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Cluster Analysis of Maxillary Dental Arch Forms

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Abstract

We conducted a cluster analysis, which accumulated similar items by grouping intensive subjects embodied with heterogeneous objects, for the establishment of criteria for diagnosis and planning treatment of dentitions by the determination of estimated items and elements affecting the morphology of dental arches. Subsequently, a principal component analysis was performed for the purpose of identification of morphological characters in each cluster. The results observed significant differences between principal components containing estimated items ⑥∠(I2-C-P1), ②(M2R-M2L), ③(A-B) and ⑤∠(CR-A-CL) which represented protrusion of transitional portion of anterior and buccal segments, width and length of the dental arch, and protrusion of the anterior teeth segment, respectively. Consequently, we concluded that the maxillary dentition could be classified mainly by evaluation of the items ③(A-B), ⑤∠(CR-A-CL) and ⑥∠(I2-C-P1).

Key Words: Cluster analysis; Maxillary dental arch

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Introduction

Evaluation of factors affecting the dental arch morphology is essential for diagnosis and formulating treatment plans in particular in the orthodontic field. In our previous studies, by preliminary differentiation of square, round-square, round and round V-shaped arches according to the classic descriptive morphological study made by Thompson and Dewey [1], we have elucidated certain important elements (factors)to determine arch forms [2-6]. However, the studies do not exclude that the results could be affected by properties of the widely -used conventional classification methods, which usually define dental arch forms depending mainly on subjective visual examination of dentitions.

On the other hand, some objective methods using quantitative analyses and mathematical evaluation were developed to classify the dental arch forms by translating the measured data of various morphological elements recorded on plaster casts into algebraic functions [7-20]; the studies proposed three to five basic arch forms for differentiation of dentitions [21,22]. A latter study has further verified hyperbolic-, parabolic- and elliptic-shaped dental arches by a quadratic equation estimation [23].Subsequently, a study superimposed measuring data developed from reference points designated on dental arches with catenary, conic section, elliptic function and fourth polynomial arches to indicate that the fourth polynomial formula is mostly acceptable for analysing dental arch forms [24]. Nevertheless, the mathematical evaluation methods were quite complicated, yet difficult to ascertain and compare distinguishing characters of different dental arch types [7-24].

Cluster analysis is a mathematical method beneficial for accumulation of similar items by grouping intensive subjects embodied with heterogeneous objects, as well as is a method widely utilized in biology, sociology and cognitive science studies nowadays. In the present study, we conducted a cluster analysis on estimating items, which were developed from designated references points and lines recorded on maxillary stone casts of parallel-standardized dental study models. We then performed principal component analysis with an attempt to elucidate characters of different clusters.

Materials and Methods

1. Materials

The study was performed following the Declaration of Helsinki Ethical Principles for Medical Research (1964). The protocol (No. 050507: Morphological Analysis of dental arches) was approved by the Ethic Review Board of Osaka Dental University. In the study, 396 sets of paired maxillary and mandibular dental casts of young adult students (18 to 26 years old; male: 257, female: 139) at Osaka Dental University were prepared to have a total height of 60

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mm with the occlusal plane adjusted to be at a height of 30 mm from the mandibular cast base [2-6]. We selected 62 sets (male:36; female:26) with normal dentition and occlusion, and dental arches of the standardised maxillary casts were investigated for the present cluster analysis.

2. Methods

Designation of references and lines for examination

The dental study models were digitally photographed, processed and prepared for estimation of items derived from reference points / lines and a developed spherical (polar) coordinate system designated on the 2-D equal-proportional images of the maxillary dentitions (Fig. 1) [2-6, 25].

Establishment and development of reference items

By connecting reference points printed on photos, we established seven items for differentiating maxillary dental arches (Fig.1) [2-6, 25]:

①(C_R-C_L): width of the anterior-teeth (anterior) segment.

②($M2_R$-$M2_L$): width of the dental arch.

③(A-B): length of the dental arch.

④(A-E): length of the anterior segment.

⑤$\angle(C_R\text{-}A\text{-}C_L)$: protrusion and curvature of the anterior segment.

⑥$\angle(I_2\text{-}C\text{-}P_1)_{R\&L}=\angle(I_2\text{-}C\text{-}P_1)_R+\angle(I_2\text{-}C\text{-}P_1)_L$: protrusion demonstrated between the anterior - and buccal - teeth segments; also used to describe the anterior-teeth curvature of a maxillary dental arch.

⑦$(r\theta5-r\theta4)_{R\&L}=(r\theta5-r\theta4)_R+(r\theta5-r\theta4)_L$: the roundness of a dental arch by estimation of the transition occurred between the anterior and buccal segments.

The width and length were measured in millimetre (mm) with the standard deviation (SD) expressed in the same unit as the data, and the angles were estimated in degree (°) with the SD (expressed in the same unit as the data).

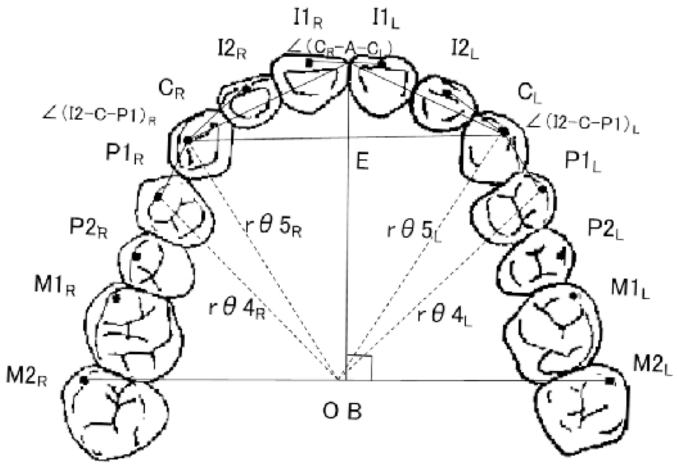

Fig. 1 Reference points, lines, and angles (the maxillary dental arch).

Cluster analysis

Hierarchical agglomerative method was used in the present study. Also, the standardised Euclidean distance was utilized to avoid the size-variance effects of examined objects in the present analysis which evaluated the distance between different clusters. The present study was evaluated by a Cluster97.xla analysis software (Excel Add-in Workshop; http://www.jomon.ne.jp/~hayakari/) with the following formula:

$$D(x,y)=\left\{\sum_{i=1}^{p}\left(z_{xi}-z_{yi}\right)^{2}\right\}^{\frac{1}{2}}$$

(x,y =1,2, ... ,62) (p=7 in the present study)

Furthermore, the Ward's method, a taxonomic categorization method based on a standard of minimal values of the sum of squares developed from examined elements in each chosen set, was used for internal cohesion and external isolation of the present cluster analysis. Hence, we categorized cluster c by an internal cohesion of clusters a and b; the distances in the clusters a and b before developing cluster c were distances d_{ab}, d_{xa}, and d_{xb}. Subsequently, we established d_{xc} for describing the distance between cluster c and cluster x (x≠a, x≠b) with the following formula recommended in the Cluster97.xla analysis software (http://www.jomon.ne.jp/~hayakari/):

$$d_{xc}^{2}=\frac{n_x+n_a}{n_x+n_a+n_b}d_{xa}^{2}+\frac{n_x+n_b}{n_x+n_a+n_b}d_{xb}^{2}-\frac{n_x}{n_x+n_a+n_b}d_{ab}^{2}$$

(nx: the number of examined items which were included in the cluster a)

Principal component (multivariate) analysis

The principal component analysis is an effective method for establishing synthetic indices by standardizing and summarizing multivariate data with a least loss of original data in differentiation of samples [2-6]. The present principal component analysis, using Excel Statistics 2010 for Windows (Community Information Services, Tokyo, Japan), removed the variance of units, and then standardized and summarized ① (C_R-C_L), ② ($M2_R$-$M2_L$), ③ (A-B), ④ (A-E), ⑤ ∠ (C_R-A-C_L), ⑥ ∠ (I_2-C-P_1) $_{R\&L}$ and ⑦ ($r\theta 5 - r\theta 4$) $_{R\&L}$ multivariate data into three new variables based on the proportion of variance (in order of large value). The ① to ⑦ items were analyzed with reference to the correlation matrix of the variables.

Statistics Analysis

The seven items (① to ⑦) were analyzed using mean value, standard deviation and estimation of population mean with 95% confidence interval [2-6]. One-way analysis of variance(one-way factorial ANOVA; $p<0.01$) was processed using Excel Statistics 2010 for Windows (Social Survey Research Information Co., Ltd., Tokyo, Japan). Furthermore, morphological differences were assessed by Scheffe's test for multiple comparison (post hoc test) of the examined data [26-30].

Results

1.Mean values of estimated items(by gender)

Mean values of the estimated items ① to ⑦, ① (C_R-C_L), ② ($M2_R$-$M2_L$), ③ (A-B), ④ (A-E), ⑤ ∠ (C_R-A-C_L), ⑥ ∠ (I_2-C-P_1)$_{R\&L}$ and ⑦ (rθ 5－rθ 4)$_{R\&L}$, were in particular summarized according to gender (Table.1). The results indicated that there was a significant difference of ② ($M2_R$-$M2_L$) between males and females, while no significant differences were observed in other items (① (C_R-C_L), ③ (A-B), ④ (A-E), ⑤ ∠ (C_R-A-C_L), ⑥ ∠ (I_2-C-P_1) R&L and ⑦ (rθ 5－rθ 4)$_{R\&L}$; **p<0.01, Table 1). However, mean values for items ⑤ ∠ (C_R-A-C_L) and ⑥ ∠ (I_2-C-P_1) $_{R\&L}$ were higher in females than in males; other items of ① (C_R-C_L), ② ($M2_R$-$M2_L$), ③ (A-B), ④ (A-E), and ⑦ (rθ 5－rθ 4) $_{R\&L}$ showed higher values in males than in females (Table 1).

2.Dendrogram of the cluster analysis

Cluster analysis of the estimated the seven items (① (C_R-C_L), ② ($M2_R$-$M2_L$), ③(A-B), ④ (A-E), ⑤ ∠ (C_R-A-C_L), ⑥∠(I_2-C-P_1) $_{R\&L}$ and ⑦(rθ 5－rθ 4) $_{R\&L}$) of the 62 maxillary dentitions was presented in the dendrogram; the combination level represented the sum of squares developed from examined elements in each chosen set (Fig. 2).

The maxillary dental arch was divided into two clusters at a combination level of 14.8 (an upper dotted line in the Fig.2). Furthermore, each of the two clusters were classified into two clusters, totally four clusters (1st, 2nd, 3rd and 4th clusters), at a combination level of 9.3 (a lower dotted line in the Fig.2) according to morphological differences of the investigated dental arches (Table 1 & Table 2).

Table 1 Mean values of estimated items (classified by gender; Mean±SD)

Mean value \ Item	①C_R-$C_{L(mm)}$	②$M2_R$-$M2_{L(mm)}$**	③A-B(mm)	④A-E(mm)	⑤∠(C_R-A-C_L)(°)	⑥∠(I_2-C-P_1)$_{R\&L(°)}$	⑦(rθ5-rθ4)$_{R\&L(mm)}$
Total	35.76±2.01	61.11±3.49	39.81±2.64	8.59±1.47	128.95±8.20	314.77±15.80	7.09±1.66
Male	35.96±2.28	62.32±3.36	39.96±2.98	8.73±1.58	128.50±8.60	313.89±17.45	7.16±1.52
Female	35.49±1.58	59.43±2.99	39.60±2.10	8.39±1.32	129.58±7.74	316.00±13.44	7.00±1.87

(**p＜0.01)

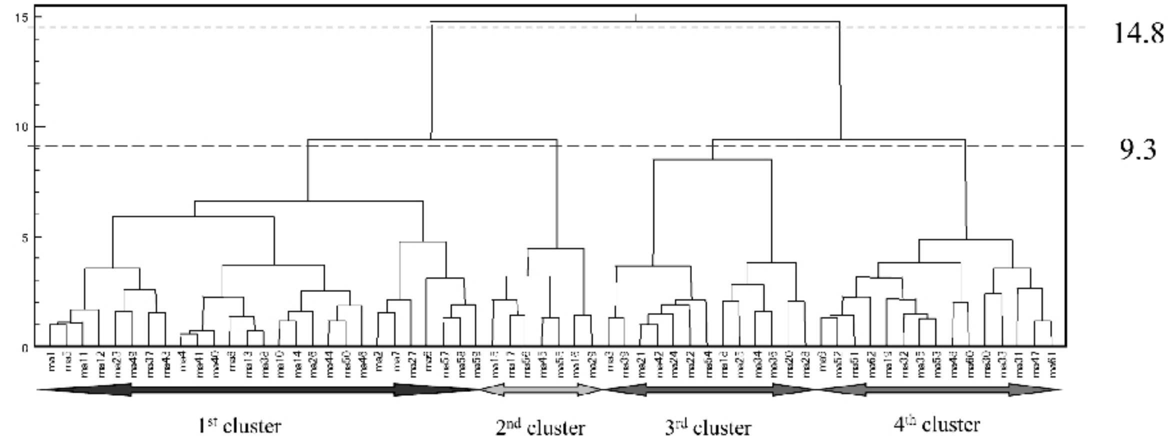

Fig. 2 Dendrogram for visualizing hierarchical cluster analysis.

3. Variance analysis of estimated items (in mean values) in each clusters

Significant differences in mean values of all estimated items (① to ⑦; mean ± SD) in each cluster (1^{st}, 2^{nd}, 3^{rd} and 4^{th} clusters) were demonstrated in the present analysis (**p<0.01; Table 2). In the 1^{st} cluster, it significantly showed a low ④ (A-E) value, while showed the most highest ⑤ ∠ (C_R-A-C_L) value (**p<0.01; Table 2). Nevertheless, we observed the highest value of ④ (A-E), and the most lowest values of ①(C_R-C_L), ②($M2_R$-$M2_L$) and ⑤ ∠ (C_R-A-C_L) in the 4th cluster (**p<0.01; Table 2).

4. Principal component (multivariate) analysis of the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} clusters

Results of the present principal component analysis of each cluster were demonstrated with factor loading (in mean value) on each principal component by four radar charts (Figs. 3-1, 3-2, 3-3 and 3-4).

Table 2 Mean values of estimated items in each cluster (Mean±SD)

Cluster	Sample	Ratio(%)	C_R-C_L(mm)**	$M2_R$-$M2_L$(mm)**	A-B(mm)**	A-E(mm)**	∠(C_R-A-C_L)(°)**	∠(I_2-C-P_1)$_{R\&L}$(°)**	($r\theta 5$-$r\theta 4$)$_{R\&L}$ (mm)**
1^{st}	27	44	36.13±1.58	61.24±2.42	38.26±1.86	7.38±0.92	136.00±4.65	309.70±11.06	6.57±1.41
2^{nd}	7	11	34.41±1.85	65.84±3.12	37.93±1.76	8.74±0.67	125.86±3.44	334.57±8.60	5.29±0.49
3^{rd}	13	21	37.41±1.77	61.26±3.84	42.40±1.87	9.34±1.18	126.69±4.94	303.31±15.79	8.64±1.27
4^{th}	15	24	34.31±1.45	58.54±2.17	41.24±1.92	10.05±0.79	119.67±4.84	324.60±10.26	7.52±1.39

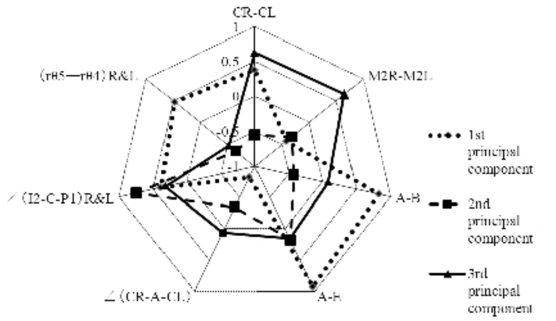

Fig. 3-1

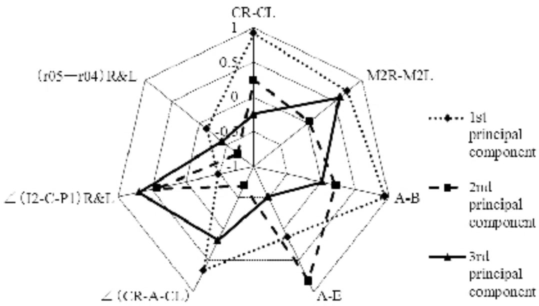

Fig. 3-2

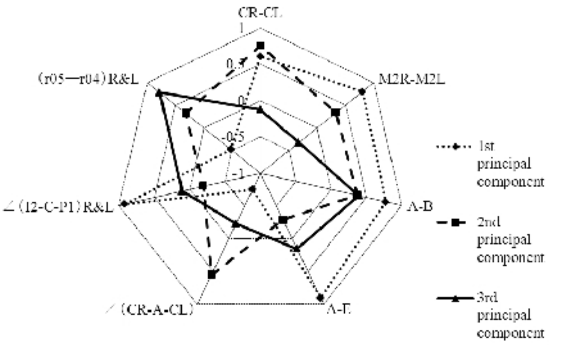

Fig. 3-3

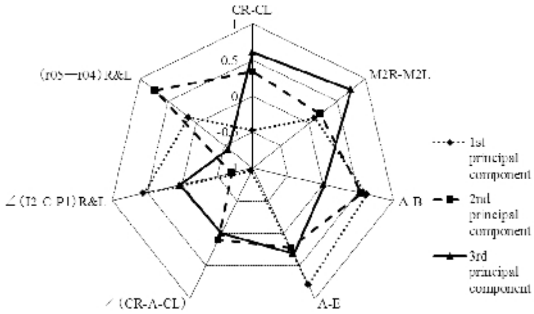

Fig. 3-4

Fig. 3 Radar charts of factor loading of 1^{st}, 2^{nd} and 3^{rd} principal components in the 1^{st} (Fig. 3-1), 2^{nd} (Fig. 3-2), 3^{rd} (Fig. 3-3) and 4^{th} (Fig. 3-4) clusters (express in the mean value).

1) The 1^{st} cluster:

The factor loading of the 1^{st} principal component distinctly showed a positive relationship with items ③(A-B) and ④(A-E), but showed a strong, negative relation with ⑤ ∠ (C_R-A-C_L); the 1^{st} principal component had a contribution ratio of 41.55% (Fig. 3-1). The 2^{nd} principal component was distinctly and positively related with ⑥ ∠ (I_2-C-P_1), but was negatively related with ⑦∠(r θ 5−r θ 4) $_{R+L}$; the 2^{nd} principal component had a contribution ratio of 24.57%. The 3^{rd} principal component was positively related with ①(C_R-C_L) and ②($M2_R$-$M2_L$); its contribution ratio was 17.52%. Additionally, the cumulative contribution ratio of the 1^{st}, 2^{nd} and 3^{rd} principal components was 83.64% in the 1^{st} cluster (Fig. 3-1).

2) The 2nd cluster:

The factor loading of the 1st principal component indicated that it had strong and positive relationships with items ①(C_R-C_L), ②($M2_R$-$M2_L$) and ③(A-B), as well as had a positive relationship with ⑤∠(C_R-A-C_L); the contribution ratio of the 1st principal component was 42.58%. The 2nd principal component was distinctly positively related with ④(A-E), negatively related with ⑦ $(r\theta 5-r\theta 4)_{R+L}$, and was negatively related with ⑤(CR-A-CL); the contribution ratio of the 2nd principal component was 27.87%. The 3rd principal component was positively related with ⑥∠(I_2-C-P_1); the contribution ratio was 19.57%. Consequently, we observed that the cumulative contribution ratio of the 1st, 2nd and 3rd principal components of the 2nd cluster was 90.03% (Fig. 3-2).

3) The 3rd cluster:

The factor loading of the 1st principal component was distinctly indicative for its strongly positive relationships with items ② ($M2_R$-$M2_L$), ③ (A-B), ④ (A-E) and ⑥∠(I_2-C-P_1). The 1st principal component was also positively related with ①(C_R-C_L), while was distinctly negatively-related with ⑤ ∠ (C_R-A-C_L). Furthermore, we observed that the 1st principal component had a contribution ratio of 57.87%. The 2nd principal component was strongly and positively related with ① (C_R-C_L); the contribution ratio of the 2nd principal component was 19.16%. Further, the 3rd principal component was distinctly and positively related with ⑦ $(r\theta 5-r\theta 4)_{R+L}$; the contribution ratio of the 3rd principal component was 13.89%. Therefore, we observed that the cumulative contribution ratio of the 1st, 2nd and 3rd principal components was 90.92% in the 3rd cluster (Fig. 3-3).

4) The 4th cluster:

The factor loading of the 1st principal component was distinctly positively-related with ④ (A-E) and positively related with ③(A-B), but strongly and negatively related with ⑤∠(C_R-A-C_L); the contribution ratio of the 1st principal component was 57.87%. The 2nd principal component has a distinct and positive relationship with ⑦$(r\theta 5-r\theta 4)_{R+L}$, but a strongly negative relationship with ⑥∠(I_2-C-P_1); the contribution ratio of the 2nd principal component was 22.03%. We observed that the 3rd principal component was distinctly and positively related with ② ($M2_R$-$M2_L$), and was positively related with ①(C_R-C_L); the contribution ratio of the 3rd principal component was 19.39%. In addition, we found that the cumulative contribution ratio of the 1st, 2nd and 3rd principal components was 77.01% in the 4th cluster (Fig. 3-4).

5. Analysis of variance (One-factor ANOVA) of the estimated items

After conducting cluster analysis of the estimated items, one-way ANOVA was performed for identification of significant differences between the clusters (*p<0.05, **p<0.01; Table 3). The analysis observed significant differences of ①(C_R-C_L) between the 1st and 4th and 2nd and 3rd, as well as between the 3rd and 4th clusters (*p<0.05, **p<0.01**; Table 3-1). Significant differences of ②($M2_R$-$M2_L$) were identified between the 2nd and other clusters (*p<0.05, **p<0.01; Table 3-2). Significant differences of ③(A-B) were also found between the 1st and either 3rd or 4th clusters, and between the 2nd and either 3rd or 4th clusters (**p<0.01; Table 3-3). Moreover, significant differences of ④(A-E) and ⑤∠(C_R-A-C_L) were evident between the 1st and other clusters (*p<0.05, **p<0.01; Tables 3-4 & 3-5). Consequently, there we observed distinct significant differences of ⑥∠(I_2-C-P_1) by comparison of the 1st cluster with either the 2nd or 4th clusters, of the 2nd cluster with the 3rd cluster, and of the 3rd cluster with the 4th cluster (**p<0.01; Table 3-6). Furthermore, we identified significant differences of ⑦ $(r\theta 5 - r\theta 4)_{R+L}$ between the 1st and 3rd clusters, as well as between the 2nd cluster and either the 3rd or 4th cluster (**p<0.01; Table 3-7).

Table 3 Analysis of variance of estimated items in each cluster (*p<0.05, **p＜0.01)

Table 3-1 ①C_R-C_L : width of the anterior-teeth (anterior) segment

Cluster		Mean		Difference of mean	P-Value	
1	2	Mean1	Mean2			
1st	2nd	36.13	34.41	1.72	0.13	
1st	3rd	36.13	37.41	1.29	0.17	
1st	4th	36.13	34.31	1.82	0.02	*
2nd	3rd	34.41	37.41	3.01	0.00	**
2nd	4th	34.41	34.31	0.10	1.00	
3rd	4th	37.41	34.31	3.11	0.00	**

Table 3-2 ②$M2_R$-$M2_L$: width of the dental arch

Cluster 1	Cluster 2	Mean 1	Mean2	Difference of mean	P-Value	
1st	2nd	61.24	65.84	4.60	0.01	**
1st	3rd	61.24	61.26	0.02	1.00	
1st	4th	61.24	58.54	2.70	0.05	*
2nd	3rd	65.84	61.26	4.58	0.02	*
2nd	4th	65.84	58.54	7.30	0.00	**
3rd	4th	61.26	58.54	2.71	0.12	

Table 3-3 ③A-B : length of the dental arch

Cluster 1	Cluster 2	Mean 1	Mean2	Difference of mean	P-Value	
1st	2nd	38.26	37.93	0.33	0.98	
1st	3rd	38.26	42.40	4.14	0.00	**
1st	4th	38.26	41.24	2.98	0.00	**
2nd	3rd	37.93	42.40	4.47	0.00	**
2nd	4th	37.93	41.24	3.31	0.01	**
3rd	4th	42.40	41.24	1.15	0.48	

Table 3-4 ④A-E : length of the anterior dental arch

Cluster 1	Cluster 2	Mean 1	Mean2	Difference of mean	P-Value	
1st	2nd	7.38	8.74	1.36	0.02	*
1st	3rd	7.38	9.34	1.96	0.00	**
1st	4th	7.38	10.05	2.67	0.00	**
2nd	3rd	8.74	9.34	0.60	0.62	
2nd	4th	8.74	10.05	1.30	0.04	*
3rd	4th	9.34	10.05	0.70	0.30	

Table 3-5 ⑤$\angle(C_R\text{-}A\text{-}C_L)$: protrusion and curvature of the anterior segment

Cluster 1	Cluster 2	Mean 1	Mean2	Difference of mean	P-Value	
1st	2nd	136.00	125.86	10.14	0.00	**
1st	3rd	136.00	126.69	9.31	0.00	**
1st	4th	136.00	119.67	16.33	0.00	**
2nd	3rd	125.86	126.69	0.84	0.99	
2nd	4th	125.86	119.67	6.19	0.06	
3rd	4th	126.69	119.67	7.03	0.00	**

Table 3-6 ⑥$\angle(I_2\text{-}C\text{-}P_1)_{R\&L}=\angle(I_2\text{-}C\text{-}P_1)_R+\angle(I_2\text{-}C\text{-}P_1)_L$: protrusion demonstrated between the anterior- and buccal-teeth segments

Cluster 1	Cluster 2	Mean 1	Mean2	Difference of mean	P-Value	
1st	2nd	309.70	334.57	24.87	0.00	**
1st	3rd	309.70	303.31	6.40	0.50	
1st	4th	309.70	324.60	14.90	0.00	**
2nd	3rd	334.57	303.31	31.26	0.00	**
2nd	4th	334.57	324.60	9.97	0.37	
3rd	4th	303.31	324.60	21.29	0.00	**

Table 3-7 ⑦ $(r\theta5 - r\theta4)_{R\&L} = (r\theta5 - r\theta4)_R + (r\theta5 - r\theta4)_L$ ： the roundness of a dental arch by estimation of the transition occurred between the anterior and buccal segments

Cluster 1	Cluster 2	Mean 1	Mean2	Difference of mean	P-Value	
1st	2nd	6.57	5.29	1.28	0.18	
1st	3rd	6.57	8.64	2.07	0.00	**
1st	4th	6.57	7.52	0.95	0.20	
2nd	3rd	5.29	8.64	3.35	0.00	**
2nd	4th	5.29	7.52	2.24	0.01	**
3rd	4th	8.64	7.52	1.11	0.20	

Discussion

Mean values of estimated items depending on gender (Result 1) indicated that only ② ($M2_R$-$M2_L$), the width of the dental arch, has significant differences between males and females($p<0.01$;Table 1); the result was similar to some previous studies [31,32]. A study has also identified significant gender differences in maxillary ($I2_R$-$I2_L$), ($M1_R$-$M1_L$) and ②($M2_R$-$M2_L$)width, and the arch length presented by either the point A to ($M1_R$-$M1_L$) or ② ($M2_R$-$M2_L$) [25]. The studies suggested that the arch width might be affected by dynamics of functional occlusion and the related head-and-neck muscles of different genders. However, in a previous Fourier analysis of maxillary dental arches subjected to Thompson classification (not discussed on gender), we did not observe significant size differences of different maxillary arch forms [4]. Collectively, we postulate that the divergence of the studies might be contributed by the myodynamic differences between genders that the detailed relations might present an important problem for future investigation [31,32].

Based on the results of the dendrogram (Fig. 2) and evaluation of estimated items by the mean value (Table 2) of the present clustering, we confirmed that the morphology of maxillary dentitions was differentiated into two main groups at the combination level of 14.8, and was essentially influenced by ③(A-B) and ④(A-E) (Fig. 2 & Table 2; Result 2 & Result 3). Subsequently, the two groups were further subdivided in 4 groups at the combination level of 9.3 (Fig. 2). The data indicated that the characteristics of clusters 1 and 2 were deeply affected by ②($M2_R$-$M2_L$) and ⑤∠(C_R-A-C_L) . On the other hand, the morphology of the anterior segment, including①(C_R-C_L), ⑤∠(C_R-A-C_L) and ⑥ ∠ (I_2-C-P_1), essentially affected the characteristics of clusters 3 and 4 (Table 2). The present analyses suggested that the morphology of dental arch could be roughly classified with the arch length, and then subdivided according to the arch width and morphology of the anterior teeth segment (Result 2 & Result 3). Results obtained in this study were coincidental with what have been described in some previous studies, which evaluated items with analytical methods of alikeness to establish that curvature of the anterior segment, and length and width of the dental arch were essential elements to determinate the dental arch morphology [2-6, 25, 33].

We reviewed the Results 3, 4 and 5, and thereby identified that the clusters 1 and 2 had their ③ (A-B) and ④ (A-E) values smaller than the clusters 3 and 4 (Table 2). While the cluster 1 was characterized by a shallow and wide anterior teeth segment, we recognized that dental arches of the cluster 2 had a deeper and narrower anterior teeth segment accompanied with a shorter and wider arch than dentitions of the cluster 1 (Table 2). On the other hand, dentitions of the 4th cluster had a narrower anterior segment with more acute curvature than those of the 3rd cluster (Table 2).

In conclusion, we have identified that 1) the width and length, and morphology of the anterior teeth segment were essential elements to determinate the maxillary dental arch form, 2) the maxillary dentitions could be roughly differentiated by the characteristic curvature and length of the anterior teeth segment, and 3) specific features of the maxillary dental arches using the present cluster analysis were described as the following: dentitions of the 1st cluster had a short and wide anterior teeth segment, dental arches of the 2nd cluster were narrow in the anterior segment, short in arch length and were divergent distally, the 3rd cluster was characterised by a wide anterior teeth segment, distinct transition between the anterior and molar segments, and a long dental arch, and dentitions in the 4th cluster had a long and strongly-curved anterior teeth segment that contributed to a long and narrow dental arch.

Further studies to clarify how and at which combination levels of a cluster analysis will differentiate dental arch forms for comparison and unification with the classification methods proposed by other subjective and objective quantitative or mathematical analyses [2-24], which were basically based on the morphological study (a descriptive evaluation) made by Thompson and Dewey [1], are next attempts we should confront.

References

1. Agata T. The basic medical statistics. Tyugaiigakusha, Tokyo, pp. 127-137, 1997. (in Japanese)
2. Aoki S. Medical statistics analysis reference manual. Igaku-Shoin, Tokyo, pp. 237-241, 1989. (in Japanese)
3. Biggerstaff RH. Three variations in dental arch form estimated by a quadratic equation. *J Dent Res* 1972; 51:1509.
4. Choi S. An orthodontic study of the teeth and dental-arch form of Koreans with normal occlusion. *J Tokyo Dent College Soc* 1984; 84:1055-1073.
5. Currier JH. A computerized geometric analysis of human dental arch form. *Am J Orthod* 1969; 56:164-179.
6. Hayashi K, Mizoguchi I. Three-dimensional analysis of dental morphology using virtual model of dental arches. *Dent J Health Sci Univ Hokkaido* 2007; 26:77-81.
7. Iwabayashi M. A study on the dental arch form by means of curve fitting. *J Stomatol Soc* 1977; 44:57-71. (in Japanese)
8. Katahira K. Textbook of statistics. New rev ed. Kiri syoboh CORP., Tokyo, pp. 108-117, 1999. (in Japanese)
9. Katayama H. Morphological study of occlusion, dental arch and palate. *J Tokyo Dent College Soc* 1958; 58(Suppl.):1-21. (in Japanese)
10. Kan T. Textbook of multivariate analysis. Gendai-Sugakusha, Kyoto, pp. 128-160, 1993. (in Japanese)

11. Kitagami T. A study on the classification of the dental arch. *J Jpn Prosthodont Soc* 1957; 1:37-43. (in Japanese)
12. Kosaka H, Kobayashi T. A study of dental-arch forms and orthodontic arch-wire forms in Japanese subjects with normal occlusion. *J Tokyo Dent College Soc* 1997; 97:1029-1036. (in Japanese)
13. Lu K.H. Analysis of dental arch asymmetry (Abst.). *J Dent Res* 1964; 43:780.
14. MIKAMI H, NAKATSUKA M, IWAI Y. Comparison of maxillary and mandibular dental arch forms by studying Fourier series developed from mathematically estimated dentitions. *Okajimas Folia Anat Jpn* 2010; 87:85-96.
15. Miyamori Y. Mathematical examination of human dental arch forms. *J Osaka Odontol Soc* 1957; 20:439-443. (in Japanese)
16. Mizuno K. Comparative study on analysis of dental arch, alveolar arch and edentulous jaw alveolar ridge curves. *J Jpn Prosthodont Soc* 1959; 3:56-80 (in Japanese).
17. Nakatsuka M, Kumabe S, Iwai Y, Kim GS, Fujiwara S. Classification of maxillary dental arches by correlation and principal component analyses. *J Osaka Odontol Soc* 2004; 67:225-234. (in Japanese)
18. Nakatsuka M, Kumabe S, Imbe H, Iwai Y. Principal component analysis of mandibular dental arches. *J Osaka Odontol Soc* 2005; 68:189-198. (in Japanese)
19. Nakatsuka M, Kumabe S, Iwai Y. A Morphological Study of Maxillary dental arch using by Fourier analysis. *J Kyushu Dent Soc* 2007; 60:158-168. (in Japanese)
20. Nakatsuka M, Tsujibayashi T, Kumabe S, Jue SS, Shin JW and Iwai Y. Fourier analysis of maxillary dental arch forms. *The Kor J Phys Anthrop* 2008; 21:137-147.
21. Okuda C. The learning of statistics for medical researchers. Kinpodo Inc., Kyoto, pp. 106-115, 1999. (in Japanese)
22. Ryu Tatsuo, Otani Shinichi, Kikuchi Hisashi, Himuro Toshihiko. Quantitative analysis of dental arch configurations: Comparison of Japanese and Indian mandibular dental arch configurations. Orthod Waves 2003; 62:224-227.
23. Sakai T. On the form of dental arch and the relations of various parts of dental arch in the Japanese. Shinshu Med J 1955; 4:332-337. (in Japanese)
24. Sekikawa M. Fourier analysis of the dental arch form. Jpn J Oral Biol 1986; 28:43-61. (in Japanese)
25. Sekimoto T. A morphological study on the deciduous dentition using Fourier analysis − the size and shape of coronal and basal arches − . Odontology, *J Nippon Dent College Soc* 1986; 70:849-868. (in Japanese)
26. Sekimoto T, Tsuji H, Kawamata J, Hamaji H, Mizorogi E, Iwabuchi N, Uwabo K, Miura M, Hagiwara Y, Sakai M. A morphological study on the dentition using Fourier analysis − The relationship between deciduous dentition and permanent dentition − Part II comparison between normal occlusion and malocculision. *Jpn J*

Ped Dent 1988; 26:146-153. (in Japanese)

27. Shimada T.A Critical Study on the Classification of Human Dental and Alveolar Arches. *J Anthrop Soc Nippon* 1988; 96:267-288.
28. Soma K, Hatate M. Consideration of the cephalometric data analysis applied to the Fourier series. *J Stomatol Soc* 1980; 47:135 -144. (in Japanese)
29. Thompson AH, Dewey M. The teeth of the higher apes and man. Comparative dental anatomy. 2nd ed. CV Mosby, St. Louis, pp. 182-204, 1915.
30. Tsugawa T, Yamada R, Hayashi, Negishi S, Saitoh K, Kanazawa E, Kasai K. Characteristics of dental arch form in the present day Japanese with normal occlusion. *Nihon Univ J Oral Sci* 2009; 35:19-26.
31. Uchida O. Textbook of multivariate analysis by means of the Excel. Tokyo Tosho, Tokyo, pp. 135-166, 1997. (in Japanese)
32. Yamaura S. The study of Japanese (Nagano Pref.) dental arch and palate form 1. Dental arch form. *J Tokyo Dent College Soc* 1970; 70:1106-1128. (in Japanese)
33. Yoshikawa Y. Morphological study on the human dental arch form by means of elliptic regression analysis. *J Osaka Odontol Soc* 1978; 41:183-184. (in Japanese)

上顎牙弓型態的群集分析

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摘要

我們進行了一項群集分析，即將欲研究的對象依數個變項去分群組，並以其對牙弓形態的影響，建立一個準則以便於診斷及擬定治療計畫。因此為了確立每一群組的形態特徵，我們應用了主成份分析法。

結果：在以下主成份項目中我們得到了顯著的差異：夾甲⑥(I_2-C-P_1)上顎前牙曲線前途程度②($M2_R$-$M2_L$)上顎前牙弓寬度③(A–B)上顎牙弓長度(C_R-A-C_L)上顎前牙凸出程度。

結論：是上顎齒列應依③⑤⑥三項予以分類評估。

關鍵字：群集分析、上顎牙弓

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