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Effects of Immediate Dental Loading Implant Therapy on Electroencephalography (EEG) and Stress

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Abstract

Purpose: Implant therapy restores masticatory function by restoring lost tooth morphology. It has been shown that mastication contributes not only to food intake and digestion, but also to the improvement of overall health. However, there have been no studies on the effects of implant treatment on electroencephalography (EEG). In this study, we investigated the effects of restoration of masticatory function by implant treatment on EEG and stress. **Methods:** 13 subjects (6 males, 7 females, age 64.1 ± 5.8 years) who had lost masticatory function due to tooth loss and 11 healthy subjects (6 males, 5 females, age 47.6 ± 2.4 years) as a control group. EEG (θ, α, β waves, α/β ratio) and salivary cortisol were measured before immediate dental implant treatment and every month of treatment for 6 months. EEG (θ, α, β waves, α/β ratio) was measured with a simple electroencephalograph miniature DAQ terminal (Intercross-410, Intercross Co., Ltd., Japan) in a resting closed-eye condition, and salivary cortisol was measured using an ELISA kit. **Results:** Compared to the control group, the appearance of θ and α waves were significantly decreased and β waves were increased, and α/β ratio was significantly decreased. The cortisol level of the subject group was significantly higher compared with the control group. With the course of implant treatment, the appearance of θ and α waves of the subject group increased, while β waves decreased. However, no significant difference was observed. The α/β ratio of the subject group increased from the first month after implant treatment and increased significantly after 5 and 6 months (0 vs. 5 months: $p < 0.05$, 0 vs. 6 months: $p < 0.01$). The cortisol levels in the subject group decreased from the first month after implant treatment and significantly decreased after 3 or 4 months (0 vs. 3 months: p <

0.05, 0 vs. 4 months: $p < 0.01$). These results suggest that tooth loss causes mental stress, which decreases brain stimulation and affects function. Restoration of masticatory function by implants was suggested to alleviate the effects on brain function and stress.

Keywords

Immediate Loading Implant, Electroencephalography (EEG), α/β, Cortisol

1. Introduction

If teeth are lost due to dental caries or periodontal disease, nutritional problems will occur. If proper masticatory function is not restored, a reduction in appetite occurs due to decreased smooth tongue, spilled food, choking, and an increase in the number of foods that cannot be chewed. Currently, this leads to subsequent undernutrition, and it also results in increased nursing care levels. Dementia worsens oral hygiene status, and worsening oral health conditions promotes the onset and exacerbation of dementia. The progression of dementia not only makes it difficult to understand and adapt to new prosthetic devices, but also increases the frequency of accidents, such as removing a lost denture unexpectedly and losing it, or accidentally swallowing an accidentally removed denture [1] [2].

One of the purposes of prosthodontic treatment for tooth loss is the recovery of chewing function. It has been clarified that chewing contributes not only to the intake and digestion of food, but also to the promotion of the health of the whole body [3].

The influence of tooth loss on the central nervous system is gaining importance as the super-aging society progresses. Tooth loss is thought to increase plasma glucocorticoid concentration, attenuate trigeminal nerves and neurotransmitters, and alter the normal function of the central nervous system [4].

An increase in plasma glucocorticoid concentration acts as a chronic stressor. In addition, the trigeminal nerve, which innervates the periodontal ligament and masticatory muscles, functions poorly, resulting in reduced sensory information in the oral cavity and suppression of higher brain activities such as learning and memory [5].

Electroencephalography (EEG) is one of the oldest technologies to measure the neuronal activity of the human brain. The frequency patterns of brain waves include α waves (8 to 13 Hz), β waves (13 Hz or higher), θ waves (4 to 8 Hz), and δ waves (0.5 to 4 Hz), each of which has its own characteristics and is closely related to physical and psychologically. α waves are associated with a state of rest and relaxation with eyes closed, β waves are associated with consciousness during wakefulness and are associated with active thinking and mental and physical tension, and θ waves are during periods of slumber, calculations and mental activity. α/β ratio is considered an indicator of tension, stress, and fatigue [6] [7]

[8].

Recently, in the choices of prosthesis treatments for patients with edentulous to recover the masticatory function and sensuousness, the recovery of occlusion function (oral rehabilitation) by applying dental implant is becoming common besides the treatment with removal dentures which has been the mainstay for a long time. The reconstruction of occlusion with implant fixture made it possible to recover the function disorder caused by the deficit of a tooth and a jawbone and the morphological disorder which were once considered difficult to do with a removal denture because it loaded the oral mucosa. This method quickly became the focus of research and development as a new trend in dental care, and grew into a reliable treatment method keeping its technical stability.

The influence of mastication on brain function has attracted attention. It has been suggested that improvement of masticatory function may have not only physical but also mental quality of life (QOL) effects, but there are few objective data to explain these effects. In this study, we investigated the effects of implant therapy on the relationship between masticatory function and EEG and on salivary cortisol, a biomarker of stress, using the same subjects.

2. Materials and Methods

2.1. Subjects

The subjects were 13 patients (6 males and 7 females, age of 64.1 ± 5.8 years) who complained of loss of contact between the maxillary and mandibular dentition due to edentulous jaws, or of crossing of the maxillary and mandibular teeth, and who desired occlusal restoration with immediate loading implants. The subjects were patients who had been diagnosed as having completely lost occlusal contact and were unable to assume the central occlusal position. No exclusion criteria were established in the present study.

This study was conducted with the consent of the subjects under the approval of the Ethics Committee of the Ebina Lion Implant Center (Protocol #ELIC2018-01) and in accordance with the Code of Ethics of the Japanese Society of Oral Implantology, a non-profit foundation established by the Ebina Lion Implant Center.

The subjects were placed a provisional bridge as the upper structure right after the implant placement surgery, and occlusion of the upper and lower jaws were recovered. Replace Select Tapered RP® (Nobel Biocare Japan K.K.) was used as the implant fixture. The temporary bridge was composed with the resin artificial tooth and dental polymerized resin, and Temporary Cylinder Plastic® (DCA468-0) and Prosthetic Screw® (29285) (Nobel Bio-care Japan K.K.) were used as its connector.

The ISQ, which is an index of bone fusion recommended by Implant Prosthetics, exceeded 70, the paradentium was stabilized, and the provisional bridge was measured for 6 months until the transition to the final prosthesis [9] [10].

The 11 healthy stable teeth (6 males and 5 females, age of 47.6 ± 2.4 years) served as the control group.

2.2. The Measurement of EEG

EEG measurements were performed before and every other month after implant placement surgery for 6 months. EEG was measured during 90 s at closed eyes in a resting sitting position using a dry electrode type simple electroencephalograph at the miniature DAQ terminal (Intercross-410, Intercross Co., Ltd., Japan). The recording site was the median center on the median line connecting the nasal bridge and occipital protrusions according to the international 10/20 method, and the reference electrodes were bilateral earlobe connections.

Analysis is performed by converting the brain wave to separate θ wave (4 - 8 Hz), α wave (8 - 13 Hz) and β wave (13 - 30 Hz). The α/β ratio was analyzed as a measure of tension, stress and fatigue [11].

2.3. Salivary Cortisol Assay

The cortisol known as a stress hormone was measured. After putting bland and innocuous Salimetrics Oral Swab (Salimetrics, USA) into the subject's mouth for 5 minutes in a sitting posture, it was collected and the saliva was taken by centrifugation (1500 rpm × 40 minutes, 4˚C). The saliva was stored at −20˚C until the measurement. The time of collection was determined from 11:00 to 15:00 at which the value of cortisol stabilizes in consideration of the circadian variation of cortisol value [12] [13].

The cortisol was measured using the Salivary Cortisol Enzyme-Linked Immunosorbent Assay (ELISA) Kit (Salimetrics LLC, USA).

2.4. Statistical Analysis

All the data are presented as mean ± standard error of the mean (SEM). The data were analyzed by the Mann-Whitney test to evaluate the difference between control and subjects. The data were analyzed by the Dunn's multiple comparisons test to evaluate the difference between pre-surgery and post-surgery. p-values of < 0.05 were defined as statistically significant.

3. Results

3.1. The Influence of Implant Treatment on EEG

The θ, α, and β waves of control group and the subject are shown in **Figure 1**. The control group had θ waves of 146.1 ± 71.2, α waves of 94.6 ± 38.7, and β waves of 79.4 ± 43.8, respectively, while the subject group had θ waves of 22.3 ± 12.0, α waves of 26.8 ± 16.1, and β waves of 118.8 ± 72.8, respectively. Compared to control group, the subject group θ and α waves were all significantly lower ($p < 0.01$), and the β waves were higher. Changes in EEG after implant therapy are shown in **Figure 2**. The subject group of the θ and α waves increased with the progress of implant therapy, while β waves decreased. However, no significant

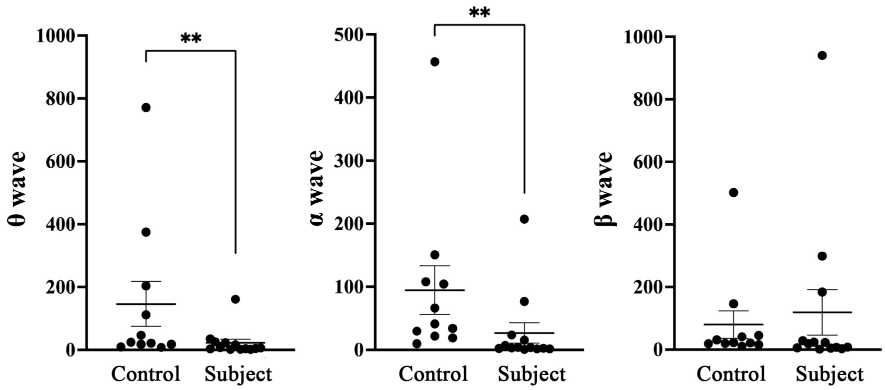

Figure 1. The θ, α, and β waves of control (normal edentates) group and the subject (patient edentuous malocclusion) group. Mean ± S.E., control: n = 11, subject: n = 13. **: p < 0.01 vs. control.

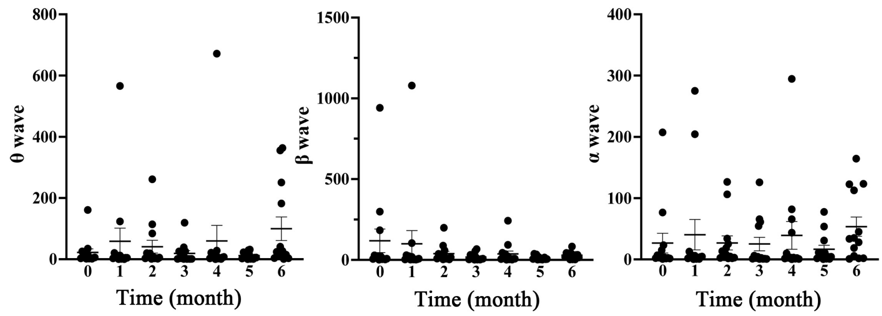

Figure 2. Changes in EEG due to implant therapy. Mean ± S.E., n = 13.

difference was observed.

The α/β ratios of control group and the subject are shown in **Figure 3**. The α/β ratio of the control group was 0.55 ± 0.24, and that of the subject group was 1.51 ± 0.35. The α/β ratio of the subject group was significantly higher compared with the control group ($p < 0.001$). The change in the α/β ratio after implant treatment is shown in **Figure 4**. The α/β ratio of the subject group increased from the first month after implant therapy and increased significantly after 5 and 6 months (0 vs. 5 months: $p < 0.05$, 0 vs. 6 months: $p < 0.01$).

These results showed that in the tooth loss and malocclusion, there was a decrease in θ waves, α waves, and α/β ratio, and stress and fatigue were observed. Both EEGs improved to the same level as those of control group after implant therapy, suggesting that the restoration of masticatory function by implant therapy affects brain function.

3.2. The Influence of Implant Treatment on Salivary Cortisol

A comparison of salivary cortisol levels, a known biomarker of stress, between control group and subjects is shown in **Figure 5**. The cortisol levels of the control group were 0.11 ± 0.02 μg/dl, and that of the subject group was 0.44 ± 0.10 μg/dl. The cortisol level of the subject group was significantly higher compared with the control group ($p < 0.001$).

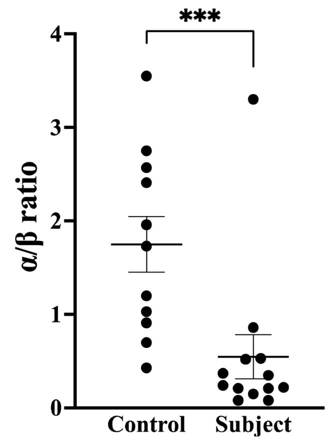

Figure 3. The α/β ratio of control (normal edentates) group and the subject (patient edentulous mal-occlusion) group. Mean ± S.E., control: n = 11, subject: n = 13. ***: $p < 0.001$ vs. control.

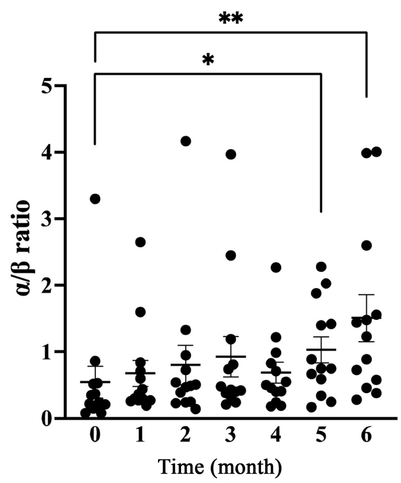

Figure 4. Changes in the α/β ratio due to implant therapy (Mean ± S.E., n = 13). *: $p < 0.05$, **: $p < 0.01$ vs. 0.

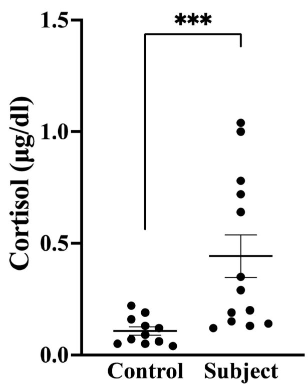

Figure 5. Salivary cortisol level of control (normal edentates) group and the subject (patient edentulous malocclusion) group. Mean ± S.E., control: n = 11, subject: n = 13. ***: $p < 0.001$ vs. control.

The change in cortisol levels after implant therapy is shown in **Figure 6**. The cortisol level in the subject group decreased from the first month after implant therapy and significantly decreased after 3 or 4 months (0 vs. 3 months: $p < 0.05$, 0 vs. 4 months: $p < 0.01$).

These results suggest that tooth loss and malocclusion is a stressful state, and that restoration of masticatory function by implant therapy alleviates stress.

4. Discussion

The influence of mastication on brain function has attracted attention. It has been suggested that improvement of masticatory function may have not only physical but also mental QOL effects, but there are few objective data to explain these effects. It is thought that improving masticatory function in dental treatment has a great potential to influence not only the improvement of eating function but also the improvement of mental activity.

In the present study, we examined the effects of implant therapy on EEG and stress.

EEG is one of the oldest technologies to measure neuronal activity of the human brain. With the analysis of the α/β ratio, it is possible to observe the evolution of stress level over time. The declined value of α/β ratio after the subjects exposed to stressful condition indicates β activity increased due to the variation in response to stress [7]. In the present study, there was a significant decrease in the α/β ratio and an increase in β waves in the subject compared with the control group (**Figure 1** and **Figure 3**).

Increase in cortisol acts as chronic stressor. Chronic social stress is known to exert its impact on the body through the neuroendocrine system, autonomic nervous system, chronic inflammation, and oxidant stress [14]. Stimulation by stress is thought to be transmitted to the hypothalamic area through the cortex and the limbic system, and promotes the production of corticotrophin releasing hormone (CRH) in the paraventricular nucleus of hypothalamus; as a result, adrenocorticotropic hormone (ACTH) is released and promotes a production and release of cortisol from the adrenal cortex [15]. This hypothalamic-pituitary-adrenal (HPA) axis has been implicated for years as a pathological mechanism of mood disorder. In the present study, the salivary cortisol level of the subject group was significantly higher compared with the control group (**Figure 5**).

These results were suggested that tooth loss and malocclusion act as chronic stress due to decreased α/β ratio and increased cortisol.

The goal of implant therapy is not only to restore the form of lost teeth, but also to improve oral functions, including occlusion and mastication, and to maintain physical and mental health throughout life. Through various studies, it is being clarified that occlusion and mastication are closely associated with mental and physical health promotion and maintenance [16]. It has been reported that restoration of masticatory function through implant therapy activates the brain [17] [18]. In the present study, patients with a diagnosis of complete

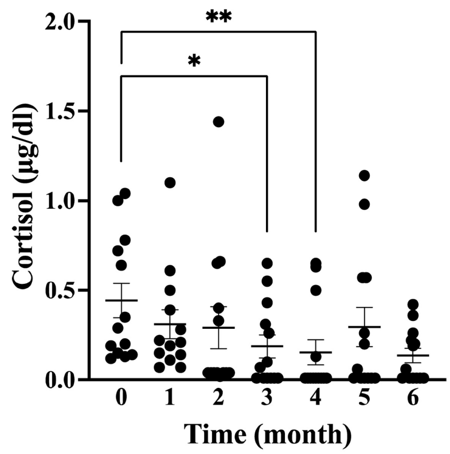

Figure 6. Changes in salivary cortisol lever due to implant therapy. Mean ± S.E., n = 13. *: $p < 0.05$, **: $p < 0.01$ vs. 0.

loss of occlusal contact and no centric occlusion were used to study how the effect of occlusal reconstruction with the application of immediate loading implants affects physical and mental. α/β ratio of the subject group increased from the first month after implant therapy and increased significantly after 5 and 6 months (**Figure 4**). The cortisol level in the subject group decreased from the first month after implant therapy and significantly decreased after 3 or 4 months (**Figure 6**). There are many unknowns regarding how physical and mental activities are improved by restoration of masticatory function. The present study, these results suggest that implant therapy restored masticatory function and relieved stress. This is thought to be due to the smooth control of the neural mechanism by increasing sensory information from the masticatory muscles as masticatory movements become more active due to the restoration of masticatory function, and the muscular mechanism related to chewing and swallowing is improved. The relationship between mastication disorders and tooth loss and overall health is attracting attention. It has been suggested that psychological and social stress not only destabilizes the psychological and mental aspects, but also affects various functions and tissues of the whole body and local areas. Physical effects are not specifically discussed, as this is a difficult area for intervention in dental treatment. A discussion of the impact of implant therapy on systemic health is a topic for future study.

Recovery of masticatory function elicits health for both the physical and mental, thus, it is important to implement widespread preventive treatment to ensure both these health factors are not lost at the same time and it was suggested that the restoration of chewing function by implant application may contribute to anti-aging medicine such as cognitive function and youthfulness of spiritual appearance. If dental treatment can control cortisol secreted by malocclusion, dental care would be extremely significant. We believe that the recovery of chewing function leads to an extension of healthy life in Japan with a declining birthrate and aging population. The rate of implants in Japan is 2.7% according to a 2016 survey by the Ministry of Health, Labour and Welfare of Japan [19]. Although the sample size of this study was limited, these are interesting data and could provide support for a new approach in immediate loading implant therapy.

5. Conclusion

The present study showed that edentulous malocclusion is a chronic stress condition. Implant therapy was suggested to activate brain function by restoring masticatory function. Furthermore, it was suggested that implant therapy reduced cortisol and alleviated stress.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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