Original Article

Patterns of Dental Crowding in the Lower Arch and Contributing Factors

A Statistical Study

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ABSTRACT

Objective: To investigate the patterns of dental crowding in the lower arch and their contributing morphological and functional factors.

Materials and Methods: Pretreatment diagnostic materials from 168 patients exhibiting dental crowding were selected, and the patients, dental casts, lateral cephalograms, and occlusal forces were evaluated. The crowding in the lower dental arch was quantified and the patterns of crowding were identified. Crowding patterns in the anterior region were classified by cluster analysis. The relationship between the crowding patterns and morphological and functional factors was investigated by correspondence analysis.

Results: The prevalence of dental crowding was highest in the anterior region and was related to the same tooth on each side (eg, right lateral incisor vs left lateral incisor). In the premolar and molar region, the prevalence of dental crowding was related to the adjacent tooth (eg, right first premolar vs second premolar). Three crowding patterns were found in the anterior region: (1) a "symmetry pattern," (2) a "rotation pattern," and (3) an "irregular pattern." The first pattern was related to the factors of discrepancy, whereas the latter two patterns were related to functional factors such as occlusal force and its center of gravity.

Conclusions: These results suggest that crowding patterns can be useful information for treatment planning and achieving dental stability.

KEY WORDS: Crowding pattern; Factor

INTRODUCTION

Individuals with dental crowding are the most frequent patients in the orthodontic clinic. Therefore, it is useful to know the contributing factors of dental crowding for the planning of orthodontic treatment and achieving stability in retention.

Many studies have reported on the factors contributing to dental crowding. Harvold[1] focused on the effect of soft tissue pressure and reported that the volume and position of the tongue are related to dental crowding. Moss and Picton[2] reported that tooth inclination was influenced by cheek pressure. Leighton and Hunter[3] and Keeling et al[4] reported on the relationship between dental crowding and the morphological characteristics of the mandible. In a longitudinal investigation, Richardson[5] pointed out that anterior movement of the erupted first molar is important for the late lower arch crowding. Furthermore, the anterior component of occlusal force[6] and anterior occlusion[7] such as overjet or overbite are also known to be associated with crowding.

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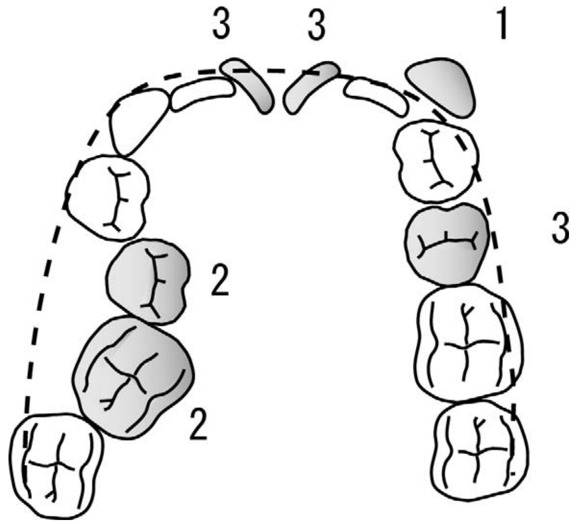

Figure 1. Scoring of crowding of each tooth. As against the ideal dental arch, the buccolingual position and rotation of each tooth was scored: 1 = labio- or buccoversion, 2 = linguoversion, 3 = rotation.

However, those reports mainly discussed the extent of dental crowding (ie, irregularity index or arch length discrepancy) and rarely referred to its pattern. Also, most of the contributing factors were related to the morphology, with only a few related to the functional aspects. Therefore, the aim of this study is to classify the patterns of lower dental crowding that are predominant and relapse easily[8] and furthermore to investigate each pattern in relation to its contributing factors.

MATERIALS AND METHODS

A total of 35 male and 133 female patients with dental crowding who visited the orthodontic clinic at the Tokyo Medical and Dental University Hospital from September 2000 to August 2003 were selected. All the subjects were healthy with complete dentitions and without a history of orthodontic treatment, supernumerary or missing teeth, periodontal disease, or poor restorations. Dental casts of the lower arch, lateral cephalograms, and the occlusal force data were utilized for this study. Approval for this study was obtained from the participating subjects and the ethics committee of Tokyo Medical and Dental University Hospital.

Method of Measurement

Each tooth from the central incisors to the second molars was scored by using the dental cast of the lower arch (score of 1 = labio- or buccoversion, 2 = linguoversion, and 3 = rotation). Labio- or buccoversion and linguoversion were given priority for scoring when an additional rotation was observed (Figure 1).

Six indices (intercanine width, dental arch length, dental arch width, basal arch length, basal arch width, sum of each tooth width) were measured with dental casts following the method of Sinclair and Little.[9]

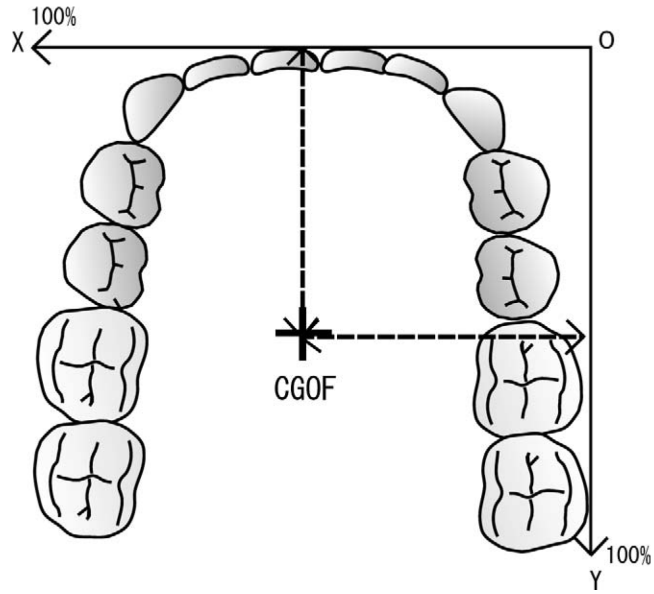

Figure 2. Measurement of the center of gravity position of occlusal force. X-axis mesial contact points of the both central incisors vertical to the median palatine suture. Y-axis parallel to the median palatine suture and passing through top of the buccodistal cusp of the left second molar.

Eleven reference points (Po, Or, Me, U1, L1, U6, L6, A, B, S, N) and four reference planes (FH plane, SN plane, mandibular plane, occlusal plane) were used for the measurement on the lateral cephalogram according to the method of Downs[10] and Graber.[11] ANB, SNB, mandibular plane angle, occlusal plane angle, and L1 to mandibular plane angle were measured. Also, the inclination of the first molar to the occlusal plane was measured.

The maximum occlusal force was measured with pressure-responsive film (Dental Prescale 50-H type R, FUJI FILM Co Ltd, Tokyo, Japan) with the subjects sitting with natural head position. The films mapping the distribution of occlusal force were fitted to the lower dental cast, and the center of gravity of the occlusal force (CGOF) was measured (%). The difference between the X-coordinate of the center of gravity and the 50% value of the X-coordinate (the median of dental arch) represented the amount of the CGOF shift with right-left dimension (Figure 2). For the measure of the accurate CGOF position, subjects with more than two adjacent teeth without occlusion were excluded to avoid the influence of open bite as far as possible.[12] In addition, subjects with any excessive three-dimensional distortion of the plane of occlusion were excluded because of the difficulty in fitting the film to the

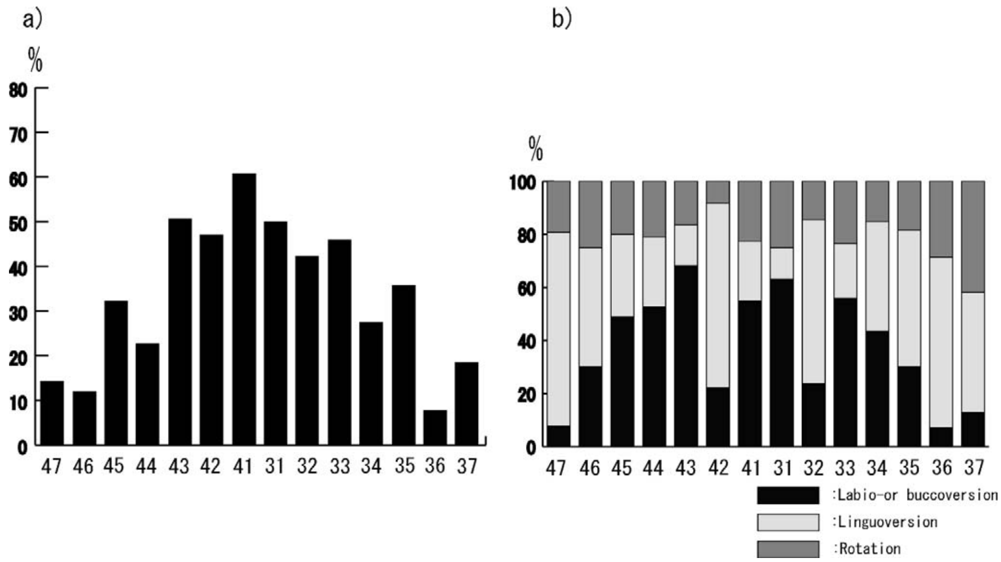

Figure 3. Prevalence and details of dental crowding of each tooth.

TABLE 1. Frequency of dental crowding of each tooth[a]

Tooth No.	Linguoversion	Labio- or Buccoversion	Rotation	P value
45	28	17	9	
44	10	20	8	
43	13	58	14	
42	55	17	7	
41	23	56	23	.000
31	10	53	21	
32	42	18	11	
33	16	43	18	
34	19	20	7	
35	31	18	11	

[a] The first and second molars were excluded because their prevalence of dental crowding was low. Chi-square test; $P < .05$.

lower dental cast. As a result, a total of 80 subjects were available for evaluation.

Method of Analysis

Patterns of dental crowding in the lower arch. The prevalence and detailed conditions (labio- or buccoversion, linguoversion, or rotation) of the dental crowding of each tooth was investigated (chi-square test), as was the relationship between the crowding of each tooth (chi-square test). Highly correlated teeth were grouped together (cluster analysis).

Patterns and factors of dental crowding in lower anterior region. The pattern of lower anterior crowding (central incisor, lateral incisor, canine) was classified by using score variables that were quantified for dental crowding in the lower anterior region (cluster analysis). The frequency of the details of dental crowding (labio- or buccoversion, linguoversion, or rotation) in each cluster was investigated (chi-square test).

The correspondence analysis was applied to explore the relationship among the patterns of lower anterior crowding, which was classified by cluster analysis, morphological variables, and occlusal force. This was divided into each group with a close relationship by cluster analysis according to the method used by Guinot et al.[13]

Correspondence analysis is a method to analyze the relationship between two or more discrete variables. Therefore, the morphological and functional variables that represent continuous variables were divided into the following three categories by the means and standard deviation (SD) of the variables: (1) large, with the variables larger than mean plus ½ SD; (2) small, with the variables less than mean minus ½ SD; and (3) medium, with the variables between mean minus ½ SD and mean plus ½ SD.

F-test and Mann-Whitney *U*-test were used to compare differences among the CGOF positions in each pattern of lower anterior crowding, with $P < .05$ being significant. The statistical analysis was made by JUSE-StatWorks/4.0 (The Institute of Japanese Union of Scientists & Engineers Co Ltd, Tokyo, Japan).

RESULTS

Patterns of Dental Crowding in the Lower Arch

The prevalence of dental crowding was higher in the anterior region, whereas it decreased in the premolar and molar region. The frequency of dental crowding of each tooth was significantly different ($P = .000$) (Figure 3; Table 1).

The dental crowding was shown to relate to each adjacent tooth and the same tooth on each side (Figure 4). Results of sampling of the dependency region

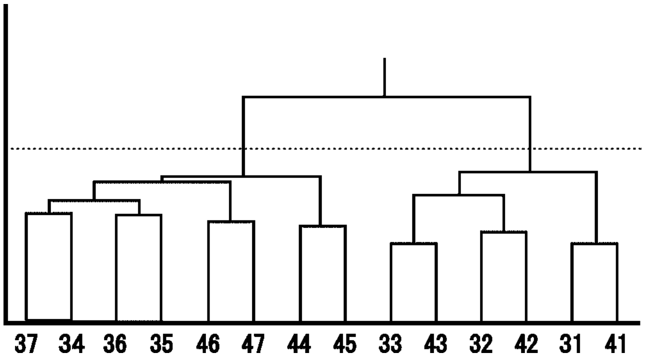

Figure 4. Dendogram by cluster analysis.

by cluster analysis indicated that dental crowding is more highly related to each adjacent tooth in the premolar and molar region, whereas it is more relevant to the same tooth on each side in the anterior region (Figure 5).

Patterns and Factors of Dental Crowding in Lower Anterior Region

The patterns of lower anterior crowding were divided into three clusters: 65 subjects as cluster 1 (41%), 43 subjects as cluster 2 (27%), and 51 subjects as in cluster 3 (32%).

Table 2 shows the prevalence of the details (labio- or buccoversion, linguoversion, or rotation) of the dental crowding in each cluster. Right and left central incisors ($P = .001$ and $P = .004$) and the right and left canines ($P = .041$ and $P = .007$) were distant in prevalence of the details in each cluster. In cluster 1, the labioversion of the central incisor and the canine and the linguoversion of the lateral incisor appeared frequently. In cluster 2, the rotation of the central incisor was frequent. In cluster 3, the linguoversion of the right central incisor and the left canine frequently appeared, and the prevalence was indicated to be asymmetric.

TABLE 2. Frequency of dental crowding in each cluster [a]

Tooth No.	Cluster 1 n = 65	Cluster 2 n = 43	Cluster 3 n = 51	*P* value
43				
Labioversion	36	7	15	
Linguoversion	5	1	7	.041*
Rotation	7	5	2	
42				
Labioversion	8	4	5	
Linguoversion	30	16	9	.717
Rotation	4	1	2	
41				
Labioversion	24	16	16	
Linguoversion	6	2	15	.001*
Rotation	2	12	9	
31				
Labioversion	25	15	13	
Linguoversion	6	2	2	.004*
Rotation	2	15	4	
32				
Labioversion	13	2	3	
Linguoversion	17	12	13	.138
Rotation	6	4	1	
33				
Labioversion	25	8	10	
Linguoversion	1	5	10	.007*
Rotation	6	4	8	

[a] Chi-square test, $P < .05$.

Table 3 shows the mean and SD values of the variables. The patterns of crowding were visually displayed in relation to the morphological variables and occlusal force (Figure 6). The results of sampling of the variables related to each other are shown as follows: group A = the crowding pattern of cluster 1 and its related variables, group B = the crowding pattern of clusters 2 and 3 and its related variables, and group C = variables without any relationship to the pattern

	46	45	44	43	42	41	31	32	33	34	35	36	37
47	21.4*	18.8*	19.3*	3.9	9.0	5.6	5.7	10.1	9.0	7.3	7.6	11.8	31.9**
46		25.5**	19.3*	6.5	16.8	4.3	6.0	7.6	12.5	3.3	9.9	16.6	30.2**
45			11.4	11.5	4.1	4.7	13.7	9.8	12.7	6.7	27.5**	16.6	10.7
44				26.6**	15.1	6.6	6.7	7.2	6.0	27.8**	14.4	7.0	22.0**
43					4.06**	29.7**	7.3	15.8	59.1**	2.7	4.5	3.0	6.3
42						47.1**	6.9	77.7**	22.9**	3.6	6.6	7.5	5.7
41							68.3**	7.4	5.9	12.8	7.4	4.2	11.7
31								27.8**	13.2	11.5	8.5	9.9	5.7
32									49.9**	13.0	20.6*	3.1	4.6
33										11.5	4.9	6.8	4.2
34											31.0**	4.6	6.8
35												22.1**	12.0
36													63.0**

Figure 5. Dependency region of dental crowding. The values indicated chi-square statistics. The area indicated in the dashed-line oval shows dental crowding correlated to each adjacent tooth in premolar and molar region, and the area indicated in the solid-line oval shows dental crowding correlated to the same tooth on each side in the anterior region.

TABLE 3. The mean and standard deviation values of the variables[a]

Variable	Mean	Standard Deviation
Overbite	1.90	2.64
Overjet	3.23	3.82
Intercanine width	27.12	2.47
Tooth width	91.11	4.49
Basal arch width	39.54	3.26
Basal arch length	29.61	2.53
Dental arch width	34.29	3.63
Dental arch length	33.44	2.61
SNB	77.88	4.45
ANB	3.35	3.58
L1 to mandibular plane	94.91	9.67
Mandibular plane angle	30.05	6.62
Occlusal plane angle	10.92	4.35
Inclination of first molar	197.30	12.58
Occlusal force	581.94	291.76
Position of the center of gravity of the occlusal force		
Anterior-posterior dimension	0.75	0.12
Right-left dimension	0.08	0.07

of crowding. Group A included categories such as small dental or basal arch width and length and large mandibular plane angle. On the other hand, group B included categories such as a large occlusal force, mesial inclination of the first molars, and a large overjet and overbite. Group C included the categories that were not related to the pattern of crowding, such as large basal arch and small ANB.

The variance of the position of the CGOF with anterior-posterior dimension was significantly larger in the crowding pattern of cluster 2 ($P = .000$) and cluster 3 ($P = .05$) than in that of cluster 1. The variance of amount of the CGOF shift with right-left dimension was significantly larger in the crowding pattern of cluster 3 than in that of cluster 1 ($P = .031$). The amount of the CGOF shift to right-left in the crowding pattern of cluster 3 was significantly higher than in that of cluster 1 ($P = .004$) (Table 4).

DISCUSSION

The Pattern of Dental Crowding

The prevalence of dental crowding was highest in the anterior region (central incisor, lateral incisor, and canine), whereas it decreased in the premolar and molar region. From this study, 96% of the subjects showed crowding in the anterior region, whereas it rarely appeared in the premolars and molars only. In a longitudinal study, Mochizuki and Machida[14] reported that more than 58% of dental crowding was observed in the anterior region at the period of eruption. According to the investigation by Little et al,[15] the dental crowding appeared and increased in the anterior region by aging. As seen in the results, it seems apparent that dental crowding easily appears in the anterior teeth, thus making it meaningful to discuss the causes and the pattern of dental crowding.

In this study, dental crowding was highly related to each adjacent tooth in the premolar and molar region, whereas it was more related to the same tooth on each side in the anterior region. The factors that influence dental crowding at the stage of eruption of the permanent dentition include the position of the permanent tooth germs, the timing of the loss of deciduous teeth and permanent tooth eruption, the order of replacement of the dentition from deciduous to permanent, the soft tissue pressure, and the position of the opposite teeth.

In particular, the crowding of the anterior region is reported to be influenced by the linguoversion of the lateral incisor germ,[16] lack of space for eruption of the lateral incisor,[17] lip pressure,[2] and tongue pressure.[1] On the other hand, the premolar region could be influenced by the irregular order of eruption, the extended period of the replacement of dentition, the early loss of the deciduous teeth, and the following mesial movement of the permanent teeth. These factors may also affect left-right asymmetry in the lower arch.

From our results, crowding pattern in the anterior region was not affected by the dental crowding of the premolars and molars. Therefore, patterns of crowding in the lower anterior region were classified without any relationship to the dental crowding in the premolars and molars.

The Patterns of Dental Crowding and Factors in the Anterior Teeth

The patterns of crowding developed in the anterior teeth were divided into three clusters by cluster analysis. In Figure 6, cluster 1 indicated the "symmetry pattern" with labioversion of central incisor and canine and linguoversion of lateral incisor; cluster 2 indicated the "rotation pattern" of characteristic tooth rotation; and cluster 3 indicated the "irregular pattern," with bucco- and linguoversion in each tooth irregularly (Figure 7).

The association between each nominal variable could be displayed graphically by each distance by using the correspondence analysis. In this study, variables were categorized by ½ SD to equalize the subjects in each category.

The symmetry pattern was related to a narrow dental or basal arch, the positions of the CGOF in anterior-posterior dimension, and amount of the CGOF shift in the right-left dimension. The lateral incisors easily present linguoversion more than the central incisor or the canine. This is because of the lingually positioned tooth germ of the lateral incisor,[16] delayed eruption of

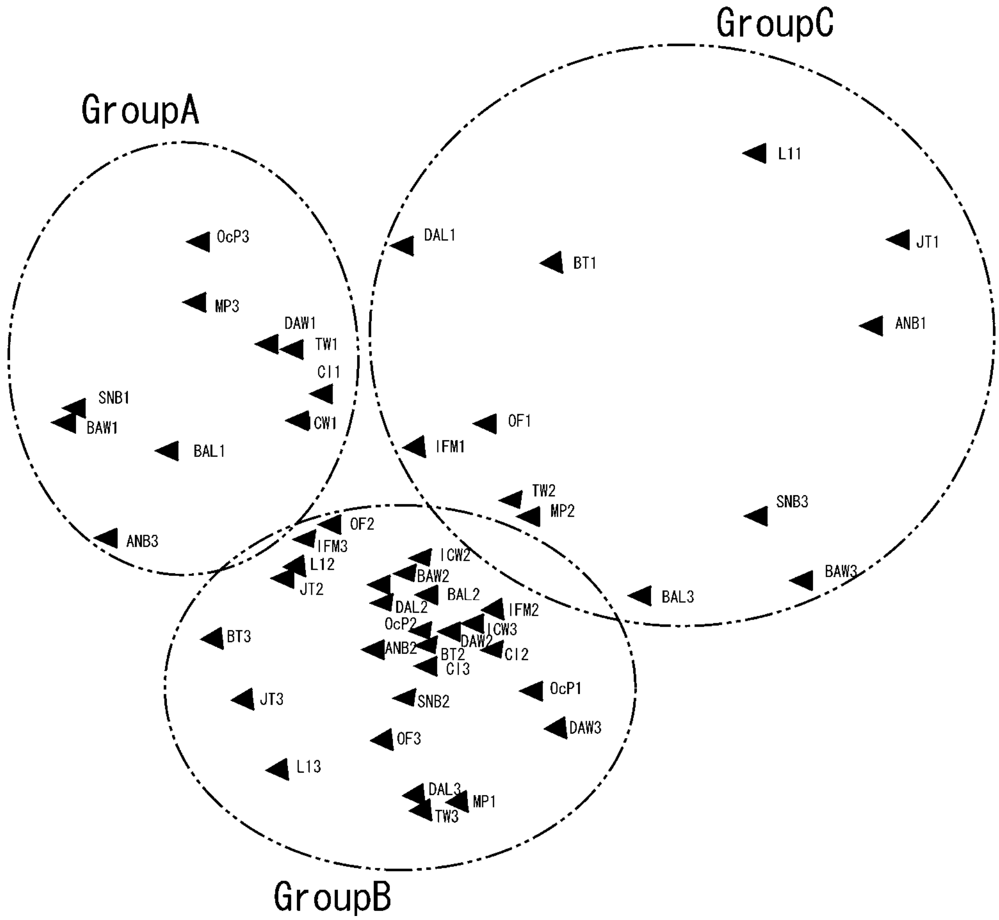

Figure 6. Correlation among the lower anterior crowding pattern, morphological variables, and occlusal force. The contribution of the first component (parameter) was 10%, and the contribution of the second component was 8%. BT indicates overbite; JT, overjet; ICW, intercanine width; TW, tooth width; BAW, basal arch width; BAL, basal arch length; DAW, dental arch width; DAL, dental arch length; SNB, Sella-Nasion-point B; ANB, point A-Nasion-point B; L1, L1 to mandibular plane angle; MP, mandibular plane angle; OcP, occlusal plane angle; IFM, inclination of first molar; OF, occlusal force; Cl1, crowding pattern of cluster1; Cl2, crowding pattern of cluster 2; Cl3, crowding pattern of cluster 3; 1, small category; 2, medium category; and 3, large category.

TABLE 4. The position of CGOF in each pattern of crowding[a]

Measurement	Crowding Pattern			*F*-value			Mean Differences		
	Cluster 1	Cluster 2	Cluster 3	1–2	1–3	2–3	1–2	1–3	2–3
Anterior-posterior dimension, %									
Mean	74	75	77				0.7	2.4*	1.8
Standard deviation	0.08	0.14	0.13	4.059*	4.909*	0.001			
Right-left dimension, %									
Mean	4.6	7.2	9.9				2.4	5.4	3.1
Standard deviation	0.04	0.06	0.08	3.153	15.272*	5.086*			

[a] *F*-test Mann-Whitney *U*-test, $P < .05$.

the lateral incisor relative to the central incisor, and lack of eruption space—if not affected by any external force at the period of permanent teeth eruption—for the lateral incisor. Thus, the symmetry pattern could be considered as a pattern of crowding caused by environmental factors at the period of dentition in addition to the advanced discrepancy.

Rotation pattern and irregular pattern were related to the categories with a large occlusal force, mesial inclination of the first molar, and a large overjet and overbite. Furthermore, the position of the CGOF in the anterior-posterior dimension and amount of the CGOF shift in right-left dimension were larger than in the symmetry pattern. The CGOF of normal subjects con-

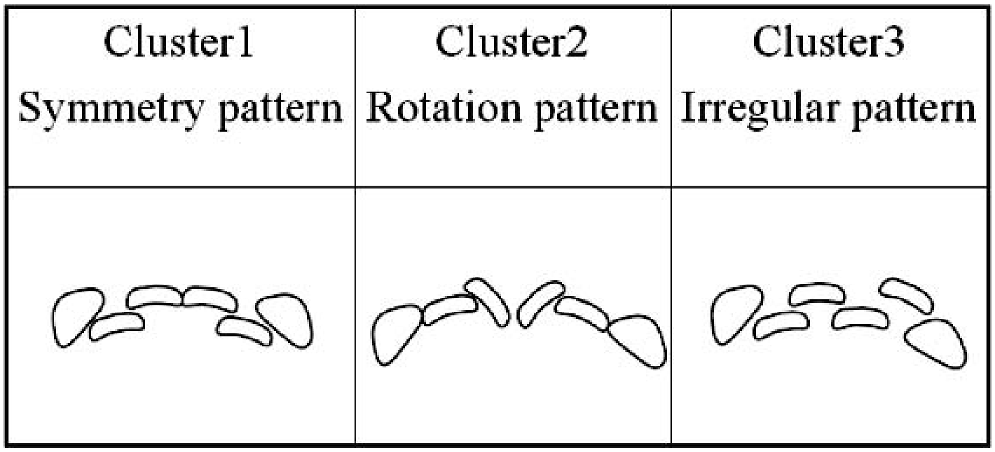

Figure 7. The characteristic patterns of anterior crowding.

verged in an anterior-posterior and right-left dimension.[18] The occlusal force reduced the gap at each adjacent tooth, and the effect became larger by the increase in mesial inclination of the first molar. In addition, it could be more effective if the CGOF were in a more posterior position. The association between the extent of dental crowding in the anterior region and overbite or the depth of the Spee curve was also reported.[19] The advanced overbite and deep curve of Spee not only prevented the anterior and lateral growth of the lower dental arch, but also resulted in a lingual inclination of the anterior teeth, and it is strongly affected if the CGOF is in an anterior position.

On the other hand, the amount of the CGOF right-left shift was larger in the irregular pattern. The irregular pattern was not symmetrical and the CGOF was shifted in the right-left dimension. On the contrary, the symmetry pattern was symmetric and the position of the CGOF in right-left dimension converged to the median. From these findings, the pattern of crowding is considered to relate to the CGOF.

The Clinical Significance of the Results

For orthodontic treatment of dental crowding, expansion of the dental arch or tooth extraction with alignment of each tooth is performed. Judgment criteria for treatment planning are often the extent of dental crowding and facial appearance. However, from the results of this study, functional factors associated with the pattern of crowding add to the dental crowding as previously reported.[1–7]

According to our study, elimination of the crowding discrepancy through expansion of the dental arch or extraction of the premolar is considered necessary in the symmetry pattern. On the other hand, in the rotation pattern and the irregular pattern, functionally inducing the CGOF to the stable position in anterior-posterior right-left dimension, further arrangement of the molars with consideration to the anterior occlusion could be helpful along with the maintenance of the space for each tooth arrangement. Thus, we suggest the pattern of crowding in the anterior region as a judgment criterion for treatment planning in orthodontic clinics.

CONCLUSIONS

a. Dental crowding in the lower premolar and molar region associated with the adjacent tooth, whereas it associated with the same tooth on each side in the anterior region.
b. The patterns in the anterior region were classified to three clusters (symmetry pattern, rotation pattern, and irregular pattern). The symmetry pattern is associated with environmental factors in the period of replacement of dentition, in addition to the extended discrepancy. The rotation pattern and the irregular pattern are possibly caused by the functional factors such as magnitude and CGOF.

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