

Determination of craniofacial growth in patients with untreated Class III malocclusions and anterior crossbites using the centroid method

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SUMMARY The aim of this investigation was to assess average Class III craniofacial growth in Japanese males and females, using cross-sectional data from infancy to adulthood. Growth was analysed using the centroid method. Centroid G was geometrically calculated from the triangle Δabc , which comprised the palatal, articulare–gnathion (Ar–Gn), and A–B planes.

Lateral cephalograms were obtained of 323 Japanese males and 611 females aged 2 years or older but under 25 years of age. Each dataset was divided into 2 year intervals according to age and categorized into 10 developmental stages. One-way analysis of variance followed by a Bonferroni's *t*-test was used to compare the results for each group of males and females separately.

No significant gender differences were observed in the palatal plane to Ar–Gn plane angle. In males, significant increases in the palatal plane to A–B angle were found up to 14–15 years of age and in the area of Δabc , G–G and Ms–Ms values up to 16–17 years. Among females, changes in these cephalometric measurements showed tendencies that were nearly identical to those of males.

These findings provide the characteristics of Class III malocclusions in the growth and developmental period, and as they can be used as standards for understanding the effectiveness of Class III treatment, they may be useful in orthodontic and/or orthopaedic diagnosis and treatment planning.

Introduction

The incidence of Class III malocclusions is high among Japanese subjects (Graber, 1961). Because malocclusions are often regarded as aesthetic problems, parents of children with such abnormalities in the primary dentition often enquire as to whether or not treatment is required.

Nagahara *et al.* (1997) reported that some patients with an anterior crossbite in the primary dentition experience self-correction during the transitional stage to the permanent dentition without orthodontic and/or orthopaedic treatment. Moreover, Nagahara *et al.* (2001) devised an algorithm that can be used to predict self-correction in the transitional dentition in 3-year-old subjects. Reyes *et al.* (2006) estimated growth in Class III malocclusions by analysing the pre-treatment lateral cephalograms of 949 untreated male and female Class III patients of Caucasian ancestry from 6 to 16 years of age and Miyajima *et al.* (1997) of untreated individuals with a Class III malocclusion and an anterior crossbite by evaluating 1376 Japanese female subjects classified into seven groups (120–256 subjects per group) according to Hellman's stages of dental development (Hellman, 1927a,b).

However, there are problems with the data and methods of Miyajima *et al.* (1997) and Reyes *et al.* (2006). The first is that the vertical parameter is not stipulated in the data. For that reason, it is possible that the data also included deep bite and open bite vertical occlusal patterns. When carrying out cross-sectional studies, sufficient attention to establishing data

selection is required. The second problem is that while Hellman's (1927a,b) stages of development are used to classify data in the study of Miyajima *et al.* (1997), the age range of 16.0–43.8 years for stage VA (eruption of third molars completed) is too broad, thereby preventing identification of the approximate time at which growth is complete. The final problem is that cephalometric parameters are not sufficiently refined and standardized, as illustrated by the use of two parameters, ANB and Wits appraisal, for evaluating maxillary and mandibular antero-posterior position.

Murata *et al.* (2006) used the centroid method, which Johnson (1960) applied to the evaluation of cranial and facial structures, of occlusion for studying mandibular and maxillary growth based on methods that express the direction of growth of the mandible and maxilla as one unit (Figure 1). This method was based on the philosophy of Angle (1907) who advocated the constancy of the position of the upper first molar—his approach is known as the 'key to occlusion' because of the importance it places on this tooth. The centroid G was geometrically calculated from the triangle Δabc , which comprised the palatal, articulare–gnathion (Ar–Gn), and A–B planes. The palatal plane connects points between the anterior and posterior nasal spine, which is adopted as the standard plane for the upper arch, and the plane connecting Ar and Gn is used as the mandibular growth axis. The A–B plane connects the dentoalveolar base of the maxilla and mandible. Among 'normal' adult subjects, Δabc is similar between genders and centroid G is located near

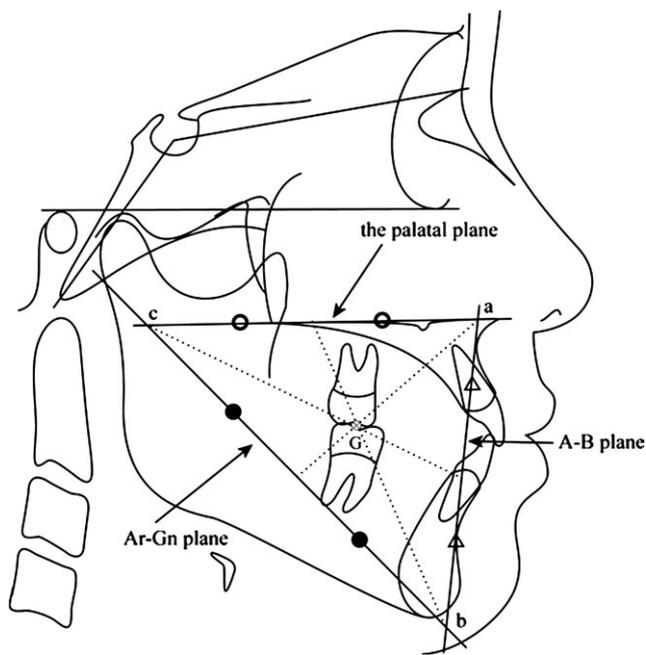


Figure 1 The centroid method of occlusion. Point a is the intersection of the palatal and A-B planes; point b the intersection of the articulare-gnathion (Ar-Gn) and A-B planes; and point c the intersection of the palatal and Ar-Gn planes. The centroid 'G' was geometrically calculated from triangle Δabc , which comprised the palatal, Ar-Gn, and A-B planes. The three median lines of Δabc naturally meet at one point, the centroid.

the occlusal surface of the upper first molar. Based on the positional relationship between centroid G and the upper first molar, it was found that the upper first molar shifts towards the lower front during the transition from Class III to normal to Class II. Moreover, Murata (2007) reported that Δabc area was significantly greater ($P < 0.01$) in an open bite than in a deep bite group among both Class II and Class III malocclusion types. There were no differences in Δabc area either between the Class II and the Class III open bite groups or between the Class II and the Class III deep bite groups. These findings suggest that the centroid method of occlusion assessment is a novel and versatile diagnostic technique that can accurately differentiate between vertical occlusal patterns of Class II and III types of malocclusion. The analytical method is also unaffected by gnathostatic differences according to Angle's classification.

The aim of this study was to determine Class III craniofacial growth in Japanese males and females from average growth using the centroid method of occlusion for studying mandibular and maxillary growth (Figure 2).

Subjects and methods

This research was conducted in accordance with the Declaration of Helsinki after receiving approval from the Ethics Committee of Toyohashi City Dental Association. All subjects, or their parents or guardians, gave informed consent before participating in the study.

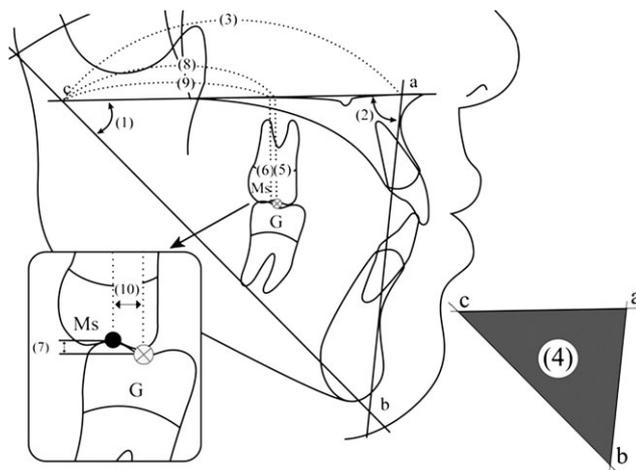


Figure 2 Cephalometric measurements using the centroid method of occlusion. Measurements were taken of the following parameters: the palatal plane to articulare-gnathion (Ar-Gn) angle (1); the palatal plane to A-B angle (2); the a-c distance (3); the area of Δabc (4); G-G', the length of a perpendicular line from G to the palatal plane (5); Ms-Ms', the length of a perpendicular line from the midpoint (Ms) of the occlusal surface of the upper first molar to the palatal plane (6); G-Ms, the difference between the length of the perpendicular lines from G and Ms to the palatal plane (7); c-G', the distance between points c and G in relation to the palatal plane (8); c-Ms', the distance between points c and Ms in relation to the palatal plane (9); and G'-Ms', the distance between points G and Ms in relation to the palatal plane (10).

Lateral cephalograms taken in centric occlusion were obtained from 934 Japanese males and females (323 males and 611 females) 2 years of age or older but under 25 years of age who met the following criteria:

1. Untreated anterior crossbite, excluding edge-to-edge occlusion.
2. An Angle Class III maxillary and mandibular first molar occlusion using data for adult subjects (26 males and 51 females) with normal occlusion reported in Murata *et al.* (2006) with Angle Class III maxillary and mandibular first molar occlusion. The distance between the distal contact points of the upper and lower first molars relative to the occlusal plane in the direction of the sagittal plane was measured (Figure 3). Average values and standard deviations (SDs) were calculated for this parameter (-2.0 ± 0.8 mm for males, -1.8 ± 0.7 mm for females) and individuals with a SD of -1 or less were selected.
3. A normal overbite of 0.5–4.0 mm according to the method of Kim (1974).
4. No missing teeth.
5. No pronounced deviation in the maxillary or mandibular median line.

Cephalometric analysis

All lateral cephalograms were taken with the same cephalostat (CX-90 SP, Asahi Roentgen Ind. Co. Ltd, Minami-ku, Kyoto, Japan) at a magnification of 1.1. The

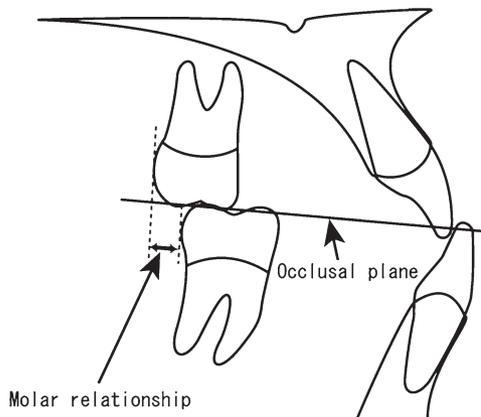


Figure 3 Measurement of molar relationship. The distance measured on the lateral cephalogram was the sagittal relationship of the distal contact points of the upper and lower first molars relative to the occlusal plane. Positive values are towards a Class I occlusion and negative values towards Class III malocclusion.

distance between the central plane of the object and the X-ray focus and the distance between the X-ray focus and the film were 150 and 165 cm, respectively. The lateral cephalogram of each subject was traced and checked to ensure that they were accurate. The selected landmarks were digitized using a special computer program written in BASIC, and measurement of craniofacial form was calculated by computer and tabulated into skeletal, dental relationships. The 10 cephalometric measurements utilized in the study were taken of the parameters derived from the centroid method of occlusion for studying mandibular and maxillary growth (Figure 2). The result of the error method using the formula of Baumrind and Frantz (1971) has been reported previously (Table 1, Murata, 2007). This indicated that the cephalometric measurements were reliable.

Developmental stages

Each dataset was divided into 2 year intervals according to age and categorized into the 10 developmental stages 2-3, 4-5, 6-7, 8-9, 10-11, 12-13, 14-15, 16-17, 18-19, and 20+ years (Table 1). The relationship between age and Hellman's (1927a,b) stages of dental development are also shown in Table 1. The data included those with congenitally absent third molars; stage VA (eruption of third molars completed) subjects were included in stage IVA (eruption of second molars completed).

Statistical analysis

The means and SDs for each of the cephalometric measurements were determined for each developmental stages. A one-way analysis of variance (ANOVA) was used to compare the 10 individual stages of development. A Bonferroni's *t*-test of multiple comparisons was also performed on the data to determine craniofacial growth in patients with untreated Class III malocclusions and anterior

Table 1 Relationship between stages of dental development as defined by Hellman (1927a,b) and chronological age.

Definition	Years		2-3		4-5		6-7		8-9		10-11		12-13		14-15		16-17		18-19		20+			
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female		
IIA Eruption of second primary molars	42	102	6	22	31	72	5	8																
IIC Eruption of permanent incisors	66	109			9	26	57	83																
IIIA Eruption of permanent first molars	23	42							23	41														
IIIB Eruption of canines and premolars	63	71							31	47														
IIIC Beginning of eruption of second molars	51	99									34	55	14	40										
IIVA Eruption of second molars	78	188										5	10	48	20	45	12	31	17	24	17	24	19	35

Table 2 Analysis of variance.

Variable (Figure 2)	Males		Females	
	F-value	Significance	F-value	Significance
Skeletal				
(1) Palatal plane to Ar-Gn plane angle (°)	0.8	ns	1.0	ns
(2) Palatal plane to A-B plane angle (°)	12.8	**	33.0	**
(3) a-c (mm)	20.0	**	17.7	**
(4) Δabc (cm ²)	77.3	**	92.2	**
Vertical				
(5) G-G' (mm)	53.7	**	86.6	**
(6) Ms-Ms' (mm)	90.2	**	96.2	**
(7) G-Ms (mm)	4.8	**	10.4	**
Horizontal				
(8) c-G' (mm)	42.5	**	58.4	**
(9) c-Ms' (mm)	30.9	**	29.1	**
(10) G'-Ms' (mm)	37.6	**	62.0	**

ns, not significant; ** $P < 0.01$.

crossbites. As the data for groups 2-3 to 6-7 years included pre-stage IIIA subjects and the eruption of the first molars were not yet complete, the maxillary second primary molars were used instead of the maxillary first molars for Ms. Accordingly, the four parameters, Ms-Ms', G-Ms, c-Ms', and G'-Ms', values for the stages 6-7 and 8-9 years were not compared.

Results

Analysis of variance

Table 2 shows the results of the ANOVA. For both males and females, there was no significant difference in the palatal plane to Ar-Gn plane angle, but there was a significant difference for all other parameters ($P < 0.01$).

Multiple comparisons

Comparisons between each stage for males and females. For the palatal plane to A-B angle, which shows the maxillary and mandibular antero-posterior position, an increase was seen from 2-3 to 20+ years in both genders (Tables 3 and 4). The a-c distance gradually increased through all stages among males and females. In both groups, the area of Δabc increased gradually. In the vertical evaluation, G-G' values increased gradually. The Ms-Ms' values increased, with significant differences between each group from 2-3 to 6-7 years and from 8-9 to 16-17 years. A decrease in G-M values was seen from 2-3 to 6-7 years. Furthermore, a slight decrease was seen from 8-9 to 20+ years of age. Horizontal evaluation showed a gradual increase in c-G' values. There was an increase in c-Ms' values from 2-3 to 6-7 years. Furthermore, an increase was

seen from 8-9 to 20+ years. The G'-Ms' values decreased from 2-3 to 6-7 years with a gradual decrease in change from 8-9 to 20+ years. Overall, there was no difference between males and females.

Discussion

Changes in the palatal plane to Ar-Gn plane angle

Murata *et al.* (2006) reported a minimal variation in the angle of the palatal plane to the Ar-Gn plane during the developmental period using Bolton standards (Broadbent *et al.*, 1975). In addition, Sakamoto (1959) identified data between childhood and adulthood which make it suitable for the study groups of maxillofacial developmental growth. The results of that study showed that this angle for males through the growth and development period ranged from 45.0 to 47.1 degrees, a change of 2.1 degrees; for females, the range was 45.3-46.9 degrees, a change of 1.6 degrees. Thus, these angles changed very little in individuals with normal occlusion as well as in individuals with a Class III malocclusion, and growth and development were not influenced.

Palatal plane to A-B angle

Kim and Vietas (1978) reported that the antero-posterior dysplasia indicator (APDI) was a good predictor of lateral disharmony between the upper and lower arches. APDI was defined as the facial plane angle \pm the A-B plane angle \pm the palatal plane angle, although geometrically it is the angle of the palatal plane to the A-B plane. Since the results of Kim and Vietas (1978) showed statistically significant increases for both males and females from 2-3 to 14-15 years, there is a tendency for a Class III malocclusion to worsen until 14-15 years of age. This suggests that early orthodontic/orthopaedic treatment is necessary when treating Class III malocclusions.

The area of Δabc

Mitani *et al.* (1993) reported that the morphological characteristics of mandibular prognathism, which are established before the pubertal growth peak, are maintained 3 years post-puberty. Baccetti *et al.* (2007) identified significant changes in total mandibular length until young adulthood (18 years on average) using 1091 (560 females and 531 males) pre-treatment lateral cephalometric records of Class III patients of Caucasian ancestry. The diagnostic method used in that study was not mandibular and maxillary length measurement, but rather the area of Δabc , a quantitative growth and development evaluation parameter. The area of Δabc is calculated using the formula $S = 1/2ab \sin\theta$. In the present study, a corresponds to the distance a-c, b to the distance b-c, and ' θ ' to the palatal plane to Ar-Gn angle. Two-dimensional parameters, such

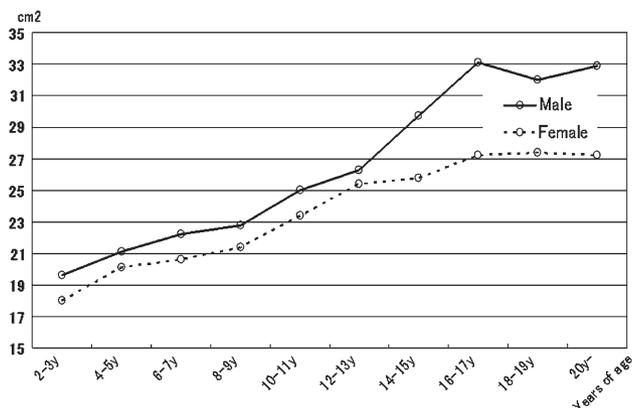


Figure 4 Changes in the area of Δabc at the 10 stages of chronological age.

as the area of Δabc , allow a more precise understanding of changes than conventional, one-dimensional measurement parameters, such as total mandibular length (Co–Gn), and they are more suitable for evaluating craniofacial growth and development. This is because in cases where there is, for example, a 10 per cent increase in both a–c and b–c distances with only slight changes in the palatal plane to Ar–Gn angle, the increase in the area of Δabc is $1.1 \times 1.1 = 1.21$, an increase of 21 per cent, which amplifies the change. The results of the present study (Figure 4, Tables 3 and 4) show statistically significant increases in the area of Δabc for both males and females up to 16–17 years of age, after which it is comparatively stable. In Japanese males and females, 16–17 years is the final development stage of a Class III malocclusion. Ohide and Machiya (1997, 1998), in a cephalometric investigation of three male and two female patients with skeletal Class III malocclusions with mandibular overgrowth in the late pubertal period, found a frequency of this type in 2.7 per cent of males and 2.5 per cent of females, which was very low. It is not possible to determine whether this type exists at the time of initial diagnosis. Consequently, it is highly likely that cases of this type will prove difficult for clinicians. These results provide data that allow the morphological characteristics and treatment efficacy/change in Class III patients during the growth and development period to be understood from average growth. During routine clinical practice, careful observation to determine the presence of undesirable changes in growth is necessary, and when such cases are encountered, to understand in advance that the treatment policies and methods developed at the time of the initial diagnosis may need to be changed.

Positional relationship of the centroid with the upper first molar

The results show that the range of G–Ms was from +1.4 to +4.0 mm for males and from +1.7 to +3.8 mm for females.

In addition, that the range of G'–Ms' was from +2.1 to +10.2 mm for males and from +1.7 to +9.1 mm for females identifies that at all stages Ms was located postero-superiorly relative to G, i.e. the Class III position. For vertical evaluation of the centroid in subjects with a normal occlusion, the mean G–Ms values were –0.1 mm for females and –1.3 mm for males; for horizontal evaluation, the mean G'–Ms' values were +1.1 mm for females and +0.4 mm for males (Murata *et al.*, 2006).

Conclusion

The aim of the present investigation was to use the centroid method of occlusion for studying mandibular and maxillary growth to understand from average growth data the dental and craniofacial morphological characteristics of Japanese individuals with mandibular prognathism. Both males and females showed no significant differences between each group in the palatal plane to Ar–Gn plane angle. Among males, increases in the palatal plane to A–B angle were seen up to 14–15 years, in the area of Δabc up to 16–17 years, and in G–G' and Ms–Ms' values up to 16–17 years of age. In females, changes in the palatal plane to A–B angle, the area of Δabc , G–G', and Ms–Ms' values indicated tendencies that were nearly identical to those for males. The results of this study allow understanding of the characteristics of Class III malocclusion in the growth and development period, and because they can also be used as standards for understanding the effectiveness of Class III treatments, they may be useful for orthodontic and/or orthopaedic diagnosis and treatment planning.

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