

Evaluation of changes in brain activity and cognitive function of diabetic patients wearing removable partial dentures

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Background/aim

Accumulating evidence suggests that tooth loss may be a major risk factor for brain and cognitive impairment. The present study aimed to evaluate the influence of restoring lost posterior occlusal contacts with removable partial denture (RPD) on the brain activity and cognitive function in controlled type 2 diabetic patients.

Patients and methods

A total of 30 partially edentulous patients with lost posterior occlusal contacts were selected with no previous partial denture experience. RPDs were constructed from thermoplastic acrylic resin. The brain activity and cognitive function were assessed using electroencephalogram (EEG) and Mini-Mental State Examination questionnaire, respectively, before and after 1 month of RPD insertion. Data were statistically analyzed using *t* test, and significance level was defined at *P* value less than 0.05.

Results

EEG assessment demonstrated an increase in the mean value after 1 month of wearing RPDs. Similarly, Mini-Mental State Examination of cognitive scores displayed an increase in the total mean value after 1 month. The outcomes were statistically significant ($P < 0.05$).

Conclusion

Restoration of lost posterior occlusal contact in controlled type 2 diabetic patients with RPD improved the brain function and cognitive status.

Keywords:

Electroencephalogram, Mini-Mental state examination, Removable partial dentures, Type 2 diabetes

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Introduction

With the increase in the percentage of elderly individuals owing to rise in life expectancy, the shift from complete tooth loss toward partial edentulism is anticipated [1].

Tooth loss affects not only esthetic, but it also impairs oral functions and masticatory efficiency. Mastication is directly related to chewing ability, nutrient intake, and consequently, the general health and the quality of individual's life [2,3]. Furthermore, tooth loss has been proposed to be a potential risk factors for noncommunicable diseases such as diabetes, heart diseases, and Alzheimer's [4].

Diabetes mellitus (DM) is one of the most common metabolic disorder worldwide. According to the WHO 2019 [5], DM was classified into type 1, type 2, hybrid forms, unclassified diabetes and hyperglycemia first detected during pregnancy. Type 2 DM accounts for 90–95% of diabetes [5]. Hypoglycemia, vascular diseases, and hyperlipidemia are among the most common complications of DM. Moreover, depression associated with DM (comorbid depression) is another serious issue for accelerated cognitive decline among patients with type 2 DM [6,7].

In DM, oral health status is jeopardized owing to the increased risk of periodontitis to three-fold compared with nondiabetic individuals [8]. Additionally, periodontitis is considered be the second cause of tooth loss [6]. Multiple teeth loss has been suggested to attenuate the trigeminal nerve sensory information provided from the periodontal ligament and masticatory muscles [9], and this was proposed to adversely affect higher brain activities such as memory and learning [10].

In the recent years, the relation between prosthetic rehabilitations and brain function has been an issue of interest owing to aging of the society [11,12]. In several studies, an improvement of the functional state of the brain with satisfactory dental prostheses was observed.

Prosthetic rehabilitation of partial edentulism with implant fixed partial denture is the contemporary treatment modality [11,12]. However, such treatment may be not accessible owing to economic or health conditions. In such cases, removable partial

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dentures (RPDs) remain an important prosthetic restoration. It is less expensive and is the treatment of choice in medically compromised patients compared with implant prosthesis [13]. Moreover, RPDs can be used in long edentulous span and as provisional restoration before final prosthesis [14].

In literature, the assessments of brain activity and cognitive function have been accomplished using noninvasive techniques [15]. The examination of brain activity can be obtained via techniques such as neuroimaging or neurophysiology. Among the neuroimaging systems are electroencephalography (EEG), magnetoencephalography, and transcranial magnetic stimulation. On the contrary, neurophysiology methods include functional MRI and near-infrared spectroscopy [16].

On the contrary, evaluation of cognitive function can be performed using Mini-Mental State Examination (MMSE) questionnaire. MMSE is a simple tool that can be applied to estimate the function of five areas of cognition via 12 questions [17]. These questions are concerned with orientation, registration, attention and calculation, recall, and language.

Although the relation between prosthetic rehabilitation and brain activity has been reported in previous studies, the assessment of brain activity in diabetic patients wearing RPDs has not been clarified. Therefore, the objectives of the present study were to evaluate the effect of restoration of lost posterior occlusal contact with RPD on brain activity and cognitive function in type 2 controlled diabetic patients.

Patients and methods

Patients

In this study, 30 partially edentulous male patients were recruited from the Dental Clinics of Medical Excellence Centre, NRC. Their age ranged from 40 to 50 years (mean age: 45 years).

Inclusion and exclusion criteria

All the participants fulfilled the following inclusion criteria: (i) loss of posterior occlusal contact unilaterally or bilaterally in both maxilla and mandible, (ii) no previous partial dentures experience, (iii) nonsmokers, (iv) skeletally Angle's class I, and (v) controlled type 2 diabetes, that is, fasting serum glucose level was higher than 126 mg/dl as well as the glycosylated hemoglobin level does not exceed 7.5% during the study period. On the contrary, exclusion criteria were (i) history of brain diseases (e.g. cerebral infarction and Alzheimer's),

(ii) neuromuscular disorders, (iii) temporomandibular joint disorder, (iv) psychiatric illness, and (v) participants with parafunctional oral habits.

Ethical approval

This study was designed and approved by the Medical Research Ethical committee (MREC Approval No. 16086) of National Research Centre (NRC), Cairo, Egypt, which is in accordance with Helsinki Declaration of 1975. All patients were informed about the practical steps of this study and signed a written approval consent.

Clinical trial registration

This study was registered in Clinical Trials.gov PRS with ID: NCT04554199.

Study design

For all patients, RPDs were fabricated using thermoplastic resins (flexible RPDs). Brain activity and cognitive function were assessed using EEG and MMSE, respectively, before denture delivery and after 1 month of denture wear.

Methods

Fabrication of flexible partial dentures

Flexible partial dentures were fabricated for all patients following conventional clinical steps and processed using injection molding technique. Thermoplastic resin (Bre-flex, pink color; Bredent, Senden, Germany) was cured using thermopress 400 injection molding unit at temperature of 260°C and at pressure of 5 bar for 26 min. After RPD processing, sprues and small flashes were removed carefully, and partial dentures were finished and polished using acrylic polishers. RPDs were delivered to the patients, and all necessary adjustments were accomplished. Participants were educated and instructed to maintain adequate oral hygiene.

Assessment brain function and cognitive performance

Brain activity and cognitive function were assessed using EEG and MMSE, respectively, before and 1 month after RPD delivery. EEG (EB Neuro S.P.A; Galileo Software, Firenze, Italy) records were obtained using 21-channel paste-less bridge electrodes. The electrodes were arranged on the scalp (EB Neuro S. P.A) according to the international 10–20 system with reference electrodes placed on both earlobes.

During the measurement, each participant was seated comfortably at rest with their eyes closed. After ensuring that the EEG activities detected from all electrodes were stable, EEG was recorded for 20 min. The EEG

machine parameters were adjusted before obtaining the record as follows: time constant 0.3 s, drawing speed 3.0 cm/s, and filter 50 Hz. Referential and bipolar montages were applied. The EEG was interpreted to detect alpha waves ($D\alpha$) which occur in frequency range of 8–12 Hz.

To validate EEG results, an MMSE questionnaire consisting of 12 questions as shown in Table 1 [17,18], with maximum scoring of 30 was used to assess the cognitive function of participants. MMSE measures orientation to time and place, immediate recall, short-term verbal memory, calculation, language, and construct ability.

Statistical analysis

Data were collected and tabulated as means and SD. Statistical analysis was made using SPSS 20, Graph Pad Prism, and Microsoft Excel 2011 (IBM SPSS

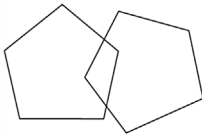
Statistics 2011 for Windows, Version 20.0. Armonk, NY, USA: IBM Corp.). Comparison of data were achieved using paired t , and the significance level was validated at P value less than 0.05.

Results

Evaluations of alpha waves ($D\alpha$) of brain activity using EEG before and 1 month after RPD insertion are displayed in Table 2 and Fig. 1. The result demonstrated statistically significant increase in the mean values from 8.5 before insertion of RPDs to be 9.7 after 1 month of using dentures ($P < 0.05$).

Evaluation of cognitive function using MMSE, with total scoring of 30, before wearing of RPD and 1 month of using RPD is presented in Table 2 and Fig. 2. The results showed statistically significant increase in the

Table 1 Mini-Mental State Examination questionnaire

	Question	Time allowed	Score
1	a. What year is this?	10 s	/1
	b. Which season is this?	10 s	/1
	c. What month is this?	10 s	/1
	d. What is today's date?	10 s	/1
	e. What day of the week is this?	10 s	/1
2	a. What country are we in?	10 s	/1
	b. What province are we in?	10 s	/1
	c. What city/town are we in?	10 s	/1
	d. IN HOME – what is the street address of this house? IN FACILITY – what is the name of this building?	10 s	/1
	e. IN HOME – what room are we in? IN FACILITY – what floor are we on?	10 s	/1
3	SAY: I am going to name three objects. When I am finished, I want you to repeat them. Remember what they are because I am going to ask you to name them again in a few minutes. Say the following words slowly at 1□s intervals □ ball/car/man	20 s	/3
4	Spell the word World. Now spell it backwards	30 s	/5
5	Now what were the three objects I asked you to remember?	10 s	/3
6	SHOW wristwatch. ASK: What is this called?	10 s	/1
7	SHOW pencil. ASK: what is this called?	10 s	/1
8	SAY: I would like you to repeat this phrase after me: No ifs, ands or buts	10 s	/1
9	SAY: read the words on the page and then do what it says. Then hand the person the sheet with CLOSE YOUR EYES on it. If the patient reads and does not close their eyes, repeat up to three times. Score only if patient closes eyes	10 s	/1
10	HAND the person a pencil and paper. SAY: write any complete sentence on that piece of paper. (Note: the sentence must make sense. Ignore spelling errors)	30 s	/1
11	PLACE design, eraser and pencil in front of the person. SAY: copy this design please	1 min	/1
			
	Allow multiple tries. Wait until person is finished and hands it back. Score only for correctly copied diagram with a 4-sided figure between two 5-sided figures		
12	ASK the person if he is right or left-handed. Take a piece of paper and hold it up in front of the person. SAY: take this paper in your right/left hand (whichever is nondominant), fold the paper in half once with both hands and put the paper down on the floor. Score 1 point for each instruction executed correctly	30 s	/1
	Takes paper correctly in hand		/1
	Folds it in half puts it on the floor		/1
	Total test score		/30

calculated MMSE mean values from 25.2 before fabrication of RPDs to 28.6 after 1 month of wearing RPDs ($P<0.05$).

Table 2 Electroencephalogram and Mini-Mental State Examination results before and after 1 month of removable partial denture insertion

Time	EEG	MMSE
Before RPDs insertion	8.5±2.02	25.2±5.21
After 1 month of RPDs insertion	9.7±2.07*	28.6±5.82*

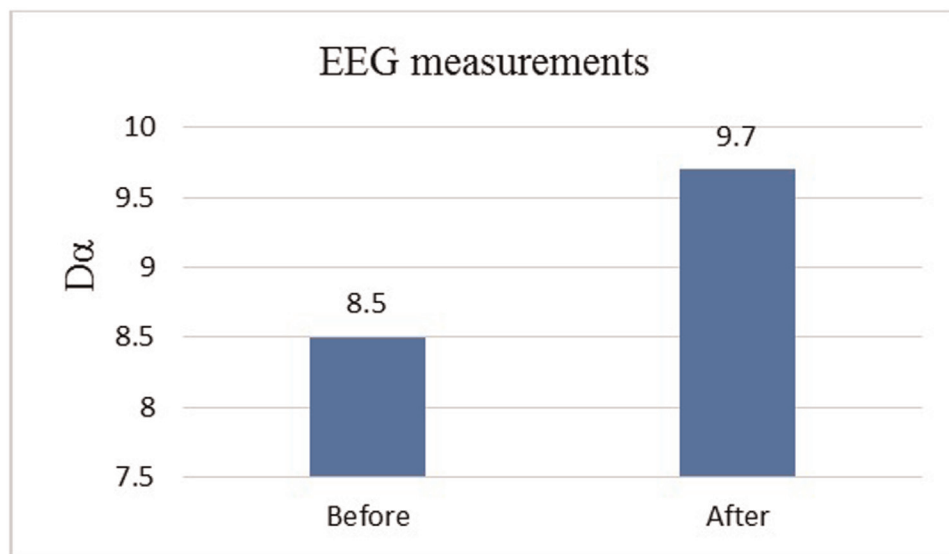
All data are expressed as mean±SD. EEG, electroencephalogram; MMSE, Mini-Mental State Examination; RPD, removable partial denture. *Significant difference than before at P value less than 0.05.

Discussion

Cognitive impairment can be attributed to unmodifiable and modifiable risk factors. Unmodifiable risk factors include age, sex, genetic factors, etc., whereas modifiable variables are diabetes, hypertension, dietary habits, physical performance, and cognitive activity [19].

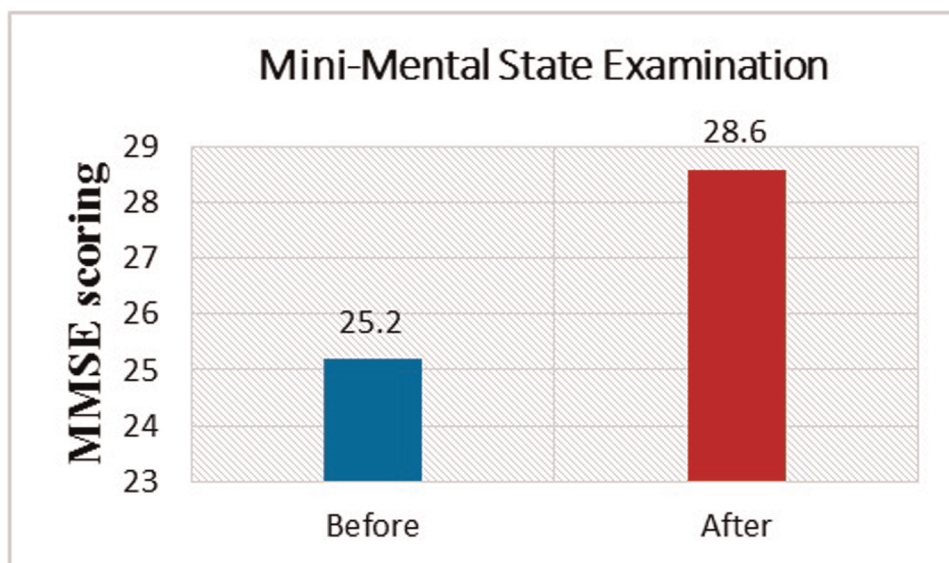
Recently, teeth loss has been suggested as possible contributing factor that impede cognition status such as memory and learning [20].

Figure 1



Bar chart comparing alpha waves before and 1 month after wearing of RPDs.

Figure 2



Bar chart comparing MMSE before and after 1 month of RPDs wearing.

In this study, type 2 controlled diabetic patients were selected for two reasons. The first is that diabetes is a modifiable risk factor that can accelerate cognitive decline [6,7]. The second reason is to avoid oral soft tissue complications that may induce pain or prohibit patients from wearing of RPDs. In uncontrolled diabetes, oral soft tissue lesions are more common such as traumatic ulcers, irritational fibroma, recurrent aphthous stomatitis, and delayed wound healing. Such complications are caused by immunosuppression and/or reduced salivary secretion [21].

To ensure successful RPD treatment of diabetic patients, the quality and aesthetics aspect of RPDs should be considered. The advent of thermoplastic resins offered nonmetal clasp RPDs that provided better aesthetics, flexibility to engage undercuts without tissue irritation, comfort, as well as absence of allergic reaction [22]. Hence, thermoplastic RPDs were implemented in the present study instead of conventional chromium cobalt RPDs to guarantee patient satisfaction and comfort.

In the current study, the influence of the RPD treatment on brain activity has been evaluated by means of EEG to detect the changes in alpha waves. Furthermore, EEG measurements were validated by the assessment of cognitive function. EEG is a simple nonharmful technique used to perceive changes in brain activity. It requires short time, and it is relatively inexpensive [15]. Assessment of cognitive status was achieved using MMSE questionnaire. It is a validated test that is used regularly since 1975. MMSE is applied to identify cognitive impairment as well as to detect the changes in cognition, and it requires only 5–10 min to be accomplished.

In the literature, it was reported that the brain activity can be altered by music, and craftwork. Moreover, Hosoi *et al.* [23] proposed that even conversation and dentist treatment can modify brain activity. Therefore, preliminary and secondary EEG were performed in a resting state to avoid possible alterations in EEG.

Unlike other studies, in this study, the preliminary and secondary EEG measurements were made without chewing performance. In addition, the second EEG was achieved after adaptation period of 1 month. This study design aimed to correlate the effect of wearing RPDs for 1 month on brain activity and cognitive function.

This time interval was required to do necessary denture adjustment. This adjustment is crucial to alleviate

pain, discomfort, or any stimulus that may interfere with brain activity and consequently EEG records [23]. Moreover, satisfactory prosthesis ensures adequate chewing ability as stated by Morokuma *et al.* [24] and Narita *et al.* [25].

The results of the present study demonstrated an enhancement of brain activity concurrent with an improvement of cognitive function. Although the outcomes of this study were in accordance with previous studies that supported the positive role of re-establishing occlusion with satisfactory prosthesis on perceived brain activity, general health, and quality of life [24,25], none of the previous investigations were conducted on controlled diabetic patients.

Narita *et al.* [25] observed that wearing of RPDs to restore lost occlusal contact did improve the brain activity. They attributed such findings to stimulation of prefrontal dorsal cortex via masticatory apparatus and consequently activation of semantic cognition. They demonstrated that satisfactory prostheses could improve quality of life, prevent neurological diseases, and consequently decelerate cognitive impairments in elderly. They also addressed the role of dentist to observe the improvement in chewing ability in patients wearing RPDs. A comparable conclusion was drawn by Ono *et al.* [26], who suggested that the sensory information sent to the brain via mastication can support the learning and memory function of the brain. Similarly, Hosoi *et al.* [23] mentioned that prosthetic rehabilitation with either partial or complete dentures does not enhance the masticatory function only but it also restores sensory information pathway to trigeminal nerve and stimulates brain activity.

Morokuma *et al.* [24] confirmed that well-fitting dentures provided adequate occlusal force for better chewing act that may enhance synaptic/neuronal dysfunction and stimulate the central nervous system via trigeminal nerve. They recognized that satisfactory dentures may be critical to improve quality of life and minimize dementia.

Conclusion

Restoration of lost posterior occlusal contact in controlled type 2 diabetic patients with satisfactory RPDs can contribute to enhancement of the brain function and cognitive status.

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Nil.

Authors' contributions

All authors made substantial contributions to conception and design of the research. All authors, Amani R. Moussa, Eman M. Ibraheem, and Asmaa N. Elborae, participated in the study design, practical work, scientific writing, and revising of the manuscript.

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Conflicts of interest

There are no conflicts of interest.

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