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Relationships between maxillofacial morphology and oral function on the habitual and non-habitual chewing sides

Tatsuhiro Suzuki[1]*, Naoki Asanuma[2], Yuko Watarai[2], Fumi Mizuhashi[1,2]

[1]Functional Occlusal Treatment, The Nippon Dental University Graduate School of Life Dentistry at Niigata, Niigata, Japan
[2]Department of Removable Prosthodontics, The Nippon Dental University School of Life Dentistry at Niigata, Niigata, Japan

ORCID
Tatsuhiro Suzuki
https://orcid.org/0009-0001-6814-0443
Naoki Asanuma
https://orcid.org/0009-0004-4928-9535
Yuko Watarai
https://orcid.org/0000-0002-4914-211X
Fumi Mizuhashi
https://orcid.org/0000-0002-0699-0637

PURPOSE. This study aimed to investigate the relationships between reference planes and oral functions on the habitual and non-habitual chewing sides. **MATERIALS AND METHODS.** Thirty-four subjects with no abnormalities in the maxillofacial region and oral functions were enrolled in this study. Relationships between angles between the reference plane (Frankfort horizontal plane, Camper's plane, and occlusal plane) and masticatory performance, occlusal force, and occlusal contact area by chewing side were examined. Regarding the measurement of reference planes, a creatively modified three-plane measuring device was used to measure angles between the reference planes. Images were taken from the right and left sides and angles between reference planes were measured. Masticatory performance was examined by measuring the amount of glucose extracted from a gummy jelly on the habitual and non-habitual chewing sides separately. Occlusal force and occlusal contact area were measured by occluding against pressure-sensitive film, and values on the habitual and non-habitual chewing sides were calculated and analyzed. **RESULTS.** The angle between Camper's plane and the occlusal plane correlated with masticatory performance on both the habitual chewing side (r = 0.47, $P < .01$) and the non-habitual chewing side (r = 0.36, $P < .05$). A correlation was observed between masticatory performance and occlusal force on the habitual chewing side (r = 0.46, $P < .01$). **CONCLUSION.** Masticatory performance became higher as occlusal plane inclination increased. This result represents essential knowledge for prosthetic treatment. [J Adv Prosthodont 2024;16:278-89]

KEYWORDS
Reference plane; Masticatory performance; Occlusal force; Occlusal contact area; Chewing side

INTRODUCTION

The human body and face develop and grow in broad symmetry.[1,2] However, no one has a completely symmetrical face.[2,3] The lines connecting the right

Corresponding author
Tatsuhiro Suzuki
Functional Occlusal Treatment, The Nippon Dental University Graduate School of Life Dentistry at Niigata, 1-8 Hamaura-cho, Chuo-ku, Niigata 951-8580, Japan
Tel +81 25 267 1500
E-mail tatsu@ngt.ndu.ac.jp

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and left pupils, ala nasi, and angle of mouth are thus not parallel, respectively. A significantly more active side of the human body is thus present even when each side of the human body works in a coordinated manner, and the human body and face would thus be asymmetrical.[4,5]

Humans unconsciously eat foods on the side for which chewing is easier. The side on which chewing is easier is defined as the habitual chewing side.[6-8] Masticatory performance and occlusal force are reportedly significantly higher on the habitual chewing side than on the non-habitual chewing side.[6,8-12] However, the habitual chewing side shows greater susceptibility to caries and attrition, and more easily suffers from aggravation of the symptoms of temporomandibular joint disorders.[13,14]

Research into oral functions and facial profile has been performed using cephalometric radiography.[15-18] Studies on oral function and maxillofacial morphology have reported that masticatory performance, occlusal force, and occlusal contact area are related.[16,19,20] However, relationships between reference planes such as the Frankfort horizontal plane (FP), the Camper's plane (CP), and the maxillary occlusal plane (OP) have not been clarified on the chewing side. Although efficient mastication might be presumed to occur on the habitual chewing side, no research has yet confirmed relationships between the occlusal plane and oral functions on the habitual chewing side. Determination of the occlusal plane is necessary for the production of accurate prostheses.

The null hypothesis for this study was that no relationships exist between maxillofacial morphology and oral functions. The aim of this study was to investigate the relationships between reference planes and oral functions on the habitual and non-habitual chewing sides.

MATERIALS AND METHODS

Thirty four subjects (17 men, 17 women; mean age 23.2 ± 2.6 years) participated in this study. Subjects were students and staff of The Nippon Dental University School of Life Dentistry at Niigata. Inclusion criteria for subjects were: 1) no abnormalities in the maxillofacial region; and 2) no missing teeth other than the third molars. Exclusion criteria were: 1) any previous or current orthodontic treatment; or 2) any history of dental treatment for occlusal surfaces. This study was approved by the Ethics Committee of The Nippon Dental University School of Life Dentistry at Niigata (approval no. ECNG-R-490) and was conducted after obtaining written consent from all subjects.

The angles formed by each reference plane (FP, CP, and OP) were measured using a three-plane measuring device (Fig. 1). The occlusal plane guide (Nippon Dental University style occlusal plane guide; Takamiya Kogyo, Saitama, Japan) (Fig. 1a, d) was attached

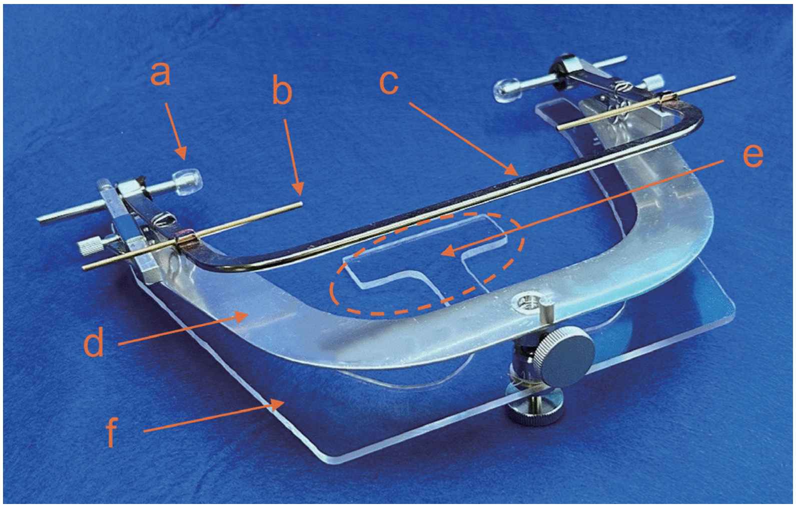

Fig. 1. The three-plane measuring device used in the present study. (a) Ear rod. This is the posterior reference point of the Frankfort horizontal plane and Camper's plane. The ear rods were inserted into the opening of external acoustic meatus. (b) Infraorbital point. This is the anterior reference point of the Frankfort horizontal plane. (c) Frankfort horizontal plane. The Frankfort horizontal plane connects the ear rod (a) and the infraorbital point (b). (d) Camper's plane. The Camper's plane connects the inferior margin of the ala nasi and the inferior margin of the tragus. (e) The area touched by the maxillary central incisor and the right and left molars. (f) Maxillary occlusal plane. In this study, the occlusal plane was set at the maxillary occlusal plane.

to this device. The FP, CP, and OP can be referenced simultaneously using this device. The FP was defined as the plane connecting the infraorbital point and the superior margin of the opening of the external acoustic meatus (Fig. 1c).[21] The CP was defined in this study as the plane connecting the inferior margin of the ala nasi and the inferior margin of the tragus (Fig. 1d). The OP was defined in this study as the plane connecting the maxillary central incisor and the right and left maxillary molars (Fig. 1e, f). Subjects were instructed to keep the plate (Fig. 1e) by fingers with touching the maxillary central incisor and the right and left molars (Fig. 2B). To measure angles between the three planes (FP, CP, and OP; Fig. 2A), images were taken from the right and left with the distance between the digital camera (EX-ZRA1100; Casio, Tokyo, Japan) and ear rod fixed at 20 cm (Fig. 2B). After images were obtained, the angles formed by each reference plane were measured using image processing software (Image J ver. 1.53t; National Institutes of Health, Bethesda, MD, USA). Images were taken and the measurements were made by one author (T.S.). Measurement parameters were the angle between the FP and CP (FP-CP), the angle between the CP and OP (CP-OP), and the angle between the FP and OP (FP-OP). CP-OP was considered plus value under the conditions in which the distance between the upper and lower anterior teeth was small and that between the posterior teeth was large (posteriorly inclined; Fig. 2Ca). CP-OP was considered minus value when the distance between the upper and lower anterior teeth was large and that between the posterior teeth was small (anteriorly inclined; Fig. 2Cb).

Masticatory performance was examined using gummy jelly (Glucolam; GC, Tokyo, Japan) as a test food (Fig. 3A). The amount of glucose extracted from 2 g of gummy jelly was measured using a glucose-measuring device (GS-II; GC, Tokyo, Japan) (Fig. 3B).[22,23] First, the gummy jelly was allowed to be chewed freely before the start of measurements to decide the habitual chewing side and familiarize the subject with the gummy jelly as the test food.[22,23] The gummy jelly was then chewed for 20 seconds on one side (Fig. 3C), and the subject was instructed to add 10 ml of water to their mouth (Fig. 3D). The water in the mouth was then spit out into a filtered cup together with the

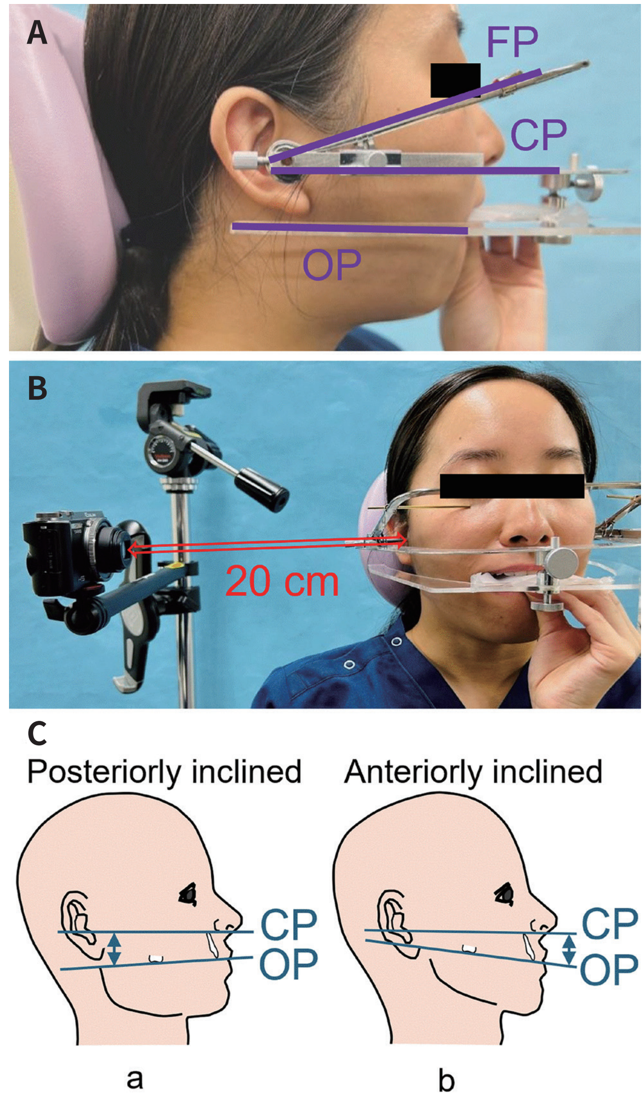

Fig. 2. Measurement of reference plane. (A) Reference plane for measurement. FP; Frankfort horizontal plane. CP; Camper's plane. OP; Maxillary occlusal plane. (B) The photographing condition of the three-plane measuring device and a digital camera. The images were taken with the digital camera 20 cm from the ear rod, with the ear rod placed at the center of the digital camera lens. (C) Classification of angles between the CP and OP. (a) Posteriorly inclined indicates the distance between the upper and lower anterior teeth was small and that between the posterior teeth was large. (b) Anteriorly inclined indicates the distance between the upper and lower anterior teeth was large and that between the posterior teeth was small.

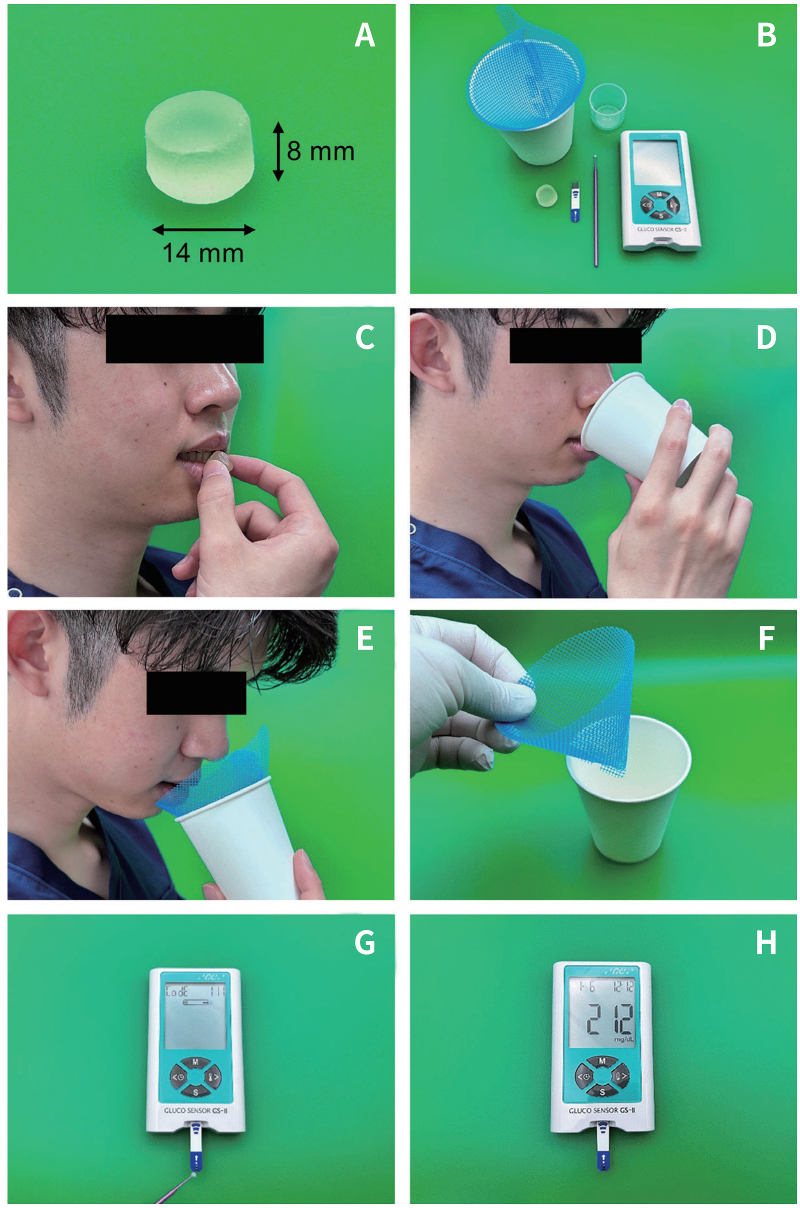

Fig. 3. Method of measuring masticatory performance with gummy jelly. (A) The gummy jelly test food (Glucolam). (B) Equipment used for masticatory performance test. (C) Chewing of the gummy jelly. (D) Pouring 10 ml of water into the mouth. (E) Chewed gummy jelly and included water being spit out into a cup with a filter. (F) Removal of gummy jelly filtered from the spat-out water. (G) Extracted glucose was attached to a brush and measured with a glucose-measuring device (GS-II). (H) Results from the glucose-measuring device.

gummy jelly (Fig. 3E), and the filtrate was stirred for 10 seconds (Fig. 3F). The filtrate was applied to the chip of the glucose-measuring device (Fig. 3G), and the amount of glucose extracted was measured (Fig. 3H). Measurements were taken twice each on the habitual and non-habitual chewing sides, and the average values of the two measurements were used for analysis. The measurement interval was 2 minutes.

Occlusal force and occlusal contact area were measured using a pressure-sensitive film (Dental Prescale II; GC, Tokyo, Japan) (Fig. 4A) and an occlusal force measurement system (Bite Force Analyzer; GC, Tokyo, Japan).[24,25] Before measurements, clenching practice was performed. The subject was seated on the dental unit and positioned with the FP parallel to the floor. The subject was instructed to perform maximum clenching of the pressure-sensitive film for 3 seconds in the maximal intercuspal position. Measurements were performed three times within a measurement interval of 2 minutes. Occlusal force and occlusal contact area were measured using the automatic cleaning function of the occlusal force analyzing system (Fig. 4B). The average values of the three measurements from each of the habitual and non-habitual

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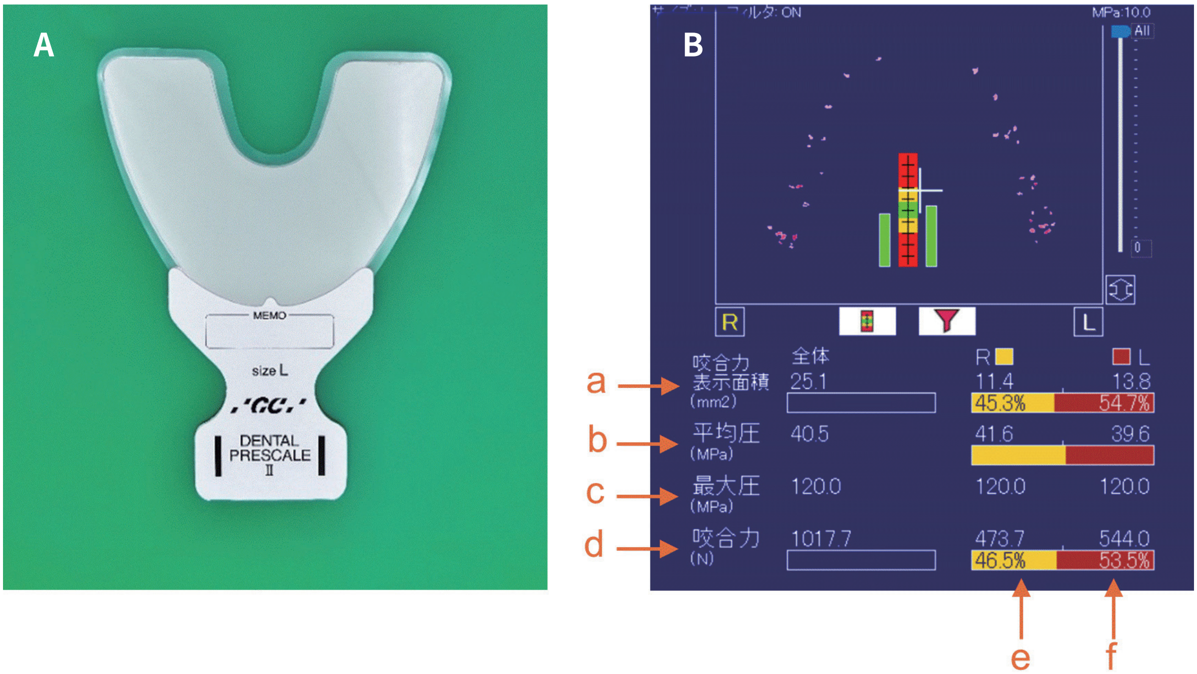

Fig. 4. Instrument and measurement screen for measuring occlusal force and occlusal contact area. (A) The pressure sensitive film used in the present study. (B) Screen of the occlusal force measurement system. The automatic cleaning function was used to remove the area that do not actually represent occlusal contact. The plot shows the occlusal state obtained using the pressure sensitive film. The crosshair in the center of the screen shows the center of gravity of the occlusal force. (a) Occlusal contact area (mm^2), (b) Average pressure (MPa), (c) Maximum pressure (MPa), (d) Occlusal force (N), (e) Right side indicator, (f) Left side indicator.

chewing sides were used for analysis.

Normality was analyzed using the Shapiro-Wilk test, and all values showed normal distributions. The sample size was determined using Pearson's correlation coefficient (statistical test: correlation; type of power analysis: a priori; alpha error, 0.05; statistical power, 80%; and correlation ρ H1, 0.5) and the paired t-test (statistical test: difference between two dependent means; type of power analysis: a priori; alpha error, 0.05; statistical power, 80%; and effect size, 0.5) using power analysis software (G*Power version 3.1.9.7; Heinrich-Heine Universität, Düsseldorf, Germany). As a result, 29 subjects were required for Pearson's correlation coefficient, and 34 subjects were required for paired t-testing. Relationships between the reference plane and masticatory performance, occlusal force, and occlusal contact area on both the habitual and non-habitual chewing sides were analyzed using Pearson's correlation coefficient. Relationships between masticatory performance, occlusal force, and occlusal contact area on both the habitual and non-habitual chewing sides were determined using Pearson's correlation coefficient. Comparisons between the habitual and non-habitual chewing sides for reference planes and oral functions were analyzed using the paired t-test. Values of $P < .05$ were considered significant in all analyses. Statistical analysis was performed using SPSS for Windows statistical software (ver. 28.0; SPSS, Chicago, IL, USA).

RESULTS

Relationships between the reference planes (FP, CP, and OP), oral functions (masticatory performance and occlusal force), and occlusal contact area are shown Table 1. Positive correlations were found between CP-OP and masticatory performance on both the habitual chewing side ($r = 0.47$, $P < .01$) and non-habitual chewing side ($r = 0.36$, $P < .05$). A positive correlation was also found between CP-OP and occlusal force

Table 1. Results of correlation between the reference planes, masticatory performance, occlusal force, and occlusal contact area

Correlation between variables	Pearson's correlation	
	Habitual chewing side	Non-habitual chewing side
FP-CP × Masticatory performance	-0.22	-0.06
FP-CP × Occlusal force	-0.19	-0.30
FP-CP × Occlusal contact area	-0.06	-0.29
FP-OP × Masticatory performance	-0.56**	-0.33
FP-OP × Occlusal force	-0.35*	-0.48**
FP-OP × Occlusal contact area	-0.20	-0.34*
CP-OP × Masticatory performance	0.47**	0.36*
CP-OP × Occlusal force	0.33	0.40*
CP-OP × Occlusal contact area	0.20	0.24

*$P < .05$; **$P < .01$.
FP-CP: angle between the Frankfort horizontal plane and the Camper's plane; FP-OP: angle between the Frankfort horizontal plane and the maxillary occlusal plane; CP-OP: angle between the Camper's plane and the maxillary occlusal plane.

Table 2. Results of correlation between masticatory performance, occlusal force, and occlusal contact area on the habitual and non-habitual chewing sides

Correlation between variables	Pearson's correlation	
	Habitual chewing side	Non-habitual chewing side
Masticatory performance × Occlusal force	0.46**	0.32
Masticatory performance × Occlusal contact area	0.36*	0.26
Occlusal force × Occlusal contact area	0.94**	0.91**

*$P < .05$; **$P < .01$.

on the non-habitual chewing side (r = 0.40, $P < .05$). Negative correlations were observed between FP-OP and masticatory performance on the habitual chewing side (r = -0.56, $P < .01$), between FP-OP and occlusal force on both the habitual chewing side (r = -0.35, $P < .05$) and non-habitual chewing side (r = -0.48, $P < .01$), and between FP-OP and occlusal contact area on the non-habitual chewing side (r = -0.34, $P < .05$). No correlations were observed between FP-CP and oral functions or occlusal contact area.

Relationships between masticatory performance, occlusal force, and occlusal contact area on the habitual and non-habitual chewing sides are shown in Table 2. Positive correlations were found between masticatory performance and occlusal force on the habitual chewing side (r = 0.46, $P < .01$), between masticatory performance and occlusal contact area on the habitual chewing side (r = 0.36, $P < .05$), and between occlusal force and occlusal contact area on both the habitual chewing side (r = 0.94, $P < .01$) and the non-habitual chewing side (r = 0.91, $P < .01$).

Table 3 shows the mean, standard deviation, and *P* value of angles between the reference planes (FP, CP, and OP), oral functions (masticatory performance and occlusal force), and occlusal contact area. There were no statistically significant differences between the habitual and non-habitual chewing sides in FP-CP ($P = .06$), FP-OP ($P = .20$), and CP-OP ($P = .65$). Mean FP-CP and FP-OP tended to be larger on the habitual chewing side than on the non-habitual chewing side. Mean CP-OP tended to be larger on the non-habitual chewing side than on the habitual chewing side. Significant differences were found between the habitual and non-habitual chewing sides in masticatory performance ($P < .01$, Fig. 5A). No significant differences in occlusal force ($P = .27$, Fig. 5B) or occlusal contact area ($P = .37$, Fig. 5C) were apparent between the habitual and non-habitual chewing sides. Mean values for occlusal force and occlusal contact area tended to be larger on the habitual chewing side than on the non-habitual chewing side.

DISCUSSION

This study examined the relationships between angles formed by reference planes (FP, CP, and OP), oral functions (masticatory performance, occlusal force), and occlusal contact area on the chewing side.

The three-plane measuring device (Fig. 1) used in this study was newly fabricated to measure three planes (FP, CP, and OP) simultaneously. The CP is used as the reference plane for determining occlu-

Table 3. Mean, standard deviation, and *P* value of angles between the reference planes, masticatory performance, occlusal force, and occlusal contact area on the habitual and non-habitual chewing sides

Measurement items	Mean value (range)		SD		*P* value
	Habitual chewing side	Non-habitual chewing side	Habitual chewing side	Non-habitual chewing side	
FP-CP (°)	18.9 (13.2 – 25.3)	18.0 (14.4 – 24.5)	2.3	2.1	.06
FP-OP (°)	17.3 (8.2 – 29.1)	16.7 (7.3 – 27.5)	4.8	4.1	.20
CP-OP (°)	1.2 (-10.3 – 7.7)	1.4 (-9.4 – 7.3)	3.7	3.4	.65
Masticatory performance (mg/dL)	176.5 (121.5 – 215.0)	159.5 (104.5 – 211.0)	23.7	23.7	< .01**
Occlusal force (N)	446.9 (114.1 – 810.9)	427.3 (146.5 – 773.8)	187.0	167.9	.27
Occlusal contact area (mm^2)	10.5 (2.4 – 19.7)	10.1 (2.7 – 16.8)	4.4	3.6	.37

**$P < .01$.
SD: standard deviation; FP-CP: angle between the Frankfort horizontal plane and the Camper's plane; FP-OP: angle between the Frankfort horizontal plane and the maxillary occlusal plane; CP-OP: angle between the Camper's plane and the maxillary occlusal plane.

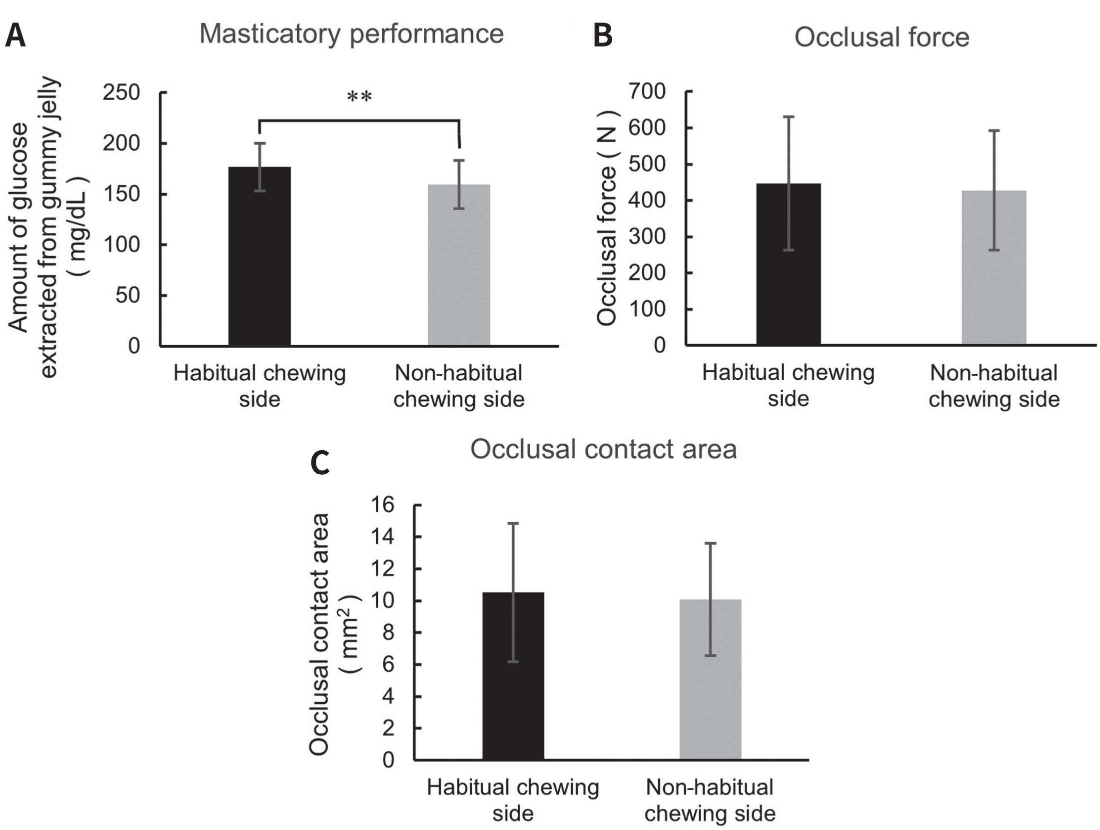

Fig. 5. Results of the comparisons between the habitual and non-habitual chewing sides in masticatory performance, occlusal force, and occlusal contact area. (A) Masticatory performance, (B) Occlusal force, (C) Occlusal contact area.
** Statistically significant differences ($P < .01$).

sal planes in dentulous and edentulous patients for prosthesis fabrication. The CP is defined by the inferior margin of the ala nasi and the superior margin of the tragus.[21] Numerous researchers have confirmed that all three parts of the tragus (i.e., the superior, middle, and inferior parts of the tragus) could guide occlusal plane orientation in edentulous patients.[26,27] Sharab *et al*.[28] suggested redefining the CP with a line extending from the inferior border of the ala nasi to the inferior border of the tragus instead of the superior border. Based on previous studies,[26-28] the line connecting the inferior margin of the ala nasi and the inferior margin of the tragus was used in this study to define the CP (Fig. 2A). The OP is defined as the plane established by the incisal and occlusal surfaces of the teeth; generally, this is not strictly a plane but represents the planar mean of the curvature of these surfaces.[21] The occlusal plane of the upper jaw was used as the OP in this study because the design of the device did not allow the OP to be recorded in the maximal intercuspal position. In addition, measurements of reference planes can be performed without using X-rays, such as cephalometric radiographs. This avoids the deleterious effects of exposure to radiation, so the device applied in this study was considered useful for measuring angles between the reference planes.

Direct and indirect examination methods are used in the measurement of masticatory performance.[29] Direct examination methods involve direct determination from masticated samples, whereas indirect methods involve indirect measurements from other elements involved in mastication. The sieve method has long been used to measure masticatory performance, but shows significant limitations, in that the procedure is complicated and the analysis is time-consuming.[22,23,30] Current research therefore generally uses color-changing chewing gum,[31] paraffin wax,[6] silicone,[16] fuchsin beads,[32] and gummy jelly.[8,9,11,12,22,23,30,33] In the present study, masticatory performance was measured using gummy jelly with standardized physical properties and shapes. Shiga *et al*.[23] reported that this method is characterized by using gummy jelly as a test food that can be standardized in terms of physical properties and shape, with easy hygiene management and simple procedures and analyses. The measurement errors of glucose extracted from gummy jelly are reportedly low.[22,23] In terms of masticatory performance, a correlation has been reported between measured values from glucose leaching and measured values from the sieve method.[33] Test for masticatory performance using gummy jelly is useful because it can measure masticatory performance objectively. In this study, masticatory performance was determined using a direct examination method with gummy jelly, and occlusal force was measured using an indirect examination method.

The habitual chewing side is not acquired at birth. Arai *et al*.[7] showed that changes in the oral environment may alter the habitual chewing side. The current oral environment must therefore be determined to identify the habitual chewing side. Several methods can be used to determine the habitual chewing side, including the gum chewing method,[10] determining the average path of mandibular movements during free movement,[19] and the side on which the majority of chewing occurs. Previous studies[8,11,12,22,23] have determined the habitual chewing side by having the subject chew gummy jelly before the experiment, and interviewing subjects. Highly reliable measurements can also be obtained when subjects become accustomed to chewing the test food before the experiment.[22,23] This study was therefore conducted with the subject chewing the gummy jelly before measurements.

For measurements of occlusal force and occlusal contact area, two types of measurement can be taken[24]: those that measure the full dentition[6,9-12,17,24,25,34,35]; and those that measure a single tooth.[18,19,20,32] In this study, the habitual and non-habitual chewing sides had to be measured simultaneously, so a device that could measure the full dentition was selected. Measured values also needed to be separated into right and left sides. A pressure-sensitive film that can measure the entire dentition at once was used in this study. Pressure-sensitive films use microcapsules of various sizes placed between two films.[24,25] When force is applied to the pressure-sensitive film, the microcapsules split and release a red color. The intensity and area of red coloration are then used to measure occlusal force. An automatic cleaning function removes marks outside areas of occlusal contact in the occlusal force an-

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alyzing system.[24,25,35] Because the pressure-sensitive film deforms and develops color during clenching, and since the optical scanner can import detailed images, the data would indicate areas that do not actually represent occlusal contact.[24,25,34,35] To ensure the indication of the accurate occlusal force and occlusal contact area measurements, the automatic cleaning function was used for measurements in this study.

When CP-OP was anteriorly inclined, occlusal force was small (Table 1). This tendency was recognized both on the habitual and non-habitual chewing sides, and positive correlations were found between CP-OP and oral functions. When CP-OP was anteriorly inclined, the anterior side of CP-OP was larger (Fig. 2Cb). The direction of the masseter muscle had a complex relationship with craniofacial morphology, and mainly related to the angle of the occlusal plane.[36] Anteroposterior inclination of the OP was shown to affect occlusal force.[37] Therefore, the masseter muscle was considered to be inclined anteriorly relative to the CP, and occlusal force was then decreased. The results of this study suggested that the inclination of the OP relative to the CP tended to be associated with occlusal force both on the habitual and non-habitual chewing sides.

When FP-OP increased, occlusal force decreased (Table 1). This tendency was shown both on the habitual and non-habitual chewing sides, and negative correlations were found between FP-OP and oral functions. Previous studies have found no significant correlation between FP-OP and occlusal force.[17,38] The present results thus differed from those previous studies. Uchida *et al*.[17] investigated a smaller cohort than this study, while Kurusu *et al*.[38] focused on female subjects. The present study showed a relationship between FP-OP and occlusal force. As FP-OP increased, the masseter muscle was considered to run more forward, resulting in decreased occlusal force both on the habitual and non-habitual chewing sides.

Correlations were observed between angles between reference planes (FP-OP or CP-OP) and masticatory performance on the habitual chewing side, and a common index for both angles between reference planes (FP-OP and CP-OP) was the OP. The results of this study suggest that masticatory performance could be improved by changing the OP inclination. Therefore, the OP inclination was considered important for producing an appropriate prosthesis.

Positive correlations were found between masticatory performance and occlusal force, between masticatory performance and occlusal contact area, and between occlusal force and occlusal contact area on the habitual chewing side (Table 2). The present study showed the same tendency as previous studies.[11,12] Larger occlusal force appears to lead to more efficient chewing, thereby increasing masticatory performance. The results of this study indicated a relationship between masticatory performance and occlusal force on the habitual chewing side.

FP-OP as measured by the three-plane measuring device was approximately 17.3° on the habitual chewing side and 16.7° on the non-habitual chewing side (Table 3). FP-OP in previous studies was reported as 6.79°,[15] 8 ± 4°,[18] 10.6°,[17] and 13.85°[37] using cephalometric analyses. Differences in inclination angle were thought to be due to different positions of the OP. Significant differences were not found between the habitual and non-habitual chewing sides in each FP-CP, FP-OP, and CP-OP. The results of this study indicated that the angles between two reference planes would not be differed by the chewing side.

A significant difference in masticatory performance was evident between the habitual and non-habitual chewing sides, and masticatory performance was higher on the habitual chewing side (Table 3, Fig. 5A). Functional differences have been reported between the habitual and non-habitual chewing sides.[12,23,30] The habitual chewing side has been reported to show better masticatory performance because of the stable path of masticatory movement compared to the non-habitual chewing side.[8] Masticatory performance was thus higher on the habitual chewing side than on the non-habitual chewing side in this study. No differences in occlusal force or occlusal contact area were seen between the habitual and non-habitual chewing sides (Table 3, Fig. 5B, C). Komino *et al*.[12] reported that occlusal force differed between the habitual chewing side (446.4 ± 96.0 N) and the non-habitual chewing side (412.9 ± 99.6 N). Values in this study were 446.9 ± 187.0 N on the habitual chewing side and 427.3 ± 167.9 N on the non-habitual chewing side. Standard deviations in this study showed a wider range than in the previous study.[12] The difference in occlusal force among subjects was thus larger in this study, with larger standard deviations. Occlusal force was not found to differ between the habitual and non-habitual chewing sides in this study. The present results confirm that masticatory performance is higher on the habitual chewing side than on the non-habitual chewing side.

The limitation of this study was that the maxillomandibular relations and facial type were not analyzed. It would be important to consider the maxillomandibular relations and facial type for the investigation of reference planes. It was considered necessary to analyze the relation between reference plane and oral function according to the maxillomandibular relations and facial type in future study. Key limitations of this study were that the sample size was too small to investigate gender differences. In future investigations, the sample size should be increased to allow such analyses. In addition, the relationships of reference planes to other oral functions (tongue pressure and mandibular mastication movements) should be clarified.

CONCLUSION

Relationships between the angle formed by each reference plane on the chewing side, masticatory performance, occlusal force, and occlusal contact area were investigated and the following conclusions were obtained. The angle between the occlusal plane and the Camper's plane was increased (distance between the upper and lower anterior teeth was small and that between the posterior teeth was large) when masticatory performance was higher, both on the habitual and non-habitual chewing sides. The angle between the Frankfort horizontal plane and the occlusal plane was decreased when masticatory performance was higher on the habitual chewing side. Oral functions changed depending on the inclination of the occlusal plane. Masticatory performance was higher on the habitual chewing side than on the non-habitual chewing side.

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