Influence of the Functional Improvement of Complete Dentures on Brain Activity

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Clinical significance
Sensory decreases in the periodontal ligament and the masticatory muscles due to tooth loss affect brain activity. However, the degree of the influence of the functional improvement of dentures resulting from complete denture treatment on brain function and patient quality of life has not been elucidated.

Abstract
Purpose: To elucidate the influence of the improvement of denture function on brain activity in complete denture wearers.
Methods: Eighteen complete denture wearers (5 males and 13 females, 63-87 years, mean: 75.2 years) participated in the study. To evaluate denture function, the occlusal contact area and occlusal force were measured for comparison before and after denture treatment using the Dental Prescale Occluzer (GC Co., Tokyo, Japan). To evaluate brain activity, electroencephalogram data obtained using an electroencephalographic measurement apparatus ESA-pro (Brain Functions Laboratory, Inc., Kanagawa, Japan) were analyzed using DIMENSION (Diagnosis Method of Neural Dysfunction). The duration of the measurement was 3 minutes before and after denture treatment.
Results: The occlusal contact area significantly increased after denture treatment in all 18 subjects (p < 0.05). The occlusal force significantly increased in 17 patients (p < 0.05). Activation of brain activity was noted in 14 of the 18 patients (p < 0.05). Measurement before denture treatment showed that 12 patients were in the sub-normal/impaired region and 6 were in the normal region. After denture treatment, brain activity was significantly activated in all 12 patients who were in the impaired/sub-normal region before treatment.
Conclusion: An improvement in denture function was observed after denture treatment in complete denture wearers, and brain activity was enhanced by the functional improvement in the complete dentures. Not only denture function improvement but also brain functional activation was achieved by denture treatment in elderly complete denture wearers who were at risk of brain activity deterioration.

Key words: Diagnosis Method of Neuronal Dysfunction (DIMENSION), electroencephalogram (EEG), complete denture, denture function, brain activity

Introduction
The population of Japanese over 65 years of age was 25,760,000 in 2005; however, it will be 35,900,000 in 2020 due to a rapidly aging society. When the number of remaining teeth is compared among age groups, although the number of lost teeth is decreasing, over half of the people in their eighties are edentulous.

As a result of a joint epidemiological investigation, the World Health Organization (WHO) and the National Institute on Aging (NIA) reported that tooth loss was a risk factor for Alzheimer’s disease. Similar results have been reported by Japanese researchers. Although the relationship between tooth loss, dementia, quality of life (QOL), and health has been investigated, the evidence is incomplete. In Japan, the program for the promotion of national health in the 21st century (Health Japan 21) has set dental health improvement and tooth loss prevention as the targets to prevent dementia and becoming bedridden and to achieve a healthy longevity. However, this goal was based on the concept that tooth loss prevention is basic for successful food mastication as well as achieving a high degree of QOL e.g., by the enjoyment of eating and conversation.

It has been reported that the trigeminal nerve innervates the periodontal ligament and masticatory muscle and, when the trigeminal nerve sensory information is attenuated due to multiple tooth loss, higher brain activity, such as learning...
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and memory, is inhibited.\textsuperscript{6,8}

Decreases in complete denture function occur as a result of a decrease in the occlusal height or a change in the mandibular position. Occlusal height and mandibular position are directly related to decreases in masticatory muscle function, and the destruction of the $\alpha$-$\gamma$ coupling mechanism may be related to senile dementia.\textsuperscript{9} In current prosthetic clinical studies, although the methods to evaluate denture function have been sufficiently reported, the degree of the influence of the functional improvement of complete dentures via denture treatment on brain activity and patient QOL has not been elucidated.

As a physiological index to evaluate dental treatment effects, the usefulness of encephalic waves has been proposed.\textsuperscript{10} When neuronal function in the cerebral cortex is absent due to Alzheimer-type dementia, the electrical potential distribution is distorted. Therefore, Hara et al.\textsuperscript{11} established DIMENSION (Diagnosis Method of Neuronal Dysfunction), which quantitatively estimates synaptic neuronal function in the brain using $\alpha$ waves. They reported that DIMENSION could distinguish between Alzheimer-type dementia patients and healthy individuals and that there were high correlations between DIMENSION and the brain blood flow measurement results obtained by Single Photon Emission Computed Tomography (SPECT), which is used for the diagnosis of dementia, and the results of a patient interview (Mini Mental State Examination).\textsuperscript{12} It was previously impossible to measure brain activity in individuals unless dementia was suspected, since the techniques used were invasive and require the use of radiation. However, by the use of DIMENSION, it became possible to investigate the relationship between the effect of complete denture treatment and brain activity.

The objective of this study was to determine whether the use of complete dentures influences brain activity and to recommend denture treatment for edentulous patients, as determined by electroencephalogram (EEG) before and after complete denture treatment.

Materials and Methods

1. Subjects and measurement conditions

The subjects were 18 complete denture wearers who contacted the Tsurumi University Dental Hospital with a chief complaint of complete denture dysfunction. Informed consent was obtained from each individual according to the method approved by the Ethics Committee of the Tsurumi University School of Dental Medicine (approval number 305: accepted on August 31, 2005). The subjects had no history of brain disease, such as cerebral infarction, and had not been diagnosed with dementia, such as Alzheimer’s disease. The subjects included 5 males and 13 females aged 63-87 years (mean age: 75.2 years) (Table 1). The alveolar ridge condition was evaluated following the method that was reported by Ohnuki et al.\textsuperscript{13} Before and after denture treatment, such as adjustment (occlusal adjustment and relief) in 11 subjects, tissue conditioning in 4 subjects, and relining in 3 subjects, complete denture function (Table 1) and the degree of brain functional activation were measured (Fig. 1). These denture treatments were performed in response to complaints of pain, reduction of denture retention, and discomfort. The chief complaint of all subjects was relieved through denture treatment (Table 1). All denture treatments were performed

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by three dentists with clinical experience in excess of 12 years in the Department of Removable Prosthodontics, Tsurumi University Dental Hospital.

2. Evaluation of complete denture function
Evaluation of denture function was performed in the semi-anechoic room (Fig. 2). As an objective evaluation of denture function, the occlusal force and occlusal contact area were measured before and after denture treatment using the Dental Prescale Occluser® (FPD-705, GC Co., Tokyo, Japan) and Dental Prescale® 50H without wax (GC Co., Tokyo, Japan). Regarding the head position of the subjects, their Frankfort plane was set parallel to the floor. Each clinician asked the subjects to open their mouths to evaluate their ability to masticate and confirm their degree of occlusion. Thereafter, the subjects clenched their teeth for three seconds on a centric occlusion to measure the occlusal force. Statistical analysis was performed using the Wilcoxon rank sum test ($p < 0.05$).

3. Evaluation of the degree of brain function activation
Electroencephalographic measurement was performed in the semi-anechoic room (Fig. 2). EEGs were taken before and after denture treatment using an ESA-pro developed by Brain Functions Laboratory, Inc. (Kawasaki, Japan) (Fig. 3). Paste-less electrodes were placed inside a helmet worn by each subject. Analysis was performed under the following conditions: analysis unit, 5.12 seconds; sampling frequency, 200 Hz; digital filter, HPF (1.6 Hz, 12 dB/oct), LPF (60 Hz, 12 dB/oct), and HUM (50 Hz, 2D). The electrodes were arranged inside the helmet according to the international 10–20 system, and a 21-channel measurement was performed on the skin of the head (Fig. 4). The reference electrode was placed in the right ear lobe. After confirming that the EEG detected from all the electrodes was stable, it was measured for 3 seconds. Data obtained were transferred to the brain wave analysis center at the Brain Functions Labora-
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In飘，Inc.，for DIMENSION analysis. DIMENSION was used to measure α waves, and the ideal condition with a smooth electrical potential distribution was defined as $D_\alpha = 1$. The value of $D_\alpha$ decreases with a reduction in brain activity. In this study, the value of $D_\alpha$ in the normal region was set to $D_\alpha > 0.952$, in which an Alzheimer-type dementia accounted for 10% and a healthy condition accounted for 90%. When $D_\alpha < 0.952$, the subject was sub-normal / impaired.

Statistical analysis was performed using the Wilcoxon rank sum test ($p < 0.05$).

**Results**

1. **Evaluation of complete denture function**
   Changes in the occlusal contact area before and after denture treatment are shown in Fig. 5. Comparisons before and after denture treatment indicated that the occlusal contact area significantly increased in all subjects ($p < 0.05$). Changes in the occlusal force on centric occlusion before and after denture treatment are shown in Fig. 6. The occlusal force increased in all but one subject who received denture treatment ($p < 0.05$).

2. **Degree of brain function activation**
   Changes in the degree of brain function activation before and after denture treatment are shown in Fig. 7.
   After denture treatment, activation of brain function was noted in 14 of 18 subjects ($p < 0.05$). All 12 subjects who were classified as sub-normal / impaired before denture treatment showed significant brain function activation after treatment ($p < 0.05$). In 6 of the 12 subjects, there was a shift from the sub-normal / impaired to normal. Brain function activation was more clearly noted in the subjects whose brain function was sub-normal / impaired before treatment.

   In addition, although the brain function in only 6 subjects was in the normal region before treatment, brain function in 11 subjects was in the normal region after treatment. After denture treatment, six subjects shifted from the sub-normal / impaired to the normal region. However, one subject who received a denture adjustment shifted from the normal region to the sub-normal / impaired.

**Discussion**

After denture treatment, the occlusal contact area increased in all subjects, and occlusal force increased in 17 of the 18 subjects. It is speculated that the marked improvement in denture function achieved was due to the disappearance of pain after denture treatment. However, occlusal force slightly decreased in one subject after denture treatment. Regarding the subject in this study who showed a decrease in occlusal force after denture adjustment, although the subject complained of denture instability (denture floating), improvement was observed after denture adjustment. Moreover, at the following visit in three weeks, the subject had a good denture condition; therefore, it was assumed that an appropriate adjustment had been performed.

Compared with the techniques of SPECT and PET (Positron Emission Tomography), which
Comparisons of brain function before and after denture treatment in complete denture wearers. In cases showing an ideal condition with a smooth electrical potential distribution, the value for the degree of activation of EEG function was set to 1. Decreases in the value suggested the deterioration of EEG function.

Fig. 7 Comparisons of brain function before and after denture treatment in complete denture wearers. In cases showing an ideal condition with a smooth electrical potential distribution, the value for the degree of activation of EEG function was set to 1. Decreases in the value suggested the deterioration of EEG function.

are used for the investigation of dementia, such as Alzheimer’s disease, DIMENSION is non-invasive and does not involve radiation exposure. In addition, since DIMENSION directly measures and evaluates neuronal cortical activity, it is highly sensitive, and its use requires no special technique. As a physiological index to evaluate the effects of dental treatment, the EEG has been found to be useful. Regarding the effects of craft therapy and robot therapy (in which robots are used as a substitute for animals in animal therapy) for dementia patients and healthy individuals, Kimura et al.\(^{15}\) reported results using DIMENSION. They reported that, although activation of brain function after therapy was observed in healthy individuals who were sub-normal / impaired prior to therapy, no activation was detected in healthy persons who were in the normal region. In this study, we observed brain function activation in all subjects in the sub-normal / impaired and normal regions after denture treatment. Mastication is performed while sensing both the taste and texture of food, and its specific control system\(^{16}\) is directly innervated by the trigeminal nerve. Masticatory stimulation is transmitted from the masticatory muscles to the hypothalamus via the trigeminal nerve. Since the hypothalamus controls learning, memory, emotion, and sleeping, the influence of masticatory improvement by denture treatment on brain function is large. Therefore, it is suggested that the effects of denture treatment to improve mastication and occlusion are markedly involved in not only denture functional improvement but also brain function.

The subjects in this study could visit a dental hospital by themselves and were not suspected of having dementia, such as Alzheimer’s disease. They showed no signs of deterioration in brain function at the time of the interview. However, before treatment, 6 of the 18 subjects were in the normal region, and the remaining 12 were sub-normal / impaired. These results support reports that edentulous persons exhibit dementia-related factors, such as advanced age, unbalanced meals, and limited physical activity, intellectual stimulation, and social interaction.\(^{17,18}\)

All 12 subjects who were sub-normal / impaired before denture treatment showed brain function activation after denture treatment. Furthermore, 6 of the 12 subjects who were sub-normal / impaired before denture treatment shifted from the sub-normal / impaired to the normal region. Therefore, it was shown that denture treatment in patients with decreased brain function was strongly related to brain function activation. For edentulous patients with risk factors for dementia, denture treatment not only improved denture function but also enhanced brain function, increasing their QOL.

**Conclusion**

This study showed that complete denture treatment for patients who had been dissatisfied with their denture function resulted in improvements in denture function and an enhancement in their EEG function. Denture treatment for complete denture wearers of advanced age with a risk of EEG functional deterioration improved denture function and resulted in the activation of cerebral function. These results suggest that complete denture treatment is associated with elevated brain activity.

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