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Original Article

Effect of Removable Complete Dentures on the Fundamental Frequency of Speech

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Abstract

Introduction: Removable complete dentures alter the spectrum of speech sounds by changing the elasto-plastic properties of certain areas of the oral cavity walls, and the geometric characteristics of the vocal resonator. These relationships predetermine largely the aims of conventional studies on the effect of prosthetic dentures on speech function.

Aim: To investigate the effect removable dentures have on the fundamental frequency of speech during different stages of the adaptation period.

Materials and methods: We analysed 96×2 digital sound recordings made by 64 patients (32 male and 32 female). Each patient was asked to say 'three, two, one, zero, start' three times: before denture placement, after denture placement, and after a two-week adaptation period. The pitch contours of F0 and the numeric values were obtained using the Speech Analyzer - SIL Language Technology software.

Results: Immediately after denture placement, in male patients F0 increased by 12% on the average, and in female patients – by 10%. Two weeks after denture placement, F0 regained its normal value ($p<0.05$).
The mean value of F0, whose raising can be interpreted as an acoustic correlate of temporary psychological stress, returned to normal after a brief adaptation period (in this case – 14 days).

Conclusions: The results on the systematic changes of F0 in the course of the complete denture prosthetics are indicative for the systematic speech impediments before, and the absence of such impediments after (in case of successful prosthetics) the adaptation.

Keywords

complete denture, fundamental frequency, speech

INTRODUCTION

Sound is a vibration with a possible auditory effect, and therefore it is in general a three-stage process: 1) generation of mechanical oscillations, 2) their propagation in an elastic medium, and 3) their auditory perception.

Speech sounds are produced because of complex (multi-frequency) vibrations of the vocal cords and/or the vocal tract walls transmitted to the air molecules within the vocal tract. The diverse frequency components of these vibrations vary in intensity depending on the momentary, geometrically conditioned resonance characteristics of the vocal tract.

Many research projects and questionnaire surveys establish that dentures (irrespective of the fabrication material[1-3], and depending on the method of artificial teeth arrangement[4-7], the thickness of denture base[8-10], as well as on

the vertical-horizontal relations[11,12]) may cause changes in the speech sounds spectrum by changing 1) the elasto-plastic properties of certain areas of the oral cavity walls, and 2) the geometric characteristics of the vocal resonator. These well-known factors of speech sound generation predetermine to a large extent the aims and methods of the most prevalent studies of the influence of prosthetic dentures on speech function.[13] They deal with articulation, but not phonation (the generating of the glottal voice source made by engaging the vocal cords).

AIM

The aim of the present study was to establish experimentally the hypothesized relation between complete denture prosthetics and the frequency level of voice, i.e. the mean of the fundamental frequency (F0) of the vocal cords. That relation is manifested in an initial temporary increase of the fundamental frequency mean value, leading on its turn to the deterioration of the timbral characteristics of most of the sounds (vowels and voiced consonants).

MATERIALS AND METHODS

Units of observation were 96×2 digital sound recordings of 64 patients (32 male and 32 female patients). Each patient uttered a sentence ("Three, two, one, zero, start" in Bulgarian) under three different conditions: 1) before denture placement, 2) immediately after denture placement, and 3) after a two-week adaptation period.

The pitch contours of F0 and the numeric values (in 20 ms intervals) were obtained by using the Speech Analyzer (SIL Language Technology). "*Auto Pitch*" – smoothed pitch contours were used, and the processing was based on two types of algorithms – statistical and psychoacoustic.

For each recording lasting from three to four seconds, the mean value of F0 was calculated, where the momentary values of F0 (about 85 in number) were defined and automatically exported as mean value per each 20 ms interval of voice presence.

The derived mean values of F0 were analysed statistically (t-test) to find a correlation between F0 and stages of treatment.

Fig. 1 shows as an example the visualization of the raw numeric data for a representative individual case.

RESULTS

In order to eliminate irrelevant influences, rigorous statistical methods were used over a substantial quantity of raw numerical data (24192 frequency values approximately: 64 patients ×3 records 2500 ms long on average with measurements acquired in 20-ms intervals). The acoustic analysis program providing raw data (SIL Speech Analyzer) also performs an initial statistical treatment: the raw pitch is smoothed and possible outliers are thus excluded. The subsequent statistical analysis on the derived mean values of F0 (t-test) reliably indicate that F0 is normalized at the third testing 14 days after denture placement.

The results given in **Table 1** are mean values of F0 before denture placement (day -1), immediately after denture placement (day +1) and after a two-week adaptation period (day +14).

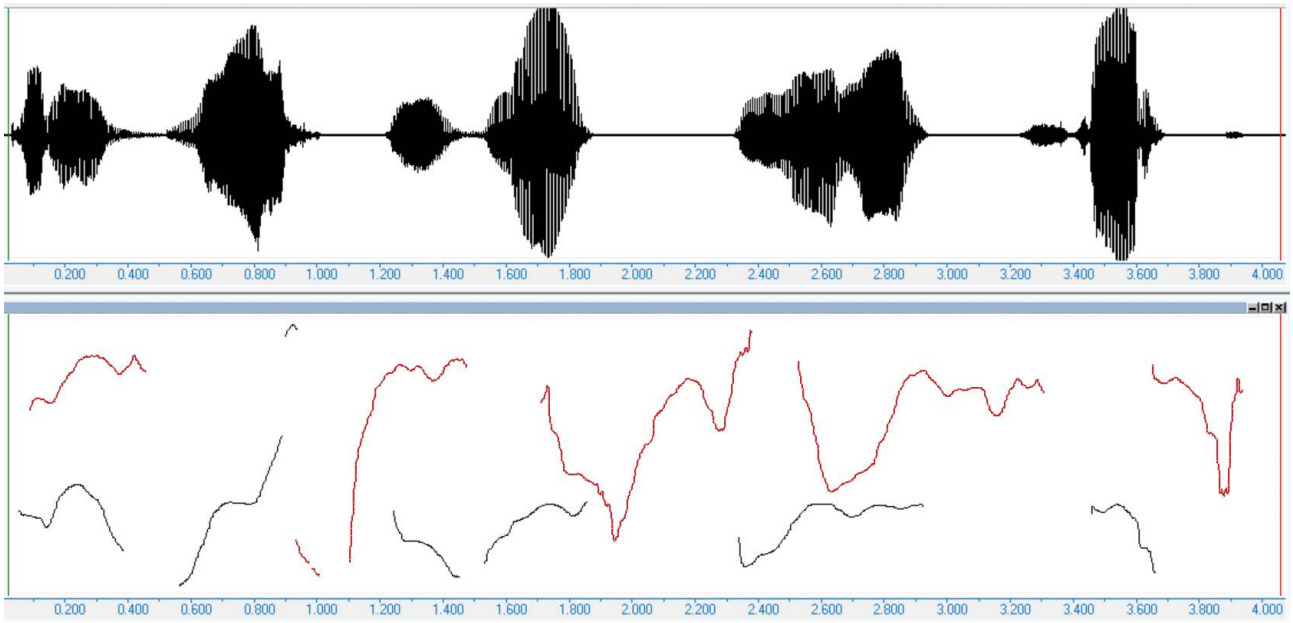

Figure 1. Pitch contours of the same sentence uttered by a patent in two different contexts: without dentures (in black) and with dentures (in red).

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Table 1. Mean values for 32 male and 32 female patients uttering the sentence 'Three, two, one, zero, start' at three different times

Groups	F0 (Hz), Day -1	F0 (Hz), Day +1	F0 (Hz), Day +14
Female patients	214	236	211
Male patients	149	169	144

The individual results were analyzed by the t-test using Excel.

Results for the relationship Before vs. After 1 are as follows:

For male patients, $p<0.001$. The null hypothesis (Hypothesized Mean Difference = 0) was rejected. The results were statistically significant. Immediately after denture placement, F0 increased by approximately 12% in male patients. The results in female patients were similar - F0 increases by approximately 10% on the average - showing a significant but a bit less important effect of prosthetics on the average voice level.

Results for the relationship Before vs. After 14

For male patients, $p=0.014$ ($p<0.05$). Two weeks after denture placement, F0 approached its normal value, with a small difference of 3.9% compared to the reference mean value 'Before'.

For female patients, $p=0.179$ ($p>0.05$, Hypothesized Mean Difference = 0). Two weeks after denture placement, F0 regained almost completely its normal value, with a small difference of 1.0% compared to the reference mean value 'Before'.

Results for the relationship After 1 vs. After 14

For male patients, $p<0.001$. The null hypothesis (Hypothesized Mean Difference = 0) was rejected. The results were statistically significant. Fourteen days after denture placement, F0 decreased by approximately 14% in male patients. The results in female patients were similar - $p<0.001$, F0 decreases by approximately 10% on the average.

DISCUSSION

The literature on the effects of removable complete dentures on the patients' speech is both large and rigorous. However, existing studies quasi-invariably relate to the quality of individual sounds (i.e. on the timbre of sounds), excluding the quality of voice (i.e. its pitch). This is understandable, since a relationship between dental prosthetics and the fundamental frequency could not be explained from the perspective of the existing biomechanical and acoustic speech production models. Such a relationship is nevertheless theoretically possible; it could be psychologically based in view of the well-known emotionally and mentally determined voice pitch variability.

The results obtained here suggest that this theoretical possibility is consistent with the acoustic reality: immediately after denture placement, with male patients, the average fundamental frequency increases considerably by 12% for the 32 male patients and by 10% for the 32 female patients.

The mean value of F0, whose raising can be interpreted as an acoustic correlate of temporary psychological stress, returns to normal after a brief adaptation period: two weeks after denture placement, F0 regains its normal value ($p<0.05$).

The increase is substantial but rather limited in time, which supports the hypothesis that it is psychologically based, and is the result of the stress caused by the abrupt change in the proprioceptive state of the patient (tactile and auditory). Another reason supporting the hypothesis is the fact described in linguistic references that oral communication in a foreign language leads to extraordinary raising of the F0 mean value that has a negative impact on the quality of speech.[16] That stress is basically expressed in higher laryngeal muscular tension leading to unusual for the patient raising of the fundamental frequency, which, in its turn, causes phonetic deterioration of their speech. The fundamental frequency of the vocal vibration is the minimal frequency in the vocal cords vibration spectrum, usually referred to as fundamental tone (designated by F0 and measured in Hz). The variation of the fundamental tone in the course of time is perceived as melody.

Our acoustic evaluation of the influence of dental prostheses on the fundamental frequency of speech also shows that the increase of F0 is more significant in the case of male (compared to female) patients. We hypothesized that the increase is due to a temporary psychological stress and therefore one could logically conclude that women are simply less reactive to stress. This may be true, but such a conclusion could not be drawn here because of the highly possible role of another factor: the voice pitch is related to the length of the vocal cords. Anatomically, the phonation apparatus is different in males and females: women tend to have shorter vocal cords than men (and tend for this reason, among others, to have higher voices than men). From a purely physical point of view, the frequency range of a vibrating cord is all the more limited as the cord is short and its expansion in restrained. Therefore, even though a woman (or especially a child) is very reactive vocally to stress, the relative global increase of their fundamental frequency will be tempered by its high initial value and the limited possibilities of straining the vocal cords.

Muscle tension (in particular tension of the intrinsic muscles of the larynx function to move the vocal cartilages and control tension), is almost a reflex reaction to stress. Physiological effects of the psychological stress caused by the changes in patients' proprioception immediately after denture placement are well known (e.g. increased gastric acidity). The fundamental frequency, when measured several days after denture placement, could be considerably affected again by the mental, emotional, and physiological state of the patient, but with no relation to prosthetics in this case.

CONCLUSIONS

The results on the systematic changes of F0 in the course of the complete denture prosthetics are indicative for the systematic speech impediments before, and the absence of such impediments after (in case of successful prosthetics) the adaptation.

The period of speech adaptation was found to be relatively short, but it relates only to patients expressing satisfaction with their prosthetics upon their placement, which was the case with all of the 64 tested patients.

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Влияние съёмных полных протезов на основную частоту речи

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Резюме

Введение: Съёмные полные протезы изменяют спектр звуков речи за счёт изменения упругопластических свойств определённых участков стенок полости рта и геометрических характеристик речевого резонатора. Эти связи во многом определяют цель традиционных исследований влияния зубных протезов на речевую функцию.

Цель: Изучить влияние съёмных протезов на базовую частоту речи на разных этапах адаптационного периода.

Материалы и методы: Проанализированы цифровые аудиозаписи 96 × 2 64 пациентов (32 мужчины и 32 женщины). Каждого пациента просили сказать «три, два, один, ноль, начало» три раза перед установкой протеза и после двухнедельного периода адаптации. Высота F0 и числовые значения были получены с помощью программного обеспечения Speech Analyzer – SIL Language Technology.

Результаты: Сразу после установки протеза F0 увеличивался в среднем на 12% у пациентов мужского пола и на 10% у пациентов женского пола.
Через две недели после установки F0 достиг нормальных значений ($p < 0.05$).
Среднее значение F0, увеличение которого можно рассматривать как акустическое соответствие временному психологическому стрессу, вернулось к нормальным значениям после короткого периода адаптации (в данном случае – 14 дней).

Заключение: Результаты систематического изменения F0 при установке протезов свидетельствуют о наличии барьеров для системной речи до и об отсутствии таких барьеров после (в случае успешной установки протезов) адаптации.

Ключевые слова

полный протез, основная частота, речь