05)

Fricatives have a relatively long duration.
Fricatives are divided into
1. Sibilants (stridents), 2. Nonsibilants (nonstridents)

Sibilants have an intense noise differentiated among themselves by voicing and noise spectrum

In Voicing there are pulses (glottal closures) for /z / (z,j) and no pulses for /s / (s,sh).

In Noise spectrum, alveolar sibilants have higher frequency energy, the Palatal sibilants have energy down to 3 kHz and Spectral irregularities aren't important in perception. (https://www.phon.ox.ac.uk/jcoleman/consonant_acoustics. htm)

Formant transition locations depend on the articulation, but the transitions are not important perceptually for sibilants (Fig.8).
Nonsibilants /f v θ ð h/ (f,v,th,dh,h)

These are less noise energy than sibilants Voiced nonsibilants will have quasi-periodic pulses. Noise spectra are fairly flat and diffuse. The relationship between noise spectrum and nonsibilant identification is not known. But Formant transitions play the primary role in perception. (https://www.phon.ox.ac.uk/jcoleman/consonant_acoustics.htm) Noise spectrum may play a secondary role. (Fig.7) Acoustical requirements for fricatives are economical-Valid and Reliable. The Problems for fricatives are ambient noise and Filtering values (Howard, 2003).

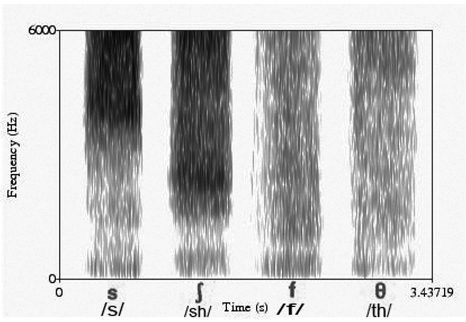

Fig. 7. Unvoiced/voiced Fricatives sounds /s/, /sh/,/f/,/th/ in spectrogram

Affricates

These are described as a combination of stop and fricative e.g. / / (ch,jh).Articulation is by complete obstruction in the vocal tract and intraoral pressure builds up and then release to generate fricative noise. (https://www.linguisticsnetwork.com/phonetics-the-basics-about-acoustic-features-of-consonants-in-standard-english) (Fig.8.) Acoustic features are the rise time, duration of frication, relative amplitude in third formant region and stop gap (Howard, 2003).

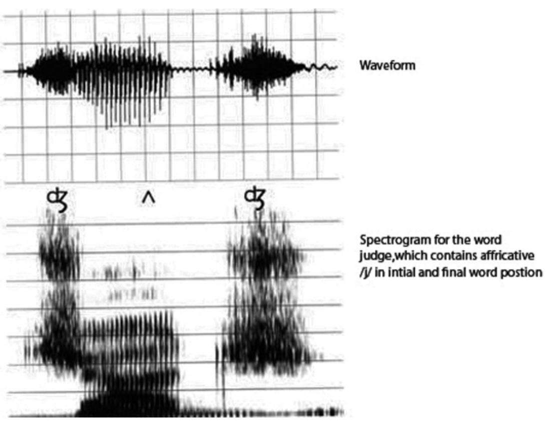

Fig. 8. Affricative sound from the word 'judge' in spectrogram

Nasals

Articulation is by complete closure in vocal tract, sound radiated through nasal cavities sometimes called nasal stops (https://www.linguisticsnetwork.com/phonetics-the-basics-about-acoustic-features-of-consonants-in-standard-english) e.g. /m n ŋ/. Acoustic features of Nasal murmur sounds are nasal and are allied strictly with nasal radiation of sound. There are many spectral peaks, but most have low amplitude with anti-formants. Nasal formant shows spectrogram in low frequency (~300 Hz) and highest energy (Cho *et al*., 2002). Consonant energy is overall reduced because of higher formants having reduced energy. Other acoustic features are highly damped formants (broad bandwidths) and formant transitions in connected speech.

Glide consonants

These are also called as approximants and semivowels e.g. /w,j /Articulation of approximants is by gradual articulatory motion and narrow, but not by closed vocal tract. Acoustics features with spectral Formants for /w/ shows F1 and F2 both low for /j/ low F1 and high F2. (https://www.linguisticsnetwork.com/phonetics-the-basics-about-acoustic-features-of-consonants-in-standard-english)

Liquid consonants (https://www.linguisticsnetwork.com/phonetics-the-basics-about-acoustic-features-of-consonants-in-standard-english)

These are also included as semivowels e.g. /r, l/ which are Characterized by rapid movements and formant structure,

DISCUSSION

We use two types of spectrogram for speech study: one which emphasis the frequency aspects by using long signal sections or narrow analysis filters, which emphasis the temporal aspects by using short signal sections or wide analysis filters (Jongman *et al*., 2000). Narrow-band spectrograms are convenient for investigating characteristics of the source: they show the harmonics of the vocal fold vibration. Wide-band spectrograms are convenient for investigating characteristics of the vocal tract filter; they highlight the vocal tract resonances (formants) by showing how they continue to vibrate after a vocal fold pulse has passed through. Formant is a concentration of acoustic energy around a particular frequency in the speech wave. There are several formants, each at a different frequency, roughly one in each 1000Hz band or, to put it differently, formants occur at every 1000Hz intervals. Each formant corresponds to a resonance in the vocal tract. In speech science and phonetics, however, a formant is also sometimes used to mean an acoustic resonance of the human vocal tract. Thus, in phonetics, formant can mean either a resonance or the spectral maximum that the resonance produces. Denture prosthesis mostly affects the resonance properties of the oral cavity.

Conclusion

During the fabrication of denture prosthesis, with the comprehensive approach on palatal thickness, replication of natural palatal anatomy (Palmer, 1979), along with reproducing convexity of the alveolopalatal tissue in the molar area (Tanaka, 1973) and anterior teeth positioning improves the acoustic quality of speech sounds, particularly consonants. On analyzing these sounds characteristics in spectrogram with denture prosthesis improve the quality of speech.

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Conflict of Interest: None Declared

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