

Original Article

Distribution of main occluding area and associated factors in adolescents

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Abstract

Purpose: This study was designed to investigate the distribution of the main occluding area in adolescents. Furthermore, the importance of the main occluding area was clarified by examining its interrelationship with oral function and craniofacial morphology.

Methods: A total of 102 patients were included in this study. The main occluding area was identified using a previously described method. Maximum occlusal force, occlusal contact area, lip-closing force, tongue pressure, and masticatory efficiency were measured to evaluate oral function. Craniofacial morphology was assessed using lateral cephalography.

Results: In terms of the degree of consistency of the main occluding area, the proportion of cases in which two matches were obtained among three trials was the highest. The most common main occluding area was the first molar. Regarding the anteroposterior position of the hyoid bone, the anteroposterior distance between the hyoid bone and the menton (Me-H) was significantly shorter in the group where the first molar was used for occlusion, relative to the group in which second premolar was used.

Conclusion: The main occluding area in adolescents was less stable than that in adults and older adults; however, first molars accounted for most of the main occlusion areas, suggesting that the position of the hyoid bone might play a role in establishing their location.

Keywords: adolescent, craniofacial morphology, main occluding area, oral function

Introduction

One of the most important considerations when discussing mastication and occlusion is the “main occluding area” [1,2]. The crushing of food during mastication does not occur randomly in the molars, but is concentrated within an occlusion area of only a few square millimeters. This main occluding area is defined as “the area of closest occlusal contact in healthy natural dentition” and in adults, it is mainly located between the inner slopes of the functional cusps of the upper and lower first molars. In other words, the main occluding area is considered key for effective mastication, receiving the greatest occlusal force during the first stroke of mastication. It has been reported previously that this main occluding area exists not only in the natural dentition of adults but also in the mixed dentition of children, as well as in the partially edentulous dentition of older adults. Goto et al. [3] reported that in the partially edentulous dentition of older patients with missing molars, the main occluding area moved to the first molars immediately after implant treatment to restore the occlusal contact of the molars. During life, seamless oral function management extends from the development of oral function in childhood to the maintenance of oral function in old age. However, the distribution of the main occluding area during the transition phase in adolescence just before completion of the adult occlusal relationship remains unclear. In addition, the relationship between oral function and the craniofacial morphology of each individual,

which is important for understanding the main occluding area, requires further exploration.

The present study was designed to investigate the distribution of the main occluding area in adolescents. Furthermore, to better clarify the significance of this area, its relationships with oral function and craniofacial morphology were examined.

Materials and Methods

Participants

A total of 102 patients (51 males and 51 females; age 12-20 years, mean 16.0 ± 2.1 years) were included in this study. All had been undergoing regular checkups since childhood at general dental clinics and had attended between March 2021 and April 2022 after the onset of second molar eruption. Patients undergoing orthodontic treatment and those who had completed such treatment were excluded. The selected patients were all adolescents who met the inclusion criteria.

Identification of the main occluding area

The main occluding area was identified using a temporary filling material (Temporary Stopping, GC, Tokyo, Japan; 3.4 mm diameter) according to a method described previously [1]. A piece of temporary stopping material was placed on the tongue of each patient, and the patient was asked to bite it once without specifying the left or right side (Fig. 1a). This step was performed three times for each participant, intraoral photographs were taken, and the stopping material was collected after biting. The stopping material was then fitted to a diagnostic model, and the main occluding area were identified by comparing them with the intraoral photographs based on whether they contained the same cusps and crowns. In the present study, if three or two of the trials matched for the same side and tooth type, that area was considered to be the main occluding area for each subject.

Assessments of oral function

Maximum occlusal force, occlusal contact area, lip-closing force, tongue pressure, and masticatory efficiency were measured to evaluate oral function. The maximum occlusal force and occlusal contact area were measured using a Dental Prescale II (GC). The patients were seated in a dental chair and instructed to bite a Prescale sheet for 3 s. Maximum occlusal force was analyzed using a bite-force analyzer (GC). The lip-closing force was measured using a lip-closing force measuring device (Lipplekun, Shofu, Kyoto, Japan). Tongue pressure was measured using a JMS tongue pressure measuring device (TPM-02; GC) three times, and the mean value was calculated. Masticatory efficiency was measured in terms of glucose elution using a masticatory efficiency testing device (Glucosensor GS-II; GC). Each measurement was performed by a trained examiner.

Assessments of craniofacial morphology

Craniofacial morphology was assessed using lateral cephalography (Vera-viewepocs 3DF X550 100CP; Morita, Osaka, Japan). The participants were instructed to stand so that the Frankfort plane was parallel to the floor. Ear rods were inserted into the bilateral external auditory canals to fix the head. The patients were asked to bite in the intercusp position, and photographs were taken. Using these photographs, the measurement points were plotted by a dentist trained in cephalometric analysis (T.G.) and confirmed by a skilled dentist (Y.M.) (Fig. 1b). Each cephalometric measurement was performed using analytical software (Win Ceph Ver. 11; Rise, Sendai, Japan). The SNA (angle formed by the sella-nasion line and nasion-A line), SNB (angle formed by the sella-nasion line and nasion-B

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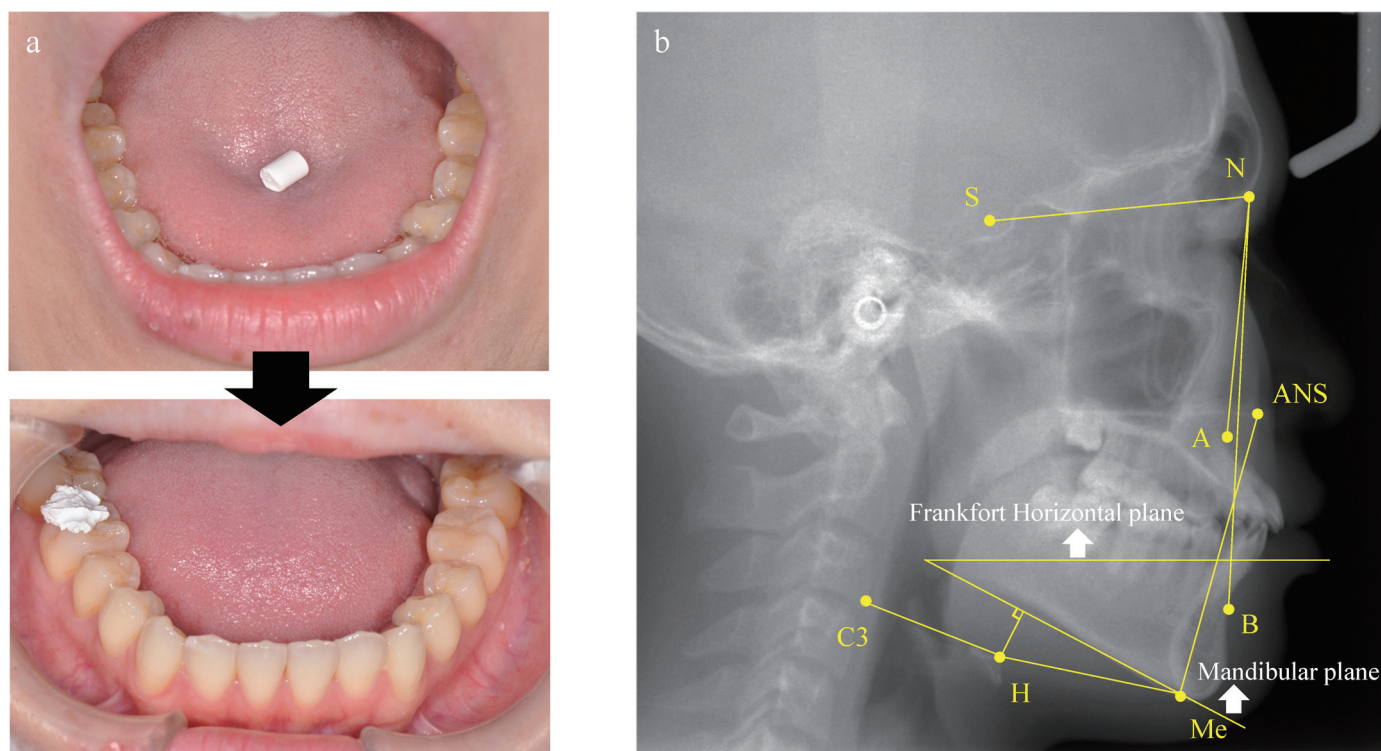


Fig. 1 Identification of the main occluding area (a) and cephalometric landmarks (b)

Table 1 Main occluding areas in the three trials

Trial	Anterior region (%)		First premolar region (%)		Second premolar region (%)		First molar region (%)		Second molar region (%)	
	right	left	right	left	right	left	right	left	right	left
1st	3 (2.9)	0 (0)	0 (0)	0 (0)	3 (2.9)	5 (4.9)	39 (38.2)	37 (36.3)	11 (10.9)	4 (3.9)
2nd	1 (1.0)	1 (1.0)	1 (1.0)	0 (0)	1 (1.0)	6 (5.9)	44 (43.1)	35 (34.3)	7 (6.9)	6 (5.8)
3rd	2 (2.0)	2 (2.0)	0 (0)	0 (0)	1 (1.0)	6 (5.9)	36 (35.3)	34 (33.2)	14 (13.7)	7 (6.9)

Numbers in parentheses indicate percentages in each trial.

line), ANB (difference between the SNA and SNB angles), FMA (angle formed between the mandibular plane and Frankfort horizontal plane), ANS-Me (distance from the anterior nasal spine to the menton), MP-H (distance from the mandibular plane to the hyoid bone), C3-H (distance from the third cervical vertebra to the hyoid bone), and Me-H (distance from the hyoid bone to the menton) for the hyoid position were used for analysis.

Statistical analysis

To compare cephalometric values and oral function in each main occluding area, normality was first checked using the Shapiro-Wilk test, and if normality was confirmed, one-way analysis of variance (ANOVA) with Bonferroni *post-hoc* test was performed. If not, the Kruskal-Wallis test with Dunn's multiple comparison *post-hoc* test was performed. In order to examine the influence of cephalometric values and oral function on the position of the main occluding area, multinomial logistic regression analysis was performed. One group in whom the main occluding area was the second premolar was set as the reference category, while other main occluding area were set as the dependent variable. Each cephalometric value and oral function was set as an independent variable, with the adjustment factor of age set as a covariate. SPSS version 25.0 (IBM, Armonk, NY, USA) was used for statistical analysis, and differences at $P < 0.05$ were considered to be significant.

Results

Table 1 presents the results for the main occluding areas in the three trials. The most common main occluding area was the first molars in the three trials, and the proportions of right (36-44 cases) and left (34-37 cases) of that were similar. Table 2 shows the degree of consistency of the main occluding areas and their distribution in each tooth age group. The propor-

tion of cases where the two areas matched in the three trials was highest in both the IIIC and IVA-IVC periods (eight cases [72.7%] in the IIIC period, 57 cases [62.6%] in the IVA-IVC period, and 65 cases [63.7%] in total [Table 2a]). In 14 cases (13.7%), the main occluding area showed no matching at all, and no specific site could be identified. Further, the most common main occluding area was the first molars in both stage IIIC and IVA-IVC (eight cases [88.9%] in stage IIIC, 59 cases [74.7%] in stage IVA-IVC, and 67 cases [76.1%] in total [Table 2b]). The second most common main occluding area were the second molars (stage IIIC, 11.1%; stage IVA to IVC, 15.2%) and second premolars (stage IVA-IVC: 7.6%).

Table 3 presents the oral function values for each main occluding area. Two patients in whom the main occluding area was an anterior tooth were excluded. Although oral function showed no uniform trend, tongue pressure and masticatory efficiency were maximal in the first molar group. However, no significant differences were observed between the groups. Table 4 presents the values of cephalometric parameters for each main occluding area. The FMA showed a tendency for the main occluding area to be higher in the molar group than in the second premolar group; however, none of the differences were significant. Regarding the anteroposterior position of the hyoid bone, Me-H was significantly shorter in the first molar group than in the second premolar group ($P = 0.046$). With respect to the results of age-adjusted multinomial logistic regression analysis of cephalometric values, only Me-H was identified as a significant independent variable in the first premolar group (odds ratio, 0.770; 95% confidence interval, 0.601-0.987; $P < 0.05$). When oral function was set as an independent variable, none of the variables were selected as significant.

Discussion

In the present study, the location of the main occluding area was identified in accordance with a previous study [1]. Several studies have investigated

Table 2 Identification of main occluding area

(a) Degree of consistency of the main occluding area in the three trials

Location	3 of the 3 trials (%)	2 of the 3 trials (%)	No matching site (%)
Hellman's dental age			
IIC (<i>n</i> = 11)	1 (9.1)	8 (72.7)	2 (18.2)
IVA, IVC (<i>n</i> = 91)	22 (24.2)	57 (62.6)	12 (13.2)
Total (<i>n</i> = 102)	23 (22.6)	65 (63.7)	14 (13.7)

(b) Location of the main occluding area

Location	Anterior region (%)	First premolar region (%)	Second premolar region (%)	First molar region (%)	Second molar region (%)
Hellman's dental age					
IIC (<i>n</i> = 9)	0 (0)	0 (0)	0 (0)	8 (88.9)	1 (11.1)
IVA, IVC (<i>n</i> = 79)	2 (2.5)	0 (0)	6 (7.6)	59 (74.7)	12 (15.2)
Total (<i>n</i> = 88)	2 (2.3)	0 (0)	6 (6.8)	67 (76.1)	13 (14.8)

Numbers in parentheses indicate percentages in each trial.

Table 3 Oral function values in each main occluding area

Location	Second premolar group	First molar group	Second molar group	No matching site group
Oral function				
Maximum occlusal force (N)*	999.4 ± 572.3	910.0 ± 390.8	861.1 ± 377.0	1120.5 ± 446.5
Occlusal contact area (mm ²)*	29.3 ± 16.4	27.0 ± 10.8	27.2 ± 11.4	33.9 ± 13.4
Lip-closing force (N)*	7.8 ± 2.6	8.4 ± 2.5	8.5 ± 3.4	6.9 ± 1.9
Tongue pressure (kPa)*	28.8 ± 10.5	32.8 ± 9.8	31.8 ± 8.0	29.3 ± 11.7
Masticatory efficiency (mg/dL)*	157.3 ± 37.6	172.0 ± 66.4	163.9 ± 50.6	168.3 ± 57.5

*Mean ± standard deviation (SD)

Table 4 Cephalometric parameters in each main occluding area

Location	Second premolar group	First molar group	Second molar group	No matching site group
Cephalometric				
SNA (degree)*	79.8 ± 3.2	79.3 ± 3.8	79.6 ± 2.4	78.9 ± 3.1
SNB (degree)*	80.2 ± 3.3	77.8 ± 3.3	78.1 ± 3.2	78.0 ± 3.6
ANB (degree)*	-0.5 ± 1.8	1.5 ± 2.4	1.5 ± 2.0	0.9 ± 1.8
FMA (degree)*	24.5 ± 6.5	26.5 ± 6.1	26.4 ± 5.3	27.5 ± 5.9
ANS-Me (degree)*	70.3 ± 6.0	70.8 ± 5.6	71.8 ± 4.8	72.9 ± 5.4
MP-H (mm)*	9.6 ± 4.7	12.0 ± 5.3	13.8 ± 4.0	13.2 ± 3.4
C3-H (mm)*	35.2 ± 2.8	37.3 ± 4.3	39.2 ± 4.4	35.7 ± 4.5
Me-H (mm)*	48.1 ± 6.7	40.1 ± 5.2	42.7 ± 4.6	43.2 ± 5.5

*Mean ± SD. **Significance of differences was assessed using one-way ANOVA with Bonferroni *post-hoc* test; *P* < 0.05

the number of trials required to identify the main occluding area. Abe et al. [1] studied the distribution of the main occluding area in adults by having the examiner designate either the left or the right side in five trials. Tsuchiya et al. [4] also studied the distribution of the main occluding area using a similar method. In a study of older patients, Goto et al. repeated the procedure three times on the side where an implant prosthesis had been placed and judged the area as the main occluding area if two or more areas matched [2]. Nakatsuka et al. [5] also employed a similar method.

In contrast, for children, Gisel [6] reported that a habitual chewing side becomes established by the age of 4 years. It has been reported that chewing during mastication was limited to a single tooth among the entire dentition. This study used a method for determining the main occluding area involving three trials without specifying left or right laterality.

Regarding the degree of consistency of the main occluding area in the three trials, the proportion of cases in which two times matched in the three trials was highest among the adolescents studied here, at 63.7%. In a previous study of adults with a mean age of 31.4 years, the highest percentage was 82% for three matchings in three trials. Similarly, in three trial groups of older patients with missing teeth or those after prosthodontic treatment, the highest percentages for three matches were 73% and 87%, respectively

[3]. Compared to these values, the degree of consistency among adolescents in the present study was low, indicating that the bite rate in adolescents was not stable. It has been reported that a close occlusal relationship is important for establishing a stable main occluding area [1]. This close occlusal relationship requires a large occlusal contact area, and there is a possibility that such a close occlusal relationship is not established in adolescents, just before or at the beginning of completion of permanent dentition, relative to adults and the elderly. It has been reported that the occlusal surface morphology of the tooth crown immediately after eruption does not necessarily have a rational relationship adapted to the individual; however, a balanced occlusal relationship becomes established after a certain period through masticatory function. Indeed, in children, the occlusal contact area of the first molars has been reported to show an increasing tendency with age. Although there have been no reports of changes in the occlusal contact area during adolescence, it is possible that a close occlusal relationship in the dentition had not been established, even in the adolescents aged 12-20 years who participated in the present study. At the same time, it is possible that the growth and development of the oral and maxillofacial systems, including the masticatory muscles, may have had an impact.

Regarding the distribution of the main occluding area, the most common

main occluding area were the first molars in adults or older adults with restored second molars after prosthetic treatment (54-56%). In contrast, in the present study, the proportion of first molars as the main area was higher in adolescents (76.1%) than in previous studies. The proportion of second molars as the main occluding area was also relatively low compared with the results obtained for older adults. The highest proportion of first molars in the distribution of the main occluding area was attributed to their ability to exert the greatest occlusal force and to be positioned so that the combined occlusal forces generated were directed towards the long axis of the tooth, making them more suitable for force exertion. In addition to these anatomical factors, it has been reported that earlier tooth eruption before other molars and a long period of masticatory involvement among permanent teeth were identified as functional factors. Accordingly, considering that the participants of this study were adolescents, both anatomical and functional factors may have influenced the results. In addition, first molars are involved in mastication for the longest time compared to other teeth and can exert the greatest occlusal force, although at the same time they are at risk of excessive force application. Tsuchiya et al. [4] reported that the imbalance between the force applied to first molars and their load-bearing capacity and sensory feedback indicated that the main occluding area was the second molars. However, in some cases, the roots of the second molars are not yet complete in adolescents, and this feedback mechanism does not work sufficiently. Therefore, the proportion of individuals in whom second molars are the main occluding area may be low, as observed in the present study, and the main occluding area may be located in the first molars. Adolescence is a period during which awareness of self-health management is crucial, and is also reported to be a period during which lifestyle habits are easily disrupted and awareness of oral health is likely to decline. Based on the present results, it is imperative to undertake meticulous observation of occlusal relationships, including that of the first molars, in order to establish the occlusal relationship during adolescence.

Regarding the relationship between oral function and the main occluding area, previous studies have examined the occlusal contact area and occlusal force within the main occluding area, but not from the perspective of the entire oral-maxillofacial system. Tanigawa et al. [7] investigated the relationship between the distribution of the main occluding area and masticatory efficiency; however, that study evaluated subjective masticatory efficiency using a questionnaire, and no objective means of determining the masticatory efficiency index was reported. In the present study, there were no significant differences between any of the groups, and no significant effects of the main occluding area on oral function were observed in the entire dentition; however, the first molar group tended to show higher values for tongue pressure and masticatory efficiency. In terms of craniofacial morphology, the Me-H was significantly shorter in the first molar group than in the second premolar group. The main occluding area tended to be distributed most commonly in the first molar. Mastication is a functional movement performed by the coordinated movement of surrounding tissues such as the lips, tongue, and buccal mucosa, in addition to the teeth [8-10]. Furthermore, the main occluding area also plays an important role in this respect. Given these factors, the present findings suggest that the tongue, and particularly the position of the hyoid bone, may influence the establishment of the main occluding area. To date, no studies have investigated the establishment of the main occluding area from the perspective of the function and structure of the oral-maxillofacial system other than the occlusal surface; therefore, further studies are needed.

The influence of sample size must be considered when interpreting the results of this study. The numbers of samples in which the main occluding area was the second premolar, first molar, and second molar were 6, 67, and 13, respectively, indicating a large bias. As this was a fact-finding study of adolescents, being the first of its kind, it was difficult to obtain a sufficient number of samples from each group for statistical examination. However, as the study represented a comprehensive examination of all adolescent patients attending a dental clinic and excluded any outside the inclusion criteria, the results are thought to be highly significant. More detailed large-scale studies are required to examine the influence of oral function and craniofacial morphology on the main occluding areas, considering stratification by age.

It has been shown here that the main occluding area in adolescents is

less stable than that in adults and older adults; however, occlusion was shown to occur mainly in the first molars, suggesting that the position of the hyoid bone might play a role in establishing their location.

Abbreviations

ANB: difference between the SNA and SNB angles; ANOVA: analysis of variance; ANS-Me: distance from the anterior nasal spine to the menton; C3-H: distance from the third cervical vertebra to the hyoid bone; FMA: angle formed between the mandibular plane and the Frankfort horizontal plane; Me-H: distance from the hyoid bone to the menton; MP-H: distance from the mandibular plane to the hyoid bone; SNA: angle formed by the sella-nasion line and nasion-A line; SNB: angle formed by the sella-nasion line and nasion-B line

Ethical Statements

This study was conducted with approval from the Ethics Review Committee of Tokushima University Hospital for Life Science and Medical Research (approval no. 3912) and in accord with the Declaration of Helsinki. Informed consent was obtained after fully explaining the experimental content to the patients or their guardians.

Conflicts of Interest

The authors have no competing interests to declare.

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Author Contributions

TG: conceptualization, investigation, methodology, data curation, project administration, formal analysis, writing original draft, and writing review and editing; YM: conceptualization, investigation, methodology, data curation, project administration, formal analysis, writing original draft, and writing review and editing; TI: conceptualization, methodology, data curation, project administration, writing original draft, and writing review, editing and supervision. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statements

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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