The impacts of prosthetic interventions on mastication predominance in Kennedy Class II patients

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Abstract

Purpose: The purpose of this study was to investigate the effects of prosthetic interventions in patients with Kennedy Class II (unilateral missing posterior teeth) on mastication predominance. Methods: The subjects comprised patients with Kennedy Class II and healthy dentate volunteers (HD group). The subjects were asked to freely chew the test foods (chewing gum, beef jerky, and peanuts). Electromyographic activity of the bilateral masseter muscles was recorded twice (before and after prosthetic intervention). The chewing side (right or left) was judged by the level of the root mean square electromyographic amplitude. Mastication predominance was assessed using the mastication predominance index (MPI; range 0–100%). Each patient was restored with a removable partial denture (RPD) or an implant-supported fixed prosthesis (IFP). The effects of prosthetic interventions were statistically evaluated by the differences between MPI before and after prosthetic interventions (pre-MPI and post-MPI, respectively). Results: There was a significant difference between pre-MPI of patients with Kennedy Class II and MPI of the HD group (HD-MPI) for all test foods (P < 0.0001). Statistical analysis also demonstrated a significant difference between pre-MPI and post-MPI measured with each of the three food items in both the RPD and IFP groups (P < 0.0001). Multiple comparisons revealed that post-MPI in the IFP group, but not in the RPD group, was statistically comparable with HD-MPI, although there were no significant differences among the three groups when MPIs were calculated using peanuts. Conclusions: Prosthetic interventions improved mastication predominance in patients with Kennedy Class II patients. Depending on the food type, IFP might contribute to better improvement of mastication predominance than RPD depending on food.

Keywords: Mastication predominance, Prosthetic intervention, Kennedy Class II, Removable partial denture, Implant-supported fixed prosthesis

1. Introduction

Mastication is an almost natural and subconscious activity in daily life. It has been shown that even healthy individuals chew more on either one right or left side (either left or right) of the dental arch (preferred chewing side) [1-6]. The habit of chewing predominantly on one side has been called mastication predominance. Mastication predominance has been thought to be related to temporomandibular disorders (TMD), temporomandibular joint disc displacement, and asymmetrical loss of teeth [7-10]. Excessive mastication predominance might be related to laterality in stomatognathic function, including jaw movement patterns, bite force, and masticatory efficiency [11-13]. Hence, chewing equally bilaterally is generally recommended to prevent these conditions from a theoretical point of view, although scientific research and evidence on this issue are lacking. In our previous study [15], using our established method [16], we found that patients with missing posterior teeth exhibited more mastication predominance than the healthy dentate subjects, although there was no significant difference in the masticatory efficiency between the two groups [17]. These findings suggest that patients with missing posterior teeth on one side generally chew on the healthy dentate side, preventing any decrease in masticatory efficiency.

Removable partial dentures (RPDs) and implant-supported fixed prostheses (IFPs) are generally used for individuals with unilateral missing posterior teeth (Kennedy Class II) to improve masticatory function and their oral health-related quality of life (OHRQoL). Previous studies have reported an improvement in mastication ability and OHRQoL following prosthetic treatment [18-22]. In addition, subjectively and objectively evaluated masticatory ability and OHRQoL was superior with IFPs compared to that with RPDs [23-26]. To date, however, no studies have investigated the effect of prosthetic interventions on mastication predominance.

The purpose of the present study was to investigate the effect of prosthetic interventions in patients with Kennedy Class II on mastication predominance and to compare the effects of two different types of prosthetic interventions (RPDs and IFPs). The null hypotheses tested in the present study were that prosthetic interventions would not improve mastication predominance and that there were no differences in the effects of different types of prosthetic interventions on mastication predominance.

2. Materials and methods

2.1. Study population

The study protocol was approved by the institutional ethics committee.
(No. 23034), and signed consent forms were obtained from all subjects prior to the study. The study enrolled healthy dentate (HD) volunteers with a complete dental arch from the staff of Kyushu University (HD group) and patients with Kennedy Class II who visited the Kyushu University Hospital between October 2013 and October 2014. For the HD group, the following individuals were excluded from this study: those receiving ongoing dental therapy, including orthodontic treatment; those exhibiting systemic or dental diseases with possible effects on mastication; those with jaw dysfunction and/or pain, such as TMD; and those with compromised mental capacity due to dementia or other psychiatric diseases. The inclusion criteria for the group of patients with Kennedy Class II were as follows: 1) those who were over 20 years old with missing posterior teeth on one side and with no history of prosthetic treatment at this edentulous site with opposing natural teeth or fixed prosthetic devices (implant-supported prostheses were excluded) and 2) those who allowed second measurements while using their final prostheses without any descriptive problems. The exclusion criteria were as follows: systemic or dental diseases with possible effects on mastication, those with jaw dysfunction and/or pain such as TMD, and those with compromised mental capacity due to dementia or other psychiatric diseases. These subjects were divided into two groups according to their prosthetic interventions: RPD group and IFP group. Patients rehabilitated with cross-arch stabilization RPDs were included in this study. In the IFP group, patients in whom any retention system (screw or cement) and material were used for implant superstructure, except provisional restorations, were included.

2.2 Test foods

According to our previous study protocol, three test foods with different textures were used in this study as our previous studies reported [15, 16]: peanuts (Batapi; Denroku Inc., Japan), beef jerky (Itoham Foods Inc., Japan), and chewing gum (Free Zone; Lotte Co., Ltd., Japan)[15, 16]. The test foods were prepared as small portions that could be chewed easily, that is, a single peanut, a single piece of beef jerky (20 × 20 × 2 mm), and a single stick of chewing gum (18 × 18 × 4 mm).

2.3 Recording Electromyography activity

For each subject, electromyographic (EMG) activity in both the left and right masseter muscles was recorded using a portable EMG recording unit (ProComp Infiniti; Thought Technology, Canada) and disposable Ag/AgCl surface electrodes (T3402M-Triode™ electrode; Thought Technology). The sampling frequency for the EMG signals was 2048 Hz. After cleaning the skin surface with ethanol, bipolar electrodes, with an inter-electrode distance of 20 mm, were placed at the middle of the masseter muscle parallel to the orientation of the muscle fiber.

The subjects were instructed to maintain their physiological rest position with the test food on their tongue prior to mastication. As per our previously established and validated protocol [16], the participants were asked to freely chew the stick of chewing gum for 40 s, whereas the peanuts and beef jerky were to be freely chewed and then swallowed. After this session, the subjects were instructed to chew the gum for 10 strokes on the right side followed by the left-side (designated chewing). Subsequently, the subjects were instructed to perform maximum voluntary clenching thrice for 3 s. These recordings were used as a reference for determining the chewing side [16]. The EMG data were saved directly into a personal computer. The above procedure was performed twice for analyses; the first measurement was performed before prosthetic intervention and the second was performed at least 1 month after prosthetic intervention.

2.4 Data analyses

Raw EMG signals were converted to root mean square (RMS) values. RMS waveforms during maximum voluntary clenching (MVC) were set as 100% MVC, and %MVC for 100% MVC of both left and right sides in each stroke were calculated. The side with greater values was determined to be the mastication side. Mastication frequency on the left and right sides during free mastication was recorded, and the following formula was used to determine mastication predominance:

\[ \text{mastication predominance value} = \frac{\text{[number of right-side chewing strokes – number of left-side chewing strokes]}}{\text{[number of right-side chewing strokes + number of left-side chewing strokes]}} \times 100(\%) \]

The absolute value (%) was then set as the mastication predominance index (MPI). MPI of 0% indicated that mastication was performed evenly on the left and right sides, whereas MPI of 100% indicated that mastication was performed only on either the left or right side. MPI before and after prosthetic intervention were defined as pre- and post-MPI, respectively; MPI in the HD-MPI group was assessed only once. To determine the mastication side, the relative values to 100% MVC were used as described above. However, to enhance the accuracy of measurement between the first and second measurements, 100% MVC for the second measurement was compared to the first measurement value, and the positions of the bipolar electrodes were set at the positions where both values were almost equal.

2.5 Statistical analysis

The distribution of MPI scores is shown as a box plot. Outliers are shown as dots. Statistical analyses of descriptive data (all variables in oral profiles and time taken for second measurement of MPI after the adjustment of final prostheses in the RPD and IFP groups) were performed using the Wilcoxon rank sum test. The difference between pre-MPI and post-MPI in Kennedy Class II (pre-KC II vs post-KC II) patients or each prosthetic intervention (pre-RPD vs post-RPD and pre-IFP vs post-IFP) was assessed using the Wilcoxon signed rank test. For comparisons between HD-MPI and each pre- or post-MPI, the Steel test, a multiple-comparison test for comparing several groups (pre and post) with a control group (HD), was used. The differences between HD-MPI and post-MPIs of the RPD and IFP groups were also statistically compared using the Steel-Dwass multiple-comparison test in each test food. A P-value less than 0.05 was considered to indicate a significant difference.

3. Results

3.1 Subjects

The study population comprised 30 HD volunteers from the staff of Kyushu University (14 males and 16 females; mean age, 27.0 years; range, 20-32 years) and 47 patients with Kennedy Class II who visited Kyushu University Hospital. Patients with Kennedy Class II were divided into the RPD group (23 subjects) and IFP group (24 subjects) according to their prosthetic interventions and the subjects’ profiles that could have affected the treatment results are shown in Table 1. There were no significant differences between the RPD and IFP groups for any of these items.

3.2 Comparison of MPI

The results of pre- and post-MPI of patients with Kennedy Class II and HD-MPI are shown in Figure 1. The measurement of post-MPI was completed in April 2015. The median time (interquartile range) taken for the measurement of post-MPI after the adjustment of final prostheses was 98 days (74-115) in the RPD group and 108 days (80-134) in the IFP group, respectively, and there were no differences between the RPD and IFP groups (P > 0.05, Wilcoxon rank sum test). In pre-MPI, the mastication side in only one patient (IFP group) was unilateral edentulous side and he did not change his mastication side after the prosthetic intervention. There were significant differences between pre-MPI and post-MPI for all test foods (Fig. 1). There were also significant differences between pre-MPI of the patients and HD-MPI in all test foods and between post-MPI and HD-MPI when MPI was measured with beef jerky (P < 0.01, Fig. 1). This means that prosthetic intervention improved mastication predominance, and post-MPIs were comparable with HD-MPI, except when MPI was measured using beef jerky. Additionally, regarding the effect of the type of prosthetic intervention on MPI, it was seen that post-MPI values were significantly lower than pre-MPI values (P < 0.0001 in all) for both RPD and IFP, suggesting that prosthetic intervention improved mastication.
post-MPIs in the RPD and IFP groups revealed that there were no significant differences between RPD group and IFP group for any variables (P>0.05).

Table 1. Demographic, sleep, and oromotor variables.

<table>
<thead>
<tr>
<th>Group</th>
<th>Gender</th>
<th>Age (mean &amp; range)</th>
<th>Number of teeth loss and subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kennedy Class II</td>
<td>Male:13</td>
<td>61.7 (44-77)</td>
<td>1 tooth: 1 2 teeth: 24</td>
</tr>
<tr>
<td>(47 subjects)</td>
<td>Female:34</td>
<td>59.0 (51-77)</td>
<td>3 teeth: 12 4 teeth: 10</td>
</tr>
<tr>
<td>RPD</td>
<td>Male:7</td>
<td>64.3 (51-77)</td>
<td>1 tooth: 0 2 teeth: 12</td>
</tr>
<tr>
<td>(23 subjects)</td>
<td>Female:16</td>
<td>59.0 (44-75)</td>
<td>3 teeth: 6 4 teeth: 5</td>
</tr>
<tr>
<td>IFP</td>
<td>Male:6</td>
<td>59.0 (51-77)</td>
<td>1 tooth: 1 2 teeth: 12</td>
</tr>
<tr>
<td>(24 subjects)</td>
<td>Female:18</td>
<td>59.0 (44-75)</td>
<td>3 teeth: 6 4 teeth: 5</td>
</tr>
</tbody>
</table>

RPD: removable partial denture, IFP: implant-supported fixed prosthesis. There were no significant differences between RPD group and IFP group for any variables (P>0.05).

Predominance regardless of treatment options (Fig. 2). Furthermore, the Steel-Dwass multiple-comparison test to compare MPI in the HD group with post-MPIs in the RPD and IFP groups revealed that there were significant differences between “RPD and HD” (chewing gum: P = 0.0025, beef jerky: P = 0.0028) and “RPD and IFP” (chewing gum: P = 0.0006) when MPIs were measured using chewing gum and beef jerky, but there were no significant differences among the three groups when MPIs were measured by peanuts (P>0.05) (Fig. 3).

4. Discussion

A number of previous studies have shown that prosthetic intervention could improve mastication [18-22]. However, most of these evaluations were based on masticatory ability or OHRQoL, and only a few studies have evaluated the effect of prosthetic intervention on the dynamics of mastication at the dental chairside. Mastication predominance is considered to be one of the dynamics of mastication. Mastication predominance, also known as the preferred chewing side, is commonly found, especially in patients with missing posterior teeth [16]. There have been no scientific studies investigating the effect of prosthetic interventions on mastication predominance, although previous studies have reported improvement in masticatory ability and OHRQoL following prosthetic interventions [18-26]. Considering that prevention of excessive mastication predominance with prosthetic intervention might result in a well-functioning stomatognathic system, assessment and improvement of mastication predominance must be significant from a clinical point of view. This study is the first to investigate the effect of prosthetic interventions on mastication predominance in patients with Kennedy Class II.

Prior to the discussion of the results in the present study, we would like to discuss the method of measurement of MPI, which was calculated from EMG activity in the left and right masseter muscles without disturbing natural mastication. MPI was used to assess the degree of mastication predominance with a value of 100%, which indicated that the subject chewed the test food on one side [15]. The reliability of the MPI was confirmed in our previous study that demonstrated high concordance rates between the instructed and judged chewing sides [16]. Regarding test foods, chewing gum has been predominantly used for assessing chewing ability because of the stability of its texture during mastication [27]. However, the physical properties of foods we usually ingest on a daily basis may change as mastication progresses, with differences in properties, such as size, hardness, cohesiveness, and crushability also influencing chewing function. It has been reported that the mechanical properties of food that influence mastication include hardness, elasticity, cohesiveness, and adhesiveness, and the hardness of foods also influences mastication predominance [30]. Therefore, in this study, three foods with different levels of hardness were chosen as test foods: chewing gum (soft), peanuts (hard), and beef jerky (tough). In addition, mastication predominance for chewing gum might be influenced by the length of chewing time [31]. Weijenberg et al. reported that it takes 30 chewing cycles to evenly mix two-color chewing gum evenly [32]. In this study, the chewing time for chewing gum was set at 40 seconds according to these studies.

The first analysis in this study clearly showed that pre-MPI of patients was significantly higher than HD-MPI, meaning that patients with Kennedy Class II in this study exhibited greater mastication predominance than the HD group. It is reasonable to suppose that patients with Kennedy Class II tend to chew on the side with more residual teeth, which is consistent with...
our previous studies [15, 17]. In addition, post-MPI in patients with Kennedy Class II were comparable with HD-MPI for all test foods except beef jerky, suggesting that prosthetic intervention can improve mastication predominance; however, it depends on the physical properties of foods.

Comparisons between pre- and post-MPI in each prosthetic intervention clearly demonstrated that prosthetic interventions played a critical role in the improvement of mastication predominance in patients with Kennedy Class II, regardless of the treatment types, although there were small but not significant differences between the numbers of subjects whose mastication side was changed to the prosthetic side. According to this result, the null hypothesis, that is, prosthetic interventions would not improve mastication predominance was rejected. This result is in agreement with those of previous studies that reported that the bite force on the missing-tooth side improved to 40–60% of that on the healthy dentate side following fitting of an RPD [33] and that IFP improved masticatory function in terms of the maximal occlusal force, masticatory efficiency, and OHRQoL [18-26]. It is considered that restoring the occlusal table in the edentulous area by prosthetic interventions contributed to the improvement in MPI.

Additionally, to evaluate the effect of treatment options (RPD or IFP) on mastication predominance, post-MPIs in the RPD group and IFP group were compared to MPI in the HD group using multiple comparisons. The results demonstrated that post-MPI in subjects restored with IFP, but not with RPD, was comparable with MPI in the HD group, depending on the test food. These findings suggest the definite superiority of IFP over RPD in the improvement of mastication predominance, although there might be subject biases, especially in the treatment cost and the difficulty of treatment. Regarding the subject biases, we attempted to reduce them as much as possible. Our statistical analyses demonstrated that there were no significant differences between general and oral profiles in the RPD and IFP groups (Table 1), indicating similar features of their general and oral structural conditions. The subjects could decide their prosthetic interventions by themselves, implicating that we did not classify the subjects according to their profiles or difficulty in the treatment.

Fig. 2. Comparisons between pre- and post-mastication predominance index (MPI) for each prosthetic intervention calculated with each test food. Number below pre or post shows the number of subjects whose mastication side was the healthy dentate side (Total subjects: removable partial denture [RPD]: 23, implant-supported fixed prosthesis [IFP]: 24). *: P<0.0001 (Wilcoxon signed rank test).

Fig. 3. Multiple comparisons of post-mastication predominance index (MPI) in removable partial denture (RPD) group and implant-supported fixed prosthesis (IFP) group with MPI in healthy dentate volunteers (HD) group for each test food. *: P<0.01 (Steel-Dwass multiple-comparison).
addition, it is extremely challenging to define the difficulty of treatment and validate the effect of treatment cost on the present results. Although we understand these backgrounds and subject biases, we decided to compare pre- and post-MPI in each group in this study. It has been reported that the masticatory efficiency in the healthy dentate side was higher than that of the edentulous side in which the occlusal table was reconstructed with an RPD and that the improvement in maximum bite force and masticatory efficiency was greater with an implant-supported fixed partial denture than with an RPD [23]. Furthermore, previous studies also reported the significant superiority of IFP over RPD in improving masticatory ability and OHRQoL [24-26]. The findings of these studies might support the understanding of our results. However, we would like to emphasize that the results should be carefully interpreted. The effect of prosthetic interventions on mastication predominance might be influenced by habituation of mastication with prosthesis and oral status, including the number and pattern of missing teeth, condition of the edentulous area, and status of existing teeth. Therefore, further longitudinal research is needed to clarify the effects of these factors on mastication predominance.

5. Conclusion

Within the limitations of the present study, prosthetic interventions improve mastication predominance in patients with Kennedy Class II. IFP might contribute to better improvement of mastication predominance than RPD depending on food, although further longitudinal research is needed to evaluate the effects of additional factors on mastication predominance.

Declaration of interest

The authors declare no conflicts of interest associated with this manuscript.

References


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