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Use of the centroid method of occlusion for studying the vertical and horizontal relationship of the mandible and maxilla

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SUMMARY The aim of the present study was to verify whether the centroid method of occlusion for studying mandibular and maxillary growth enables accurate determination of vertical occlusal patterns (open and deep bite). Lateral cephalograms were obtained of Japanese adult females aged over 18 years of age with a Class II malocclusion (61 open bite and 47 deep bite), or a Class III type open bite (70 subjects) or deep bite (21 subjects) malocclusion. One-way analysis of variance followed by a Bonferroni's *t*-test was used to compare the results among these four groups.

The Δabc area, which comprised the palatal, Ar-Gn, and A-B planes, was shown to be significantly larger in the open bite than in the deep bite group for both Class II and Class III malocclusion types ($P < 0.01$). There was no difference in the Δabc area between the Class II and Class III open bite groups or between the Class II and Class III deep bite groups.

These findings suggest that the centroid method of occlusion is a versatile diagnostic technique that can accurately differentiate between vertical occlusal patterns of Class II and III types of malocclusion limited to Japanese adult females. The analytical method is also unaffected by gnathostatic differences according to Angle classification.

Introduction

Broadbent (1931) devised a cephalometer for standardizing cephalometric radiographs to study morphological changes of the dentition and maxillo-facial cranium that accompany growth. This method made it possible not only to establish measurement reference points up to the inner structure of the maxillo-facial cranium but also to analyse morphological changes by superimposing consecutive images taken during growth using constant reference points.

The most widespread and commonly used parameter for evaluating the vertical occlusal pattern is the Frankfort horizontal (FH) plane angle (porion to orbitale) to the mandibular plane. Hyper- and hypodivergences, first introduced by Schudy (1964), are also used as specific diagnostic terms. However, Kim (1974) reported that this measurement has limitations because it cannot accurately differentiate between vertical occlusal patterns. As a result, it could not contribute sufficiently to diagnosis and the formulation of treatment plans and methods.

Murata *et al.* (2006) used the centroid method, which Jonson (1960) applied to the evaluation of cranial and facial structure 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. This technique involves two planes: a palatal plane that connects points between the anterior and posterior nasal spine, which is adopted as the standard plane for the upper arch, and the standard plane connecting articulare (Ar) and gnathion (Gn), which is used as the mandibular growth axis. The centroid method of occlusion geometrically calculates the centroid 'G' from the triangle Δabc (Figure 1), which is composed of three planes including the A-B plane that connects the dentoalveolar base of the maxilla and mandible. The technique can be used to carry out maxillo-facial and dental evaluation (Figure 2).

The aim of the present study was to verify whether the centroid method could be used to accurately discriminate between vertical occlusal patterns (open and deep bite).

Subjects and methods

Subjects

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 gave informed consent to participate in the study.

Lateral cephalograms were obtained from Japanese adult female subjects aged over 18 years, who had not undergone orthodontic treatment, with either a Class II malocclusion (overjet of >6 mm; 61 subjects with an open bite and 47 subjects with a deep bite) or a Class III malocclusion (overjet of <0 mm; 70 subjects with an open bite and 21 subjects with a deep bite). Vertical occlusal patterns were grouped according to the method of Kim (1974), where an open bite was defined as <0 mm and a deep bite as >4.5 mm.

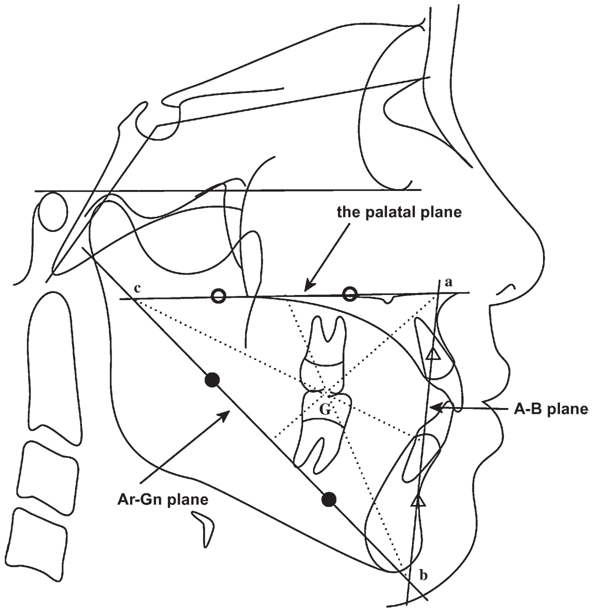

Figure 1 The centroid method of occlusion. Point a is the intersection of the palatal and A-B planes, point b the intersection of the Ar-Gn and A-B planes, and point c the intersection of the palatal and Ar-Gn planes. The centroid 'G' was geometrically calculated from the triangle Δabc, which comprised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

Measurements

All lateral cephalograms were taken at the same magnification of 1.1 times. The distance between the central plane of object and X ray focus and the distance between the X ray focus and X ray film were 150 cm and 165 cm, respectively. The lateral cephalograms were traced and checked to ensure they were accurate. The selected landmarks were digitized using a computer program written in BASIC, and measurement of craniofacial form was calculated by computer and tabulated into skeletal–dental relationships. Figure 2 shows the cephalometric measurements utilized in the study. Overjet and overbite were also included as dental measurements. The angle of the FH plane to the mandibular plane, which is conventionally used to evaluate vertical occlusal patterns, was also included. The result of the error method using the formula of Baumrind and Frantz (1971) is shown in Table 1. The number of lateral cephalograms was 10 and the number of tracings per lateral cephalogram was three. Consequently, 30 tracings were used. This indicated that the cephalometric measurements were reliable.

Statistical analysis

The means and standard deviations for each measurement were determined from the cephalograms. Class II and III malocclusion subjects with the same Angle classification were compared to determine variations between vertical occlusal patterns in both the open and deep bite groups. One-way analysis of variance (ANOVA) followed by Bonferroni's *t*-test of multiple comparison was used to compare the results among the Class II open bite, Class III open bite, Class II deep bite, and Class III deep bite with the same vertical occlusal pattern but different Angle classifications.

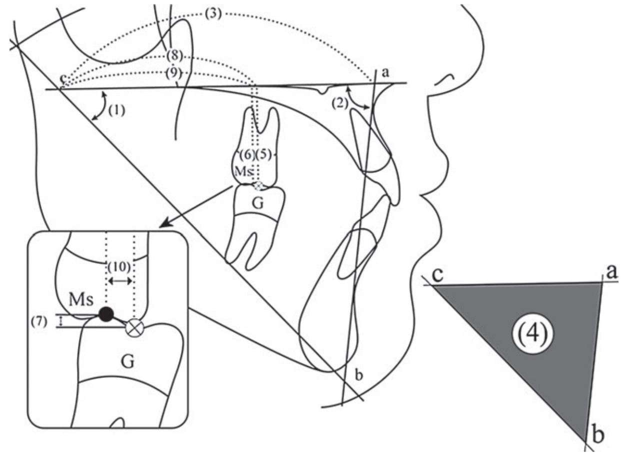

Figure 2 Cephalometric measurements using the centroid method of occlusion. Measurements were taken of the following parameters: the palatal plane to Ar-Gn angle (1); the palatal plane to A-B angle (2); the a-c distance (3); the area of Δabc (4); G-G′, the length of a perpendicular line from G to the 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).

Table 1 Error method analysis.

Variable (Figure 2)	SD
Skeletal	
Palatal plane to Ar-Gn plane angle (°)	0.7
Palatal plane to A-B plane angle (°)	1.2
a-c (mm)	1.1
Δabc (cm^2)	0.6
Vertical	
G-G′ (mm)	0.6
Ms-Ms′ (mm)	0.6
G-Ms (mm)	0.8
Horizontal	
c-G′ (mm)	0.8
c-Ms′ (mm)	1.1
G′-Ms′ (mm)	0.7
Dentition	
Overjet (mm)	0.7
Overbite (mm)	0.6
Conventional analysis	
FH plane to mandibular plane angle (°)	0.8

Ar-Gn, articulare-gnathion; FH plane, porion to orbitale; SD, standard deviation.

Results

Analysis of variance

Table 2 shows the results of the ANOVA. All parameters were significantly different at $P < 0.01$.

Table 2 Analysis of variance.

Variable (Figure 2)	*F* value	Significance
Skeletal		
Palatal plane to Ar-Gn plane angle (°)	32.2	**
Palatal plane to A-B plane angle (°)	244.9	**
a-c (mm)	48.9	**
Δabc (cm^2)	10.8	**
Vertical		
G-G′ (mm)	63.7	**
Ms-Ms′ (mm)	7.1	**
G-Ms (mm)	51.1	**
Horizontal		
c-G′ (mm)	16.2	**
c-Ms′ (mm)	11.0	**
G′-Ms′ (mm)	79.8	**
Dentition (mm)		
Overjet	711.1	**
Overbite	290.5	**
Conventional analysis		
FH plane to mandibular plane angle (°)	22.9	**

**$P < 0.01$.

Comparison of groups with the same Angle classification but different vertical occlusal patterns

Open and deep bite Class II malocclusion subjects. The angle of the palatal plane to the Ar-Gn plane was significantly larger ($P < 0.01$; Figure 2; Table 3). There was no significant difference in the angle of the palatal plane to the A-B plane. In the open bite group, the a-c values were significantly smaller ($P < 0.05$) and the G-G′ values were significantly larger ($P < 0.01$) than in the deep bite group, so the area of Δabc was significantly greater in the open bite group ($P < 0.01$). The Ms-Ms′ values and G-Ms values were significantly larger in the open bite than in the deep bite group ($P < 0.05$ and $P < 0.01$, respectively). In the open bite group the c-G′ values and c-Ms values were significantly smaller than those in the deep bite group ($P < 0.01$ and $P < 0.05$, respectively), but there was no significant difference in the G′-Ms′ values. Overjet and overbite were significantly smaller in the open bite compared with the deep bite group ($P < 0.01$).

Open and deep bites among Class III malocclusion subjects. The angle of the palatal plane to the Ar-Gn plane was significantly larger ($P < 0.01$; Table 3), the angle of the palatal plane to the A-B plane was significantly smaller ($P < 0.01$) and the a-c values and Δabc area were significantly larger in the open bite than in the deep bite group ($P < 0.01$). In addition, the Ms-Ms′ values were significantly larger ($P < 0.01$) in the open bite compared with the deep bite group, but there was no significant difference in the G-Ms values between the two groups. There was no significant difference in the c-G′ values between the two groups, but the c-Ms′ values were significantly larger ($P < 0.05$) and the G′-Ms′ values significantly smaller ($P < 0.01$) in the open bite than in the deep bite group. The overjet was significantly smaller ($P < 0.01$) and the overbite significantly larger ($P < 0.01$) in the deep bite group compared with the open bite group.

Comparison of groups with the same vertical occlusal pattern but different Angle classifications

Class II and Class III open bite. The angle of the palatal plane to the Ar-Gn plane was significantly larger ($P < 0.01$; Table 2). In contrast, as shown in Figure 2, the angle of the palatal plane to the A-B plane was significantly smaller ($P < 0.01$) in the Class II open bite group compared with the Class III open bite group. The a-c values were significantly larger but the G-G′ values were significantly smaller in the Class II than in the Class III open bite group ($P < 0.01$). As a result, there was no significant difference in the Δabc area between the two groups. There was also no significant difference in the Ms-Ms′ values between the two groups, but the G-Ms values were significantly smaller in the Class II open bite group compared with the Class III open bite group ($P < 0.01$). The c-G′ and G′-Ms′ values were significantly smaller ($P < 0.01$), and the c-Ms′ values significantly larger ($P < 0.05$) in the Class II compared with the Class III open bite group. Overjet was significantly larger in the Class II open bite group ($P < 0.01$), but there was no significant difference in overbite between the two groups.

Class II and Class III deep bite subjects. The angle of the palatal plane to the Ar-Gn plane was significantly larger ($P < 0.05$; Table 2). While the angle of the palatal plane to the A-B plane was significantly smaller in the Class II than in the Class III deep bite group ($P < 0.01$), the a-c values were significantly larger ($P < 0.01$) and the G-G′ values significantly smaller ($P < 0.01$) in the Class II deep bite group compared with the Class III open bite group. As a result, there was no significant difference in the Δabc area between the two groups. There was also no significant difference in the Ms-Ms′ values between the two groups, but the G-Ms values were significantly smaller in the Class II than in the Class III deep bite group ($P < 0.01$). Even though there was no significant difference between the two groups in terms of c-G′ values, the c-Ms′ values were significantly larger ($P < 0.01$) and the G′-Ms′ values significantly smaller ($P < 0.01$) in the Class II deep bite group than in the Class III deep bite group. On the other hand, overjet was significantly larger in the Class II deep bite group than in the Class III deep bite group ($P < 0.01$), while there was no significant difference in overbite between the two groups.

Discussion

Occlusal classifications based on lateral cephalograms include an antero-posterior classification according to Angle and a vertical classification of open or deep bite (Kim, 1974). Contrary to the study of Murata *et al.* (2006), Class II and III data were randomly extracted regardless of the

Table 3 Comparison of the four groups investigated.

Variable (Figure 2)	Class II open (n=61)		Class II deep (n=47)		Class III open (n=70)		Class III deep (n=21)		Significance			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Class II open versus Class II deep	Class III open versus Class III deep	Class II open versus Class III open	Class II deep versus Class III deep
Skeletal												
Palatal plane to Ar-Gn plane angle (°)	54.3	4.4	48.4	4.2	48.8	4.1	45.8	3.9	**	**	**	*
Palatal plane to A-B plane angle (°)	75.7	4.6	76.4	4.3	93.9	5.5	99.2	5.3	ns	**	**	**
a-c (mm)	75.3	4.9	77.7	5.1	68.6	5.7	65.2	3.8	*	**	**	**
Δabc (cm^2)	29.0	2.8	26.7	3.4	29.1	3.2	26.1	2.1	**	**	ns	ns
Vertical												
G-G′ (mm)	25.7	1.7	22.9	2.0	28.4	2.5	26.7	2.0	**	**	**	**
Ms-Ms′ (mm)	26.0	2.2	25.0	2.4	26.3	2.2	24.0	2.4	*	**	ns	ns
G-Ms (mm)	−0.3	1.8	−2.1	1.7	2.1	2.2	2.7	2.5	**	ns	**	**
Horizontal												
c-G′ (mm)	43.6	3.7	46.2	3.4	47.7	3.7	47.8	3.0	**	ns	**	ns
c-Ms′ (mm)	45.4	4.5	47.5	5.0	43.3	5.7	40.7	4.7	*	*	*	**
G′-Ms′ (mm)	−1.8	2.5	−1.3	2.7	4.4	3.7	7.0	3.2	ns	**	**	**
Dentition												
Overjet (mm)	9.1	2.0	10.3	2.0	−2.5	1.9	−4.4	1.5	**	**	**	**
Overbite (mm)	−2.2	2.1	5.9	1.1	−2.0	2.1	6.4	1.7	**	**	ns	ns
Conventional analysis												
FH plane to mandibular plane angle (°)	34.4	5.9	25.6	6.2	27.5	5.6	28.3	6.9	**	ns	**	ns

SD, standard deviation; *P < 0.05; **P < 0.01; ns, not significant.

extent of overbite of the upper and lower anterior teeth; in the present investigation, data that differed from the vertical occlusal pattern were included. In addition, conditions were established up to the vertical occlusal pattern. The following four groups were therefore established as the most representative of malocclusions: Class II open bite, Class II deep bite, Class III open bite, and Class III deep bite groups.

The present study was based on Japanese adult females aged over 18 years. The morphological characteristics of each type of malocclusion in adults can be clearly expressed compared with the stage of occlusal development. Therefore, these morphological characteristics are an important source of information for understanding the type of growth changes that will occur by the end of childhood development.

Conventional method of evaluating vertical occlusal pattern

Using the most widespread parameter (the angle of the FH plane to the mandibular plane) for evaluating vertical occlusal pattern, the four groups of patients were compared based on data that used these parameters (Tables 2 and 3). The results showed that there was a significant difference between the open and deep bite groups with a Class II type of malocclusion (P < 0.01), but no significant difference between the two groups with a Class III malocclusion. Thus, it is possible to clearly differentiate between the vertical occlusal patterns in Class II but not in Class III subjects. Finally, a significant difference was seen between the Class II and Class III open bite groups (P < 0.01), but not between the Class II and Class III deep bite groups.

Kim (1974) devised the overbite depth indicator method (angle of the A-B plane to the mandibular plane plus the angle of the FH plane to the palatal plane) to overcome the inadequacies in differentiating between vertical occlusal patterns using cephalometric analysis. The indicator was based on data from 500 subjects, 10 of whom were reported to have a Class III open bite, two a Class III normal overbite, but surprisingly, none with a Class III deep bite.

Research on the mean growth in Japanese female Class III malocclusion subjects revealed that overbite gradually decreased from Hellman's III B stage (eruption of canines and premolars; Hellman, 1927a,b), then decreased markedly from III C (2.5 mm, at the beginning of second molar eruption) to IV A (1.4 mm, at completion of second molar eruption; Miyajima *et al.*, 1997b). Sana *et al.* (1995) also found that the largest decrease in deep bite was from III C (26 per cent) to IV A (14 per cent). This suggests that eruption of the second molars is involved in the decrease in overbite. However, the incidence of a Class III deep bite is extremely low, and information is difficult to obtain. To date, only Murata *et al.* (1995b) and Miyajima *et al.* (1997a) have presented data on adult subjects with a Class III deep bite.

Dung and Smith (1988) previously indicated the limitations of univariate analysis and emphasized the need for a multivariate analytical method. An algorithm was therefore developed that differentiated between vertical occlusal patterns among Class II malocclusion subjects (Murata *et al.*, 1995a). A similar technique was later used to develop an algorithm for differentiating vertical occlusal patterns among Class III malocclusion subjects (Miyajima *et al.*, 1997a). These vertical indicators discriminated vertical occlusal patterns at a higher probability than diagnostic methods available up to that time. However, the vertical indicators were designed separately for Class II and Class III types of malocclusion as no universal indicator was available that was not affected by gnathostatic differences. Extracted cephalometric parameters (explanatory variable) were also heavily reliant on statistical techniques, so it became difficult to conduct cephalometric anatomical examinations.

Conclusion

The angle of the FH plane to the mandibular plane, which is the most widespread and commonly used parameter for evaluating vertical occlusal patterns, showed that there was a significant difference between open bite and deep bite groups with a Class II type of malocclusion ($P < 0.01$), but no significant difference between the two groups with a Class III malocclusion. A significant difference was seen between the Class II and Class III open bite groups ($P < 0.01$), but not between the Class II and Class III deep bite groups.

The Δabc, which comprised the palatal, Ar-Gn, and A-B planes, area was significantly greater in the open bite than in the deep bite group among both Class II and Class III malocclusion types ($P < 0.01$). This parameter is thus a diagnostic method that enables vertical occlusal patterns to be accurately differentiated among Japanese adult females. There were no differences in the Δabc area either between the Class II and Class III open bite groups or between the Class II and Class III deep bite groups. Thus, the centroid method as a two-dimensional quantitative analysis rather than one-dimensional cephalometric analysis is a novel analytical method to evaluate vertical morphological deviations that are unaffected by antero-posterior gnathostatic differences according to Angle classification.

Even though this research is based on data collected from Japanese adult females, it could be replicated in other parts of the world as long as the area of Δabc, which comprises the palatal, Ar-Gn, and A-B planes, is correctly identified. These findings suggest that the centroid method of occlusion for studying mandibular and maxillary growth could contribute to diagnosis and the formulation of treatment plans.

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References

Baumrind S, Frantz R 1971 The reliability of head film measurements, 1. Landmark identification. American Journal of Orthodontics 60: 111–127

Broadbent B H 1931 A new X-ray technique and its application to orthodontia. Angle Orthodontist 1: 45–66

Dung D J, Smith R J 1988 Cephalometric and clinical diagnoses of open bite tendency. American Journal of Orthodontics and Dentofacial Orthopedics 94: 484–490

Hellman M 1927a Changes in the human face brought about by development. International Journal of Orthodontia, Oral Surgery and Radiography 13: 475–516

Hellman M 1927b The face and occlusion of the teeth in man. International Journal of Orthodontia, Oral Surgery and Radiography 13: 921–945

Jonson J S 1960 The use of centres of gravity in cephalometric analysis: a preliminary report. Dental Practitioner and Dental Record 10: 107–113

Kim Y H 1974 Overbite depth indicator with particular reference to anterior open-bite. American Journal of Orthodontics 65: 586–611

Miyajima K, McNamara Jr J A, Murata S 1997a A diagnostic index of vertical problems for Class III malocclusions. International Journal of Adult Orthodontics and Orthognathic Surgery 12: 189–195

Miyajima K, McNamara Jr J A, Sana M, Murata S 1997b An estimation of craniofacial growth in the untreated Class III female with anterior crossbite. American Journal of Orthodontics and Dentofacial Orthopedics 112: 425–434

Murata S, Kimura T, Miyajima K, Nagahara K 1995a Development and clinical application of algorithm for discriminating vertical patterns of Class II malocclusions. Japanese Journal of Jaw Deformities 5: 146–155 (in Japanese)

Murata S, Kimura T, Miyajima K, Nagahara K, Iizuka T 1995b Algorithm for discriminating vertical problems of Class III malocclusions. Aichi-Gakuin Journal of Dental Science 33: 335–346 (in Japanese)

Murata S, Nakamura S, Nagahara K 2006 Evaluation of the centroid method of occlusion for studying mandibular and maxillary growth. European Journal of Orthodontics 28: 345–351

Sana M, Murata S, Kimura T, Nagahara K, Miyajima K 1995 Cross-sectional study of skeletal characteristics in the female mandibular protrusion. Aichi-Gakuin Journal of Dental Science 33: 265–271 (in Japanese)

Schudy F F 1964 Vertical growth versus anterioposterior growth as related to function and treatment. Angle Orthodontist 34: 75–93