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

Uddipta Prafulla Saikia¹, N. Gopi Chander¹, Muthukumar Balasubramanian¹

ORCID IDs of the authors: U.P. 0000-0002-5683-5715; N.G.C. 0000-0002-2040-4530; M.B. 0000-0002-4022-6456

¹Department of Prosthodontics, SRM Dental College, Ramapuram, Chennai, Tamilnadu, India
Corresponding Author: N. Gopi Chander
E-mail: drgopichander@gmail.com

Received: 19 October 2018
Revised: 26 March 2019
Accepted: 25 May 2019
DOI: 10.26650/eor.20200032

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...
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, temporomandibular 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 of the spectrum. Power line noise and movements during EEG recording resulted in artefacts requiring filtration of the acquired data. EEG signal baseline wander 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:

\[
X(k) = \sum_{k=1}^{N-1} x(n)W_{N}^{kn} : k = 0, ..., N-1
\]

As,

\[
W_{N} = e^{-\frac{2\pi i}{N}}
\]

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. \( P_{SE}(f) = \lim_{T \to \infty} \frac{E_{X_{F}(f)}}{2T} \)

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

| Sl. No. | Pre-treatment PSD Value | Post-treatment PSD Value one day after FDP Cementation | Post-treatment PSD Value three months after FDP 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      | 0.0014                  | 0.014                                                 | 0.014                                                    |
| 9      | 0.0013                  | 0.013                                                 | 0.013                                                    |
| 10     | 0.0046                  | 0.047                                                 | 0.058                                                    |
| 11     | 0.010                  | 0.0010                                                 | 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                                                    |

| Effect        | Value | F     | Hypothesis df | Error df | Sig. |
|---------------|-------|-------|---------------|----------|------|
| factor 1      | 0.483 | 6.065a | 2.000         | 13.000   | 0.014|
| Pillai’s Trace|        |       |               |          |      |
| 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|
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 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 pre-treatment. The results displayed improved brain function with FDP treatment in partially edentulous situation.
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 dışız hastalardan beyn fonksiyonlarına etkisi- spektral güç yoğunluğu analizi ile pilot çalışma. Amaç: Bu çalışma, sabit dental protezler (SDP) parsiyel dışız hasta- lardan beyn fonksiyonlarına etkisini analiz etmek için yapılmıştır. Gereç ve Yöntem: Çalışmaya tek taraflı alt çağı eski kilimli olan hastalar dahil edilmiştir. Hastalar, üç üye metal seramik SDP resorasyonları ile tedavi edilmiştir. Kavramsal faהיסטורי mental durum anketi ile analiz edilmiştir. EEG alfa dalgaları non spektral güç yoğunluğu (SGY) analizi tedavi- iden önce, tedaviiden sonra vé ve tedaviyeden 3 ay sonra beyn fonksiyonlarının analiz etmek için yapılmıştır. Değişik fazlardaki data, çiğneme arasındaki analiz ve sonrasi elde edilmiştir. Sonuç: Çalışmada sabit dental protezlerin (SDP) parsiyel dışız hasta- lardan beyn fonksiyonlarının arttırıldığı tespit edilmiştir. Annotoller kelimel- er: Beyn aktivitesi, Elektrofazetolar, 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 consent.

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 de-clare.

Financial Disclosure: The authors declared that they have received no financial support.

Acknowledgements: The authors thanks Dr. J. Ramesh Reddy, SRM Dental College, Ramapuram, Chennai, for his support.

References

1. Chananah HB, Talwar PP. Aging in India: Its socioeconomic and health implications. Asia Pac Popul J 1987;2(3):23-38. [CrossRef]
2. Weijenber RA, Scherder EJ, Lobbezoo F. Mastication for the mind— The relationship between mastication and cognition in ageing and dementia. Neurosci Biobehav Rev 2011;35(3):483-97. [CrossRef]
3. Bandodkar KA, Aras M. Psychological considerations for complete denture patients. J Indian Prosthodont Soc 2007;7:71-6. [CrossRef]
4. Backman L, Jones S, Bergere AK, Laukka J, Small BJ. Multiple cognitive deficits during the transition to Alzheimer’s disease. J Intern Med 2004;256:195–204. [CrossRef]
5. Okamoto N, Monikawa M, Okamoto K, Habu N, Iwamoto J, Tomioka K, Saeki K, Yanagi M, Amano N, Kurumatani N. Relationship of tooth loss to mild memory impairment and cognitive impairment: findings from the fujimura-kyo study. Behav brain funct 2010;6(1):1. [CrossRef]
6. Masakazu. Influence of the Functional Improvement of Complete Dentures on Brain Activity. J Jpn Prostheth Soc 2008; 52:194-199. [CrossRef]
7. Okamoto N. Effect of occlusal support by implant prostheses on brain function. J prostodont Res 2011;55(4):206-13. [CrossRef]
8. Acharya JN, Hani A, Cheek J, Thirumala P, Tsusichikad TN. American Clinical Neurophysiology Society Guideline 2: Guidelines for Standard Electrode Position Nomenclature. J ClinNeurophysiol 2016;33: 308–311. [CrossRef]
9. Perumal P, Chander GN, Anitha KV, Reddy JR, Muthukumar B. Power spectrum density analysis for the influence of complete denture on the brain function of edentulous patients - pilot study. J Adv Prosthodont 2016;8(3):187-93. [CrossRef]
10. Sangappaa SB. Patient satisfaction in prosthodontic treatment: multidimensional paradigm. J Indian Prosthodont Soc 2012;12(1):21-6. [CrossRef]
11. Tucha L, Koerts J. Gum chewing and cognition: an overview. NeurosciMedi 2012;3(03):243. [CrossRef]
12. Allen AP, Smith AP. A review of the evidence that chewing gum affects stress, alertness and cognition. J BehavNeurosci Res 2011;9(1):7-23.
13. Kamiya K, Fumoto M, Kikuchi H, Sekiyama T, Mohri-Lkuzawa Y, Umino M, Arita H. Prolonged gum chewing evokes activation of the ventral part of prefrontal cortex and suppression of nociceptive responses: involvement of the serotonergic system. J Med Dent Sci 2010;57(1):35-43.
14. Hioki Y, Iinuma M, Kurata C, Ichihashi Y, Tamura Y, Kubo KY. Effects of early tooth loss on the hippocampus in senescence-accelerated mice. Pediatr Dent J 2009;19(2):196-205. [CrossRef]
15. Iinuma M, Kondo H, Kurahashi M, Ohnishi M, Tamura Y, Chen H, Kubo KY. Relationship between the early toothless condition and hippocampal functional morphology. Anat&Physiol: Current Research 2014;18:2014. [CrossRef]
16. Teixeira FB, Fernandes LD, Noronha PT, dos Santos MA, Gomes-Leal W, Maia CD, Rodrigues R. Masticatory deficiency as a risk factor for cognitive dysfunction. Int J Med Sci 2014;11(2):209-14. [CrossRef]
17. Tamura T, Kanayama T, Yoshida S, Kawasaki T. Functional magnetic resonance imaging of human jaw movements. J Oral Rehabil 2003;30(6):614-22. [CrossRef]
18. Valipour S, Shaligram AD, Kulkarni GR. Spectral analysis of EEG signal for detection of alpha rhythm with open and closed eyes. Int J Eng Innovative Technol 2013:3:1-4.
19. Vialatte FB, Bauwels J, Maurice M, Musha T, Cichocki A. Improving the specificity of EEG for diagnosing Alzheimer’s disease. Int J Alzheimers Dis 2011 May 30. [CrossRef]
20. Dressoler S, Schneider G, Stootmanns G, Kochs EF. Awareness and the EEG power spectrum: analysis of frequencies. Br J Anaesth 2004;93(6):806-9. [CrossRef]
21. Ile N, Berg P, Scherg M. Artifact correction of the ongoing EEG using spatial filters based on artifact and brain signal topographies. J ClinNeurophysiol 2002;19(2):113-24. [CrossRef]
22. Hossi T, Morokuma M, Shibuya N, Yoneyama Y. Influence of denture treatment on brain function activity. Jpn Dent Sci Rev 2011;47(1):56-66. [CrossRef]
23. De Cicco V, Barresi M, Fantozzi MP, Cataldo E, Parisi V, Manzoni D. Oral Implant-Prostheses: New Teeth for a Brighter Brain. PloS ONE 2016;11(2):e0148715. [CrossRef]
24. Kamiya K, Narita N, Iwaki S. Improved Prefrontal Activity and Chewing Performance as Function of Wearing Denture in Partially Edentulous Elderly Individuals: Functional Near-Infrared Spectroscopy Study. PloS ONE 2016;11(6):e0158070. [CrossRef]
25. Dhingra S, Rajesh G, Rao A, Pai UY, Shenoy R, Pai M. Impact of occlusal support and perceived chewing ability on oral health-related quality of life among patients attending a private dental institution in India. J Indian Prosthodont Soc 2017;17(1):15-21.