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Review article

Influence of denture treatment on brain function activity

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Diagnosis method of neural dysfunction (DIMENSION);
Dental Prescale®

Summary The objective of the present study was to clarify whether the treatment of complete dentures and the use of partial dentures influence brain function activity as determined by electroencephalograms (EEG). Eighteen complete and twenty partial denture wearers participated in the study. In order to evaluate denture function, the occlusal contact area and occlusal force were measured using a Dental Prescale Occluzer®. To evaluate brain function activity, EEG data obtained employing ESA-pro were analyzed using DIMENSION.

The occlusal contact area significantly increased after complete denture treatment in all 18 subjects and significantly increased with wearing partial dentures in all 20 subjects. The occlusal force of complete and partial denture subjects significantly increased. An increase in brain function activity was noted in 14 of the 18 complete denture wearers, and after gum chewing with dentures in the 20 partial denture wearers.

In this study, it was revealed that brain function activity was enhanced by the improvement of complete dentures, and by wearing partial dentures. Not only denture function improvement but also brain functional activation was achieved in elderly denture wearers at risk of brain activity deterioration.

Contents

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1. Introduction

The population of Japanese over 65 years of age was 28,980,000 in 2009; however, it is estimated that it will rise to 35,900,000 by 2020 due to a rapidly aging society [1]. 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 [2]. Similar results have been reported by many researchers [3—10]. Although the relationship between tooth loss, dementia, quality of life (QOL), and health has been emphasized, the evidence is insufficient.

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 targets to prevent dementia and a bed-ridden state, and to achieve healthy longevity. It has been reported that the trigeminal nerve innervates the periodontal ligament and masticatory muscle, and that when trigeminal nerve sensory information is attenuated due to multiple tooth loss, higher brain activities, such as learning and memory, are inhibited [11—13]. The deterioration of the occlusal force and the shift of mandibular position are directly related to decreases in the masticatory muscle function, and destruction of the $\alpha-\gamma$ coupling mechanism may be related to senile dementia [14]. The purpose of this article was not only the diagnosis of dementia and Alzheimer's disease but also the evaluation of the brain function. Therefore, it has been necessary to assess the influence of tooth loss and denture use on brain function activity. Examinations of brain function activity are roughly classified into an electrophysiological method and a method depending on blood flow movement. The former includes electroencephalogram (EEG), magnetoencephalography (MEG), and transcranial magnetic stimulation (TMS). The latter includes magnetic resonance imaging (MRI), positron emission tomography (PET), single photon emission computed tomography (SPECT), and near infrared spectroscopy (NIRS).

As a physiological index for evaluating the effects of dental treatment, the usefulness of encephalic waves has been suggested [15]. When neuronal function in the cerebral cortex is absent due to Alzheimer-type dementia, the electrical potential distribution is distorted. Therefore, Hara et al. [16] established the diagnosis method of neuronal dysfunction (DIMENSION), which quantitatively estimates synaptic neuronal function in the brain using electroencephalographs (EEG). EEG can be used to instantly record brain waves through the head skin using electrodes. Musha et al. [17] reported that DIMENSION could distinguish between Alzheimer-type dementia patients and healthy individuals, and that there were strong correlations between DIMENSION and brain blood flow measurement results obtained using single photon emission computed tomography (SPECT), which is applied for the diagnosis of dementia, and the results of patient interviews (Mini-Mental State Examination).

Jelic and Kowalski [18] reported that evidence for the diagnostic utility of resting EEG in dementia and mild cognitive impairment is still insufficient to establish this method for the initial evaluation of subjects with cognitive impairment in routine clinical practice. Indeed, MRI shows high-level diagnostic accuracy in Alzheimer's disease, dementia, and cognitive impairment, and is frequently used for a differential diagnosis in these diseases [19—22]. However, several reports described abnormal brain waves in Alzheimer's disease patients using EEG analysis [23—27]. The purpose of this study was not to diagnose dementia, but evaluate brain function activity using EEG. In this research, it was necessary to measure in a short time brain function of denture wearers who sought denture treatment at the prosthodontic clinic. Also, they had no suspected brain disease. MRI can only be used in facilities, which have the required equipment. MRI measurement is necessary 10 or 20 times compared with EEG measurement. Furthermore, to estimate the brain function activity before and after denture treatment or before and after gum chewing, we need to catch dynamic changes in brain function activity. EEG can perform dynamic measurement, but MRI cannot. The advantages of EEG are as follows: (1) EEG measurements are possible at prosthodontic clinics which have the device. (2) EEG measurements can be performed in a short time, so changes in the brain activity before and after denture treatment or before and after gum chewing can be measured easily. (3) Dynamic EEG can be measured. (4) EEG can be measured without damaging the living body such as through radiation or a strong magnetic field. (5) The EEG system is relatively inexpensive. Considering the above merits, brain function activities are evaluated by DIMENSION analysis using EEG data [28,29]. It was previously impossible to measure brain activity in individuals unless dementia was suspected, since the techniques were invasive and required the use of radiation. However, with the use of DIMENSION analysis, it was become possible to investigate the relationship between the effects of denture treatment and brain function activity.

2. EEG measurement

Initially, Morokuma applied DIMENSION to the dental field and reported on the brain function activity of complete denture wearers, and then Shibuya reported the brain function activity of partial denture wearers employing the same method.

Electroencephalographic (EEG) measurement was performed in a semi-anechoic room (Fig. 1). EEG were recorded using an ESA-pro developed by Brain Functions Laboratory, Inc. (Kawasaki, Japan) (Fig. 2). Pasteless electrodes were placed inside a helmet worn by each subject. Analysis was performed under the following conditions: 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 21-channel measurement was performed on the skin of the head (Fig. 3). Reference electrodes were placed on the left and right earlobes. The subjects were seated in a resting position with their eyes closed. After confirming that the EEG detected from all the electrodes was stable, 3-min measurements were made. The data obtained were transferred to the brain wave analysis center at Brain Functions Laboratory, Inc., for DIMENSION analysis. DIMENSION was used to measure α waves, and the optimal condition with a smooth electrical potential distribution was defined as $D_\alpha = 1$. D_α decreases with a reduction in brain activity. In this study, the value of D_α in the normal region was set to $D_\alpha > 0.952$, in which Alzheimer-type dementia accounted for 10% and a healthy condition accounted for 90%. When the value of D_α was set to $D_\alpha < 0.952$, the subject was classified as sub-normal/impaired [17].

Figure 1 Electroencephalographic (EEG) measurement in a semi-anechoic room. Measurements were performed while the subjects were seated in a resting position with their eyes closed.

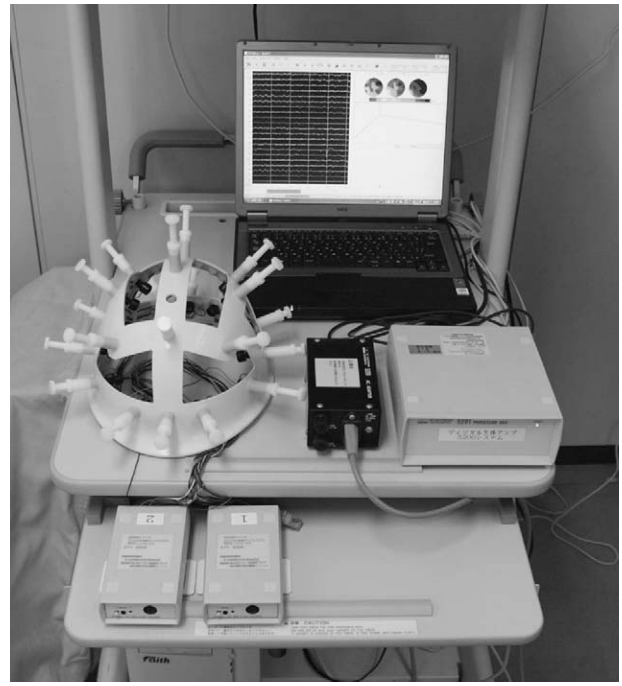

Figure 2 EEG measurement apparatus ESA-pro (Brain Functions Laboratory, Inc., Kawasaki). From the far left: host computer, helmet for pasteless electrodes. Processor box, digital bio-amplifier, and head box.

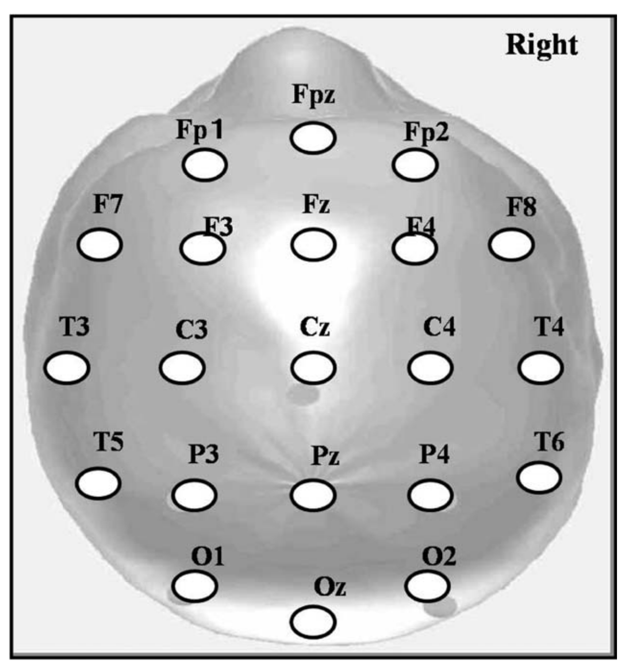

Figure 3 Arrangement of pasteless electrodes in a helmet. According to the international 10—20 system, 21-channel measurement was performed. The reference electrode was placed on the left and right earlobes.

Table 1 Condition of the subjects.

Subject	Chief complaint	Treatment	Ridge condition
A	Pain	Adjustment	Poor
B	Pain, disharmony	Adjustment	Poor
C	Pain	Adjustment	Good
D	Pain	Adjustment	Good
E	Pain	Adjustment	Poor
F	Pain	Adjustment	Good
G	Poor retention	Adjustment	Poor
H	Pain	Adjustment	Good
I	Pain, poor retention	Adjustment	Good
J	Pain, poor retention	Adjustment	Good
K	Pain	Adjustment	Good
L	Pain, disharmony, poor retention	Tissue conditioning	Good
M	Pain	Tissue conditioning	Good
N	Pain, poor retention	Tissue conditioning	Good
O	Pain	Tissue conditioning	Poor
P	Pain	Relining	Good
Q	Pain	Relining	Poor
R	Poor retention	Relining	Poor

3. Influence of the functional improvement of complete dentures on brain activity

3.1. Subjects and measurement conditions

The subjects were 18 complete denture wearers who contacted 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 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-related illnesses such as Alzheimer's disease. They comprised 5 males and 13 females, aged 63—87 years (mean: 75.2 years). The conditions of the subjects are shown in Table 1. The alveolar ridge condition was evaluated using the method described by Ohnuki et al. [30].

Complete denture treatments, such as denture adjustment (occlusal adjustment and relief) in 11 subjects, tissue conditioning in 4 subjects, and relining in 3 subjects, were performed in response to complaints of pain, reduction of denture retention, and disharmony. The chief complaint in all subjects was resolved through denture treatment (Table 1). All denture treatments were performed by three dentists with clinical experience in excess of 12 years in the Department of Removable Prosthodontics, Tsurumi University Dental Hospital.

3.2. Evaluation of the complete denture function

As an objective evaluation of the denture function, the occlusal force and occlusal contact area were measured before and after denture treatment using a Dental Prescale Occluzer® (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 dentist asked the subjects to open their mouths to evaluate their ability to masticate and confirm their degree of occlusion. Thereafter, the subjects clenched their artificial teeth for 3 s in centric occlusion in order to measure the occlusal force [31]. Statistical analysis was performed using the Wilcoxon rank sum test ($p < 0.05$).

Changes in the occlusal contact area before and after denture treatment are shown in Fig. 4. A comparison of before and after denture treatment indicated that the occlusal contact area significantly increased in all subjects ($p < 0.05$). Changes in the occlusal force in centric occlusion before and after denture treatment are shown in Fig. 4. The occlusal force increased in all but one subject who received denture treatment ($p < 0.05$).

It was speculated that the marked improvement in denture function achieved was due to the disappearance of pain after denture treatment. Therefore, it was assumed that appropriate adjustment had been performed.

3.3. Evaluation of the degree of brain function activation

The degree of brain function activation was measured according to the flowchart employing an EEG measurement system (Fig. 5). A box-and-whisker diagram comparing changes in D_α before and after denture treatment is shown in Fig. 6. Medial D_α value increased from 0.945 before treatment to 0.956 after treatment. A statistically significant increase in brain function activity ($p < 0.05$) was observed, with a total of 14 subjects exhibiting increased D_α after denture treatment. Compared with the techniques of SPECT and Positron Emission Tomography (PET), which are used for the examination of dementia-related illnesses such as Alzheimer's disease, DIMENSION is noninvasive 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 techniques. As a

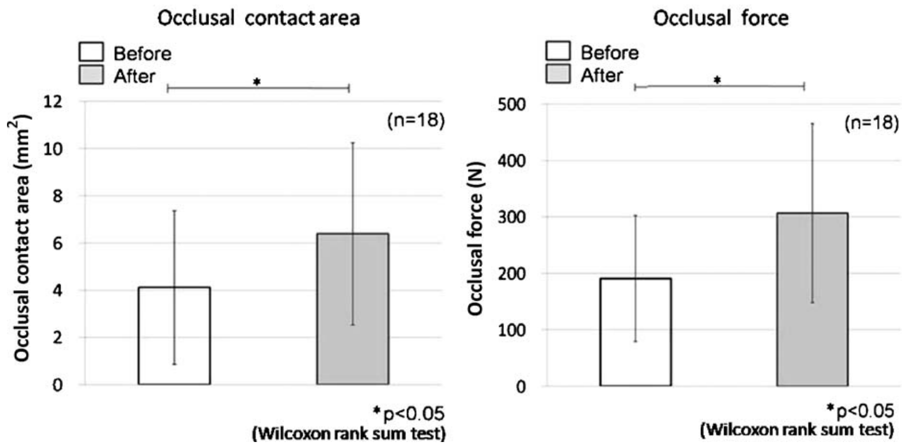

Figure 4 Comparisons of the occlusal contact area and the occlusal force before and after complete denture treatment. The occlusal contact area significantly increased after treatment in all subjects ($p < 0.05$). The occlusal force significantly increased after treatment in all but one subject ($p < 0.05$).

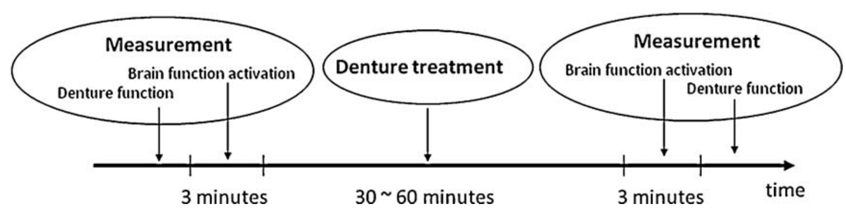

Figure 5 Flow chart of an EEG measurement system.

physiological index for evaluating the effects of dental treatment, EEG has been found to be useful [32]. Regarding the effects of craft and robot therapy for dementia patients and healthy individuals, Kimura et al. [17,33] reported results using DIMENSION. They observed that although the brain function was activated after therapy in healthy individuals who were in the sub-normal/impaired region prior to therapy, no activation was detected in healthy persons who were in the normal region [34]. In the present study, we observed brain function activation 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 is directly innervated by the trigeminal nerve [35]. Masticatory stimulation is transmitted from the masticatory muscles to the hypothalamus via the trigeminal nerve. Since the hypothalamus controls learning, memory, emotion, and sleep, the influence of masticatory improvement by denture treatment on the brain function may be marked [36—38]. The subjects in this study could visit a dental hospital by themselves and were not suspected of having dementia-related illnesses such as Alzheimer's disease. They exhibited no signs of deterioration of the brain function at the time of the interview. However, before treatment, six of the 18 subjects were in the normal region, and the remaining 12 were in the sub-normal/impaired region. These results are consistent with reports that edentulous persons exhibit dementia-related factors, such as an advanced age, unbalanced meals, and limited physical activity, intellectual stimulation, and social interaction [39,40].

All 12 subjects who were in the sub-normal/impaired category before denture treatment exhibited brain function activation after treatment ($p < 0.05$). Furthermore, six of the 12 subjects who were in the sub-normal/impaired region before denture treatment shifted to the normal region after treatment. Therefore, it was revealed that denture treatment in patients with a decreased brain function was strongly related to brain function activation. For edentulous patients with risk factors for dementia, denture treatment not only improved their denture function but also enhanced the brain function, increasing their QOL [41,42]. It has not yet been

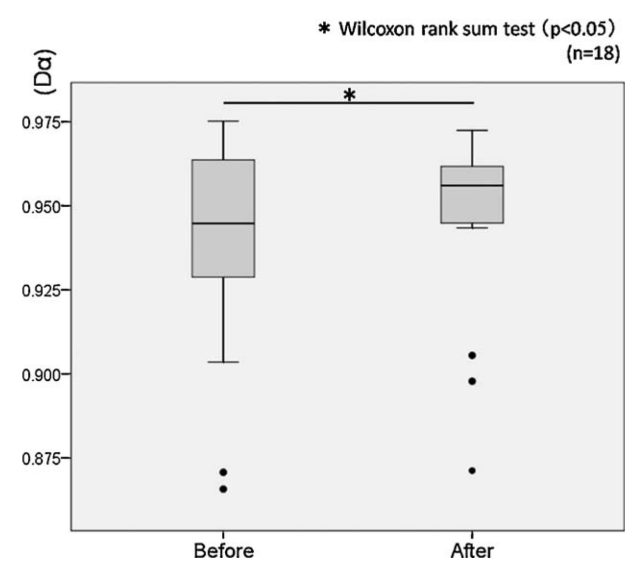

Figure 6 Changes in brain function activity before and after denture treatment. A box-and-whisker diagram comparing changes in $D\alpha$ before and after denture treatment.

sufficiently resolved how the brain controls the masticatory, swallowing, and respiratory nerves. However, it is thought that the thalamus, cerebral cortex, and basal ganglia are closely involved in mastication, swallowing, and respiration [12,13]. Especially, the hypothalamus regulates learning, memory, emotion, and sleep. It is possible that the hypothalamus is closely linked with the brain function. We treated denture relief, tissue conditioning or relining in complete denture patients who complained of pain, ill-fitting or instability, these complaints were resolved, and, consequently the occlusal force and occlusal contact area were increased. Denture treatment is believed to have led to an

Table 2 Status of the subjects.

Subject	Dental formula	Eichner's Classification	Duration of denture use	Type of artificial teeth
A	7654321 │ 1234567 4321 │ 1234567	B-l	25M	Hard resin
B	7654321 │ 1234567 4321 │ 123456	B-l	48M	Hard resin
C	54321 │ 1234567 4321 │ 1234567	B-l	2M	Hard resin
D	7654321 │ 12345 7654321 │ 1234567	B-l	2M	Resin
E	54321 │ 1234567 7654321 │ 1234567	B-l	9M	Hard resin
F	54321 │ 1234 7654321 │ 1234567	B-2	Unknown	Hard resin
G	7 5 321 │ 1 76543 │ 12	B-2	18M	Hard resin
H	4321 │ 12 7 7654321 │ 1234567	B-2	2M	Hard resin
I	7654321 │ 1234567 321 │ 1234 7	B-2	3M	Hard resin
J	54 │ 4567 321 │ 12345	B-2	12M	Hard resin
K	7654321 │ 123 7 4321 │ 1234567	B-3	Unknown	Hard resin
L	54321 │ 123 5 7 7 4321 │ 1234	B-3	2M	Resin
M	765 321 │ 1234 321 │ 1234	B-3	75M	Hard resin
N	65432 │ 1234567 321 │ 1234	B-3	2M	Hard resin
O	321 │ 1234 54321 │ 1234567	B-3	36M	Hard resin
P	1 │ 1234567 32 │ 123	B-4	34M	Hard resin
Q	321 │ 12 43 │ 1234	B-4	36M	Hard resin
R	54321 │ 123 321 │ 12345	B-4	12M	Hard resin
S	76 4321 │ 123 321 │ 12345 7	B-4	65M	Hard resin
T	7654321 │ 1234567 321 │ 123	B-4	15M	Hard resin

increase in the occlusal contact area and the occlusal force, as well as enhanced the retention and stability of dentures [28].

Reduction of the occlusal force due to the use of an inappropriate denture not only attenuates motion information from the masticatory muscles but also disrupts the α neuron—γ neuron coupling mechanism that governs masticatory movements, which can cause the deterioration of brain function activity [11].

4. Influence of wearing partial dentures on brain function activity

4.1. Subjects and measurement conditions

The subjects were 20 partial denture wearers who showed occlusal stop based on Eichner's Classification. The subjects included 5 males and 15 females aged 54—82 years (mean age: 67.6 years) (Table 2). All subjects had periodically received maintenance with prosthodontists in excess of 20 years, and their denture conditions were favorable. All measurements were performed by one trained dentist. The subjects had no history of brain disease and had not been diagnosed with Alzheimer's disease. 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 occlusal contact area and occlusal force were measured with and without dentures for functional assessment. For the subjective assessment of dentures, the Visual Analog Scale (VAS) was used to evaluate comfort during chewing and the degree of satisfaction. After gum chewing with and without dentures, electroencephalograms (EEG) were taken for 3 min (Fig. 7). EEG were analyzed employing the diagnosis method of neuronal dysfunction (DIMENSION) for brain function assessment.

4.2. Evaluation of the occlusal condition

For objective evaluation of the denture function, the occlusal contact area and occlusal force were measured between with and without dentures using a Dental Prescale Occluzer® (FPD-705; GC Co., Tokyo, Japan) and Dental Prescale® (50H without wax, GC Co., Tokyo, Japan). The subjects clenched their teeth for 3 s in centric occlusion in order to measure the occlusal contact area and occlusal force. Statistical analysis was performed using the Wilcoxon rank sum test ($p < 0.05$).

Changes in the average occlusal contact area and occlusal force between with and without dentures are shown in Fig. 8. The average occlusal contact area and occlusal force significantly increased with compared to without dentures in all subjects ($p < 0.05$).

It has been reported that the occlusal contact area and occlusal force are closely correlated with the masticatory efficiency [43—46]. These results suggest that subjects could safely masticate due to an increase in the occlusal contact area and an adequately distributed occlusal force.

4.3. Evaluation of removable partial dentures using the VAS method

After whole measurements, to evaluate the stress of wearing dentures, Comfort on chewing and the degree of satisfaction were evaluated using the Visual Analog Scale (VAS). The subjects were asked two questions (How is the level of comfort while chewing with or without dentures? What is the degree of satisfaction with or without dentures?). VAS between discomfort (left end (0)) and comfort (right end (100)) on a line 100 mm long was filled out by subjects. The subjective assessments of dentures using VAS are shown in Fig. 9. Comfort during chewing with dentures significantly increased in 17 of the 20 subjects ($p < 0.05$). The degree of satisfaction significantly increased in 13 of the 20 subjects compared to those without dentures ($p < 0.05$). Correlations were noted between comfort on chewing and the degree of satisfaction with dentures ($r = 0.471$). Table 3 shows the results regarding the occlusal condition in groups showing an increase or decrease in comfort while chewing and the degree of satisfaction. Groups with an increase in comfort while chewing showed a large average occlusal force compared to groups showing a decrease. In addition, groups with an increase in the degree of satisfaction showed both a large average occlusal contact area and large average occlusal force compared to those showing a decrease.

Comfort during chewing decreased in 3 of the 20 subjects, and the degree of satisfaction decreased in 7 of the 20,

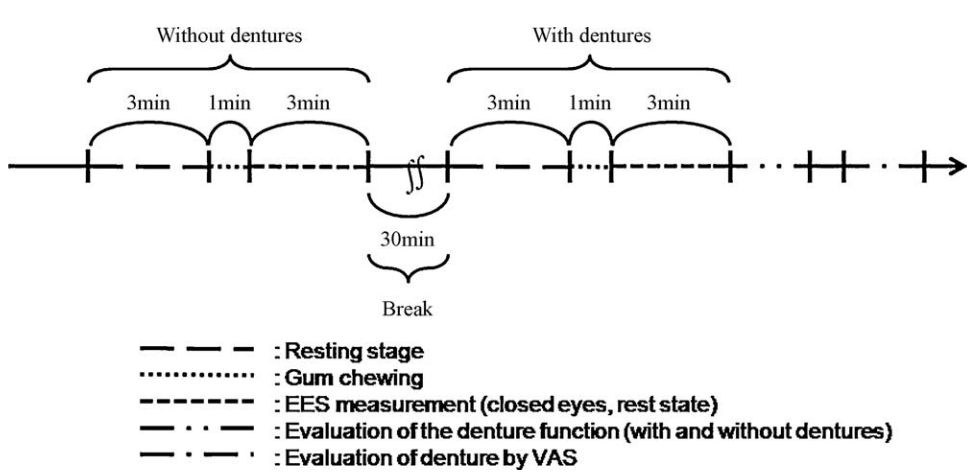

Figure 7 Flowchart of measurement.

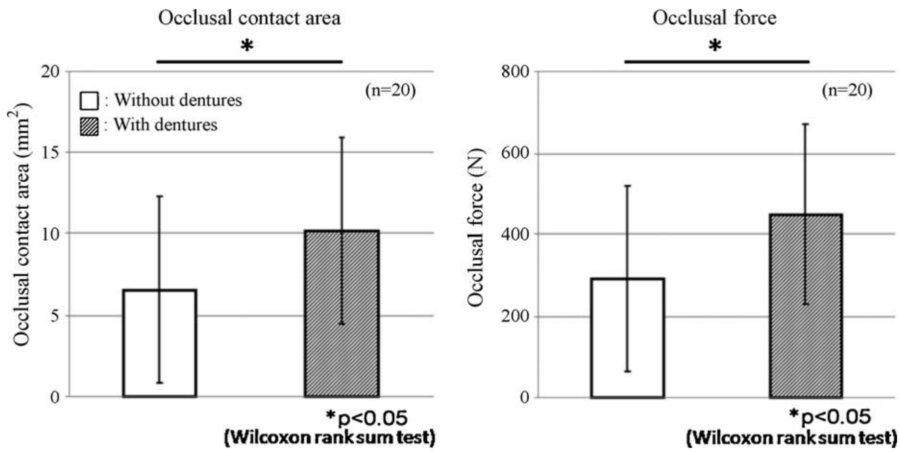

Figure 8 Comparison of the average occlusal contact area and occlusal force between with and without dentures. The occlusal contact area and the occlusal force significantly increased with dentures in all subjects ($p < 0.05$).

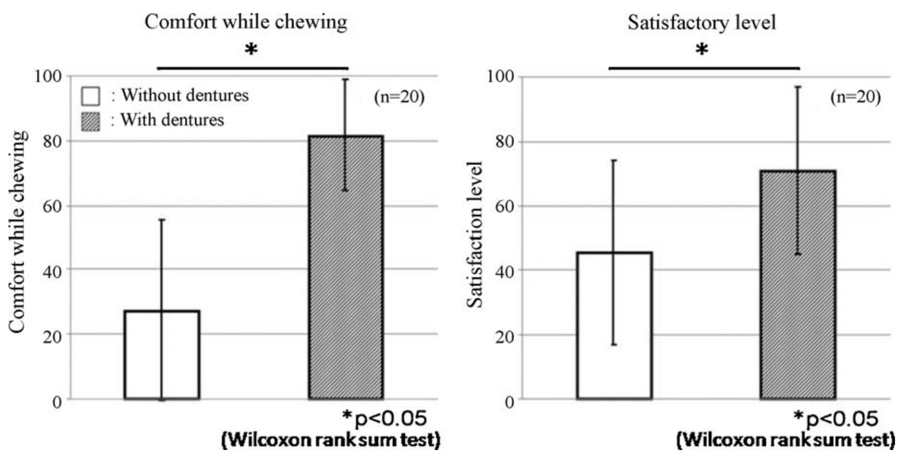

Figure 9 Comparison of chewing comfort and the satisfaction level between with and without dentures using VAS. Comfort during chewing and the degree of satisfaction with dentures significantly increased compared to those without dentures ($p < 0.05$).

whereas improvement of the occlusal condition was recognized in all subjects with dentures. In these results, it was considered that chewing feeling and the degree of satisfaction was added the foreign object and the anticipation to the dentures in the subjects. Kikuchi explained by brain wave measurement that discomfort in subjects with palatal dentures increased due to a change in the oral environment [47]. It was suggested that wearing dentures was not entirely associated with the degree of satisfaction in patients.

4.4. Evaluation of brain function activity

The subjects were seated in a resting position with their closed eyes in a semi-anechoic room. After confirming that

Table 3 Results for the occlusal state in groups showing increases or decreases in comfort during chewing and the degree of satisfaction.

		Occlusal contact area (mm^2) (SD)		Occlusal force (N) (SD)	
		Without dentures	With dentures	Without dentures	With dentures
Comfort while chewing	Increased (n = 17)	6.78 (6.12)	10.36 (612)	295.86 (241.86)	453.84 (235.23)
	Decreased (n = 3)	5.33 (3.07)	9.00 (2.31)	266.73 (161.23)	422.30 (135.51)
		Occlusal contact area (mm^2) (SD)		Occlusal force (N) (SD)	
		Without dentures	With dentures	Without dentures	With dentures
Degree of satisfaction	Increased (n = 13)	5.08 (4.12)	9.00 (4.88)	227.68 (156.13)	392.51 (174.74)
	Decreased (n = 7)	9.31 (7.52)	12.31 (6.81)	409.99 (301.75)	554.23 (270.54)

the EEG detected from all electrodes were stable, EEG were measured for 3 min. The subjects were instructed to chew gum (xylitol, Lotte, Tokyo, Japan) for 1 min without dentures. Right after gum chewing, EEG were measured for 3 min by the dentist. After measurements, the subject had a 30-min rest. Then, the subject chewed gum again with dentures, and EEG were measured for 3 min using the same procedure. A comparison of the degree of brain function activity after gum chewing between with and without dentures is shown in Fig. 10.

The average degree of brain function activity with dentures after gum chewing was 0.929, whereas that without dentures was 0.913. Activation of the brain function with dentures significantly increased compared to that without dentures in 20 subjects ($p < 0.05$).

The 20 subjects were classified based on Eichner's Classification into B-1, B-2, B-3, and B-4 (each $n = 5$).

The brain function activity with dentures significantly increased in B-1 and B-3 ($p < 0.05$) (Fig. 11).

Statistical analysis was performed using the Spearman's rank correlation coefficient.

The correlation between brain function activity and the occlusal contact area is shown in Fig. 12. The regression line was $Y = 0.020X + 98.05$, so a positive correlation ($r = 0.454$) was recognized between the brain function and occlusal contact area. The correlation between the brain function activity and occlusal force is shown in Fig. 13.

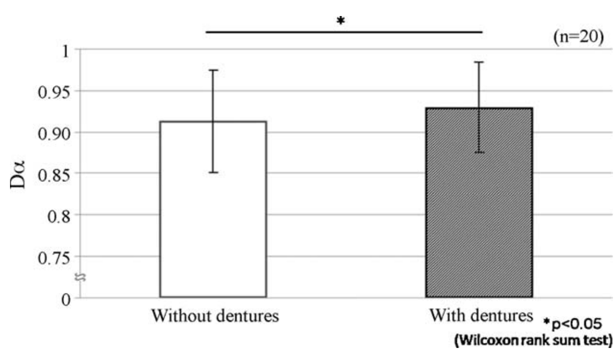

Figure 10 Comparison of brain function activity after gum chewing between with and without dentures. The brain function activity with dentures significantly increased compared to that without dentures in all subjects ($p < 0.05$).

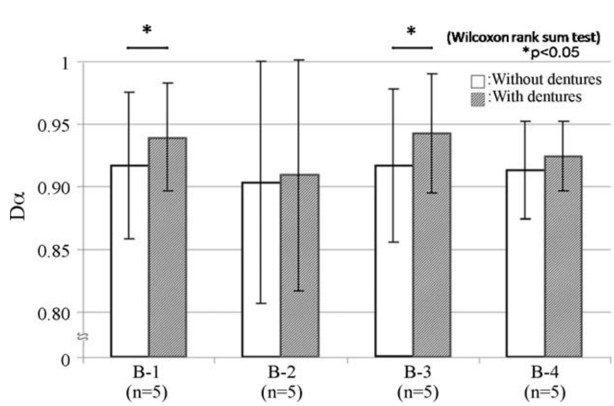

Figure 11 Comparison of brain function activity according to Eichner's Classification.

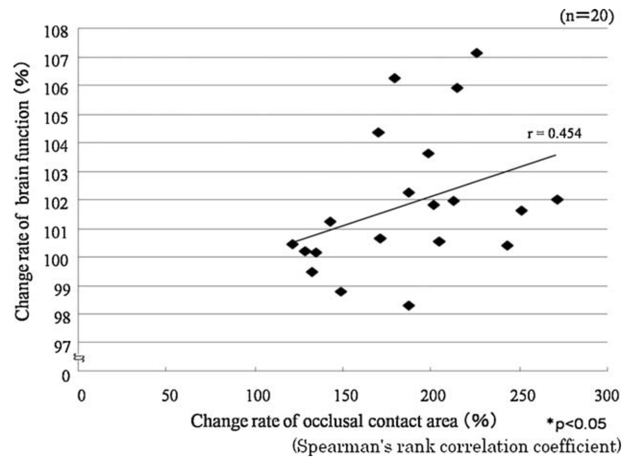

Figure 12 Correlation between brain function activity and occlusal contact area.

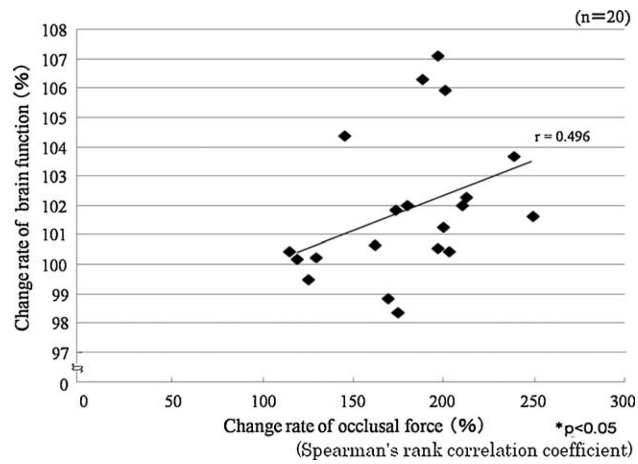

Figure 13 Correlation between brain function activity and occlusal force.

The regression line was $Y = 0.023X + 97.62$, as the occlusal contact force increased the brain function activity rose. A positive correlation ($r = 0.496$) was recognized between the brain function activity and occlusal force. However, no correlation between brain function activity and chewing comfort or the degree of satisfaction was recognized. The correlation between brain function activity and the occlusal contact area according to Eichner's Classification is shown in Fig. 14. A positive correlation coefficient between the brain function activity and occlusal contact area was noted, but no correlation was recognized in each Eichner's Classification. The correlation between the brain function activity and occlusal force according to Eichner's Classification is shown in Fig. 15. A positive correlation coefficient between the brain function activity and occlusal force was shown excluding Eichner's Classification B-3, but no correlation was shown in each Eichner's Classification. A positive correlation coefficient between the brain function activity and comfort during chewing was shown only for B-3, but no correlation was shown in all classification. A positive correlation coefficient between brain function activity and the degree of satisfaction was shown in B-1 and B-2, but no correlation was shown in all classifications. The brain function is activated through

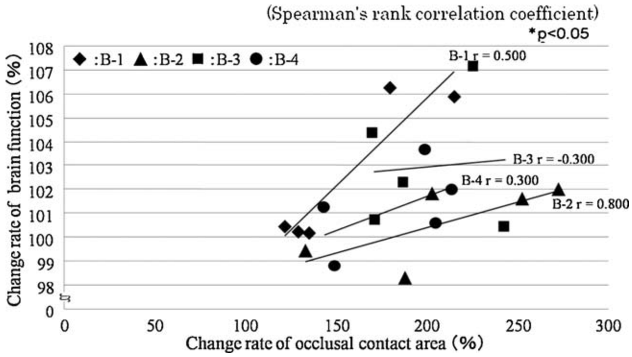

Figure 14 Correlation between brain function activity and occlusal contact area according to Eichner's Classification.

various stimulations. Kodama et al. [48] reported that brain function was activated by music therapy, cooking, and craftwork. In this study, it was possible that the brain function of the subject was activated through conversation and treatment by the doctor. Therefore, in the preliminary examination, we confirmed that the brain function activity was not influenced by conversation and treatment by the doctor, by wearing and removing dentures, by visual stimulation, and by time through measuring brain function activity in a resting state. Furthermore, when the measurement of the brain function activity was performed twice on the same day, the activity could have been influenced by the measurement order. So, brain function activity was evaluated on changing the measurement order for gum chewing with and without dentures. As a result, brain function activity was barely influenced by the measurement order.

In this study, brain function activation in subjects with dentures was significant compared to that in those without dentures after gum chewing ($p < 0.05$). It was suggested that trigeminal nerve sensory information transmitted through the periodontal ligament, masticatory muscles, temporomandibular joint, and residual mucous membrane increased when subjects could chew comfortably with appropriate dentures [49]. Ikebe et al. [50,51] reported that satisfactory dentures enriched the oral function and health of elderly patients. Therefore, the increase in the occlusal contact area and occlusal force appear to be important factors related to brain function activity.

Thus, denture treatment in edentulous and partially edentulous patients dose not only improve the masticatory function, but it also restores the appropriate mechanism for conveying sensory information to the trigeminal nerve and eventually activate brain function activity. It is necessary for the brain function mechanism to be further analyzed through diversified research.

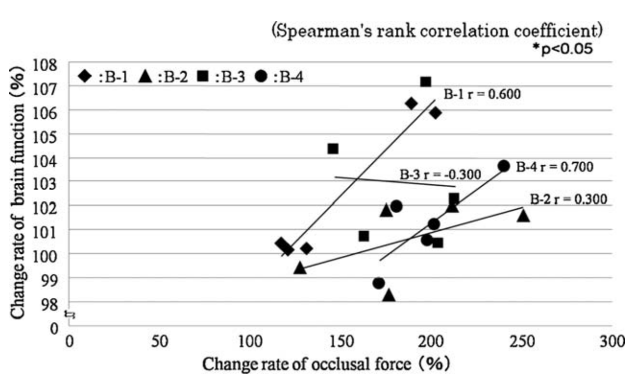

Figure 15 Correlation between brain function activity and occlusal force according to Eichner's Classification.

5. Conclusion

This paper reviewed the relationship between the brain function activity by means of EEG measurement and denture treatment in elderly complete and partially edentulous patients. Denture treatment for complete denture wearers improved not only the denture function but also activation of the cerebral function. In addition, the wearing of partial dentures by patients classified based on Eichner's Classification increased brain function activation after chewing. These results also suggest that the occlusal contact area and occlusal force have an influence on brain function activation.

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