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Original research

Effect of fixed dental prosthesis on the brain functions of partially edentulous patients – pilot study with power spectrum density analysis

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Purpose
This study was done to analyse the influence of fixed dental prosthesis (FDP) on brain function by analysing power spectral density of partially edentulous patients.

Materials and Methods
The study included unilateral missing mandibular molar replacement patients. The patients were restored with three-unit metal ceramic FDP restorations. The cognitive function was analysed with a mental state questionnaire. Power spectral density (PSD) analysis of EEG alpha waves was made pre- treatment, post treatment and 3 months after FDP treatment to analyse the brain function. The data in various phases were obtained before and after chewing. The results were statistically analysed.

Results
The mean pre and post treatment PSD was 0.0175 (SD ±0.0132) and 0.0178 (SD ±0.0135). The mean post treatment PSD after three months was 0.024 (SD± 0.019). The results were analysed with repeated ANOVA and were statistically significant. ($p<0.01$).

Conclusion
The study displayed improvement in brain function of partially edentulous patients with FDP rehabilitation.

Keywords: *Brain activity; Electroencephalogram; Fixed dental prosthesis; Power spectral density; Cognition; Fast Fourier Transform*

Introduction

Efficient health care systems equipped with reliable diagnostic and treatment measures have improved the quality of life (QOL) (1). Average life expectancy of individuals has increased over the years and this occurrence is identified as "population ageing (2,3).

There are many underlying causes of neurodegenerative diseases, Alzheimer's disease (AD) being the most common one. Pathology of AD according to strong genetic and clinical evidence is due to cumulative neurotoxicity. In patients, symptoms start gradually but eventually develop severe enough to interfere with activities of daily life (4). Electroencephalographic (EEG) signals of neurodegenerative disease patients are generally less synchronous than in age matched control subjects. Researchers have described that tooth loss can be a risk factor for brain function deterioration and mild memory impairment which could progress to dementia in later life (5).

Researches had been done to analyse the effect of complete denture and dental implant on brain function improvement (6, 7, 8). But the effect of brain function on early interventional replacement of the missing teeth

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with fixed dental prosthesis (FDP) has not been analysed. It is important to interpret the effect of FDP on brain function and to verify if early rehabilitation of missing teeth could depict any significant change in electro encephalographic reading. This study evaluated the effectiveness of FDP on brain function by studying its power spectral density (PSD).

Materials and Methods

The study proposal was approved by Institutional Review Board. The study was conducted in the Department after obtaining the patient consent. The study had a definitive inclusion and exclusion criteria in recruiting the participants. Power of the study was determined to be 95% power with 5% alpha error. 15 Healthy individuals between 25 to 35 years with missing right first molar in mandible for duration of two months with completely healed socket, requiring dental prosthesis for the first time were considered. On examination subjects were excluded if they demonstrated any prior systemic conditions with oral manifestations, already existing fixed dental prosthesis, complete edentulism, temporo-mandibular disorder, bruxism and prior use of removable partial denture. Patients suffering from diabetes, any neuromuscular disorder affecting the chewing efficiency and patients already suffering from cognitive disorders were also excluded from the study. EEG recordings had to be made for each patient before and after the prosthetic treatment. After the explanation of research procedure, fifteen patients were selected for the study and an informed consent was collected from each patient.

Before EEG recording hair-wash was advised for the patients with shampoo to keep the hair dry for EEG recording. Patients were advised sufficient sleep of at least 8 hours the night before the procedure. Patients were asked to maintain abstention from caffeinated product for eight hours before the test. Recordings were done with the subjects seated in a resting position. "10-20 electrode placement system" was employed for the procedure which is a standardisation for electrode placement. This standardisation was provided by the international federation in electroencephalography (IFCN) and clinical neurophysiology (9). EEG recordings were made in three stages. First part of EEG was taken before the treatment; second part one day after the cementation of the FDP and final EEG was recorded three months after the treatment completion. The subjects were seated in a resting position with their hands resting on the thighs and eyes closed. Stable EEGs were detected and recordings were made for 20 minutes. Each time same procedure was followed for all patients. EEG recordings were taken after chewing paraffin gum (saliva-check kit, GC Corporation, Japan) for three minutes followed by one minute of rest. Signal sampling was done at 256 samples per second with 16-bit resolution. The data obtained with this procedure was compared with the data attained one day after the FDP cementation and three months post cementation to analyse presence of any difference (8). (Figure 1 and 2)

3 Unit FDP with metal ceramic restoration was cemented for each patient. Algorithm testing was done using single channel (C3-P3) recording alpha waves of the greatest amplitude. The data were pre-processed computing average spectrum with 50% overlap in the epoch signal to find the peak

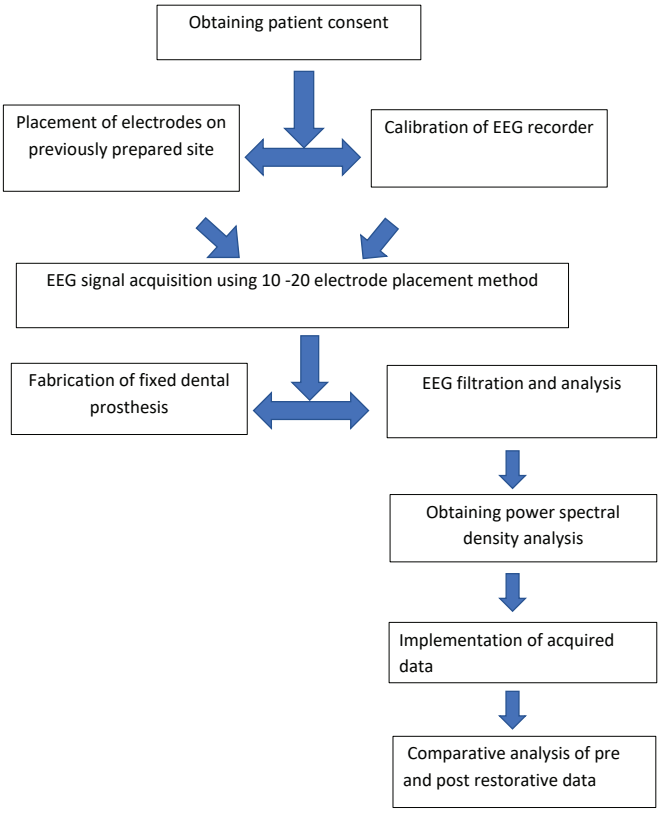

Figure 1. *Flow chart of study procedure.*

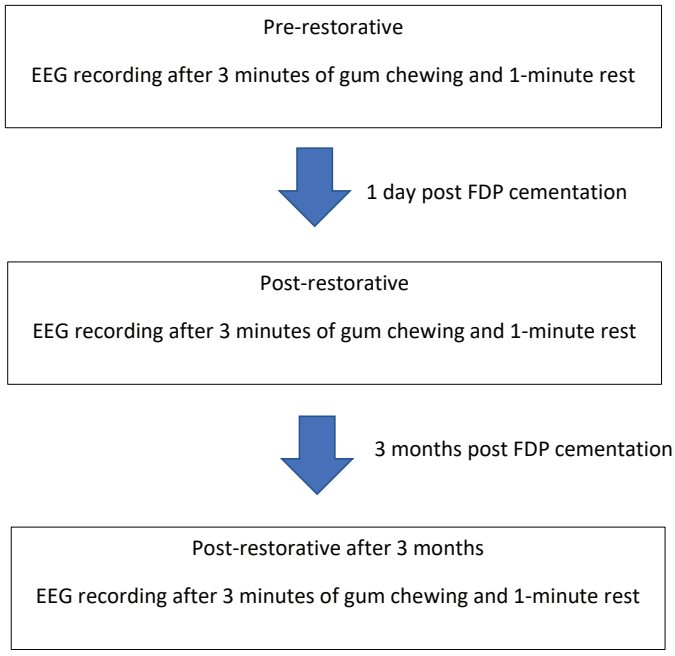

Figure 2. *Procedure of EEG data acquisition.*

of the spectrum. Power line noise and movements during EEG recording resulted in artefacts requiring filtration of the acquired data. EEG signal baseline wanders was corrected in the LAB VIEW platform and signal amplitude was quantified to micro volts. A digital low pass finite impulse response (FIR) filter was used to filter the EEG signal. Power line noises were removed using hamming window technique and filtered EEG segments were selected for analysis. Spectral analysis was approximation of power from the observation of the signal over time. Fast Fourier transformation (FFT) was used for every two second window with an overlap of one second

of the signal to achieve the power spectrum of the signal.

PSD portrays the signal power distribution over frequency. It expresses the variations of strong and weak frequency. The establishment of strong frequency in relation to time aids in further computation analysis. The computation of PSD is done through Fourier transformation. The equation for FFT is given in equation formula

$$X(k) = \sum_{k=1}^{N-1} x(n) W_N^{kn} : \quad k = 0,\ldots, N\text{-}1$$

As,

$$W_N = e^{-j\frac{2\pi}{N}}$$

For one value of 'k' observe that the multiplication of x(n) and wkn as done for 'N' times, since n=0 to N-1. That is there are 'N' complex multiplications for one value of k. since, 'k' also has 'N' values (since k=0,1,…,N-1)

Spectral analysis is the distribution of power over frequency. EEG signals obtained from the patients provided for the spectral analysis of various signals. This resulted in useful materials for diagnosis. A random signal had finite average power and, therefore, could be characterized by an average power spectral density as in Eqn. $PSD_f(w) = \lim_{T\to\infty} \frac{\left|F_{X_T}(w)\right|^2}{2T}$

where F (w) XT represent the FFT output. T is the total duration of the input signal.

Digitalisation of the recorded EEG was done to collect the EDF (European data format) for further investigation. The data was transferred to the software (eeglab software, for pre-processing followed by selection of the suitable segment which was analysed to obtain the power spectral density value (PSD). For each patient three PSD values were made before treatment, one day after cementation of the FDP and three months after treatment. The PSD values were compared to observe the difference (Figure 3-8).

Result

The values for power spectral density were categorized as, "Pre-treatment EEG PSD value", "Post-treatment EEG PSD value one day after FDP cementation" and "Post-treatment EEG PSD Value after three months". The values increased with the post treatment phase in many patients (Table 1). The mean pre-treatment PSD was 0.0175 and post treatment PSD was 0.0178. The three months post-treatment PSD measure was 0.024. The mean PSD values increased with the post treatment with FDP treatments (Table 2).

A repeated measures ANOVA was conducted to analyse the influence of FDP on brain function by analysing power spectral density of partially edentulous patients. There was a significant effect of FDP on brain function, Wilks' Lambda =0.517, F (2,13) = 6.065, p=0.014 (Table 3). The Mauchly's test of sphericity showed that assumptions were met, $\chi 2(2) = 66.313$ (Table 4). There was a significant effect with post treatment FDP on brain function, Greenhouse-Geiser (F (2, 28) = 11.729, p = .004) (Table 5). The tests showed significant effect of brain function in post treatment (mean = 0.245, SD = 0.018) compared to pre- treatment (mean = 0.175, SD= 0.013). However, 1-month post treatment showed less significant effect (mean = 0.178, SD= 0.013) in comparison with

Table 1. *Pre and Post treatment PSD values obtained from EEG analysis (relative units)*

Sl. No.	Pre-treatment PSD Value	Post-treatment PSD Value one day after Cementation	Post-treatment PSD Value three months after FPD Cementation
1	0.004	0.003	0.005
2	0.004	0.004	0.006
3	0.010	0.010	0.011
4	0.010	0.012	0.013
5	0.021	0.022	0.041
6	0.010	0.010	0.012
7	0.012	0.013	0.015
8	0.014	0.014	0.016
9	0.013	0.013	0.015
10	0.046	0.047	0.058
11	0.010	0.010	0.013
12	0.028	0.029	0.045
13	0.045	0.047	0.060
14	0.012	0.012	0.013
15	0.021	0.021	0.045

Table 2. *Descriptive statistics*

	Mean	Standard Deviation	N
Pre restorative EEG PSD Value	0.175	0.013	15
Post restorative EEG PSD Value one month after FDP Cementation	0.178	0.013	15
Post restorative EEG PSD Value three month after FDP Cementation	0.0245	0.018	15

Table 3. *Multivariate Tests*

Multivariate Tests

Effect	Value	F	Hypothesis df	Error df	Sig.
factor 1 Pillai's Trace	0.483	6.065a	2.000	13.000	0.014
Wilk's lambda	0.517	6.065a	2.000	13.000	0.014
Hotelling's Trace	0.933	6.065a	2.000	13.000	0.014
Roy's Largest Root	0.933	6.065a	2.000	13.000	0.014

Table 4. *Mauchly's Test of Sphericity*

Mauchly's Test of Sphericity

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
factor 1	0.006	66.313	2	0.000	0.502	0.502	0.500

Table 5. *Tests of Within-Subject Effects*

Tests of Within Subjects Effects

Source	Type III Sum of squares	Df	Mean Square	F	Sig.
factor 1 Sphericity Assumed	0.000	2	0.000	11.729	0.000
Greenhouse-Geisser	0.000	1.003	0.000	11.729	0.004
Huynh-Feldt	0.000	1.004	0.000	11.729	0.004
Lower-bound	0.000	1.000	0.000	11.729	0.004
Error (factor 1) Sphericity Assumed	0.001	28	2.003E-5		
Greenhouse-Geisser	0.001	14.043	3.994E-5		
Huynh-Feldt	0.001	14.053	3.991E-5		
Lower-bound	0.001	14.000	5.006E-5		

pre-treatment. The results displayed improved brain function with FDP treatment in partially edentulous situation.

Discussion

Prosthodontic treatment and outcome have a direct influence on patient's satisfaction and expected to lay an impact for entire life time (10). Weijenberg et al (2) stated that index for QOL has a direct correlation between masticatory capability and cognitive disorder. The studies have revealed evidence of tooth loss and interference in mastication leading to memory loss, learning inability and eventual decline in QOL.

Morphological and physiological studies have proven that early tooth loss have greatly resulted in chronic stress and elevated levels of corticosterone. This eventually results alteration in the hippocampus and in due course leads to reduced capacity in spatial learning and memory. Tucha et al (11) observed the effect of gum chewing improved the cognitive functions, skill and memory. Allen et al suggested that duration of chewing could be a key moderator on health, attentiveness and reduction of chronic stress (12). Kamiya et al proposed that that prolonged rhythmic gum chewing causes improved function by suppressed nociceptive flexon reflex via serotonergic (5-HT) descending inhibitory pathway (13). Edentulous or partially edentulous state has a direct effect on cognitive impairment and early rehabilitation of defective teeth is required (14). Epidemiological data implicate a positive correlation between masticatory deficit and neurological diseases. Improved chewing capability has important implications for the mechanisms underlying certain cognitive abilities (15). The mean PSD in this study was 0.0175, 0.0178, and 0.024. It increased with pre to post treatment with FDP. The result of the study is indicative of improved brain function with the restoration of missing teeth with FDP.

Electroencephalographic (EEG) measurements are commonly used for brain function research. Loss of EEG synchronicity can be interpreted as early onset of AD (16). Tamura et al (17) studies with fMRIs resulted in major artefacts. Valipour et al (18), Vialatte et al (19) displayed the use of EEG and PSD in obtaining improved data when compared to other methods . PSD is an established method of evaluating EEG (9,19,20) and spectral parameters can be achieved from all available EEG machines. The use of spatial filters, canonical correlation analysis (CCA) and blind source separation technique (BSS) can effectively reduce the artefacts that might arise with this technique (21).

Hosoi et al (22) observed a positive connection between improved occlusal function and enhanced brain activity in complete denture. The analysis stated the brain functional activity improved of complete and partial denture prosthesis. De Cicco et al (23) explained that the implant-prosthesis therapy can reduce the unbalance of trigeminal proprioceptive afferents and the asymmetry in pupil's size, improving performance in a complex sensor motor task. Kamiya et al (24) elucidated that intrinsic prefrontal activation during chewing with a denture may prevent prefrontal depression induced by tooth loss in edentulous patients. This study had increase in post treatment PSD values in partially edentulous patients. Similar changes of increase were observed by Praveen et al (8) in brain function post treatment in edentulous patients with complete denture prosthesis. This study was supportive in accordance to earlier studies that the replacement of teeth can improve the PSD and the brain function activity.

This study makes a positive impact on QOL with teeth replacement (25). The importance of early replacement of teeth can be stressed with the result of this study. This study was limited to localised population, larger sample size and evaluation of multi-centric population is necessary to legitimate the findings. Rehabilitation of single missing molar with FDP followed

in this study can be considered as initial benchmark for comparative evaluation on brain. Additional investigations and studies in terms of multiple missing teeth rehabilitation with FDP, implants and removable prosthesis are required in future.

Conclusion

Within the limitations of the study, it can be concluded that, the mean power spectral density value of post treatment alpha waves recorded is higher in comparison with pre-treatment mean value. Early rehabilitation of missing teeth with FDP facilitate improved brain function.

Türkçe Özet: *Sabit dental protezlerin parsiyel dişsiz hastalardın beyin fonksiyonlarına etkisi- spektral güç yoğunluğu analizi ile pilot çalışma. Amaç: Bu çalışma, sabit dental protezlerin (SDP) parsiyel dişsiz hastalardın beyin fonksiyonlarına etkisini analiz etmek için yapılmıştır. Gereç ve Yöntem: Çalışmaya tek taraflı alt çene azı eksikliği olan hastalar dahil edilmiştir. Hastalar, üç üye metal seramik SDP restorasyonları ile tedavi edilmiştir. Kavramsal fonskiyon mental durum anketi ile analiz edilmiştir. EEG alfa dalgalarınon spektral güç yoğunluğu (SGY) analizi tedaviden önce, tedaviden sonra v eve tedavişden 3 ay sonra beyin fonksiyonlarını analiz etmek için yapılmıştır. Değişik fazlardaki data, çiğneme öncesi ve sonrası elde edilmiştir. Sonuçlar istatistiksel olarak analiz edilmiştir. Bulgular: Tedavi öncesi ve sonrası ortalama SGY 0.0175 (SS ±0.0132) and 0.0178 (SS ±0.0135) bulunmuştur. Üç ay sonraki ortalama SGY 0.024 (SS± 0.019) bulunmuştur. Sonuçlar tekrar eden ANOVA ile analizedilmiştir ve istatistiksel olarak anlamlı bulunmuştur (P < 0.01). Sonuç: Bu çalışmada sabit dental protezlerin (SDP) parsiyel dişsiz hastalardın beyin fonksiyonlarını arttırdığı tespit edilmiştir. Anahtar kelimeler: Beyin aktivitesi, Elektroensefalogram, Sabit dental protez, spektral güç yoğunluğu, kavramsal, hızlı forier dönüşüm*

Ethics Committee Approval: The study proposal was approved by Institutional Review Board.

Informed Consent: Participants provided informed constent.

Peer-review: Externally peer-reviewed.

Author contributions: Author contributions: UPS and NGC designed the study. UPS and NGC participated in generating the data for the study. UPS and NGC participated in gathering the data for the study. UPS, NGC and MB participated in the analysis of the data. UPS and NGC wrote the majority of the original draft of the paper. UPS participated in writing the paper. All authors approved the final version of this paper.

Conflict of Interest: The authors had no conflict of interest to declare.

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