Increase in masseter muscle activity by newly fabricated complete dentures improved brain function

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Abstract

**Purpose:** To reveal effects of improvement of masseter muscle activity on brain function in elderly people wearing complete dentures.

**Methods:** Subjects were 14 edentulous patients with a chief complaint of the inconvenience of their complete dentures. The surface electromyographic (EMG) activity of the masseter muscles was measured. Brain activities were analyzed with functional magnetic resonance imaging (fMRI), employing chewing gum as the task program. Cognitive functions were evaluated with Trail Making Test Part A (TMT-A), Rey Auditory Verbal Learning Test (RA VLT) and Rey-Osterrieth Complex Figure Test (R-OCFT). Those evaluations were performed in which subjects wore their old dentures (OD) or newly fabricated dentures (ND).

**Results:** We compared ND condition with OD condition. The masseter muscle activity significantly increased in ND condition (p < 0.05, Wilcoxon signed rank test). The brain activity increased significantly in the superior frontal gyrus, precentral gyrus, putamen, inferior parietal lobule, cerebellum, inferior frontal lobe, and middle frontal gyrus under the ND condition than under the OD condition (p < 0.01, uncorrected, cluster size > 10 voxels). Results of TMT-A, RA VLT, and R-OCFT were also significantly improved (p < 0.05, Wilcoxon signed rank test).

**Conclusions:** In the edentulous elderly, the brain activity was increased following the improvement of the masseter muscle activity. Consequently, it is possible that the improvement of the masseter muscle activity might influence on the attention, verbal skills, and visual memory.

**Keywords:** Oral function, Cognitive function, Brain activity, Complete denture, Edentulous elderly

1. Introduction

According to the World Alzheimer Report 2015 [1], 47 million people live with dementia worldwide, and the number of patients with dementia is expected to increase up to more than 131 million by 2050. Although the risk factors for dementia are known to be age, sex, depression [2], diabetes [3], smoking [4], and underactivity [5], the cause and exact mechanism of dementia remain unclear. Dementia is currently not curative. Dementia is managed with only symptomatic treatment. Therefore, the prevention of dementia is a critical issue. Several effective prevention methods for dementia have been reported, including regular exercise [6], intake of antioxidants or anti-inflammatory components of foods [7], maintenance of social networks [8], and working memory training [9]. Intervention studies of dementia prevention indicated that non-drug therapies, such as dietary modifications, exercises, and behavioral strategies may be effective. Verghese et al. reported that leisure activities such as reading, playing board games, playing musical instruments, and dancing, were associated with a reduced risk of dementia [10]. Erickson et al. reported that exercise training increased the size of the hippocampus and improved memory in elderly people [11].

In the field of dentistry, several studies have reported on the relationship between oral and cognitive functions. Animal studies exploring the relationship between tooth loss and cognitive function indicated that reduction of mastication ability due to missing molar tooth might lead to impairment of spatial memory and degeneration of hippocampal neurons [12,13]. In human studies, Takeuchi et al. reported that the risk of dementia was 1.63 times greater in those with no teeth than those with 20 teeth or more [14]. Also, Kobayashi et al. observed that the volume of the hippocampus of edentulous elderly people was more significant reduction than that of dentulous elderly people. In addition, they suggested that the missing tooth caused the organic change of brain [15]. These reports show that maintaining as many teeth as possible may contribute to preventing dementia. On the other hand, Campos et al. reported that the masticatory function of patients with mild cognitive impairment was lower than that of healthy elderly people [16]. Lexomboon et al. also reported that the reduction of masticatory function affected the cognitive function [17]. Moreover, Takeshita et al. suggested that the oral function including maximum bite force might be a predictive factor of cognitive impairment [18].

According to those reports, there should be tight correlation between reduction of oral function and cognitive impairment. The dentist can recover the reduction of masticatory function and consequently maintain...
cognitive function by prosthetic treatment. However, there have been few studies which reported the relationships between oral function, brain activity, and cognitive function. Furthermore, the masseter muscle is trigeminal nerve dominant and masseter muscle activity might be more directly related to brain activity [19]. Therefore, we hypothesized that the recovery of the masseter muscles activity could contribute to maintenance of the cognitive function. The purpose of the present study is to clarify the influence of masseter muscle activity on brain activity and cognitive function.

2. Materials and methods

2.1. Subjects

Subjects of the present study were edentulous patients who are over the age of 65 years and visited the Iwate Medical University Hospital Dental Center with a chief complaint about inconvenience of their complete dentures. To determine the sample size, the statistical power analysis was performed. We defined the following factors: level of significance: 0.5, power: 0.8, and expected effect size: 0.8. As a result of this analysis, the sample size of this study should be at least 11 participants, and we recruited 14 participants. Regarding the denture design, fitness, jaw position, occlusal wear of artificial teeth, and repair mark, one prosthodontist inspected their complete dentures, according to the denture inspection guideline provided by Japan Prosthodontic Society. After the inspection, the prosthodontist divided their complete dentures into appropriateness, slight inappropriateness, inappropriateness, and considerable inappropriateness. Subjects included in the study were those who wore their inappropriately or considerably inappropriately dentures for at least one year and for whom the prosthodontist made new complete dentures according to the conventional method. Subjects excluded were those who had metals and magnets in their body, could not be evaluated for all examinations, were diagnosed IV or V of State trait anxiety inventory (STAI) which is the anxiety examination during cognitive examination. In addition, the new dentures were evaluated by another prosthodontist. New dentures that were diagnosed as slight inappropriateness, inappropriateness, or considerable inappropriateness were excluded.

The oral function, brain activity, and cognitive function were evaluated at the time of wearing the old dentures (OD) and three months after wearing the new dentures (ND). The analysis focused on comparing those two conditions. The present study was approved by the Ethical Committee for Human Research of the School of Dentistry, Iwate Medical University (No.01233).

2.2. Measurement of surface electromyographic (EMG) activity of masseter muscles

EMG activity of left and right superficial masseter muscles was measured using a mandibular movement measure system (K7 DIAGNOSTIC SYSTEM©, Myo-Tronics, Inc., Tukwila, WA, USA). The first measurement was performed on the same day as the newly fabricated denture was provided. Subjects clenched as hard as they could for three seconds, and this task was repeated three times. The integral EMG per unit time was calculated, and we defined the average of the three measurements as masseter muscle activity.

2.3. Measurement of brain activity

The brain activity was analyzed with functional magnetic resonance imaging (fMRI), performed on a 7.0 T MR scanner (MR950, GE, Medical Systems, Milwaukee, WI, USA). The first measurement was performed on the same day as the newly fabricated denture was provided. The structural data was acquired by steady state T1-weighted 3D fast-spoiled gradient-recalled acquisition with the following parameters: repetition time (TR) = 3000 ms, echo time (TE) = 23 ms, flip angle (FA) = 12°, field of view (FOV) = 256×256 mm, slice thickness = 1.0 mm, slice gap = 0 mm, number of slices=60, matrix size =256×256 mm, and voxel size = 1.0×1.0×1.0 mm. The echo planar imaging (EPI) sequence was used for the functional imaging with the following parameters: TR = 3000 ms, TE = 23 ms, FA = 80°, FOV = 210×210 mm, slice thickness = 2.2 mm, slice gap = 0.0 mm, matrix size = 96×96 mm, and voxel size = 2.18×2.18×2.2 mm. Subjects alternated restoration and the task of chewing gum. This alternateness was repeated three times in each scanning run. Figure 1 shows the task assignment. The gum had no odor or taste. We also evaluated whether the subjects felt pain and discomfort by the visual analogue scale (VAS).

2.4. Evaluation of cognitive function

Three validations of neuropsychological tests were used to assess frontal lobe functions, auditory-verbal memory, and visuospatial memory. TMT-A, which evaluates attention ability and RAVLT and R-OCFT, which evaluate memory in elderly people, were employed because previous studies reported that chewing could increase the level of brain activity in the areas of frontal lobe and hippocampus. Another reason was that patients with dementia display a multiplicity of cognitive deficiencies concerning memory, visuospatial cognition, language and attention ability, and hippocamps and frontal lobe are involved in memory and attention ability, respectively.

The first evaluation was performed on the same day as the newly fabricated denture was provided. All neuropsychological tests were scored by an experienced psychologist. The subjects were assessed for their anxiety with STAI before their neuropsychological tests.

The evaluation of the frontal lobe function (Trail Making Test Part A: TMT-A) measures scanning and visuomotor tracking abilities and involves cognitive processing as well as psychomotor speed. The subject was assigned to draw lines sequentially connecting 25 encircled numbers, which were distributed on a sheet of paper. The obtained score represents the amount of time required to complete the task [20].

Rey Auditory Verbal Learning Test (RAVLT) is a word list learning test. For the RAVLT, the subject was given 15 unrelated words by the psychologist and asked to recall as many words as possible. The total recall score was defined as the sum of all correctly recalled items from the five trials [21]. The present study assessed immediate recall.

Rey-Osterrieth Complex Figure Test (R-OCFT) was used to assess visuospatial ability and visual memory. A complicated geometrical figure was presented to the subject, who was then requested to copy the figure as accurately as possible. When the copying was completed, the figure and the copy were removed from their sight. The subject should be given another sheet of paper and asked to draw the design from memory (immediate recall). Drawings were scored for accuracy using Taylor’s scoring system (maximum score = 36) [22].

2.5. Data analysis

Regarding the oral function and cognitive function, we statistically compared the OD condition with the ones on ND condition using SPSS version 23 (IBM SPSS Statistics, IBM Corporation, Armonk, New York, USA). The significance level was set at p < 0.05.

Statistical analysis for the brain activity was performed using SPM12 (Well-come Department of Imaging Neuroscience, London, UK) with MATLAB version R2014a (The MathWorks, Inc., Natick, Massachusetts, USA). All images were realigned first to correct for head motion and were confirmed that the motion of the head did not exceed 1.5 mm for any subject. After realignment, a custom template was created using Advanced Neuroimaging Tools (ANTS, http://stnava.github.io/ANTS/). Each subject’s EPI was matched to this custom template; subsequently, the images were normalized to Montreal Neurological Institute (MNI) space using SPM. The normalized images were finally smoothed following convolution with a Gaussian kernel of 5 mm full-width-at-half-maximum to reduce the individual variability before statistical mapping. Chewing gum under the ND condition was compared with the ones on OD conditions using a mixed-effect general liner model in SPM. The second-level (group) analysis was performed with a one-sample t-test. The statistical threshold was set at p < 0.01 (uncorrected, cluster size > 10 voxels). Analyzed brain area was identified by superimposing MNI coordinates on the anatomical.
Identification of brain activity area that showed a change due to an increase in muscle activity was performed using regression analysis. The significance level was set at $p < 0.01$, uncorrected for multiple comparisons.

### 3. Results

#### 3.1. Subjects

Eight of the 22 subjects who consented to the present study were excluded owing to the following reasons: 1, poor physical condition; 3, non-contactable; 1, refusal to continue in the present study; 1, unable to be evaluated for all the measurements; and 2, presence of metals and magnets in the body. In total, 14 subjects were included (four men, 10 women; mean age: $80.2 \pm 5.9$ years) in the present study.

#### 3.2. EMG activity of masseter muscles

Masseter muscle EMG activity in the left and right masseter muscles under the ND condition was significantly higher than that under the OD condition {OD: $86.45 (46.79–111.36) \mu V \cdot S$; ND: $125.47 (94.80–173.00) \mu V \cdot S$; $p < 0.05$, Wilcoxon signed rank test; Fig. 2}.

#### 3.3. Brain activity

The brain activity on the ND condition was significantly higher than that under the OD condition. Especially, brain activity in area of the superior frontal gyrus, precentral gyrus, putamen, inferior parietal lobule, cerebellum, inferior frontal lobe, and middle frontal gyrus increased significantly during the task (Fig 3, Table 1). Pain as measured using VAS scores was not significantly different between the OD and ND conditions {OD: 0 (0–0.25); ND: 0 (0–5); $p < 0.05$, Wilcoxon signed rank test}. Moreover, discomfort was also not significant {OD: 0 (0–0); ND: 0 (0–14.25); $p < 0.05$, Wilcoxon signed rank test}.

Regression analysis revealed a positive correlation between masseter muscles and brain activity, and the increase in brain activity of parahippocampal gyrus (CA1, CA3), postcentral gyrus, inferior temporal gyrus, hippocampus, and superior medial gyrus was remarkable (Fig. 4, Table 2).

#### 3.4. Cognitive function

The time to complete TMT-A under the ND condition was significantly shorter than the one under the OD condition {OD: $143.5 (122.5–162.3)$ seconds; ND: $117.5 (95–132.5)$ seconds; $p < 0.05$, Wilcoxon signed rank test; Fig. 5A}. The total recall score of RAVLT under the ND condition was significantly higher than the one under the OD condition {OD: $37.5 (29.5–45.8)$ words; ND: $43 (38.5–53)$ words; $p < 0.05$, Wilcoxon signed rank test; Fig. 5B}. Additionally, the score of R-OCFT under the ND condition was significantly higher than the one under the OD condition {OD: $15.5 (6.8–17.9)$ point; ND: $18 (17–21.75)$ point; $p < 0.05$, Wilcoxon signed rank test; Fig. 5C}.

### 4. Discussion

Oral functions of patients who wear dentures are commonly evaluated by analyses of bite force [23,24], surface EMG signal recording [25-28] and masticatory performance [29,30]. Previous studies demonstrated that the integral EMG values of masticatory muscles could be a parameter that directly represents masticatory performance [25-28]. Surface EMG signal recording is useful for evaluating effects of denture treatment on masticatory muscle activity [31-33] because there is a positive correlation between the bite force and the surface EMG signal recording of the masseter and anterior temporalis muscles [34]. Moreover, the value for activity of the temporalis anterior muscle was still unstable at 3 months after wearing new dentures [35]. Thus, we measured the surface EMG record of the masseter muscle, which links directly to the brain, and evaluated the oral function of subjects in the OD and ND conditions. As a result, the EMG activity of the masseter muscles under the ND condition was significantly higher than the one under the OD condition.
Positron emission tomography, near infrared spectroscopy, electroencephalography, and fMRI are the noninvasive ways to measure the brain activity. The principal advantage of fMRI is its higher spatiotemporal resolution than other measurement systems [36]. Several studies have reported brain activity which based on change of cerebral blood flow using fMRI [37-40]. In the present study, we also used fMRI to examine the brain activity of the frontal lobe and hippocampus that are related to the cognitive function. Regarding the scanning of fMRI, horizontal posture might be inappropriate for occlusal performance during scans. However, there is a report that the maximum bite force is not affected by horizontal posture [41]. Thus, we considered that masseter muscle activity was not also affected by horizontal posture during fMRI scan. Since the subjects may experience pain and discomfort during the scan, we evaluated whether the subjects felt pain and discomfort using the VAS. The results showed no significant difference between the OD condition and the ND condition. Thus, we considered that we were able to evaluate the brain activity during scans without discomfort, pain, and other factors related to sensory stimulation caused by wearing dentures and/or postural changes. Yan et al. used fMRI to analyze the brain activity during clenching in three edentulous

Table 1. The brain area of significant increases in the fMRI signals during chewing gum.

<table>
<thead>
<tr>
<th>R/L</th>
<th>Region of Activation</th>
<th>Maximal t Value</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>Z-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Superior Frontal Gyrus</td>
<td>5.162590027</td>
<td>28.5</td>
<td>13.5</td>
<td>63</td>
<td>3.7419386</td>
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<tr>
<td>L</td>
<td>Superior Frontal Gyrus</td>
<td>4.922014713</td>
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<td>-7.5</td>
<td>70.5</td>
<td>3.63411323</td>
</tr>
<tr>
<td>R</td>
<td>Precentral Gyrus</td>
<td>4.764995575</td>
<td>42</td>
<td>-3</td>
<td>43.5</td>
<td>3.56110152</td>
</tr>
<tr>
<td>R</td>
<td>Putamen</td>
<td>4.422444344</td>
<td>27</td>
<td>13.5</td>
<td>9</td>
<td>3.39411739</td>
</tr>
<tr>
<td>L</td>
<td>Inferior Parietal Lobule</td>
<td>3.987716675</td>
<td>-48</td>
<td>-10.5</td>
<td>51</td>
<td>3.16574342</td>
</tr>
<tr>
<td>R</td>
<td>Cerebelum (X)</td>
<td>3.740415335</td>
<td>25.5</td>
<td>-30</td>
<td>-42</td>
<td>3.02691374</td>
</tr>
<tr>
<td>L</td>
<td>IFG (part of Orbitalis)</td>
<td>3.698326826</td>
<td>-28.5</td>
<td>19.5</td>
<td>-15</td>
<td>3.00260649</td>
</tr>
</tbody>
</table>

Table 2. The brain area of positive correlation between masseter muscle and brain activity.

<table>
<thead>
<tr>
<th>R/L</th>
<th>Region of Activation</th>
<th>BA</th>
<th>Maximal t Value</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>Z-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>ParaHippocampal Gyrus</td>
<td>CA3</td>
<td>6.868117458</td>
<td>24</td>
<td>-18</td>
<td>-19.5</td>
<td>4.303163</td>
</tr>
<tr>
<td>R</td>
<td>ParaHippocampal Gyrus</td>
<td>CA1</td>
<td>3.304640293</td>
<td>33</td>
<td>-18</td>
<td>-25.5</td>
<td>2.73297</td>
</tr>
<tr>
<td>L</td>
<td>Postcentral Gyrus</td>
<td></td>
<td>4.223235607</td>
<td>-64.5</td>
<td>-16.5</td>
<td>25.5</td>
<td>3.24325</td>
</tr>
<tr>
<td>R</td>
<td>Inferior Temporal Gyrus</td>
<td></td>
<td>6.160713673</td>
<td>58.5</td>
<td>-19.5</td>
<td>-30</td>
<td>4.061938</td>
</tr>
<tr>
<td>R</td>
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<td></td>
<td>5.59612751</td>
<td>39</td>
<td>-19.5</td>
<td>-13.5</td>
<td>3.852636</td>
</tr>
<tr>
<td>L</td>
<td>Hippocampus</td>
<td>CA3</td>
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<td>-19.5</td>
<td>-19.5</td>
<td>3.649944</td>
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<tr>
<td>R</td>
<td>Superior Medial Gyrus</td>
<td></td>
<td>4.627786636</td>
<td>6</td>
<td>34.5</td>
<td>58.5</td>
<td>3.439759</td>
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<tr>
<td>L</td>
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<td>3</td>
<td>49.5</td>
<td>45</td>
<td>3.426699</td>
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BA, Brodmann’s area; CA, Cornu Ammonis
subjects who wore implants supported fixed dentures. They suggested that the implants supported fixed dentures increased the blood oxygen level dependent (BOLD) signals of the primary sensorimotor cortex, prefrontal cortex, Broca’s area, insula, and hippocampus. The authors concluded that activation of the primary sensorimotor cortex in patients with implant-supported dentures explained the improved tactility, stereognostic ability, and mastication function improved [40]. In addition, Hirano et al. used fMRI to analyze the brain activity when healthy volunteers chewed odorless and tasteless gum. The results showed that chewing activated the BOLD signals in the right premotor cortex, precuneus, thalamus, hippocampus, and inferior parietal lobe. They suggested that chewing might effectively engage the ventral prefrontal network; thus, reflecting high cognitive performance [37].

According to previous studies, we considered that the brain activity during mastication could be evaluated using fMRI. In the present study, the brain activity areas increased significantly on the task of chewing gum were the superior frontal gyrus, precentral gyrus, putamen, inferior parietal lobule, cerebellum, inferior frontal lobe, and middle frontal gyrus. Thus, our data were consistent with the stimulated brain areas described in previous studies [37,40].

Several studies have reported that the recovery of oral function might stimulate improvement of cognitive functions, governed by the frontal lobe and hippocampus [42-44]. A previous study reported that the brain activity of the anterior cingulate cortex and left frontal gyrus were increased and attentional networks were affected by chewing [44]. Chewing stimulated the neuronal activity within a network between the right prefrontal cortex and the hippocampus [38]. In contrast, the result of regression analysis between masseter muscle activity and brain activity, in this study, revealed that the positive correlation in the areas of para-hippocampal gyrus (CA1 and CA3), postcentral gyrus, inferior temporal gyrus, and hippocampus superior medial gyrus in this study. Few studies have reported the relationship between masseter muscle activity and brain activity. Thus, this new finding suggests that increase in masseter muscle activity, which was caused by wearing ND for three months, could stimulate the different areas from where are stimulated by the chewing. Moreover, increase in masseter muscle activity due to ND wearing might accelerate trigeminal sensory input, resulting in the upregulation of signal transduction to hippocampus and para-hippocampal gyrus (CA1, CA3), mediated by postcentral gyrus, superior medial gyrus, and entorhinal cortex. Those hypotheses might be a possible explanation for the different types of brain activity induced by increase in masseter muscle activity. However, further experiments, such as PET analysis to track neurotransmitters, are required to clarify the details of those neural transduction system.

Considering these studies, we observed changes of cognitive function using the neuropsychological tests to evaluate the frontal lobe and hippocampus function. Attentional ability was assessed using the TMT-A that measures the amount of time required to complete the task. TMT-A is the measurement of the maintenance of attention ability during the test; therefore, the time is longer if subjects have lower attention ability. On the other hand, if the subject’s attention ability improves, the time is shorter. Since a previous study reported that TMT-A scores are related to the frontal lobe function [45], it could evaluate the relation between the frontal lobe and brain activity, and thus we used TMT-A in the present study. Also, we used RAVLT and R-OCFT to evaluate hippocampus related to the short

Fig. 5A. Changes in TMT A.
The ND condition was reduced the time to complete TMT-A significantly, compared to the one on OD (*p < 0.05, Wilcoxon signed rank test).

Fig. 5B. Changes in RAVLT scores.
The total recall score of RAVLT on the ND condition was significantly higher than the one on OD (*p < 0.05, Wilcoxon signed rank test).

Fig. 5C. Changes in R-OCFT scores.
The score of R-OCFT on the ND condition was significantly higher than on the one OD (*p < 0.05, Wilcoxon signed rank test).
memory. Generally, RAVLT is used to evaluate the verbal memory. A previous study reported that RAVLT correlates with Wechsler Memory Scale-Revised Logical Memory and California Verbal Learning Test (CVLT) [46]; additionally, we used RAVLT because it is faster and easier to evaluate than CVLT. Moreover, we used R-OCFT because it can evaluate visuospatial constructional ability and visual memory, and it is not affected by biases in education level or culture. In the present study, the scores of TMT-A, RAVLT, and R-OCFT under the ND condition improved significantly, compared with those under the OD condition. Thus, we considered that attention ability, verbal memory, and visual memory improved.

A previous study reported that chewing is controlled by the central nervous system and sensory feedback from a variety of intraoral conditions and the characteristics of the food. Thus, chewing while wearing dentures may also be controlled by the central nervous system and sensory feedback from the oral mucosa or masticatory muscles. In the present study, the EMG activity of the masseter muscles under the ND condition might be increased following improvement of several factors, such as fitness, wear of artificial teeth, and denture design. Therefore, we considered that the sensory feedback from muscle or mucosa was upregulated and the brain activity areas of the frontal lobe, hippocampus, and so on were increased. Chen et al. reported that chewing might represent a useful approach in preserving and promoting the hippocampus-dependent cognitive function in older people [43]. In addition, the brain activity of hippocampus and parahippocampus are thought to be transmitted to the hippocampus via the frontal lobe or entorhinal cortex [48]. Those previous studies supported our results that increase in the EMG activity of the masseter muscles activated the brain activity areas of the hippocampus and frontal lobe.

Moreover, the present study clarified that appropriate prosthetic treatment could improve the EMG activity of the masseter muscles, resulting in activation in the frontal lobe and hippocampus. We also found that improvement of attention ability and memory related to the frontal lobe and hippocampus. Since the results of this study revealed a positive correlation between masseter muscle activity and brain activity of frontal lobe and hippocampus, we considered that improvement of cognitive function was associated with significant brain activity and cerebral blood flow increase of them by the masseter muscle activity. Intermediary factors of improvement of cognitive function are generally affected by brain activity, cerebral blood flow [49], brain volume [50], sleep [51], physical activity [11], and mental condition [52]. A previous study clarified the effects of chewing on cognitive function by measuring brain activity and neuropsychological tests [37]. We inferred that the brain area activated significantly under the ND condition and that cerebral blood flow increased at every meal. Therefore, we speculated that increase in the cerebral blood flow was a factor in the improvement of brain function. However, it was difficult to accurately evaluate the changes in brain activity and cognitive function using the protocol of the present study. Although continuous or frequent measurements could be conducted for researchers, it is too tough for elderly subjects to undergo repeated examinations. Moreover, Piancino et al. previously reported that it should take three months for most patients to acquire stable masseter muscle activity [35]. Thus, an interval of three months was deemed suitable for the neurophysiological tests and fMRI imaging. In addition, it is necessary to evaluate the behavioral, social psychology, and nutrition. Therefore, to clarify the mechanism by which the increase in the EMG activity of masseter muscles affects the brain activity and cognitive function, further experiments must be required, such as long-term observation of brain metabolism, brain volume, nervous system, systemic disease, physical activity, social activity, and nutrition.

5. Conclusions

The improvement of the EMG activity of the masseter muscles might affect attention, verbal memory, and visual memory. The findings of this study suggest that improvement of masseter muscle activity by prosthetic treatment may contribute to maintaining cognitive function.

Conflict of interests

No conflict of interests declared.

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