It has become clear that food crushing is performed in the circumscribed region between functional cusps, that is, at "the main occluding area". However, the position of the main occluding area in patients with fixed partial dentures (FPDs) has not been investigated quantitatively yet. There is a possibility that the load onto the abutment teeth of FPDs is loaded excessively depending on the position of the main occluding area at the early stage of mastication. Therefore the position of the main occluding areas of the FPDs was investigated. The purpose of this study was to evaluate the position of the main occluding area in patients with FPDs quantitatively. We compared the position of the main occluding area between the control subjects who had complete dentition and the patients who wore FPDs for replacing missing first lower molars. Pieces of temporary filling material were used as test material to decide the position of the main occluding area. The centroid coordinate of the test material was calculated and projected onto the reference axis in order to evaluate the position of the main occluding area. Moreover, we recorded the occlusal contact areas at the intercuspal position in order to evaluate the relationship between the position of main occluding area and occlusal contacts.

As a result, the position of the main occluding areas in the FPD group were significantly posterior to those in the control group and tended to be less stable. Besides occlusal contact area, existence of periodontal ligaments in the pontic region may cause the difference of the positions of the main occluding area between the FPD group and the control group.

Key word: main occluding area, fixed partial denture, pontic, mastication, occlusal contact area

Introduction

Fixed partial dentures (FPDs) are commonly used as prostheses for replacing a few missing teeth. According to the meta-analysis of the FPDs\(^1\), the survival probability decreased sharply after 10 years. About the masticatory force in patients with different types of dental prostheses, it is reported that the masticatory forces were 80%, 35%, and 11% of natural dentition for fixed partial denture, removable partial denture and complete denture group, respectively\(^2\). Although the number of teeth in FPD patients is smaller than in subjects with natural dentition, the magnitude of masticatory forces are similar. Especially, in the case of the FPDs located molar region where the mastication has to perform, the abutments are likely to be over loaded. Previous studies unveiled the characteristics of the mandibular movements\(^3,6\), the masticatory forces\(^7,11\), the muscle activities\(^12-15\), and the displacements of teeth during mastication\(^16-22\). It has been indicated in those studies that the mastication consists mainly in two stages: the early stage performs food crushing, and the last stage performs food bolus formation. In the early stage of mastication, masticatory force is larger and the food property changes rapidly than in the final stage.
In the early stage of mastication, food crushing is performed in the circumscribed region between functional cusps. Especially, the maximal masticatory force is performed in the first stroke of mastication. On the other hand, there is a concept for the evaluation of the food crushing area in the first stroke. This circumscribed area was called “the main occluding area”. The main occluding area was defined for an index to measure the location where the food crushing was performed, and it was thought that the maximal masticatory force loaded onto this area. The main occluding area was related to occlusal contact area at intercuspal position and was located on the first molar in most cases.

In addition, it is suggested that the position of the main occluding area was related to food impaction or tooth fracture, too. Moreover, the relation between the position of the main occluding area and occlusal contacts in natural tooth, the position of the main occluding area in children, and comparison of the position of the main occluding area between adults and adolescents have been reported. Recently, the position of the main occluding area in patients with reduced occlusal support has been reported. Among the factors that can affect on the survival probability of the FPDs, the masticatory force may be one of the most important things. Therefore the detail analysis of the main occluding area may profit the increasing “the survival probability of the FPDs” because the first stroke of mastication need the maximal masticatory force. However, the position of the main occluding area in patients with FPDs has not been investigated quantitatively yet.

There was a possibility that the load onto the abutment teeth of FPDs might be different depending on the position of the main occluding area at the early stage of mastication. Therefore we investigated the position of the main occluding areas of the FPDs. The aim of this study was to compare the position of the main occluding area in patients with FPDs with that of fully dentate individuals, and to evaluate the relationship between the position of main occluding area and occlusal contacts.

Materials and Methods

1. Subject selection
In this study, six control subjects (two males, four females, average 28.5 ± 1.0 years old) who had complete dentition (totally 12 sides) and six patients (one male, five females, average 57.7 ± 9.1 years old) who wore FPDs for replacing missing first lower molars were enrolled. Totally we investigated eight FPDs in six patients.

Inclusion criteria were:
1. normal occlusal relationship in the molar region;
2. no experience of orthodontic treatment or stomatognathic disorder;
3. complete dentition except for the third molars without cusp covered restorations (control group);
3-2. no missing tooth except for the lower first molar and third molars (FPD group).

The sufficient explanation about this study was given to all subjects and informed consent was obtained prior to this study. This study was approved by the Ethics Committee of Tokyo Medical and Dental University (the approval number: 432.2009).

2. Decision of the main occluding area
We decided the position of the main occluding area in accordance with the method of Kato et al. Temporary filling material (Temporary Stopping; GC Corporation, Tokyo, Japan) which was cut into 4-mm long (φ3.4 mm) was put on the center of the tongue of each participant. The participant was asked to bite once at the area where he liked. After that, the test bolus was carefully removed from the oral cavity; subsequently the position of the bolus was confirmed by placing it on the occlusal surface of the study model for each subject. The participants were instructed to perform this step five times on left and right sides respectively. Furthermore, pictures of test bolus on the dental stone model were taken from the occlusal direction.

3. Recording of the occlusal contact
The occlusal contact areas with moderate biting force at the intercuspal position were recorded with occlusal contact checking materials (Bite-checker; GC Corporation, Tokyo, Japan). They were put on the lighting board parallel to digital camera and constant in distance and digital images were taken by a digital camera to be analyzed by means of light density. The thickness of silicone occlusal records was calibrated using a steel ball of 50.8 millimeters in diameter by Nakao’s method. The areas of occlusal contact below 50 μm were analyzed and picked out with image processing software (Win
Main occluding area

4. Definition of the coordinate system

In order to evaluate the positions of the main occluding area within the dental arch quantitatively, the coordinate system defined in accordance with Tsuchiya et al. The occlusal plane was defined as the standard plane and the origin of coordinates was chosen at the midpoint between the tops of the distobuccal cusp of the right and left second molar teeth. The Y-axis (the anterior-posterior direction) was defined as the straight line passing through the origin to the mesial edge of the left central incisor (lower incisal point). The y-coordinate of anterior reference point was defined as 100. The X-axis (the left-right direction) was defined as the straight line passing through the origin and vertical to Y-axis (Fig.1).

2) The reproducibility of the main occluding area in the anterior-posterior direction.

To evaluate the reproducibility of the main occluding area, mean deviation was used. In this study, the reproducibility was defined as the mean deviation of five times of trials on each side. The mean deviation was calculated by averaging absolute values of differences between the mean value of the centroid coordinate of the test bolus and the value of each trial.

3) The relation between the position of the main occluding area and the occlusal contact.

1. There was the pontic in the first molar region in FPD group. In order to evaluate the difference between the occlusal contact area of the natural tooth and that of the pontic, the occlusal contact area below 50 μm in the first molar region of the FPD group and the control group were compared.

2. The ratio of the occlusal contact area below 50 μm included within each test bolus to the total occlusal contact area in the molar region was calculated.

5. Analysis

1) The analysis of the position of the main occluding area in the anterior-posterior direction.

In order to analyze the position of the main occluding area on the dental arch, the centroid coordinate of the test bolus was calculated with the image processing software (Win ROOF; Mitani Corporation, Fukui, Japan). This centroid coordinate was defined as the representative position of the main occluding area.

6. Statistical Analysis

The statistical analysis was performed using commercially available software (SPSS for Windows 12.0J, SPSS Japan Inc.). T-test was performed for the comparison of the position of the main occluding area between two groups, for the comparison of the reproducibility of the main occluding area between two groups, and for the comparison of the ratio of the occlusal contact area below 50 μm included within each test bolus to the total occlusal contact area in the molar region between two groups. Mann-Whitney U test was performed for the comparison of the occlusal contact areas below 50 μm in the first molar region between two groups. The level of significance was set at p < 0.05.

Results

1. Comparison of the anterior-posterior position of the main occluding area between two groups

The position of the main occluding area using the previously-mentioned coordinate system was quantified (Fig.1). The mean value of the anterior-posterior positions of the main occluding area was 25.1 ± 6.3 for the control group (n=12) and 16.4 ± 6.1 for the FPD group (n=8), respectively. The t-test revealed a significant difference in the mean value...
of the positions of the main occluding area between two groups (p<0.05) (Fig.2, Fig.3).

2. Comparison of the reproducibility of the main occluding area in the anterior-posterior direction.

The mean values of the anterior-posterior positional variations of the main occluding area were 2.9 ± 1.7 for the control group and 5.4 ± 2.1 for the FPD group, respectively (Fig.4). There was a significant difference in the positional variations of the main occluding area between two groups (p<0.05).

3. The relation between the main occluding area and the occlusal contact

The occlusal contact area below 50 μm in the first molar region was 6.1 ± 2.2 mm² for the control group and 8.8 ± 8.1 mm² for the FPD group, respectively (Fig.5). There was no significant difference between two groups.

The mean ratio of the occlusal contact areas within the main occluding area to those of the whole molar region was 29.3 ± 9.1% for the control group and 23.3 ± 14.4% for the FPD group, showing no significant difference between two groups (Fig.6).

The relation between the ratio of the occlusal contact areas within the main occluding area to those of the whole molar region and the value of Y-axis of centroid coordinate of the main occluding area is shown in Fig.7.

Discussion

1. Position of the main occluding area

The results of this study revealed that the positions of the main occluding area in the FPD group were more posterior to those in the control group. Most of the positions in the control group were on the first molar. These results corresponded to the previous reports.

According to the previous report, the occlusal contact area had influence on the position of main occluding area of the subjects with a natural dentition. In this study, there was no significant difference between the FPD group and the control group on the occlusal contact area. The positions of main occluding area in FPD group were different from those in the control group. There might be other factors to influence on the position of main occluding area. It was shown in the Fig.7 that there may be another factor affecting the position of main occluding area besides occlusal contact area. In the control group, the value of Y-axis of centroid coordinate of the main occluding area was concentrated around 25-30 and the ratio of the occlusal contact area was comparatively high. The value from 25 to 30 on Y-axis was almost equivalent to the position of the first molar. On the
To evaluate the reproducibility of the main occluding area, mean deviation was used. The bar represents mean ± SD. Statistical analysis was performed using t-test to compare between two groups. There was a significant difference between two groups (p<0.05).

The bar represents mean ± SD. Statistical analysis was performed using Mann-Whitney U test to compare between two groups. There was no significant difference between two groups (p>0.05).

The bar represents mean ± SD. Statistical analysis was performed using t-test to compare between two groups. There was no significant difference between two groups (p>0.05).

The relation between the ratio of the occlusal contact areas within the main occluding area and the value of Y-axis of centroid coordinate of the main occluding area.
other hand, in the FPD group, the value of Y-axis of centroid coordinate of the main occluding area was concentrated around 15-20 and some of the patients show the low ratio of the occlusal contact area. The low ratio of the occlusal contact area means that the main occluding area was located where the occlusal contacts were not concentrated.

Most of the positions of main occluding area were on the first molar according to previous reports. Therefore, it was reported that the relation between the position of the main occluding area. Therefore we measured occlusal contact areas in the first molar region and compared between the control and the FPD group (Fig. 5). As a result, there was no significant difference between two groups. Also this result showed the existence of another reason, except occlusal contact areas. why the positions of the main occluding area in FPD group were more posterior to those in the control group.

In previous report about the comparison of the main occluding area between adults and adolescents, it was mentioned that the activity of the masseter muscle predominated over that of the temporal muscle in childhood, but the activity of the temporal muscle predominated over that of the masseter muscle in adults. In this study, the measurement of activity of the masseter muscles was not carried. However, the ratio of the activity of the masseter muscle to the temporal muscle might be almost same between the two groups because all subjects were adults in both groups. Furthermore, it was reported that the biting force of the subjects with a natural dentition was almost same with the biting force of the FPD wearers. However there is a report that the existence of periodontal ligament affected the activity of masticatory muscles because of receptor. The future examination including the measurement of the masticatory muscles activity will be needed.

One of the major different points between natural teeth and FPDs is the existence of periodontal ligaments of the first molar. Supporting ability by periodontal ligaments of the first molar region might influence the position of main occluding area. According to Takamizawa, it was reported that the magnitude of individual biting forces are 730 N for the first molar, 690 N for the second molar, 543 N for the second premolar and 434 N for the first premolar in the case of the lower jaw. The magnitude of individual biting force might be decided by the pain threshold of periodontal tissues in consideration of his method and could evaluate supporting ability of each tooth. It was said that this individual biting force was depended on root surface area. The result of present study suggests that the positions of the main occluding area in the FPD group were more posterior in order to support masticatory force on the second molar, of which root surface area is larger and individual biting force is larger than second premolar. The importance of the periodontal ligament of the first molar was also compatible with the previous report. This report showed the position of main occluding area shifted immediately after alteration of occlusal contacts in the first molar. If the subjects find the main occluding area while repeating mastication, the position of main occluding area did not change immediately.

Also splinting teeth should be discussed as different points between natural teeth and FPDs. Periodontal afferents exhibited receptive fields broadly tuned for the direction of tooth loading. The sensitivity of periodontal ligaments should change if the direction of tooth displacement during mastication changes by splinting. According to the previous study that examined the effect of splinting on the tooth displacement, splinting teeth might not be influenced on the direction of tooth displacement during mastication. Therefore, there might not be influence on the position of the main occluding area by splinting teeth.

2. Reproducibility of the main occluding area

The main occluding areas in the FPD group were less reproducible than those in the control group significantly. Tsuchiya et al. reported the positions of main occluding area in the adults were anterior to those in the adolescents, and exhibited higher reproducibility in the adults than in the adolescents. They described that the adults already had finished the growth and development of the stomatognathic system and had established a stable occlusal relation. In this study, all subjects already had finished the growth and development of the stomatognathic system because subjects in both groups were adults. Therefore, explanations as Tsuchiya et al. described do not support result of this study.

Tokuda et al. investigated the relation between the occlusal contact area and the position of the main occluding area quantitatively in normal dentate subjects. They concluded that one of the important...
factors for reproducibility of the main occluding area was occlusal contact area. However, in this study, though there was a significant difference in the reproducibility of the main occluding area between the control group and the FPD group, there was no significant difference in the ratio of the occlusal contact area included within each test bolus to the occlusal contact area in the whole molar region between two groups (Fig.6). In the study of Tsuchiya et al.,

though there was a significant difference in the reproducibility of the main occluding area between adults and adolescents, there was no significant difference in the ratio of the occlusal contact areas between two groups. This result is similar as a result of our study. Besides occlusal contact area, there might be other factors which stabilized the main occluding area.

The lack of periodontal ligaments in the pontic region may affect the low reproducibility of the main occluding area in the FPD group. In this study, the occlusal sensitivity in pontic region might be transmitted to the periodontal membrane of the abutment teeth (the second premolar, the second molar) in mandible, but it might be also input into the periodontal membrane of the opposing tooth, that is, the first molar in maxilla. Therefore incompatibility of perception might occur between maxilla and mandible, and the incompatibility would decrease reproducibility of the main occluding area. Further studies are needed to clarify these points.

This study clarify that the position of the main occluding area in patients with FPDs locates posterior to that in control subjects. The results of this study may be important information for not only increasing the survival probability of the FPDs but also setting the loading point in the loading tests of the FPD models, photoelastic analysis of the FPD models, or finite element analysis of FPDs.

Conclusion

The positions of the main occluding areas in the FPD group were significantly posterior to those in the control group. The positions of the main occluding areas in the FPD group exhibited less reproducibility compared to those in the control group.

Acknowledgments

This work was supported in part by Grants-in-Aid for Scientific Research form the Ministry of Education, Science and Culture of Japan (No. 19209059).

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