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Relationships of maxillofacial morphology and malocclusion with handgrip strength in adult women

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Author contributions

S. Nakagawa and A. Maeda-Iino contributed equally to this study.

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Conflicts of interest

There are no conflicts of interest to declare.

Abstract

Objectives: Maxillofacial morphology and malocclusion are related to maximum occlusal force (MOF). Although it has been reported that MOF was related with handgrip strength (HS), the relationships between maxillofacial morphology/malocclusion and HS remain unclear. This study aimed to examine the relationships between maxillofacial morphology, malocclusion, and HS.

Setting and Sample Population: Eighty-five women with malocclusion, aged 18–40 years, were selected.

Materials and Methods: Lateral cephalometric radiographs (SNA, SNB, ANB, mandibular plane-FH, and gonial angles, overjet, and overbite), the Peer Assessment Rating (PAR) index, and HS were measured. Subjects were classified by the Japanese normal mean value of cephalometric analysis or the reference value which was defined by degree of malocclusion in each PAR index measurement item (small/low: value < mean/reference value, large/high: value ≧ mean/reference value). Measurements were then compared between groups.

Results: HS of the large-gonial angle group was lower than that of the small-gonial angle group. In the small-overbite group or high-transverse (PAR index score showing crossbite/scissor bite in the canine and molars) group, HS in the larger-gonial angle group was significantly lower than that in the small-gonial angle group.

Conclusions: Our results suggest that gonial angle is the largest factor affecting HS. HS may be especially low in those subjects with a large gonial angle and a small overbite or a crossbite/scissor bite in the molar section.

Keywords: handgrip strength, maxillofacial morphology, malocclusion, PAR index, maximum occlusal force

INTRODUCTION

The goal of orthodontic treatment is to improve dentofacial aesthetics and function.[1] It has been reported that masticatory function such as masticatory chewing pattern, masticatory muscle activity, maximum occlusal force (MOF), and occlusal contact area (OCA) improved after orthodontic treatment.[2, 3]

Recent studies have focused on the relationship between masticatory function such as MOF and body function such handgrip strength (HS).[4,5] In a measurement of physical function, HS is used as a convenient and useful measurement method, and collated with lower arm and leg strength.[6] On the other hand, MOF and OCA is associated with maxillofacial morphology, such as high mandibular plane (Mp) angle and long face,[7] and with malocclusion such as open bite,[7] posterior crossbite,[8] and scissor bite.[3] However, the relationships between maxillofacial morphology/malocclusion and HS remain unclear. Furthermore, there is no one investigating simultaneously the relation between maxillofacial morphology, malocclusion, and MOF, OCA, and HS.

We hypothesized that maxillofacial morphology/malocclusion is associated with HS. This study aimed to examine this hypothesis by evaluating maxillofacial morphology, malocclusion, MOF, OCA, and HS.

MATERIALS AND METHODS

Subjects

The present study participants were consecutively selected from the patients who visited the Department of Orthodontics at ******* University Medical and Dental Hospital, ********, ***** from 2005–2017. The patients were diagnosed using panoramic and cephalometric radiographs and dental casts. Among the consecutive patients, all patients who met the inclusion and exclusion criteria were selected as subjects in the present study (n=85) (Figure 1). The study design was approved by the ******** University Ethics Committee (#***).

Evaluation of skeletal morphology by lateral cephalometric radiographs

Lateral cephalometric radiographs were used to evaluate anterior-posterior or vertical skeletal morphology and overjet/overbite (Figure 2). The measurements on the lateral cephalometric radiographs were determined using the WinCeph 9.0 software (Compudent, Koblenz, Germany). The subjects were classified by the Japanese normal mean value of each cephalometric measurement[9,10] into two groups (small group: value < Japanese normal mean value, large group: value ≧ Japanese normal mean value), and HS or other measurements were compared between the two groups (Table 1 and 2). To assess the intra-examiner reproducibility and reliability of the measurements, 20 randomly selected cephalometric radiographs were retraced after a minimum interval of 2 months. Evaluation of discrepancies in measurement between the original and retraced radiographs (matched paired t-test) revealed no statistically significant differences.

Peer Assessment Rating (PAR) index

We examined the PAR index scores using dental casts. The PAR index score is designed to estimate how far a case deviates from normal alignment and occlusion. In this study, the PAR index scores were measured using a modified version of the PAR index (Table 1 and 2 [11,12]). Subjects were classified, using the reference value defined by degree of malocclusion for each measurement item on the PAR index, into two groups (Table 1). To assess the intra-examiner reproducibility and reliability of the measurements, 20 randomly selected dental casts and PAR index scores were measured after a minimum interval of 2 months. Evaluation of discrepancies in measurement between the original and re-examined data (matched paired t-test) revealed no statistically significant differences.

Measurement of MOF and OCA

Pressure-sensitive sheets (Dental Prescale 50 H, Type R) were used to measure the MOF and OCA.[13] Each subject was instructed to bite on a Dental Prescale sheet in centric occlusion as strongly as possible for 3 s. The films were scanned using an Occluzer FPD-709 scanner (Fuji Film Corp., Tokyo, Japan).

Evaluation of HS

HS was used as an indicator of muscle strength and was measured using a Smedley dynamometer (As one, Osaka, Japan). The HS on each side with one hand was measured twice while they stood[4]; the average value was used in the analysis.

Measurement of body height and calculation of body mass index (BMI)

We examined body height and BMI, since HS is associated with body height and BMI.[14,15] BMI (kg/m^2) was calculated as weight divided by the square of body height.

Statistical analysis

Z-scores were used to evaluate how well the data fit the norms for Japanese women. The Z-score was calculated as (value-norm)/1 SD, using means and SD of norms for Japanese women.[9,10,13,16,17] Differences in distributed variables between groups were evaluated using a Mann–Whitney *U* test. The probability of significance was calculated for each comparison, and $P < 0.05$ was considered statistically significant. We used the linear mixed model approach for the varying data (categorical data: large/high or small/low groups; continuous variables: MOF, and OCA) and evaluated the effects of parameters on HS or MOF. HS or MOF values in the maxillofacial morphology group (gonial angle groups) and the malocclusion group (overbite or transverse groups) were compared using generalized linear models. Statistical significance was set at $P < 0.05$ after Bonferroni adjustment for multiple comparisons. Statistical tests were performed using SPSS version 24.0 for Windows (IBM, Armonk, NY, USA).

Sample size

The sample size was calculated using a conventional alpha level of 0.05 and a power level of 0.8. The sample size for the Mann–Whitney *U* value or the generalized linear model required at least 27 or 13 subjects in each group, respectively (effect size: 0.8 or 0.4). If the sample size was lower than the limit, we performed post-hoc power calculations (1-β), and we defined P values as < 0.05 with a power calculation of > 0.8 as significant.

RESULTS

HS was compared between the two groups. The HS in the large-gonial angle group was significantly lower than it in the small-gonial angle group (Table 1, P = 0.002). There were no significant differences in HS between two groups classified by the other cephalometric measurements and the measurements of PAR index (Table 1). The Z-score of HS was -1.70 (Table 2).[16]

Next, measurements other than maxillofacial morphology were compared between gonial angle groups. Overbite, MOF, and OCA in the large-gonial angle group were significantly lower than those in the small-gonial angle group (Table 2, P = 0.024, P = 0.003, and P = 0.005, respectively). Transverse score (PAR index score showing crossbite/scissor bite in the canine and molars) in the large-gonial angle group was significantly higher than that in the small-gonial angle group (Table 2, P = 0.006). We evaluated the effects of factors related with gonial angle on HS. The MOF, OCA, and gonial angle groups (small or large gonial angle), gonial angle groups (small or large gonial angle) × overbite groups (small or large overbite), and gonial angle groups (small or large gonial angle) × transverse groups (low or high transverse score) statistically significantly affected the HS (P = 0.009, 0.029, 0.010, 0.025, and 0.048, respectively, Table 3). The OCA and gonial angle groups (small or large gonial angle) statistically significantly affected the MOF (P < 0.001 and 0.013, respectively, Table 3).

Within the small-overbite group and high-transverse group, HS in the large-gonial angle group was significantly lower than that in the small-gonial angle group (P = 0.018 and 0.015, respectively, Figure 3). However, within the large-overbite group and low-transverse group, there was no significantly difference in HS value between gonial angle.

DISCUSSION

In this study, we found that gonial angle was the largest factor affecting HS. Particularly, those subject with a large gonial angle and a small overbite or a crossbite/scissor bite in the molar section had low HS. Thus, our hypothesis that maxillofacial morphology/malocclusion is associated with HS was accepted.

Reportedly, HS is associated with age, sex[6,14], body height and BMI.[14,15] Therefore, we evaluated age, body height, BMI, HS, maxillofacial morphology, malocclusion, and MOF in women only. In the results, there was no significant difference in age, body height, and BMI between the large- and small-gonial angle groups which showed a significant difference of HS value. This leads us to believe that age, sex, body height, and BMI had no effect on HS in our study.

We found that gonial angle in maxillofacial morphology was associated with HS. It is widely known that there is an interaction between craniofacial morphology, MOF, and jaw muscle size.[18,19] Reportedly, there is a close relationship between gonial angle and the direction of the muscle forces including the masseter and temporalis muscles[20] and that gonial angle is correlated with MOF.[19] In this study, the subjects with large gonial angle had both low HS and low MOF, and gonial angle was a main fixed effect for HS and MOF. We think that maxillofacial morphology may be related to not only MOF but muscle limb skeletal muscle strength, since HS is associated with muscle strength in the upper and lower limbs.[6]

To measure MOF, we used the dental prescale system. This method is calculated using OCA, which is reported to give excellent quantitative as one of the evaluation methods for occlusion.[2,3,7] In this study, to evaluate both malocclusion and MOF, the dental prescale system was used, as it is the most suitable method for measurement of MOF and OCA. In addition, it had been reported that reliability of the dental prescale system is greater than that of ordinary measuring systems that use strain-gage transducer[21], especially when measuring occlusal loading force on occlusal contacts at a clenching strength ≥ 60% of the maximum voluntary contraction.[22] Since MOF by maximum clenching were measured in present study, we believe that the method is acceptable.

In subjects with a small overbite or a crossbite and/or scissor bite from the canine and molars (higher transverse score in the PAR index), the large gonial angle was related to lower HS. However, in the subjects with a large overbite or without a crossbite and/or scissor bite, there was no significant difference in HS value between small and large gonial angles (Figure 3). This means that subject with both a large gonial angle and a small overbite or a crossbite/scissor bite had low HS, and HS may not depend on degree of gonial angle in subjects without those types of malocclusion. Reportedly, since open bite and crossbite or scissor bite are associated with MOF and OCA,[3,7,8] low MOF/small OCA by those malocclusions may relate to low HS. Thus, the relationship between malocclusion and low HS may be an early indicator of general health.

On the other hand, it is possible that clenching may relate to HS. It has been reported that clenching has an effect on muscle activity including HS.[23,24] Clenching/masseter muscle activity has been shown to occur during physical activities where strength is involved[24], which likely represents a form of body control acquired when learning to improve performance through so-called feed-forward mechanisms.[24,25] The facilitation of stretch reflexes in the extremities by the contraction of remote muscles is a well-known phenomenon in neurology. For instance, the H-reflex of muscles in the upper limbs is facilitated by teeth clenching.[26] In contrast, recent studies have suggested that supraspinal mechanisms may play a role in remote facilitation in addition to spinal mechanisms. One report found that facilitation of the reflexes preceding remote muscle activity by clenching was due to a signal from supraspinal motor structures, possibly the motor cortex.[27] We consider that voluntary/involuntary clenching may cause the facilitation of H-reflex in upper limb muscles through a signal from the motor cortex, which may increase HS. Gonial angle or malocclusion, such as an open bite crossbite/scissors-bite, related with masticatory functions such as MOF, masticatory jaw movement, and masseter and temporalis muscle activity,[3,7,18,19] may affect clenching and the H-reflex of muscles, which may affect HS. However, we could not clarify this based on our results. In order to clarify why craniofacial morphology/malocclusion is related to HS, further research is required.

Regarding HS, the Z-score for subjects was -1.70 (Table 2). All study participants demonstrated some kind of malocclusion (range: 8-45 score). It is considered that malocclusion may affect HS. However, we could not compare data from subjects with malocclusion to those with normal occlusion because cephalometric data in the subjects with normal occlusion were absent. Therefore, we evaluated the relationship between the degree of craniofacial morphology/malocclusion and HS. However, our study was limited by the fact that it was not possible to state the malocclusion type classification per subject and whether skeletal types or malocclusion, alone, affected HS. Further studies in subjects with the same skeletal morphology is needed to clarify which type of malocclusion is associated with HS.

CONCLUSIONS

Our results suggest that gonial angle is the most prominent factor affecting HS. In particular, subject with a large gonial angle and a small overbite or a crossbite/scissor bite in the molar section may have low HS.

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FIGURE LEGEND

Figure 1. Flow chart of subject enrolment

Figure 2. Lateral cephalometric analysis. 1, SNA angle (angle between the SN plane and NA line); 2, SNB angle (angle between the SN plane and NB line); 3, ANB angle (angle between the NA line and NB line); 4, Mandibular plane (Mp)-FH angle (angle between Mp and FH plane); 5, Gonial angle (angle between the ramus plane and Mp); 6, Overjet; 7, Overbite

Figure 3. Effects of interaction between overbite groups/transverse groups and gonial angle groups on handgrip strength.

Table 1. Each measurement value in the all subjects and comparison of handgrip strength between the two groups classified by the Japanese normal mean value of each cephalometric measurement[ab] or reference value set for each measurements of PAR index scores

		Cephalometric measurement or PAR index scores								Handgrip strength (N)				
					All subjects (n = 85)			Norm (Japanese women)						Small/Low vs Large/High
Measurements	Group	n	Mean	SD	Mean	SD	Z-score	Mean	SD	Mean	SD	Median	Minimum-maximum	P value[c]
Lateral cephalometric measurements														
Angular analysis (°)														
SNA angle	Small	48	79.19	2.00	82.02	3.95	-0.09	82.32[a]	3.45	208.93	47.65	205.92	124.46-319.73	0.635
	Large	37	85.69	2.56						212.89	49.36	210.46	104.62-357.95	
SNB angle	Small	44	75.33	2.46	78.96	4.80	0.02	78.90[a]	3.45	211.47	51.27	208.62	124.46-319.73	0.979
	Large	41	82.87	3.43						209.77	45.18	205.80	104.62-357.95	
ANB angle	Small	41	-0.02	2.83	3.06	3.77	-0.19	3.39[a]	1.77	205.41	46.44	191.84	104.62-357.95	0.336
	Large	44	5.92	1.70						215.53	49.72	214.62	124.46-319.73	
Mp-FH angle	Small	47	23.94	3.67	28.32	6.07	-0.09	28.81[a]	5.23	215.18	44.03	210.70	104.62-306.25	0.091
	Large	38	33.73	3.52						205.05	52.87	188.04	124.46-357.95	
Gonial angle	Small	42	117.37	3.85	122.55	6.76	0.07	122.23[a]	4.61	223.98	41.05	218.66	148.96-312.62	0.002**
	Large	43	127.60	4.89						197.64	51.39	186.69	104.62-357.95	
Linear analysis (mm)														
Overjet	Small	29	0.18	2.37	3.63	3.26	0.38	3.1[b]	1.4	212.14	41.49	208.50	128.63-296.45	0.660
	Large	56	5.43	1.94						209.88	51.60	205.92	104.62-357.95	
Overbite	Small	60	0.42	1.71	1.64	2.50	-0.66	3.1[b]	2.2	204.60	47.31	191.47	104.62-357.95	0.044[d]
	Large	25	4.58	1.38						225.16	47.97	217.81	124.46-312.62	
PAR index scores (score range)														
Total score (0-132)	Low (< 20)	35	15.00	3.43	23.15	9.10	-	-	-	219.11	52.75	217.81	128.63-357.95	0.251
	High (≧ 20)	50	28.86	7.30						204.73	44.24	194.65	104.62-319.73	
Displacement scores														
Total (0-104)	Low (< 12)	31	7.45	2.62	15.01	7.51	-	-	-	214.60	52.20	205.80	128.63-357.95	0.869
	High (≧ 12)	54	19.35	5.74						204.73	46.02	208.62	104.62-319.73	
Upper segment (0-52)	Low (< 6)	29	3.55	1.15	8.22	4.54	-	-	-	205.03	49.98	191.84	128.63-357.95	0.247
	High (≧ 6)	56	10.64	3.65						213.56	47.37	210.58	104.62-319.73	
Lower segment (0-52)	Low (< 6)	34	2.74	1.75	6.79	3.97	-	-	-	215.45	49.57	209.84	128.63-357.95	0.584
	High (≧ 6)	51	9.49	2.42						207.45	47.41	204.82	104.62-319.73	
Overjet (0-8)	Low (< 1)	15	0.00	0.00	2.18	1.43	-	-	-	215.01	56.34	210.21	128.63-357.95	0.899
	High (≧ 1)	70	2.64	1.12						209.72	46.62	206.41	104.62-319.73	
Overbite (0-4)	Low (< 1)	44	0.00	0.00	0.75	1.00	-	-	-	209.02	48.09	204.09	128.63-357.95	0.589
	High (≧ 1)	41	1.56	0.90						212.40	48.75	211.19	104.62-312.62	
Centerline (0-2)	Low (< 1)	42	0.00	0.00	0.68	0.76	-	-	-	216.18	49.03	210.58	146.02-357.95	0.466
	High (≧ 1)	43	1.35	0.48						205.25	47.22	196.98	104.62-312.62	
Buccal occlusion assessments														
Total (0-14)	Low (< 1)	10	0.00	0.00	4.53	3.22	-	-	-	206.56	48.02	182.89	146.02-303.80	0.535
	High (≧ 1)	75	5.13	2.94						211.20	48.46	208.50	104.62-357.95	
Antero-posterior (0-4)	Low (< 1)	11	0.00	0.00	2.48	1.32	-	-	-	206.98	45.58	184.73	146.02-303.80	0.596
	High (≧ 1)	74	2.85	0.96						211.20	48.79	207.76	104.62-357.95	
Vertical (0-2)	Low (< 1)	81	0.00	0.00	0.07	0.34	-	-	-	210.63	48.44	208.50	104.62-357.95	0.787
	High (≧ 1)	4	1.50	0.58						211.13	48.47	192.57	178.12-281.26	
Transverse (0-8)	Low (< 1)	44	0.00	0.00	1.98	2.42	-	-	-	214.11	53.40	210.33	104.62-357.95	0.641
	High (≧ 1)	41	4.10	1.84						206.94	42.15	204.82	124.46-306.25	

PAR: Peer Assessment Rating, Mp: mandibular plane
The PAR index scores were measured using a modified version of the PAR index.

The PAR index score is designed to estimate how far a case deviates from normal alignment and occlusion.[11] PAR index scores (range: 0–132) were classified by score 20 because an average PAR index score of above 20 was required for treatment.[12] The total displacement score (range: 0–104), which was the sum of six segments scores (upper or lower: right, anterior, and left), was classified by score 12. The upper or lower segment score was classified by score 6. If each segment score is more than 2 (discrepancy is 2.1–4.0 mm), the total score and upper/lower segment score exceed score 12 and 6, respectively. Thus, we classified by score 12 or 6. Other measurements were classified by score 1. Overjet and overbite ≧1 measured above 3.1 mm/anterior-crossbite and openbite/deepbite with greater than 1/3 coverage of the lower incisor, respectively. The centreline ≧ 1 shows a discrepancy greater than 1/4 to 1/2 the lower central incisor width. Antero-posterior, vertical, and transverse of buccal occlusion assessments ≧1 show the presence of bad interdigitation, presence of more than 2 teeth of lateral open bite, and the presence of more than one tooth of posterior cross bite (including cross bite tendency) and/or scissor bite.

Small/Low: value < Japanese normal mean value of each cephalometric measurement[ab] or reference value set for each measurements of PAR Index scores
Large/High: value ≧ Japanese normal mean value each cephalometric measurement[ab] or reference value set for each measurements of PAR Index scores
[a] According to Iizuka et al. (1969) ;
[b] According to Sakai et al. (1974)[10] ; [c]
** P< 0.01

Table 2. Comparison of measurements between the two groups classified by gonial angle

	Small-gonial angle group (n=42)				Large-gonial angle group (n=43)				Small vs Large	All subjects (n = 85)			Norm (Japanese women)	
Measurements	Mean	SD	Median	Minimum-maximum	Mean	SD	Median	Minimum-maximum	P value[a]	Mean	SD	Z-score	Mean	SD
Handgrip strength (N)	223.98	41.05	218.66	148.96-312.62	197.64	51.39	186.69	104.62-357.95	0.002**	210.65	48.15	-1.70	289.1[b]	46.1
Age (y)	23.83	4.49	22.75	18.25-40.17	24.99	5.98	23.08	18.00-40.50	0.613	24.41	5.30	-	-	-
Body height (cm)	159.09	5.70	158.20	146.10-169.00	156.85	5.88	156.10	145.00-168.00	0.119	157.96	5.87	-0.03	158.1[c]	5.3
BMI (kg/m^2)	19.62	2.12	19.55	15.52-25.20	19.67	2.44	19.19	16.44-27.64	0.772	19.64	2.27	-0.30	20.57[c]	3.12
Maximum occlusal force (N)	677.8	271.6	671.1	20.9-1494.0	530.8	267.9	499.5	121.9-1417.2	0.003**	603.4	278.1	-0.27	680.5[d]	289.7
Occlusal contact area (mm^2)	16.4	9.9	14.9	0.6-59.7	12.0	7.8	10.7	1.8-40.8	0.005**	14.2	9.1	0.12	13.4[d]	6.7
Lateral cephalometric measurements														
Linear analysis (mm)														
Overjet	4.33	3.08	4.47	-3.70-10.90	2.96	3.32	3.47	-4.50-9.10	0.112	3.63	3.26	0.38	3.1[e]	1.4
Overbite	2.29	2.76	2.45	-3.70-9.10	1.01	2.05	0.92	-4.50-5.50	0.024*	1.64	2.50	-0.66	3.1[e]	2.2
PAR index scores														
Total score	21.74	9.38	19.60	8-45	24.53	8.71	23.40	10-42	0.115	23.15	9.10	-	-	-
Displacement scores														
Total	14.31	7.48	13.29	2-36	15.70	7.56	16.33	4-28	0.346	15.01	7.51	-	-	-
Upper segment	7.74	4.32	7.13	2-20	8.70	4.75	8.20	2-17	0.339	8.22	4.54	-	-	-
Lower segment	6.57	4.19	6.17	0-16	7.00	3.78	7.40	0-14	0.578	6.79	3.97	-	-	-
Overjet	2.19	1.31	2.27	0-4	2.16	1.56	2.24	0-5	0.936	2.18	1.43	-	-	-
Overbite	0.88	1.09	0.67	0-4	0.63	0.90	0.50	0-4	0.304	0.75	1.00	-	-	-
Centerline	0.62	0.73	0.56	0-2	0.74	0.79	0.68	0-2	0.477	0.68	0.76	-	-	-
Buccal occlusion assessments														
Total	3.74	2.60	3.38	0-10	5.30	3.60	5.17	0-12	0.057	4.53	3.22	-	-	-
Antero-posterior	2.48	1.29	2.57	0-4	2.49	1.35	2.68	0-4	0.863	2.48	1.32	-	-	-
Vertical	0.05	0.31	0.05	0-2	0.09	0.37	0.07	0-2	0.332	0.07	0.34	-	-	-
Transverse	1.21	1.87	0.54	0-6	2.72	2.68	2.45	0-8	0.006**	1.98	2.42	-	-	-

BMI: body mass index, PAR: Peer Assessment Rating

The PAR index scores were measured using a modified version of the PAR index.

Small-gonial angle group: value < Japanese normal mean value of gonial angle[f]

Large-gonial angle group: value ≧ Japanese normal mean value of gonial angle[f]

[a]: Mann-Whitney U-test, [b]: According to Hara et al., (2001)[16], [c]: According to mean ± SD of subjects 25–29 years old in Takimoto et al. (2004)[17], [d]: According to Abe et al. (2012)[13], [e]: According to Asai et al. (1974)[10], [f]: According to Iizuka et al. (1969)[9]

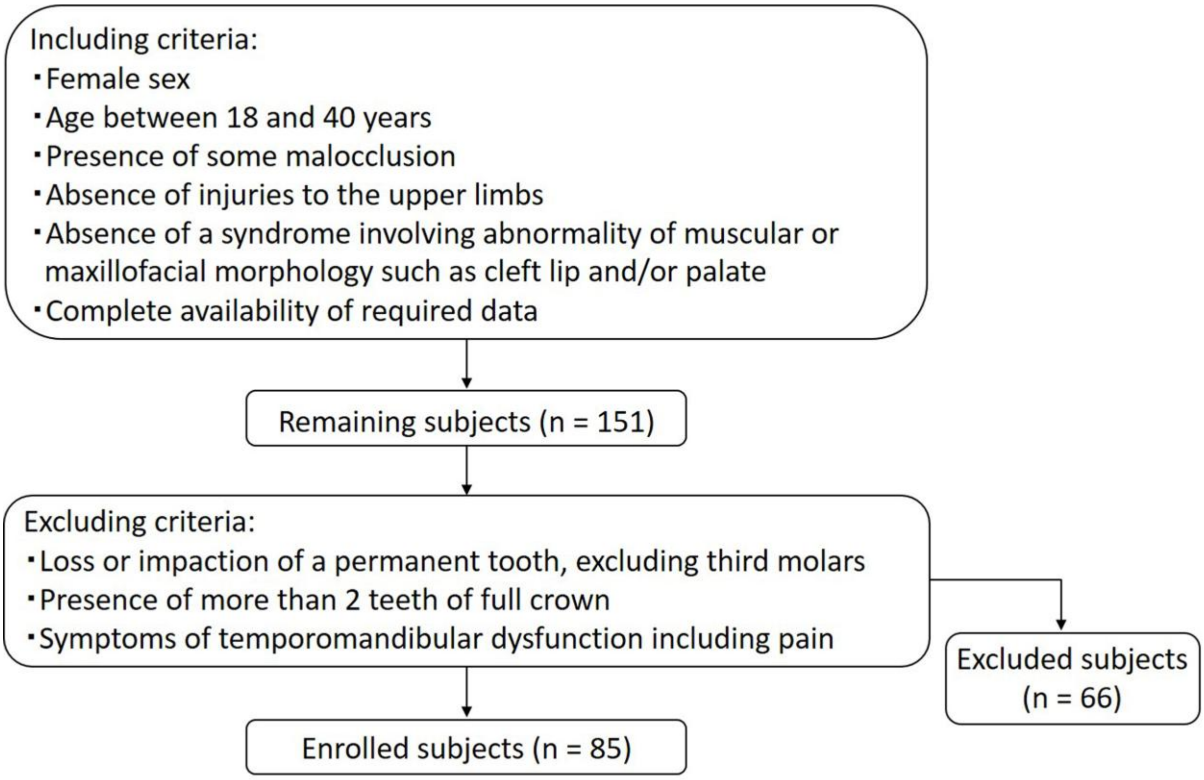
*: $P < 0.05$, **: $P < 0.01$

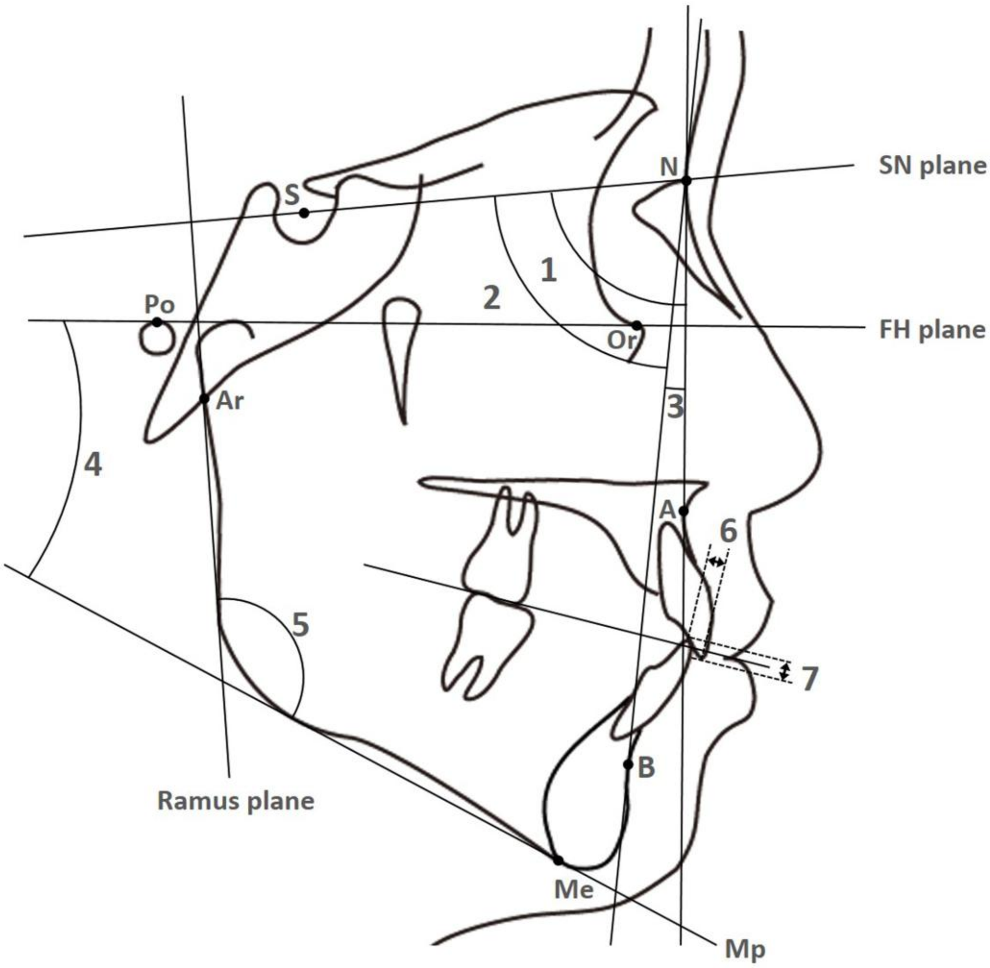
Table 3. Results of fixed effects analysis of handgrip strength and maximum occlusal force

	Handgrip strength		Maximum occlusal force	
Fixed effects	F value	P value[a]	F value	P value[a]
Maximum occlusal force	7.110	0.009**	-	-
Occlusal contact area	4.954	0.029*	420.063	< 0.001***
Gonial angle groups	6.961	0.010*	6.462	0.013*
Overbite groups	3.386	0.069	3.024	0.086
Transverse groups	0.478	0.491	1.106	0.296
Gonial angle groups × overbite groups	3.258	0.025*	2.515	0.064
Gonial angle groups × transverse groups	2.749	0.048*	2.353	0.078

[a]: The liner mixed model

*: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$


Including criteria:
・Female sex
・Age between 18 and 40 years
・Presence of some malocclusion
・Absence of injuries to the upper limbs
・Absence of a syndrome involving abnormality of muscular or maxillofacial morphology such as cleft lip and/or palate
・Complete availability of required data
Remaining subjects (n = 151)
Excluding criteria:
・Loss or impaction of a permanent tooth, excluding third molars
・Presence of more than 2 teeth of full crown
・Symptoms of temporomandibular dysfunction including pain
Excluded subjects (n = 66)
Enrolled subjects (n = 85)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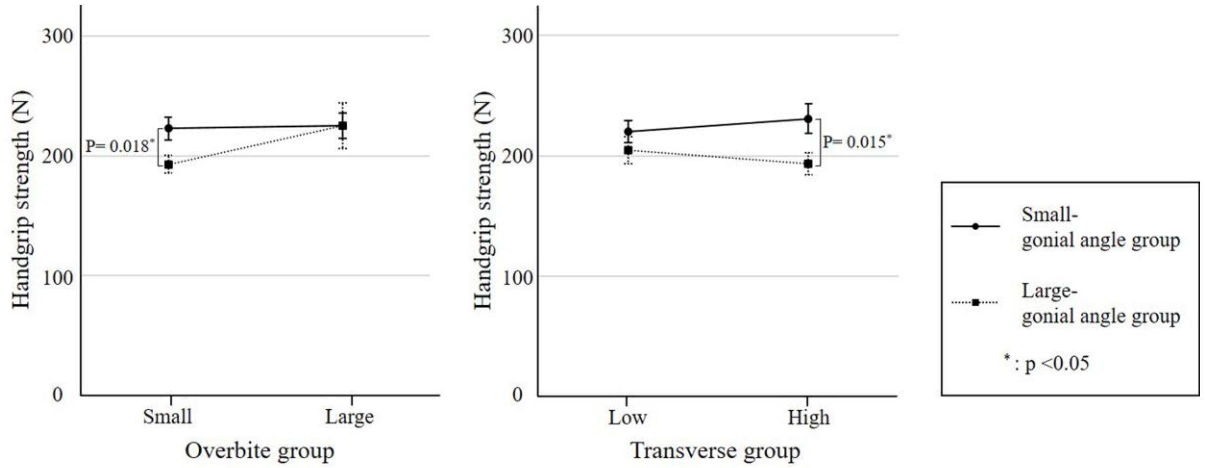

Handgrip strength (N)
300
200
100
0
P= 0.018*
Small
Large
Overbite group
Handgrip strength (N)
300
200
100
0
P= 0.015*
Low
High
Transverse group
Small-
gonial angle group
Large-
gonial angle group
* : p <0.05