Objective Assessment of Mastication Predominance of the Complete Denture Wearers

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Abstract: Aims: The purpose of this study was to evaluate the degree of the mastication predominance of edentulous individuals with complete dentures by comparing with healthy dentate, and bilateral and unilateral posterior missing teeth subjects using electromyographic (EMG) analysis and visual analogue scale (VAS).

Methods: Twenty-five edentulous individuals with complete dentures were instructed to chew on the right side and then on the left side, and EMG activity of the bilateral masseter muscles was recorded simultaneously. The Concordance rates between instructed and judged chewing sides were calculated. Then, 30 healthy dentate subjects, 19 bilateral posterior missing teeth subjects, 30 unilateral posterior missing teeth subjects, and 25 edentulous subjects were instructed to freely chew three kinds of test foods (chewing gum, peanuts, and gummy jellies). In each trial, EMG activities were recorded from bilateral masseter muscles and the mastication predominant index (MPI) was calculated. Self-awareness of mastication predominance (SAMP) was evaluated by using a modified visual analogue scale. The data were compared in all subject groups.

Results: Concordance rate—the percentage of events (chewing cycles) where the instructed chewing side coincided with the chewing side, as judged by EMG analysis—was >93% for all test foods among complete denture wearers. The MPIs of the edentulous group for each test food were as follows: peanuts 68.4%, gummy jellies 50.0%, and chewing gum 47.4%. Statistical analyses showed no significant difference in MPI between edentulous and the other three groups. In edentulous group, there was significant correlations between SAMP and mastication predominance score (MPS) in chewing gum.

Conclusion: Our analysis suggests that chewing side evaluation of edentulous subjects with EMG was effective to reveal mastication predominance.
Introduction

Continuous mastication predominance may cause difficulty in using a dental prosthesis, asymmetrical loss of teeth, altered stomatognathic function (e.g., asymmetrical muscle activity) or craniofacial morphology (e.g., facial appearance and skeleton), and/or temporomandibular disorders. Thus far, questionnaires have been considered for subjective evaluation of mastication predominance on the chewing side. In addition, first chewing cycle, jaw movement patterns, electromyographic (EMG) activity, bite force, and mastication efficiency are used for objective evaluations. In a previous study, objective determination of the actual chewing side during mastication was achieved for healthy dentate individuals by measuring bilateral masseter muscle EMG with a portable EMG recording unit. Further, we revealed that the individuals with missing unilateral posterior teeth exhibited greater mastication predominance, relative to healthy dentate individuals. In general, individuals with complete dentures are advised to masticate evenly on bilateral sides. In most studies of complete denture occlusion, individuals’ mastication predominance has not been considered. In addition, it is not clearly understood whether mastication predominance exists for edentulous individuals. Moreover, there are few detailed reports regarding the ability of individuals with complete dentures to recognize the chewing side or mastication predominance. The purpose of this study was to evaluate the chewing side, i.e., masticatory predominance, of edentulous complete denture wearers by EMG analysis, and to investigate the degree of self-awareness of mastication predominance (SAMP) and its relevance to the results obtained with EMG. In addition, the feature for the degree of the mastication predominance of edentulous patients with complete dentures was investigated by comparing with healthy dentate, and bilateral and unilateral posterior missing teeth subjects.

Materials and Methods

Participants who had regular checkups in Kyushu University Hospital and whose dentures were fabricated by prosthodontists with more than 5 years of experience were consecutively selected during the period from December 2013 to June 2017. Data measurement was performed after a sufficient acclimatization period (1 month to 5 years) after wearing the prosthesis.

Study 1: Twenty-five complete denture wearers (edentulous group: 10 males and 15 females; average age, 78.92 ± 8.77 years) were included. The degree of mastication predominance was evaluated by a portable EMG device (ProComp INFINITI, Thought Technology, Montreal, Canada), which measured EMGs of masseter muscles on both sides. In accordance with previous studies, Ag/AgCl electrodes (T3402M-TriodeTM electrode, Thought Technology) were affixed to the centers of masseter muscles on both sides. Three test foods were included: peanuts (Batapi; Denroku Inc., Yamagata, Japan), gummy jellies (Glucolumn; GC Co., Ltd., Tokyo, Japan), and chewing gum (Free Zone; LOTTE Co., Ltd., Tokyo, Japan). Participants were instructed to chew each test food (a single peanut, a single gummy jelly (φ15 × 8 mm) and a single stick of chewing gum (18 × 18 × 4 mm) for 10 strokes on the right side, and to chew another piece of test food for 10 strokes on the left side. The measured EMG data were evaluated to determine whether the data could be used to identify the chewing side; EMG data were analyzed by using a software program (BioGraph; Thought Technology, Montreal, Canada). The concordance rate (CR) of the chewing side where the subjects were instructed to chew (instructed chewing side) and the chewing side, as judged by %MVC (judged chewing side), was calculated.

Study 2: In addition to the subjects in study 1, the mastication predominant index (MPI) of 30 volunteers with normal dentition (control group: 14 males, 16 females, mean age 26.4 ± 2.92 years), 29 individuals with unilateral missing posterior teeth (unilateral group: 9 males, 20 females, mean age 63.44 ± 10.45 years) and 19 individuals with bilateral missing posterior teeth (bilateral group: 5 males, 14 females, mean age 79.79 ± 6.08 years) were included. The control group included volunteers aged 20 years or older with 28 natural teeth. Unilateral and bilateral groups included individuals aged 20 years or older with missing posterior teeth on either one or both sides, with no history of prosthodontic treatment, and with opposing teeth that were natural teeth or fixed prosthetic devices. The test foods were the same as in Study 1. For peanuts and gummy jellies, subjects were asked to chew the test foods freely, and then swallow them. For chewing gum, subjects were asked to chew a stick of chewing gum freely for 60 s. The data were analyzed in a similar manner to that of study 1. The numbers of right-side and left-side strokes were counted from the EMG data.
obtained when chewing the test food freely. In accordance with the previous study, the mastication predominant score (MPS) was calculated by using the following formula: \( \text{MPS} = \frac{(\text{number of right-side strokes} - \text{number of left-side strokes})}{(\text{number of right-side strokes} + \text{number of left-side strokes})} \times 100\% \). The absolute value (%) was then set as the MPI.

In addition, SAMP was evaluated by using a modified visual analogue scale (VAS). Subjects were asked to put a mark on the line of a 100-mm VAS. The left extreme of the scale represented the subject being aware that he/she had been chewing only on the left side (-100), and the right extreme represented the subject being aware that he/she had been chewing only on the right side (100). The middle point of the scale, i.e., zero, represented the subject being aware that he/she had been chewing equally on both sides.

Before conducting the present study, approval of the Kyushu University Institutional Review Board for Clinical Research (approval no.: 29-135) and the written informed consent of all participants were obtained.

### Statistical Analysis

IBM SPSS 19.0 for Windows (International Business Machines Corp., NY, USA) was used to conduct statistical analysis, and a \( P \) value of less than 5% was considered to indicate statistical significance. Comparisons of the MPI of each test food and of the MPI for each group of subjects were evaluated by using the Kruskal-Wallis test followed by multiple comparisons with Bonferroni correction. Correlations between the MPS and SAMP of each group were verified by the Pearson rank correlation test.

### Results

**Study 1:** For all test foods, the CRs of instructed and judged chewing sides for each subject are shown in Table 1. The CRs of the edentulous group showed were ≥93%. There were no significant differences in CRs among the test foods (Kruskal-Wallis test; \( P = 0.645 \)).

**Study 2:** The MPIs of the edentulous group for each test food were as follows: peanuts 68.4%, gummy jellies 50.0%, and chewing gum 47.4%. Table 2 and Table 3 shows the averages and results of comparisons of MPI for each test food among all subject groups. Peanuts showed no significant difference in MPI among subject groups (Kruskal-Wallis test; \( P = 0.240 \)). Multiple comparisons with Bonferroni correction revealed significant differences in MPI among subject groups (Kruskal-Wallis test; \( P = 0.240 \)). Multiple comparisons with Bonferroni correction revealed significant differences in MPI between the control and unilateral groups (gummy jellies: \( P = 0.003 \), chewing gum: \( P = 0.002 \)). There were no significant differences in MPI among the other subject groups. The distributions of SAMP for all groups are shown in Fig 1. There were statistically significant differences in SAMP between control and
unilateral groups (Kruskal-Wallis test; $P = 0.002$).

In all groups, the correlation coefficients of MPS and SAMP for peanuts, gummy jellies, and chewing gum are shown in Table 3. In the control group, there were no significant correlations among the test foods. In the unilateral and bilateral groups, correlations were recognized among all tested foods. In the edentulous group, a correlation was recognized in chewing gum.

**Discussion**

The CRs of the edentulous group were ≥90%, which were similar to the values of healthy dentate individuals in our previous study. There were no significant differences in CRs among the test foods. In addition, no difficulty was observed during measurement, data acquisition, or analyses. Taken together, these results indicate that EMG measurement of bilateral masseter muscles can be used for the objective determination of actual chewing side during mastication for complete denture wearers.

Significant differences in objective mastication predominance were not detected among the edentulous, control, unilateral, and bilateral groups, indicating that mastication predominance exists regardless of the number and position of the remaining teeth. A proportion of left and right strokes ≥30% has been reported as mastication predominance. When we applied this criterion, mastication predominance existed in approximately half of our edentulous participants. This finding was the first report of mastication predominance during mastication in edentulous individuals with complete dentures, using the objective evaluation method.

Complete denture wearers showed greater mastication predominance, compared with healthy dentate individuals, but reduced mastication predominance relative to individuals with unilateral and bilateral missing posterior teeth. Previous studies suggested that individuals with unilateral missing posterior teeth tended to chew on the side with teeth remaining, indicating that reduced occlusal support due to the loss of teeth is a predominant factor in mastication predominance. For edentulous individuals with complete dentures, factors that may explain the existence of mastication predominance include pain in denture-supporting tissues or other masticatory structures, as well as morphological factors (e.g., severe absorption of mandibular and/or maxillary bone). Further studies are required to investigate this issue.

There was no correlation between SAMP and MPS in all test foods in the control group. This result was quite reasonable, because this group showed no evident differences in occlusal support between right and left sides, indicating that they were not conscious of chewing side in daily life. For the unilateral and bilateral groups, there was a significant correlation between MPS and SAMP in all test foods. In

**Table 4** Correlation coefficients between MPS and SAMP for peanuts, gummy jellies, and chewing gum

|                | Peanuts | Gummy jellies | Chewing gum |
|----------------|---------|---------------|-------------|
| Control group  | rs=0.017| rs=0.092      | rs=0.134    |
|                | $p=0.900$ | $p=0.627$    | $p=0.480$   |
| Bilateral group| rs=0.575| rs=0.575      | rs=0.382    |
|                | $p=0.002$| $p=0.002$    | $p=0.050$   |
| Unilateral group| rs=0.518| rs=0.481      | rs=0.557    |
|                | $p=0.021$| $p=0.017$    | $p=0.013$   |
| Edentulous group| rs=0.404| rs=0.280      | rs=0.426    |
|                | $p=0.056$| $p=0.260$    | $p=0.043$   |

MPS: mastication predominance score, SAMP: self-awareness of mastication predominance.
consequence, regardless of whether the missing area is present on one or both sides, it appeared that partially edentulous individuals who were aware of mastication predominance exhibited mastication predominance in their preferred chewing side, which was mainly determined by the status of occlusal support.

In the edentulous group, there was a correlation between MPS and SAMP in chewing gum, but no correlation was found in other foods. For chewing gum, subjects were asked to chew a stick of chewing gum for 60 s instead of using already softened one. The FREE ZONE used in the present study was a relatively soft (not tough) chewing gum. Although the texture was changed during a 60-s measurement, we speculate that the subjective and objective chewing sides agreed with each other for chewing gum because it is similar to soft foods ingested by complete denture wearers on a daily basis with respect to the texture among three test foods used in the present study. In this study, for peanuts and gummy jellies, subjects were asked to freely chew the test foods, and then swallow them; for chewing gum, subjects were asked to freely chew a stick of chewing gum for 60 s. Peanuts have been frequently used for chewing ability measurement, whereas gummy jellies were used to evaluate chewing function in complete denture wearers19, 20. In a previous study of the chewing side in healthy dentate subjects21, 70% of subjects did not have consciousness of chewing side before the experiment; however, subjects recognized an awareness of chewing side as a result of the experiment. In this study, we explained the purpose of this research at the time of recruitment, and we measured the degree of SAMP after all test foods chewed. Therefore, some subjects may have been conscious of the chewing side.

There were several limitations in the present study. The study population of this research was patients who required prostodontic treatments in a university hospital and they may not represent individuals who visit dental clinics of general practitioners. The present study did not include the detailed information on subjects’ condition such as the degree of absorption of alveolar ridge, the period of usage of dentures, and the dryness of oral cavity. In this regard, more studies are required for understanding the status of mastication for edentulous individuals with complete dentures.

Within the limitations of the present study, we suspect that the evaluation of chewing side with bilateral masseter muscle EMG for complete denture wearers could be useful for comprehending chewing events on one side. Individuals with complete dentures showed mastication predominance similar to that of other groups, indicating that mastication predominance exists regardless of the number of existing teeth and location of the missing area. We must carefully consider these findings when we treat patients with complete dentures.

Conclusion

EMG measurement of bilateral masseter muscles can be used for the objective determination of actual chewing side during mastication for complete denture wearers. Mastication predominance existed in approximately half of our edentulous participants. However significant differences in objective mastication predominance were not detected among the edentulous, control, unilateral, and bilateral groups. In edentulous group, there was significant correlations between SAMP and mastication predominance score (MPS) in chewing gum.

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