It has become clear that foods crushing is performed in the circumscribed region between functional cusps, that is, at "the main occluding area". However, it is not established to evaluate this area objectively.

The purpose of this study was to establish the positional evaluation of the main occluding area quantitatively and evaluate the positional change depending on the age with this method. The subjects were fifteen adults and ten adolescents who had no stomatognathic disorder. Temporary Stopping was used as test material in this study.

In order to analyze the position of the main occluding area, the projected centroid coordinate of the test material was calculated and projected onto the reference axis. It was possible to quantitatively evaluate positional changes of the main occluding area depending on growth process. As a result, the main occluding areas of the adults were significantly posterior to those of the adolescents and tended to be more stable. There was a significant difference in the occlusal contact area between two groups. The occlusal contact area had great influence on the stability of the main occluding area. However, besides occlusal contact area, there might be other factors which stabilized the main occluding area.

Key words: main occluding area, mastication, occlusal contact area

Introduction

Mastication is one of the most important functions of the stomatognathic system. Therefore, the jaw movements, the masticatory forces, the muscle activities, and the displacements of teeth during mastication have been measured by various kinds of medical electronics. Mastication consists mainly of two stages; the early stage performs food crushing, and the final stage performs food bolus formation. As for measurements of the jaw movements, there are currently many studies about the final stage whose masticatory patterns are stable, while there are few studies which evaluate the early stage whose masticatory patterns are not constant.

Recently, it has become clear that food crushing during mastication is performed in the circumscribed region between functional cusps, that is, at "the main occluding area." In the adults, the main occluding area corresponds to the close occluding area in the intercuspal position, and is often located on the first molar. In addition, according to Nakata et al., it has been made clear that the location of main occluding area depends on dental age because in infant the main occluding area located on the primary second molar during the primary dentition period shifts to the first molar due to the eruption of the first molar and the loss of the primary second molar. The main occluding area is observed in the early stage of chewing which is considered important for mastication and requires stronger masticatory force compared to the final stage (the grinding stage). Since the main occluding area is
observed in the posterior region and in many cases these positions are stable, these areas may influence mastication. Kato et al.\textsuperscript{15,16} reported that occlusal trauma and food impaction were improved by shifting the location of the main occluding area. Therefore, it is useful in diagnosis and examination prior to prosthetic treatments to assess the main occluding area.

The purpose of this study was to quantitatively evaluate positional relations of the main occluding area within the dental arch and make a comparative examination of the main occluding area in the adults and in the adolescents with their undeveloped stomatognathic system in order to observe positional changes of the main occluding area in growth process.

Materials and methods

1. Subjects
In this study, as the subjects enrolled were fifteen adults (nine males, six females with age of 25.4\(\pm\)1.3 years) and ten adolescents (two males, eight females with age of 15.0\(\pm\)1.6 years) who had complete dentition except for the third molar and were free from restorations covered with cusp. All of them had no experience of orthodontic treatments or stomatognathic disorder. Sufficient explanation about this study was given to all the subjects and the parents of the adolescents and then informed consent was obtained prior to this study approved by the Ethics Committee of Tokyo Medical and Dental University.

2. Test material
Temporary filling materials (Temporary Stopping, SHOFU, Japan) of 3.4 mm in diameter and 4.0 mm in length were used as test material in this study.

3. Decision of the main occluding area
In order to determine the main occluding area, Temporary Stopping was put on the center of the tongue of each subject, and then the subjects were asked to bite once at the area they liked (Fig. 1). After that, Temporary Stopping was carefully removed from the oral cavity, and subsequently Temporary Stopping was confirmed by adjusting it to the dental stone model prepared in advance. The position of Temporary Stopping on the dental arch after biting was defined as the main occluding area. The subjects were instructed to perform this step up to five times on left and right sides.

4. The analysis of occlusal contact area
It is reported that the distribution and area of occlusal contact below 50 \(\mu\)m are very important for stabilizing the main occluding area\textsuperscript{19}. Therefore, the occlusal contact areas with moderate biting force at the intercuspal position were recorded with occlusal contact checking materials (Black Silicone, GC Dental Industrial Corp., 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 concentration and thickness of silicone occlusal records were proofread using a steel ball of 50.8 millimeters in diameter according to Nakao’s method\textsuperscript{20}. The areas of occlusal contact below 50 \(\mu\)m were analyzed and pick out with an image processing software (Win ROOF, Mitani Corp., Fukui, Japan). Then, the images of the occlusal contact area and the dentition with Temporary Stopping of the stone cast were superimposed on the personal computer.
5. Standard coordinate

In this study, the standard plane and reference axis were required in order to analyze the position of the main occluding area in the antero-posterior direction. The occlusal plane was defined as the standard plane and the origin of coordinates was chosen at the mid-point between the tops of the disto-buccal cusp of the right and left lower second molar. As the Y-axis (the antero-posterior direction) was defined as the straight line passing through the origin to the mesial edge of the left incisal (hereinafter called lower incisal point). As the X-axis (the left-right direction) was defined the straight line passing through the origin and vertical to Y-axis (Fig. 2). Y-axis was chosen as the reference.

6. Analysis

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

In order to analyze the position of the main occluding area on the dental arch, the centroid coordinate of the Temporary Stopping was calculated with the image processing software. This centroid coordinate was defined as the representative position of the main occluding area. Then, this coordinate was projected onto the reference axis. The ratio of the distance from the origin to the projected centroid coordinate of the Temporary Stopping to the distance from the origin to the mesial edge of the central incisal was calculated. (It was assumed that the distance between the origin and the mesial edge of the central incisal was 100.)

2) The stability of the main occluding area in the antero-posterior direction.

To evaluate the stability of the main occluding area, the representative value was determined by averaging absolute values of differences between the mean value of the projected values of the centroid coordinate of the Temporary Stopping and the projected values of each trial.

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

1. Comparison between two groups of the occlusal contact area below 50 μm in the whole molar region among the subjects: The occlusal contact areas below 50 μm of the whole right and left side molar region were averaged.

2. Comparison of the occlusal contact area below 50 μm included within the main occluding area among the subjects: The ratio of the occlusal contact area below 50 μm included within each Temporary Stopping to the occlusal contact area below 50 μm included in the whole molar region was calculated and a comparison was made between two groups.

Fig. 2. Standard coordinate. The standard plane: the occlusal plane, O: the mid-point between the posterior reference points, Y axis: antero-posterior direction, X axis: left-right direction.
7. Statistical analyses.
The statistical analysis was performed using a commercially available software (SPSS for Windows 12.0, SPSS Inc.). For comparison among the subjects, T test was used except for comparison of the occlusal contact areas below 50 μm in the whole molar region applied to Mann-Whitney U test. A significance level of p<0.05 was chosen.

Results

1) Comparison of the antero-posterior positional relation of the main occluding area among the subjects.

The mean value of the antero-posterior positions of the main occluding area was 23.1±6.5 for the adults and 31.2±9.0 for the adolescents, respectively (Fig. 3). As for the antero-posterior position of the main occluding area in the adults, 20 % of the centroids of the main occluding area were located within the first molar, 33.3 % of those were located within the second molar, and the other 46.7 % of those were located in the contact region between the first and second molars.

On the other hand, 60 % of the centroids of the main occluding area were located within the first molar, 20 % of those were located in the contact region between the second premolar and the first molar, and other 10 % of those were located in the contact region between the first and second molar in adolescents. 10 % of those were located within the second molar (Fig 4, 5, 6). 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). That is, the main occluding areas of the adolescents were significantly anterior to those of the adults.

2) Comparison of the stability of the antero-posterior positional variations of the main occluding area among the subjects.

The mean values of the antero-posterior positional variations of the main occluding area were 3.5±1.4 for the adults and 5.2±2.3 for the adolescents, respectively (Fig.7). There was a significant difference in the positional variations of the main occluding area between two groups (p<0.05). That is, the main occluding areas of adults were more stable than those of the adolescents.

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

1) Comparison of the occlusal contact area below 50 μm in the whole molar region

The occlusal contact area below 50 μm in the whole molar region was 28.2±15.1 mm² for the adults and 16.0±14.0 mm² for the adolescents, respectively (Fig. 8). There was a significant difference between two groups. The adults had larger occlusal contact area than the adolescents.

2) Comparison of the occlusal contact area below 50 μm included in the main occluding area.

The mean ratio of the occlusal contact areas within the main occluding area to those of the whole molar area...
region was 24.5±9.5 % for the adults and 20.8±11.5 % for the adolescents, respectively (Fig. 9). There was no significant difference in the ratio of the occlusal contact areas between two groups.

Discussion

1) Measurement and analysis methods.

Mastication is one of the most important functions of the stomatognathic system. Especially, since the molar region plays an important role in the masticatory function, many researchers have investigated occlusal forms of posterior teeth morphologically and functionally.

Recently, it has become clear that food crushing during mastication is performed in the localized region between functional cusps, that is, "the main occluding area". Furthermore it has been revealed that there were several main occluding areas depending on dental age. However there was no method of evaluating the position of the main occluding area objectively. To reveal the function of the main occluding area, it was important to establish an objective method of...
analysis to evaluate the antero-posterior positional relationship of the main occluding areas.

The purpose of this study was to quantitatively evaluate positional relations of the main occluding area within the dental arch and compare the positional difference of the main occluding area between the adults and the adolescents depending on the growth process.

In order to quantify the antero-posterior positions of the main occluding area within the dental arch, the standard coordinate was established. In this study, the occlusal plane was defined as the standard plane and three reference points were chosen on the lower dental arch. When this coordinate system was applied, there was the possibility that the anterior reference axis deviated away from the actual midline because the anterior reference point was not always placed at the midline and two posterior reference points were not always symmetric. For this reason, the angular difference between X-axis and the straight line passing through two posterior reference points was calculated. The angular difference between the reference axis and
actual midline was 0.88 degrees for the adults and 1.16 degrees for the adolescents, respectively. These angular differences corresponded to the positional differences of 0.03 mm and 0.05 mm on the reference axis, respectively. Taking into consideration the mean value of crown width in the Japanese, this error derived from the coordinate system had little influence on the result.

It is also important to quantitatively evaluate the bucco-lingual relationship of the main occluding area as well as the antero-posterior position of the main occluding area within the dental arch in consideration of masticating or the occlusal relationship during lateral excursions. However, there is no objective method of classifying the occlusal relationships concerning the bucco-lingual direction. The purpose of this study was to evaluate the position of the main occluding area depending on the dental age. It was expected that the positional change of the main occlusal area between the adults and the adolescents was easier to evaluate in the antero-posterior direction than in the bucco-lingual direction. Even if the positional change of the main occluding area between the adults and the adolescents was observed in the bucco-lingual direction, the amount of this positional change might be slight and it did not make much sense in analyzing this difference. So this study evaluated only the positional change of the main occluding area in the antero-posterior direction within the dental arch.

Temporary Stopping was used in order to determine the main occluding area. The reasons for using Temporary Stopping as the test material are following,

1) It was easy to remove Temporary Stopping from the oral cavity without changing the shape after clenching.
2) It was easy to replace Temporary Stopping for the dental stone model prepared in advance and to analyze its position.

In addition, in order to evaluate the position of the main occluding area, the centroid coordinate of Temporary Stopping was used as the typical position of the main occluding area. Not only projected figures of the main occluding area to the standard plane but also three-dimensional forms themselves were important. However, this study addressed only the two-dimensional relation, for the three-dimensional analysis was too complicated. It was useful to establish the method
of using the centroid coordinate of Temporary Stopping as the typical position, because Temporary Stopping crushing behaviors were influenced by biting force and the relation of opposing teeth.

2) Positional changes of the main occluding area depending on growth process.

The results of this study revealed a tendency that the positions of the main occluding area of the adolescents were more anterior to those of the adults. Most of the main occluding areas in the adults were between the first molar and second molar and some of them were on the second molar. These results corresponded to the report of Kato et al.28 The main occluding area is a main area of food crushing and receives the largest masticatory force.

The reasons why the main occluding area is on the first molar are following,

1) There is a relationship between the existence of the first molar and chewing efficiency29,30.
2) The first molar has the largest occlusal surface31.  
3) The first molar has the largest root surface32.  
4) The first molar has the greatest biting force33.  
5) As the arrangement of masseter muscle fiber corresponded to the axis of first molar, these muscles can act efficiently at the first molar34.

For these reasons, the first molar may be suitable for the main occluding area.

However 33.3% of the main occluding areas of the adults were on the second molar. The first molar is suitable for the main occluding area so far as tolerance to forces is concerned. In addition, sensations of the periodontal ligament strongly triggered inhibit masticatory movements as well as jaw opening reflexes35,36. The first molar is expected to receive considerable occlusal force because the first molar is the first to erupt among posterior teeth, which means that the first molar has the longest time for abrasion. This abrasion may prevent the periodontal ligament from being excessively loaded. This control system prevents tooth and periodontal ligament from being damaged. However, the fact that some of the main occluding areas were on the second molar may reflect that the position of the main occluding area was related to the number and position of the receptor, the threshold level, the resorption of the root, besides tolerance to force. These reasons explained why some of the main occluding areas were located on the second molar.

On the other hand, most of the main occluding areas of the adolescents were located on the first molar. However, some of them were dispersed from the second premolar toward the second molar. This result corresponded to the report of Nakata et al.18 on the main occluding area of the stage IV A. The positions of the main occluding area of the adolescents were located significantly more anterior than those of the adults, though most of the main occluding areas of the adolescents were on the first molar. This fact can be explained as follows. Though the adolescents had already completed eruption of permanent dentition, the root of the second molar has just completed. The age of the completion of the root of the second molar is usually 14-16 years old, that is, the age of the adolescents. As eruption of the second premolar is earlier than that of the second molar, the topesthesia at the second premolar may be superior to that of the second molar. Moreover, the functional adjustment of the second premolar may be done earlier than that of the second molar. In addition, the second premolar is successive tooth of the deciduous second molar which plays an important role in mastication (the main occluding area) in the primary dentition period18. Therefore, the main occluding areas of the adolescents were located anterior to those of the adults.

As for the stability of the main occluding area in the antero-posterior direction, the main occluding areas of the adults were more stable than those of the adolescents.

The factors of mastication include the form of the occlusal surface, the masticatory muscle activity, the jaw movement, the occlusal relationship during mastication, the control of the central nervous system and the sensitivity from the peripheral nervous system from the periodontal ligament. The adults already had finished the growth and development of the stomatognathic system and established a stable occlusal relation which harmonized with jaw movements with occlusal adjustment by habitual functional movement. In addition, in the adults the masseter muscle which is placed almost at the same position of molars in the antero-posterior direction is more active than temporal muscle37. For all of these reasons, the main occluding area of the adults was stable.

Meanwhile in adolescents with an undeveloped stomatognathic system, there was the possibility of luck of stability in the muscle activity because of incompleteness of the occlusal relation and condition of the masticatory muscle.

Though, in childhood, the activity of the masseter muscles predominates over that of the temporal muscle, the activity of the temporal muscle predominates over that of the masseter muscle in adults. So, it is a
time to change from the temporal muscle predominance to the masseter muscles in adolescents and this alternation is related to the influence of morphological changes associated with growth of mandible. In addition, during the lateral excursion in childhood, the displacement of the condyle on the working side is significantly larger than that of adults and the intermaxillary axis does not converge around the condyle as it does in adults. This means that as muscle and ligament around the temporomandibular joint are immature, there is little limitation of movement at the condyle in opposition to adults. This fact might influence the instability of the main occluding area in adolescents.

Mori proved the followings experimentally.

1) The topesthesia of the teeth was found to be more accurate in mesially located teeth than in distally located teeth.

2) The topesthesia of the permanent teeth decreased as the root formation developed.

These results can be interpreted by thinking that exquisite topesthesia of the teeth identifies food behavior and blunt topesthesias of the teeth performs food crushing during mastication. Thus, it appeared that in the adults food was crushed with posterior teeth, especially the first molar and in the adolescents the main occluding area shifted to more posterior teeth depending on the development of stomatognathic system.

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

There was a significant difference in the occlusal contact area in the whole molar region between the two groups, that is, the adults had larger occlusal contact area than the adolescents. The occlusal contact area in the whole molar region increased with age due to abrasion of teeth during habitual functional movements and this fact might result in the stability of occlusal relationship.

In addition, Tokuda et al. investigated the relation between the occlusal contact area and the main occluding area quantitatively. They reported that the groups whose biting regions of Temporary Stopping were coincident with all the five trials had significantly larger occlusal contact area which was included in the biting regions than those of group whose biting regions of Temporary Stopping were coincident with four or less trials. That report concluded that one of important factors for position of the main occluding area was occlusal contact area.

In other words, for the adults, the main occluding area worked as the important region for mastication for a long time and resulted in having a larger occlusal contact area, compared to the adolescents. The occlusal contact area had great influence on the stability of the main occluding area. However, since there was no significant difference in the ratio of the occlusal contact area below 50 µm included within the main occluding area between two groups, besides occlusal contact area, there might be other factors which stabilized the main occluding area.

Conclusion

1. The main occluding areas of the adolescents were significantly anterior to those of the adults and exhibited lack of stability compared to those of the adult.

2. There was a significant difference in the occlusal contact area between two groups. The occlusal contact area had great influence on the stability of the main occluding area. However, besides occlusal contact area, there might be other factors which stabilized the main occluding area.

References


