Molar Inclination Plays a Functionally Compensatory Role in Patients with Mandibular Prognathism

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Abstract

The inclination of the tooth axis is often seen as dental compensation to adapt to malocclusion, and it is considered that the inclination of the tooth is affected by the chewing pattern. In this study, the relationship between buccolingual molar inclination and chewing pattern was analyzed to clarify the actual condition of dental compensation in the mandibular prognathism. Seventy-seven patients (37 males and 40females; mean age, 25.9 years) diagnosed with mandibular prognathism in the Department of Orthodontics, Nihon University's hospital at Matsudo were included. The mandibular prognathism was classified into three groups: Mild, Moderate, and Severe. The masticatory movement was evaluated using Gnatho-Hexagraph (GC, Tokyo, japan), and the chewing patterns were classified as normal (N), reverse (R), and crossover (C). We divided the patients into two groups: N pattern group and R&C pattern group. The intermolar arch width and molar inclination were measured on dental models. Normal buccolingual occlusal relationship of the first molar occurred 51.4% of patients In the N pattern group, and 30.0% of patients in the R&C pattern group. In the N pattern group, the maxillary buccolingual inclination was significantly larger in the Severe than in Mild ($p<0.05$), while the mandibular buccolingual inclination was smaller ($p<0.05$). In the skeletal mandibular prognsthism, molar teeth there incline due to dental compensation. The chewing pattern and buccolingual occlusal relationship of the first molars affect molar inclination. It is concluded that N pattern predicted longer treatment period due to the pronounced buccolingual inclination of the molars.

Keywords: buccolingual inclination, mandibular protrusion, chewing pattern, dental compensation, skeletal Class Ⅲ

Introduction

In mandibular prognathism, incisors are inclined labially in the maxilla but lingually in the mandible. The incisor inclination compensates for skeletal disharmony and is physiologically adapted for occlusion, also known as dental compensation (1). Dental compensation is a term used to describe a compensatory change in the position or inclination of the teeth to maintain a functional oral environment in individuals with disharmonious counterpart of jaw relationships. The width of the dental arch is related to tooth inclination, and the increase in the mandibular intermolar arch width is influenced by the upright toward buccal side after the tooth crown erupts toward the lingual side (2-5).

Similarly to the incisors region, the maxillary molars tend to be inclined to buccally and the mandibular molars lingually (1). When the positional relationship between the maxilla and mandible is improved by mandibular osteotomy, it is necessary to control the buccolingual inclination of the molars preoperatively, by predicting the postoperative occlusion (decompensation). In the case of the amount of molar movement is large for a decompensation, it is likely to prolong the treatment period and also to affect postoperative stability.

Molar inclination is closely related to masticatory function. We have previously reported that the mandibular molars, affected strongly by masticatory function, have an upright buccolingually and a large intermolar width (6-13). However, these reports focused only on normal occlusion. Kobayashi et al. (14) reported a significant change in masticatory efficiency after orthognathic surgery in mandibular prognathism.

Furthermore, Negishi et al. (15) suggested that masticatory training using a large hard gum tended to change the masticatory movement pattern from a reverse and crossover pattern (R&C pattern) to normal pattern (N pattern). In clinical practice, we prepare for postoperative occlusion using preoperative morphological adjustment; however, oral function should also be treated preoperatively.

During preoperative orthodontic treatment in cases with skeletal mandibular prognathism, some patients have severely inclined molars, while others have slightly inclined (2). There are various masticatory patterns involved in the inclined molars (16,17). Although many studies have analyzed masticatory patterns and dental arch dimensions, individual differences in the preoperative orthodontic conditions including molar inclination as dental compensation have not been elucidated. Since the orthodontic condition before orthodontic surgery affects the prognosis such as the treatment period and relapse, it is considered to be useful information for the diagnosis. We hypothesized that the N pattern would pay special attention control of the tooth axis due to the expected longer treatment period because of buccolingual inclination during the preoperative treatment is pronounced.

The purpose of this study was to clarify the relationship between masticatory patterns and buccolingual inclination of the molars in mandibular prognathism patients.

Materials and Methods

Participants

The participants were 77 patients (37 males, 40 females; mean age, 25.9 ± 7.9 years), who met the inclusion and exclusion criteria, of 543 patients from 8635 patients who visited the Department of Orthodontics, Nihon University's hospital at Matsudo and were diagnosed with mandibular prognathism (Fig. 1). The inclusion criteria were as follows: (1) no prior orthodontic treatment, (2) minimal dental wear, (3) less than 5.0 mm of crowding per arch, and (4) no missing teeth other than the third molars. The exclusion criteria were as follows: (1) limited mouth opening, (2) crowns or significant restorations on any molars, (3) presence of excess teeth, (4) extensive dental wear, and (5) craniofacial deformities. This study was approved by the Ethics Committee of Nihon University's School of Dentistry at Matsudo (approval no.EC 21-002)

Measurement of masticatory movement

The patients' masticatory movement was measured using Gnatho-Hexagraph III (GC, Tokyo, Japan). A clutch was attached to the mandibular anterior teeth, and the head frame and face bow were attached after the patients was seated in an upright position so that the Frankfurt plane was horizontal, when the patients was relaxed, without fixing the head. The reference plane, Frankfurt plane, measurement points, bilateral mandibular condyles, mandibular left and right first molars' mesiobuccal cusps, and mandibular left and right central incisor contact were set (12). A piece of gum (1.5 g, 100% xylitol gum, Oral Care Co., Ltd., Tokyo, Japan; hereinafter referred to as "soft gum") was used as the test food. Masticatory movement was analyzed for 10 strokes from the 5th to the 14th stroke on the primary masticatory side at the mandibular incisal point (18,19), and the masticatory movement path was recorded using the jaw movement measuring instrument with the analysis software JM-3000 (GC). After the participants were allowed to chew freely and sufficiently soften the soft gum, they were instructed to chew the soft gum from the cusp fitting position on each side for 30 s. The masticatory movement was recorded, and the movement patterns were analyzed.

Description of chewing patterns

During 30 s of free chewing, the number of strokes on the right and left sides were counted. This process was repeated three times, and the dominant side was defined as the preferred chewing side. Chewing patterns were classified as follows (20): N pattern (opening from the central occlusal position to the masticatory or non-masticatory side, followed by convex opening to the central occlusal position), R pattern (open/close chewing movements opposite to N pattern), and C pattern (crossed open and closed chewing movements). We divided the patients into two groups depending on the chewing patterns: N pattern group and R&C pattern group (some of the patients with an R&C pattern) (Fig. 2) (15,19,21).

Dental model measurements (Buccolingual inclination and Intermolar arch width)

The measurements were based on the method outlined by Kasai et al. (5) and the measurement items are shown in Fig. 3. The three-dimensional (3D) data of the dental model were recorded using a 3D digital scanner and measured using the 3D analysis software Body-Rugle (Medic Engineering, Kyoto, Japan). The reference planes were designated between the incisive papilla and the right and left mesial first molar papillae. Reference planes were set mathematically horizontal with the two related to the right and left lingual mesial papillae of the first molars aligned parallel to the X-axis. The Y-axis ran in the anteroposterior direction, and the Z-axis was vertical (22).

The measurement points of the maxillary first molar were the intersection of occlusal edge and buccal groove, and the intersection of occlusal edge and distolingual groove. Those of the mandibular first molar were the intersection of occlusal edge and buccal groove, and the intersection of occlusal edge and lingual groove.

The buccolingual inclination (BLI) was formed between the line passing through two points on the molar and the Z-axis (Fig. 3). The maximum distance from the lingual groove of the maxillary and mandibular first molars to the clinical cervical line of the teeth was the intermolar dental arch width (U6W, L6W; Fig. 4).

The measured values were compared for each chewing pattern, and the occlusal relationship was determined through macroscopic observation from the buccal side based on the occlusal relationship obtained by a wax bite before treatment.

Degree of mandibular prognathism (Anteroposterior mandibular position)

The degree of the mandibular prognathism was categorized as follows: Moderate (the mesiobuccal surface ridge of the maxillary first molar coincided with the distal surface of the mandibular first molar), Severe (the mandibular molars are located mesial to the location in the Moderate), and Mild (the mandibular molars are located distal to the location in the Moderate) (Fig. 5).

Buccolingual occlusal relationship of the first molars

The buccolingual occlusal relationship of the first molars was classified into the following three types: normal occlusion (the inner slope of the mesiolingual cusp of the maxillary molar is in contact with the inner slope of the mesiobuccal cusp of the mandibular molar), crossbite occlusion (the inner slope of the mesiobuccal cusp of the maxillary molar is in contact with the inner slope of the mesiolingual cusp of the mandibular molar), cusp to cusp occlusion (the mesiobuccal and the mesiolingual cusps of the maxillary molar and those of the mandibular molar are in contact with each other, that is, an intermediate positional relationship between normal and crossbite occlusion; Fig. 6).

Cephalometric analysis

Cephalometric analysis was performed using WinCeph (Rise Corporation, Sendai, Miyagi, Japan), and the angles and distances were measured according to the manufacturer's instructions. Of the five items measured through cephalometry, one was linear and four were angular (Fig. 7).

Statistical analysis

To assess the importance of errors that occurred during the measurements, 20 variables were re-evaluated 1 month after the first measurement. There were no systematic errors according to paired t-test (confidence interval 95%), and Dahlberg's double determination method ($EM=\sqrt{(\Sigma d^2/2n)}$) was used to calculate the percentage of error variance to total variance (Error%) (d is the difference between the first and second determinations, and n is the number of determinations).

We categorized the patients into two groups: N pattern group and R&C pattern group (some of the patients with an R&C pattern). Statistical significance testing was performed between the groups to compare Mild, Moderate, and Severe BLI. The statistical software JMP16 Statistical Discovery (SAS Institute Inc., Cary, NC) was used for statistical processing. The Shapiro-Wilk normality test showed that all variables were non-normally distributed within each group. Therefore, non-parametric statistical tests were used. Differences between the N pattern group and R&C pattern group in normal occlusion were evaluated using Pearson's chi-square test. The Mann-Whitney U test was performed for BLI comparisons in the N pattern group and R&C pattern group. The Steel-Dwass test was performed for BLI comparisons in Mild, Moderate and Severe Class III occlusion. Finally, the correlation coefficient between the measurement items for lateral cephalograms, U6W, L6W, and tooth axis inclination was calculated. The threshold for statistical significance was set at $P < 0.05$.

Results

Reliability of measurements

No systematic methodological errors were identified in the angular and linear measurements on the dental models between first and second determinations, based on paired t-tests. Mean differences in the angular measurements were -3.1 to +3.1° and in linear measurements were -0.9 to +0.7 mm. Random errors calculated using Dahlberg's equation were 0.98° for angular measurements and 0.49 mm for linear measurements. The error variance of each measurement item accounted for less than 1.86% of the sample total variances for angular measurements and less than 2.35% for linear measurements.

In the cephalometric analysis, random errors in angular measurements were within 2.02° and linear measurements were within 0.32 mm. The error variance of each measurement item as a percentage of the sample variance was less than 2.77% for angular measurements and less than 0.78% for linear measurements. Therefore, statistically, the influence of the measurement errors was limited and unlikely to affect the results.

Chewing pattern, Buccolingual occlusal relationship, degree of mandibular prognathism

Relationship between buccolingual occlusal relationship of the first molars and degree of mandibular prognathism

Table 1 shows the ratio of each classification item to the total number of items. In the Mild, normal occlusion was most frequently. In the Severe, cusp to cusp occlusion was the most common.

Relationship between chewing pattern and buccolingual occlusal relationship of the first molars

Table 2 shows the ratio of the normal, cusp to cusp, and crossbite occlusions of the first molar from the coronal view in the N pattern group and R&C pattern group. Comparing the N pattern group and the R&C pattern group, the proportion of normal occlusion was 51.4% in the N pattern group and significantly lower at 30% in the R&C pattern group. Further, the proportion of cusp to cusp occlusion was 27.0% in the N pattern group and significantly higher at 57.5% in the R&C pattern group.

Buccolingual inclination (BLI)

The measurement values of the maxillary and mandibular BLI in the N pattern group and R&C pattern group at each mandibular position (Mild / Moderate / Severe) are presented in Fig. 8 and Table 3. In the N pattern group, the maxillary BLI was significantly greater and mandibular BLI was significantly smaller in the Severe than in the Mild groups. In addition, there was no significant difference among the Mild, Moderate, and Severe R&C patterns.

Intermolar arch width (U6W, L6W)

Table 4 shows average of the intermolar widths of the maxillary and mandibular. The intermolar width of classⅢwere almost the same values as class Ⅰ（9).

Correlations between BLI and positional relationships of both jaws and intermolar arch width

The correlations between the BLI and the measurement items of the lateral cephalograms and U6W/ L6W in the N pattern and molar relationship normal occlusion is presented in Table 5. The maxillary BLI was negatively correlated with convexity (distance), Frankfort horizontal plane (FH) to mandibular, and convexity (angle) and positively correlated with mandibular arc (mandibular A.). The BLI of the mandibular molar was not significantly correlated with any measurement item (Table 5).

Discussion

Suzuki et al. (20) found that the axial inclination of molars was associated with the chewing pattern after orthognathic surgery, which affected molar occlusion, because of the chewing pattern in normal occlusion was mostly the N pattern, and the amount of change in BLI (i.e., relapse) after surgery was also mild. Several researchers have reported that when the molar relationship was crossbite occlusion, the masticatory movement pattern tends to be the R pattern (23-29), with a skeletal crossbite mechanism and mandibular asymmetry. Furthermore, there are various classifications of masticatory movement patterns. For example, Proeschel et al. (16) divided masticatory movement patterns into eight categories, and Takeda et al. (17) divided them into five. In all reports, approximately 80% or more of the total sample had three masticatory movement patterns (N pattern, R pattern and C pattern). In this study, we classified the masticatory patterns into N pattern, a typical pattern of masticatory movement, R pattern, a masticatory movement pattern with the opposite opening and closing paths, and C pattern, which has a narrow masticatory movement width and intersects.

It has been reported that maxillofacial skeletal development is closely related to occlusal function (23). Although skeletal mandibular prognathism is believed to have a strong genetic contribution, the occlusal relationship of the molars is affected by oral functions such as chewing patterns during the growth period, just as in normal skeletal patients (1).

Table 1 shows the ratio of each classification item to the total number of classification items. The reason why the cusp to cusp occlusion accounted for the largest percentage of types of occlusion is because of the wide range of an intermediate positional relationship between normal occlusion and crossbite occlusion.

As shown in Table 2, only 30% of the patients in the R&C pattern group showed normal occlusion. It is considered that the masticatory path is restricted by the crossbite occlusion of the molar teeth, causing occlusal interferences, and leading to reversal of the masticatory movement pattern. On the other hand, the majority (51.4%) of participants with an N pattern group showed normal occlusion. Cusp to cusp occlusion (27.0%) and crossbite occlusion (21.6%) were found in approximately half of the cases because in this study, only the occlusal relationship of the first molar was determined and measurement of mandibular prognathism was performed. Therefore, difference could be attributable to variance in the main occluding area. In normal occlusion, the main occluding area comprises the maxillary and mandibular first molars, but in mandibular prognathism, the mandible is positioned forward, suggesting that the main occluding area may not involve the first molars.

Regarding the BLI, there was no significant difference between the N pattern group and the R&C pattern group in either the maxilla or mandible in the Moderate, but there was a significant difference between Mild and Severe (Table 3). Suzuki et al. (20) investigated the effect of masticatory movement on BLI after treatment of mandibular asymmetry. There was a significant difference between Mild and Severe, in the N pattern group for both the maxillary and mandibular molars (Fig. 8(a)). A significant difference between Moderate and Severe was seen in the N pattern group for the mandibular molar only (Fig. 8(c)). This may be because the disharmony of the basal arch width of the maxilla and mandible was changed by the degree of mandibular prognathism, and the dental compensation in the N pattern changed the BLI of the first molars.

Spearman's correlation analysis was performed between the BLI in the N pattern group and with normal occlusion and the measurement items of the cephalometric analysis (Table 5). The maxillary BLI showed a negative correlation with the mandibular plane, convexity (distance), FH to mandibular, and convexity (angle), and a positive correlation with the mandibular arc. Conversely, no correlation was observed between the mandibular BLI and any measurement item. In the N pattern group, the entire mandible protrudes forward, suggesting that the maxillary first molar causes substantial dental compensation as shown in Table 5. Both U6W and L6W were almost the same as those measured in skeletally normal Japanese adults (Table 4) (9). However, there was no correlation with the BLI, suggesting that BLI is not a result of disharmony between the maxillary and mandibular intermolar widths but rather an effect of tooth type in occlusal. These findings suggest that the N pattern involves a particularly greater inclination of the molars when preoperative orthodontic treatment.

We found that in mandibular prognathism, the degree of BLI in the N pattern group was larger than that in the R&C pattern group, and the percentages of molar crossbite and scissor bite were smaller, indicating that the inclination of the tooth axis tended to compensate for the disharmony of the dental arch width and positioning of the maxilla and mandible.

For the conclusion, the N Pattern would pay special attention control of the tooth axis due to the pronounced buccolingual inclination during preoperative treatment.

Conflict of Interest

The authors have declared that no conflict of interest exists.

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Figure Legends

Fig. 1.

The participants were 77 patients (37 males, 40 females; mean age, 25.9 ± 7.9 years) who met the selection and exclusion criteria out of 543 patients diagnosed with skeletal mandibular prognathism from a total sample of 8635 patients who visited the Department of Orthodontics, Nihon University's hospital at Matsudo and were diagnosed with mandibular prognathism.

Fig. 2.

Normal pattern (N pattern): from centric occlusion, the mandible moves downward and then laterally toward the chewing side or the non-chewing side before returning to centric occlusion along a concave, convex, or linear path.

Reverse pattern (R pattern): the reverse of normal pattern

Crossover pattern (C pattern): the mandible moves slightly laterally, downward, slightly laterally again, and then returns to centric occlusion.

Centric occlusion (CO)

Fig. 3.

The measurement points of the maxillary first molar were the intersection of occlusal edge and buccal groove, and the intersection of occlusal edge and distolingual groove. Those of the mandibular first molar were the intersection of occlusal edge and buccal groove, and the intersection of occlusal edge and lingual groove.The maxilla and mandibular first molar buccolingual inclination (BLI) was formed between the line passing through two points on the molar and Z-axis.

Fig. 4.

Maximum distance from the lingual groove of the maxillary and mandibular first molars to the clinical cervical line of the tooth (U6W, L6W).

Fig. 5.

Moderate mandibular prognathism (Moderate) was defined when the mesio buccal surface ridge of the maxillary first molar coincided with the distal surface of the mandibular first molar. The mandibular molars located mesial to the Moderate were classified as severe mandibular prognathism (Severe), and those located distal to the Moderate position were classified as mild mandibular prognathism (Mild).

Fig. 6.

Normal occlusion: The lingual cusp inner incline of the maxillary first molar is contact with the buccal cusp inner incline of the mandibular first molar.

Crossbite occlusion: The buccal cusp inner incline of the maxillary first molar is contact with the lingual cusp inner incline of the mandibular first molar.
Cusp to cusp occlusion: Normal occlusion to crossbite occlusion.

Fig. 7.
Xi: The center of the mandibular ascending ramus.
N: nasion, Or: orbitale, Po: porion, A: point A, B: point B, XI: XI point, PM: protuberane menti, Pog: pogonion, Me: menton, Go: gonion, PTV: pterygoid vertical,
Po-Or: Frankfort plane (FH), Go-Me: Mandibular Plane
FH to mandibular and mandibular arc were used to determine the mandibular position.
Convexity (distance) and convexity (angle) were used to determine the maxillary position.

Fig. 8.
The comparison of buccolingual inclination at maxilla and mandibular first molar between Mild, Moderate and Severe class Ⅲ occlusion in the N pattern and R&C pattern by the Steel-Dwass test (*：$p<0.05$).

The rectangular box represents the interquartile range, and the line across the box indicates the median value. From the two ends of the box, lines extending outward to the upper end represent the maximum value, and the lower end represents the minimum value.
(a) The buccolingual inclination of maxilla first molar in the N pattern.
(b) The buccolingual inclination of maxilla first molar in the R&C pattern (some of the patients with an R&C pattern).
(c) The buccolingual inclination of mandibular first molar in the N pattern.
The buccolingual inclination of mandibular first molar in the R&C pattern (some of the patients with an R&C pattern).

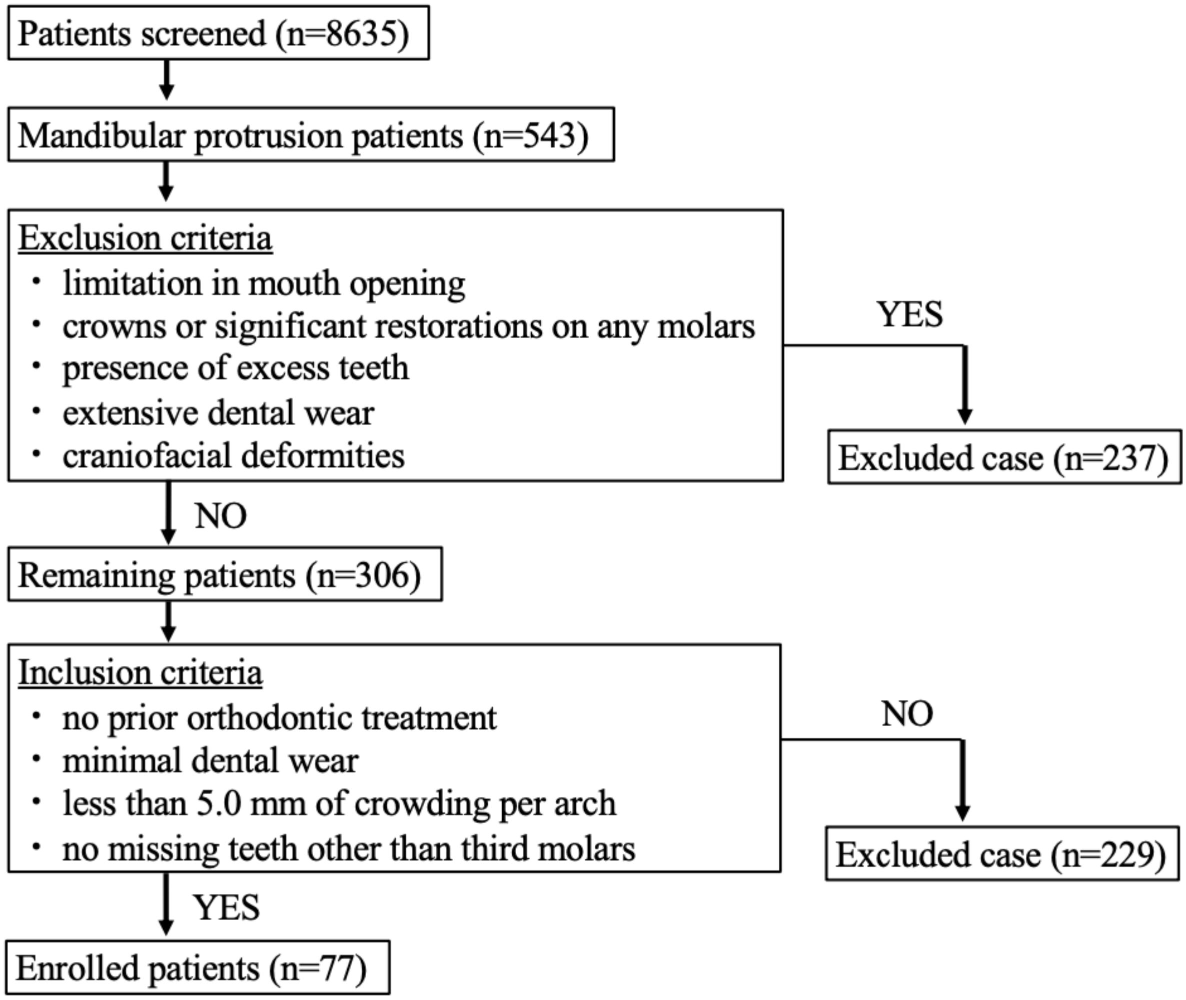

Fig. 1. Flowchart of patients enrollment.

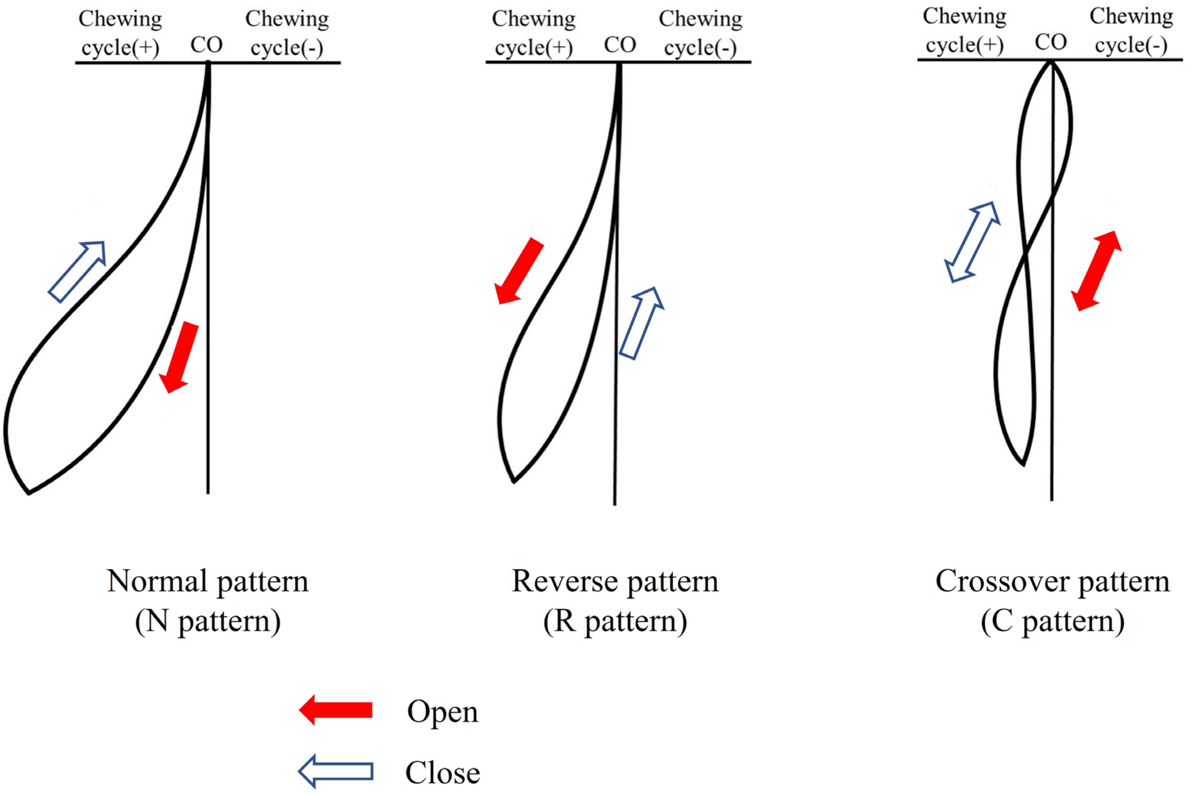

Fig. 2. Classification of chewing pattern.

Normal pattern (N pattern): from centric occlusion, the mandible moves downward and then laterally toward the chewing side or the non-chewing side before returning to centric occlusion along a concave, convex, or linear path.
Reverse pattern (R pattern): the reverse of normal pattern
Crossover pattern (C pattern): the mandible moves slightly laterally, downward, slightly laterally again, and then returns to centric occlusion.
Centric occlusion (CO)

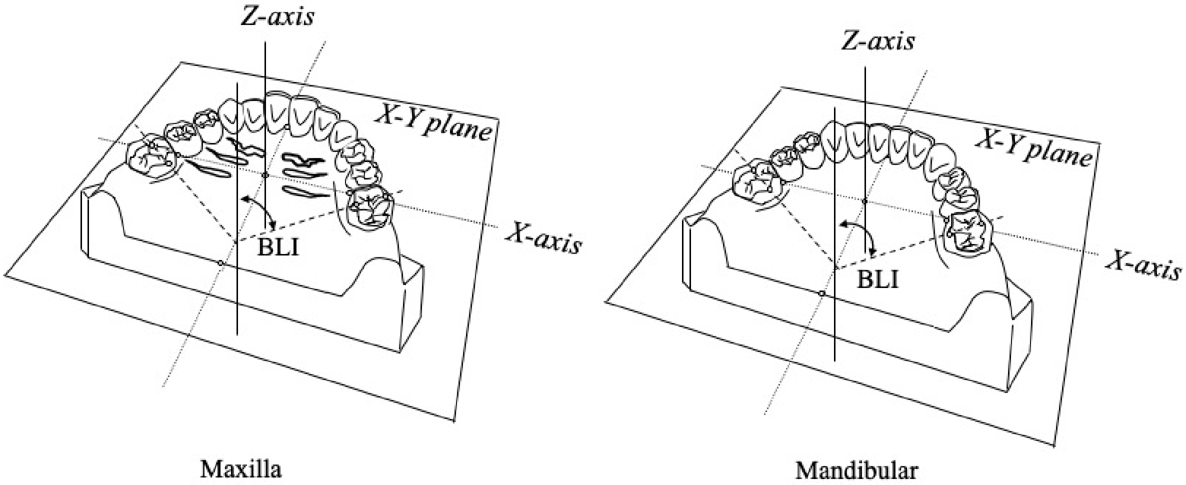

Fig. 3. Maxillary and mandibular buccolingual inclination (BLI).

The measurement points of the maxillary first molar were the intersection of occlusal edge and buccal groove, and the intersection of occlusal edge and distolingual groove. Those of the mandibular first molar were the intersection of occlusal edge and buccal groove, and the intersection of occlusal edge and lingual groove. The maxilla and mandibular first molar buccolingual inclination (BLI) was formed between the line passing through two points on the molar and Z-axis.

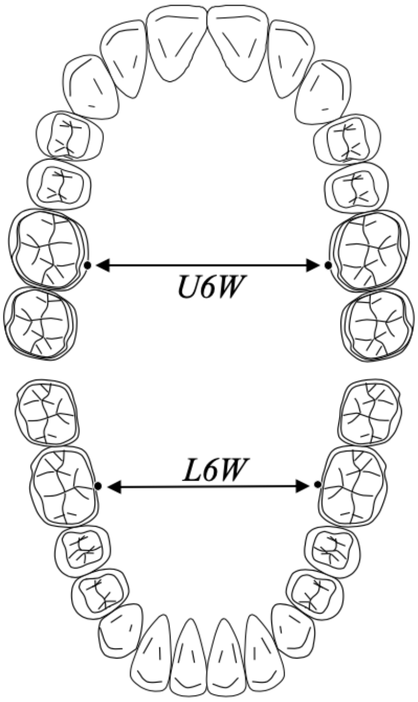

Fig. 4. Inter molar width in the maxillary and mandibular dentition.

Maximum distance from the lingual groove of the maxillary and mandibular first molars to the clinical cervical line of the tooth (U6W, L6W).

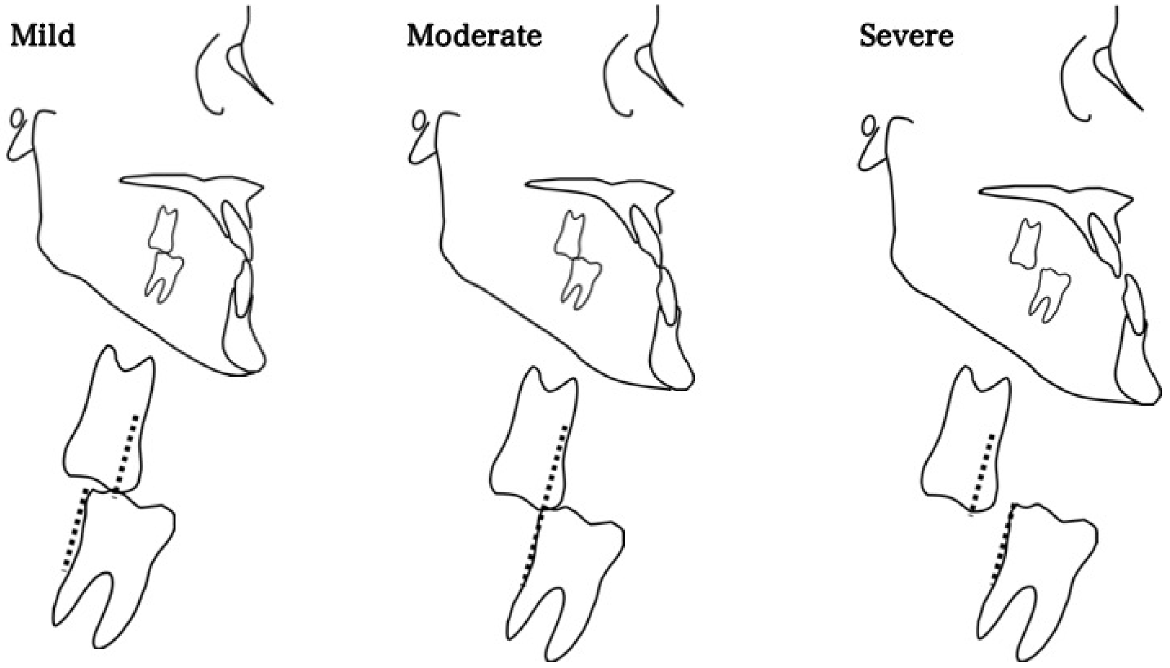

Fig. 5. Degree of mandibular prognathism.

Moderate mandibular prognathism (Moderate) was defined when the mesiobuccal surface ridge of the maxillary first molar coincided with the distal surface of the mandibular first molar. The mandibular molars located mesial to the Moderate were classified as severe mandibular prognathism (Severe), and those located distal to the Moderate position were classified as mild mandibular prognathism (Mild).

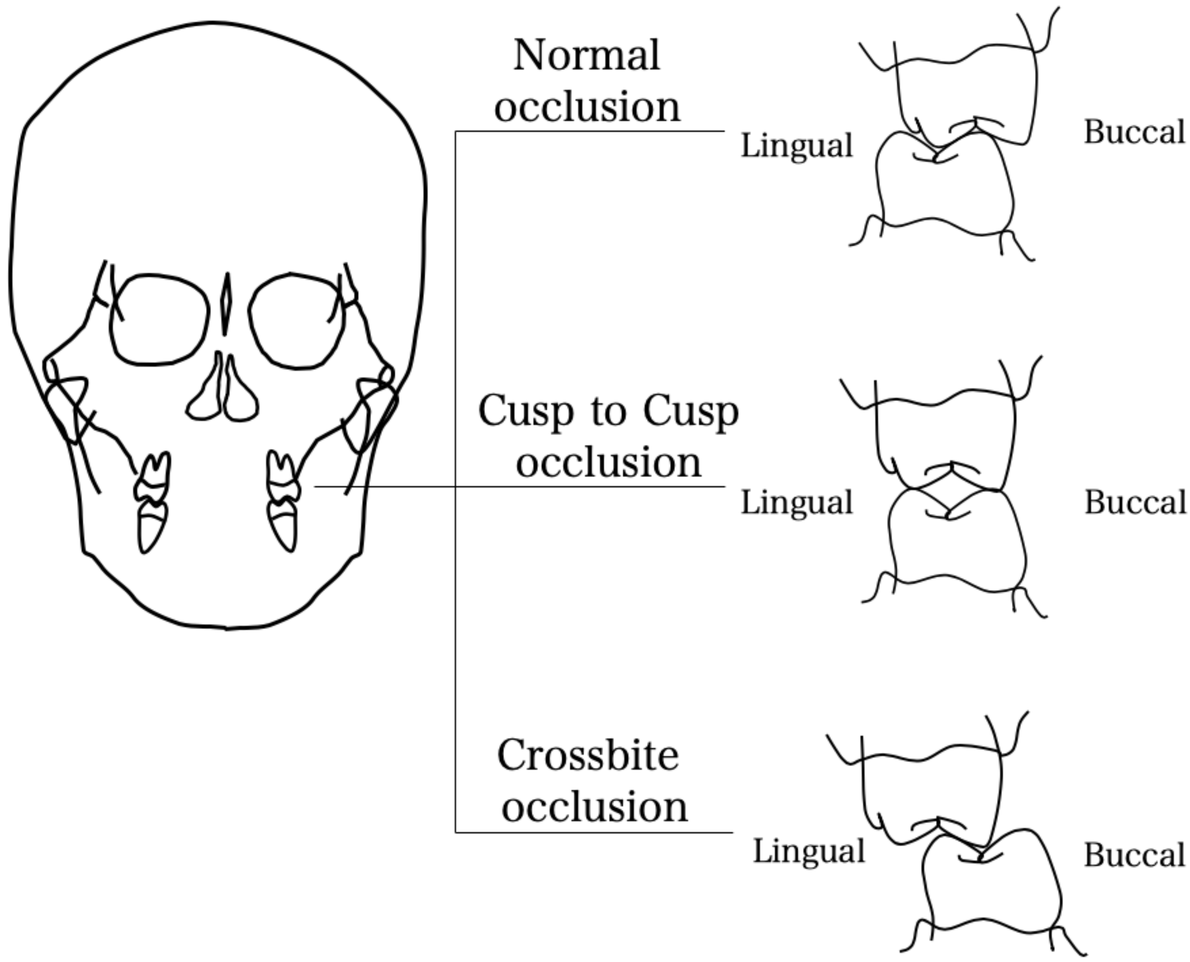

Fig. 6. Buccolingual occlusal relationship of first molars.

Normal occlusion: The lingual cusp inner incline of the maxillary first molar is contact with the buccal cusp inner incline of the mandibular first molar.

Crossbite occlusion: The buccal cusp inner incline of the maxillary first molar is contact with the lingual cusp inner incline of the mandibular first molar.

Cusp to cusp occlusion: Normal occlusion to crossbite occlusion.

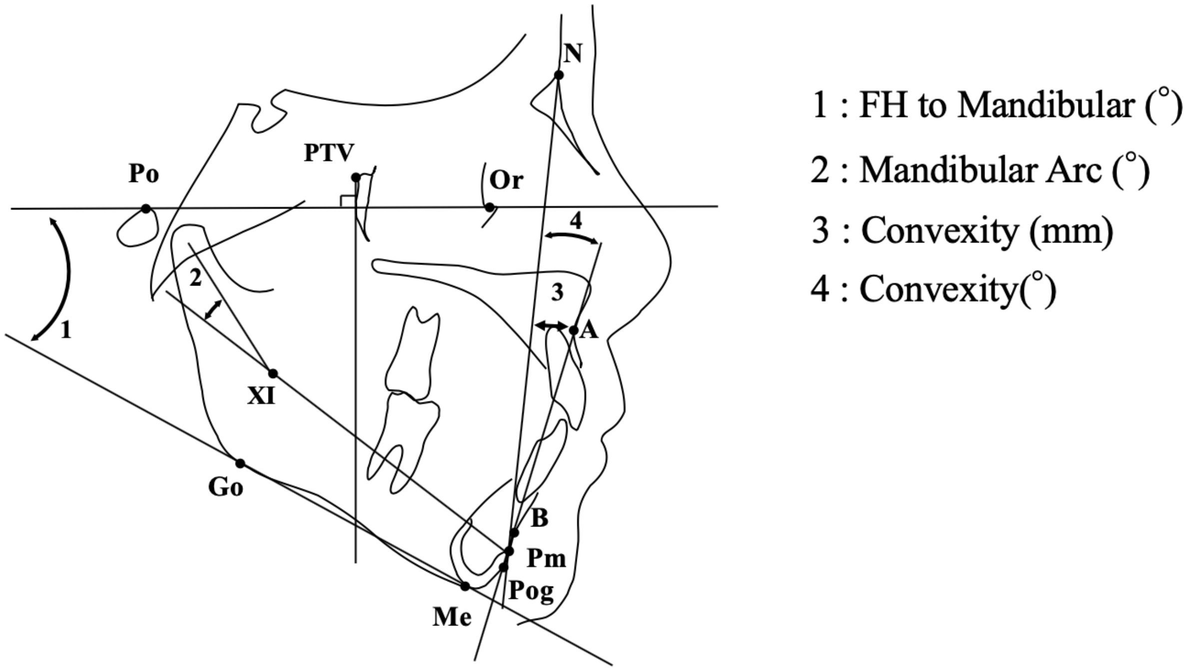

Fig. 7. Cephalometric analysis

Xi: The center of the mandibular ascending ramus.

N: nasion, Or: orbitale, Po: porion, A: point A, B: point B, XI: XI point, PM: protuberane menti, Pog: pogonion, Me: menton, Go: gonion, PTV: pterygoid vertical,

Po-Or: Frankfort plane (FH), Go-Me: Mandibular Plane

FH to mandibular and mandibular arc were used to determine the mandibular position.

Convexity (distance) and convexity (angle) were used to determine the maxillary position.

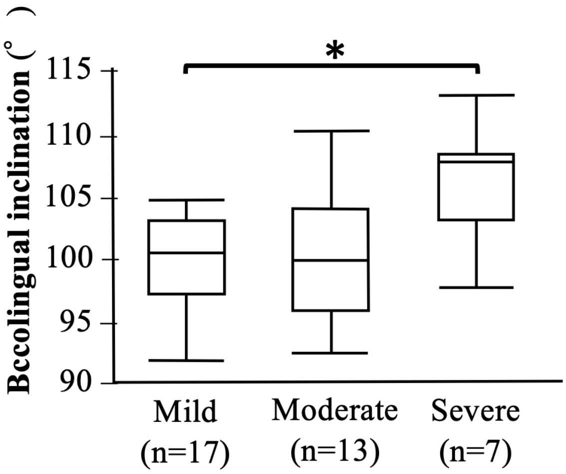

Fig. 8 (a) Maxillary, N pattern

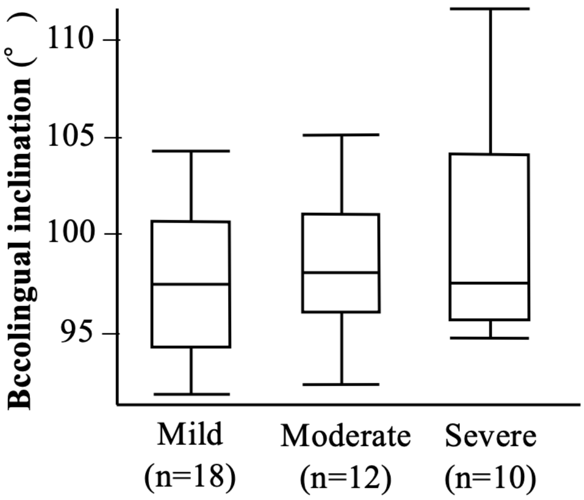

Fig.8 (b) Maxillary, R&C pattern

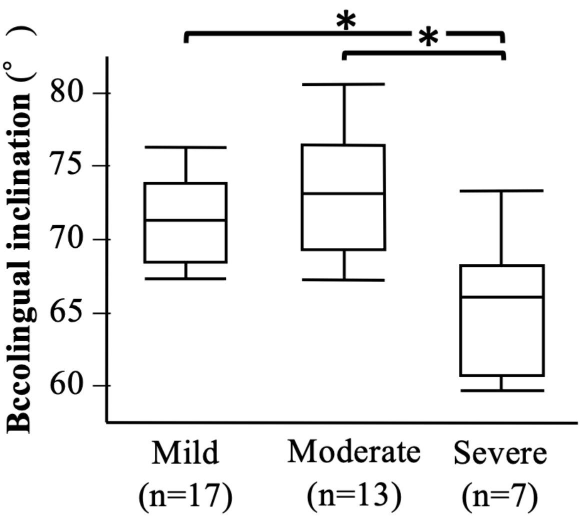

Fig.8 (c) Mandibular, N pattern

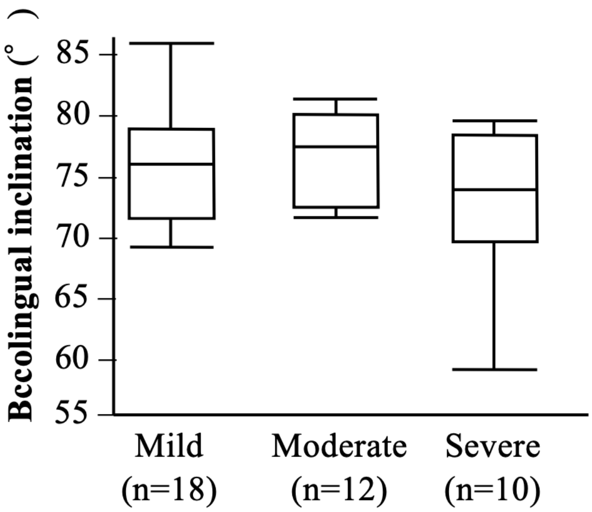

Fig.8 (d) Mandibular, R&C pattern

Fig. 8 (a-d)

The comparison of buccolingual inclination at maxilla and mandibular first molar between Mild, Moderate and Severe class Ⅲ occlusion in the N pattern and R&C pattern by the Steel-Dwass test (*：$p<0.05$).

The rectangular box represents the interquartile range, and the line across the box indicates the median value. From the two ends of the box, lines extending outward to the upper end represent the maximum value, and the lower end represents the minimum value.

(a) The buccolingual inclination of maxilla first molar in the N pattern.
(b) The buccolingual inclination of maxilla first molar in the R&C pattern (some of the patients with an R&C pattern).

(c) The buccolingual inclination of mandibular first molar in the N pattern.

(a) The buccolingual inclination of mandibular first molar in the R&C pattern (some of the patients with an R&C pattern).

Table 1. The relationship between buccolingual occlusal relationship of the first molars and degree of mandibular prognathism.

	Degree of mandibular prognathism			
Buccolingual occlusal relationship of the first molars	Mild	Moderate	Severe	total
Normal	20.8 (16)	14.3 (11)	5.2 (4)	40.3 (31)
Cusp to Cusp	15.6 (12)	13.0 (10)	14.3 (11)	42.9 (33)
Cross bite	9.1 (7)	5.2 (4)	2.6 (2)	16.9 (13)
total	45.5 (35)	32.5 (25)	22.1 (17)	100.0 (77)

% (n)

Table 2. The relationship between chewing pattern and buccolingual occlusal relationship of the first molars.

	Buccolingual occlusal relationship of the first molars			
Chewing pattern	Normal	Cusp to Cusp	Cross	total
N pattern	51.4 (19) ┐*	27.0 (10) ┐*	21.6 (8)	100.0 (37)
R&C pattern	30.0 (12) ┘	57.5 (23) ┘	12.5 (5)	100.0 (40)

% (n), Pearson's chi-square test, *: $p<0.05$

N pattern: Opening from the central occlusal position to the masticatory or non-masticatory side, followed by convex opening to the central occlusal position.

R pattern: Open/close chewing movements is opposite to N pattern.

C pattern: Crossed open and closed chewing movements.

Table 3. Comparison of buccolingual inclination by degree of mandibular prognathism.
(degree)

Degree of mandibular prognathism	**Mild**		**Moderate**		**Severe**	
Chewing pattern	N (n=17)	R&C (n=18)	N (n=13)	R&C (n=12)	N (n=7)	R&C (n=10)
U6	100.2 (91.8-104.5)	96.2 (90.3-103.6)	99.6 (92.3-109.9)	97.0 (90.9-104.5)	107.5 (97.6-112.7)	96.3 (93.3-111.3)
	*				*	
L6	71.4 (67.5-76.3)	75.9 (69.1-85.4)	73.3 (67.2-80.8)	77.0 (59.4-80.9)	66.3 (59.8-73.1)	73.6 (59.3-79.2)
	*				*	

Degree, Median (Range), Mann-Whitney U test, *: $P < 0.05$

U6: Maxilla first molar buccolingual inclination.
L6: Mandibular first molar buccolingual inclination.
BLI: Buccolingual inclination.

Table 4. Intermolar width of the maxillary and mandibular first molars(distance).

	Class Ⅰ[9] (n= 31)	Class Ⅲ (n= 77)
	Mean (± S.D.)	Mean (± S.D.)
U6W (mm)	38.7 ± 2.2	38.6± 2.6
L6W (mm)	35.7 ± 2.4	36.1± 2.7

9) : Okano M: Orthod Waves Jpn Ed: 112-121, 2006.

Class Ⅰ: Normal relationship between the maxillary and mandibular.

ClassⅢ: Skeletal mandibular prognathism.

Table 5. Spearman's correlation analysis was performed between the buccolingual inclination in the normal occlusion of N pattern and the measurement items of the cephalometric analysis.

	U6	**L6**
FH to Mandibular	- .520*	- .173
Mandibular arc	.492*	- .133
Convexity (angle)	- .464*	.046
Convexity (distance)	- .525*	.055
U6W	- .080	- .016
L6W	.029	.175

n=19, Spearman Correlation Coefficients, *: $P < 0.05$

U6: Buccolingual inclination of the upper first molars.
L6: Buccolingual inclination of the lower first molars.
U6W: Intermolar width of the maxillary first molars.
L6W: Intermolar width of the mandibular first molars.