A comparison of dental arch forms between Class II Division 1 and normal occlusion assessed by euclidean distance matrix analysis

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Introduction: The purpose of the study was to use euclidean distance matrix analysis to compare dental arch forms between subjects with Class II Division 1 malocclusions and normal occlusions. **Methods:** The sample consisted of 60 subjects with Class II Division 1 malocclusions and 60 subjects with normal occlusions, all between 13 and 17 years of age. Fourteen landmarks, corresponding to cusp tips and incisor edges, were identified on the dental casts with a 3-dimensional measuring machine. All possible linear distances between pairs of landmarks in an arch were computed, and arch-form differences between Class II Division 1 and normal-occlusion subjects were tested by euclidean distance matrix analysis. **Results:** In both sexes, the maxillary arches of the Class II Division 1 subjects were larger than the arches of the normal-occlusion subjects (1.8% and 2.7% larger for girls and boys, respectively), and arch shape was also significantly different ($P < .001$). The posterior teeth contributed to the shape difference between 2 groups more than the anterior teeth, moreover the main factor was narrow maxillary posterior arch width in the Class II Division 1 subjects. The mandibular arches of the Class II Division 1 subjects were also slightly larger, and arch shape was not significantly different regardless of sex. **Conclusions:** Expanding the maxillary posterior arch width in Class II Division 1 subjects might be an important method to harmonize maxillary and mandibular arch forms. (Am J Orthod Dentofacial Orthop 2006;129:528-35)

Dental-arch form consists of both size and shape. The most suitable approach for comparing dental-arch forms between 2 groups of subjects is to quantitatively compare size and shape simultaneously. Analysis of a number of linear measurements from landmark data was often used to compare dental-arch forms of 2 groups of subjects,[1-3] but it did not completely separate size and shape differences. Finite-element analysis was also used in the comparison of dental-arch form, but it was affected by homology function and element design.[4] Multivariate principal component analyses were performed by Buschang et al[5] to determine size and shape factors from several linear measurements, but these did not provide good information about major variations. Fortunately, euclidean distance matrix analysis (EDMA) successfully overcomes the shortcomings of those methods, provides a good measurement of form differences, separates the contributions of size and shape, and supplies information about major variations by suggesting which landmarks are more interesting in the form-difference matrix.[6,7] Therefore, EDMA has been extensively used in craniofacial morphology studies, such as comparisons between races, analysis of growth changes and patterns,[6,8,9] changes before and after orthodontic or orthopedic treatment,[10,11] and analyses of dental-arch forms.[12-15]

In the analysis of dental-arch form with EDMA, a successful example was shown by Ferrario et al[12-14] for dental-arch asymmetry, sexual dimorphism, and maxillary versus mandibular arch-form differences in healthy subjects with sound dentitions. It should be also interesting to apply EDMA to compare dental-arch forms between subjects with malocclusions and normal occlusions to aid in diagnosing and planning the treatment for malocclusion. However, to our knowledge, to date, there has been no research on this topic.

Class II Division 1 malocclusions are common in orthodontic practices, although Buschang et al[5] compared arch-morphology difference between untreated Class I and Class II malocclusions by multivariate principal component analyses. In that study, the relationship of malocclusion to skeletal pattern was not

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mentioned, and no normal-occlusion subjects served as controls. Moreover, multivariate principal component analysis did not provide good information about the major variations between the 2 groups. In our study, the analysis and evaluation of the arch-form differences between subjects with untreated Class II Division 1 malocclusions (whose occlusal type coincided with skeletal type) and normal occlusions were performed by EDMA for a complete dental-arch form comparison.

MATERIAL AND METHODS

The samples consisted of 2 groups, 1 with normal occlusions and the other with Class II Division 1 malocclusions. Each group comprised 30 adolescent boys and 30 adolescent girls aged 13 to 17 years. All subjects were of Han nationality, born and living in China (mainland). The malocclusion subjects were selected randomly from the clinical practice of the Department of Orthodontics, School of Stomatology, Peking University, in the 1990s. They were classified as having Class II Division 1 malocclusions based on the following criteria: bilateral Class II molar and canine relationships in centric occlusion, protruding maxillary incisors, and ANB angles greater than 5° in cephalometric measurements. The subjects with normal occlusions were selected from the study of growth and development (supported by National Nature Science Foundation of China), whose models were recorded in the 1990s. Each subject had a sound, full permanent dentition including second molars, with good alignment of teeth, bilateral Angle Class I molar and canine relationships in centric occlusion, normal overjet and overbite, a balanced profile, no previous or current orthodontic treatment, no temporomandibular disorders, and an ANB angle of 2.43° ± 1.40°. Informed consent was obtained from all subjects.

The models were the major objects for investigation. Fourteen landmarks (midpoints of incisal edges, canine cusps, and buccal cusps of premolars and first molars) were selected to represent the dental-arch form. The mesial contact point of the central incisors to the mesiobuccal cusps of the first molars was selected as the maxillary standard plane; the mesial contact point of the central incisors to the distobuccal cusps of the first molars was selected as the mandibular standard plane (Fig). All measuring points were identified by the YM-2115 three dimension measure machine (Chinese Academy of Metrology, Beijing, China). The corresponding x, y, and z coordinates were automatically recorded in a computer data file. The selection criteria for the models, figure, and measuring error of YM-2115 three dimension measure machine were described previously.[16] With a computer program, 14 landmarks representing both arches were projected to the corresponding standard plane. Then, a 2-dimensional EDMA was prepared to compare the arch forms between sexes in the 2 groups and between the Class II Division 1 and the normal-occlusion groups by sex.

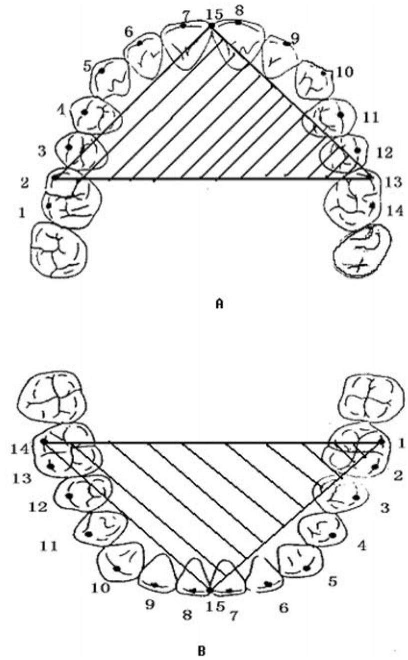

Fig. A, Landmarks in maxillary arch and standard plane. **B,** Landmarks in mandibular arch and standard plane.

Table I. Statistics for arch-form difference by sex matrix

Group	*Arch*	*T*	*M*	*P*
Normal occlusion	Maxilla	1.089	0.966	.53
	Mandible	1.081	0.970	.67
Class II Division 1	Maxilla	1.124	0.963	<.001
	Mandible	1.077	0.969	.74

T, Maximum ratio/minimum ratio; *M,* medium ratio.

In this study, the EDMA for arch form comparison was calculated as described by Lele and Richtsmeier[6] and Ferrario et al.[12-14] The procedure was as follows: all possible linear distances between pairs of landmarks were computed from the coordinates of the corresponding standard plane in each subject. This produced 30 male maxillary matrices of 91 distances (14 × [14 – 1] ÷ 2), 30 male mandibular matrices, 30 female maxillary matrices, and 30 female mandibular matrices in each group. Form matrices were then averaged for each sex, arch, and group, thus obtaining maxillary or mandibular matrices of 8 mean form matrices. Next, the arch-form differences by sex were determined, like linear dis-

Table II. Maxillary arch-form difference matrix for Class II Division 1 sorted from lowest to highest ratio

Landmark	*Ratio**	*Landmark*	*Ratio*	*Landmark*	*Ratio*	*Landmark*	*Ratio*
4–6	0.901	1–6	0.952	3–13	0.963	10–13	0.976
4–7	0.919	4–11	0.952	3–14	0.964	1–5	0.977
5–6	0.925	8–9	0.953	9–13	0.965	5–9	0.977
9–10	0.932	10–11	0.953	3–10	0.965	5–11	0.977
13–14	0.933	6–7	0.954	6–12	0.966	5–14	0.977
3–6	0.935	4–10	0.954	2–8	0.967	2–5	0.977
3–7	0.938	9–12	0.956	2–9	0.967	2–12	0.978
7–11	0.938	4–13	0.957	1–8	0.967	5–13	0.979
4–5	0.940	8–12	0.958	1–9	0.968	11–14	0.979
9–11	0.943	4–14	0.958	6–10	0.968	1–12	0.980
7–10	0.943	6–11	0.959	2–13	0.968	5–10	0.981
7–9	0.943	3–8	0.960	10–14	0.969	11–12	0.982
5–7	0.944	3–9	0.960	2–14	0.969	6–8	0.983
4–8	0.946	8–14	0.960	1–13	0.970	12–14	0.985
4–9	0.947	6–14	0.960	2–11	0.970	5–12	0.985
7–12	0.948	9–14	0.961	3–5	0.971	1–3	0.985
7–14	0.948	6–13	0.962	1–14	0.971	1–4	0.992
2–7	0.948	7–8	0.963	6–9	0.971	11–13	0.994
8–11	0.949	3–11	0.963	2–10	0.972	3–4	0.998
7–13	0.949	1–2	0.963	1–11	0.972	2–4	1.003
8–10	0.949	8–13	0.963	3–12	0.972	2–3	1.003
2–6	0.950	4–12	0.963	1–10	0.973	12–13	1.013
1–7	0.950	10–12	0.963	5–8	0.975		

$T_1 = 1.124$; $M_1 = 0.963$; $P_1 < .001$.
$T_2 = 1.113$; $M_2 = 0.964$; $P_2 = .08$.
$T_3 = 1.113$; $M_3 = 0.950$; $P_3 < .001$.
T_2, M_2, P_2: EDMA when deleting posterior teeth; T_3, M_3, P_3: EDMA when deleting anterior teeth.
*Mean distance between 2 landmarks in maxillary arch of female Class II Division 1 subjects divided by corresponding distance of male Class II Division 1 subjects.

tances from matrices of each sex were paired, and a ratio was computed for each corresponding linear distance (linear distances from the girls were the numerators; distances from the boys were the denominators). Thus, 4 form-difference matrices were obtained (maxillary sex-difference matrix for normal occlusion, mandibular sex-difference matrix for normal occlusion, and 2 similar matrices for Class II Division 1). The 91 ratios were then sorted from lowest to highest, and the statistics, T = maximum ratio/minimum ratio, M = medium ratio, were calculated. *T* represented the total range of arch-shape differences between the groups, and *M* was a measure of general size difference by the form-difference matrices.

The statistical significance of the form difference (ie, H_0 = similarity of forms, H_a= difference between forms) was tested by using a "bootstrap" procedure.[17] The level of significance was set at 5%. The procedure was performed as briefly described by Corner and Richtsmeier.[8] For example, if we want to compare 30 male maxillary matrices with 30 female maxillary matrices in normal occlusion, these 60 subjects were randomly split into 2 groups of 30 each, and the resulting sample was considered the bootstrap sample. This procedure was repeated 500 times. In each of the 500 bootstrap samples, T and M values were computed, and this large number of repetitions was used to obtain normal T null distribution. Then the positions of observed practical values of the 2 statistics relative to the T null distribution were tested. The null hypothesis (no arch-form difference between sexes in normal occlusion) was rejected if the observed T statistics were in an extreme tail of the distribution—equal to or less than 5% ($P \leq .05$). If the null hypothesis was rejected in the form-difference matrix, anterior (incisors and canines) and posterior (premolars and molars) teeth, respectively, were grouped by morphology and function, and EDMA calculations were repeated for the 2 groups, obtaining new T and *P* values (T_1, P_1 is the result of the original EDMA calculation; T_2, P_2 is the result of deleting anterior teeth; T_3, P_3 is the result of deleting posterior teeth). Thus, the statistical increase of *P* value compared with the first result (T_1, P_1) suggests that the deleted landmarks explain most of the form differences.

The results showed significant sexual dimorphism in

Table III. Maxillary arch-form difference matrix between Class II Division 1 and normal occlusion in males sorted from lowest to highest ratios

Landmark	*Ratio**	*Landmark*	*Ratio*	*Landmark*	*Ratio*	*Landmark*	*Ratio*
4–5	0.912	8–10	0.954	2–4	0.973	4–10	1.032
10–11	0.930	7–12	0.955	12–13	0.975	5–12	1.033
6–7	0.935	9–12	0.956	7–9	0.976	2–10	1.033
8–9	0.937	7–11	0.957	13–14	0.977	5–11	1.035
11–12	0.938	3–4	0.958	12–14	0.977	4–11	1.037
10–12	0.939	9–11	0.958	2–3	0.982	3–10	1.037
3–5	0.941	9–14	0.959	6–8	0.982	6–9	1.038
8–11	0.941	9–13	0.960	5–8	0.988	1–11	1.039
8–12	0.941	11–13	0.960	6–14	0.997	5–9	1.040
7–8	0.941	11–14	0.961	5–6	1.003	4–12	1.041
8–14	0.941	1–4	0.963	6–13	1.005	5–10	1.042
8–13	0.943	1–8	0.963	1–9	1.010	3–14	1.043
4–7	0.944	1–3	0.964	5–14	1.013	2–11	1.047
1–2	0.945	9–10	0.964	6–12	1.014	3–11	1.047
1–7	0.947	4–6	0.966	2–9	1.019	1–14	1.048
7–14	0.949	1–6	0.966	6–11	1.019	3–13	1.048
3–7	0.949	4–8	0.966	5–13	1.021	2–14	1.049
1–5	0.950	5–7	0.969	4–9	1.023	1–13	1.050
10–13	0.951	3–8	0.969	3–9	1.024	2–13	1.053
10–14	0.952	2–8	0.970	1–10	1.024	1–12	1.054
2–7	0.953	3–6	0.970	4–14	1.025	3–12	1.057
7–13	0.953	7–10	0.972	4–13	1.032	2–12	1.059
2–5	0.954	2–6	0.973	6–10	1.032		

$T_1 = 1.161$; $M_1 = 0.973$; $P_1 < .001$.
$T_2 = 1.126$; $M_2 = 0.971$; $P_2 < .001$.
$T_3 = 1.099$; $M_3 = 0.966$; $P_3 = .08$.
T_2, M_2, P_2: EDMA when deleting posterior teeth; T_3, M_3, P_3: EDMA when deleting anterior teeth.
*Mean distance between 2 landmarks in maxillary arch of male normal occlusion subjects divided by corresponding distance of male Class II Division 1 subjects.

maxillary arch form for Class II Division 1 (Tables I and II). Therefore, the arch-form differences between Class II Division 1 and normal occlusion by sex were evaluated by EDMA (linear distances from the normal-occlusion group were the numerators; distances from the Class II Division 1 group were the denominators).

RESULTS

The normal-occlusion data (Table I) showed no arch-shape difference by sex in either arch, but arch sizes were 3.4% larger in boys in the maxillary arch and 3.0% larger in the mandibular arch. In the Class II Division 1 group, male arch size was also larger than that of the female (3.7% in maxillary arch, 3.1% in mandibular arch). There was a significant arch-shape difference by sex in the maxillary arches of the Class II Division 1 group ($P < .001$). Details of the form-difference matrix are shown in Table II; by deleting the group of teeth, the results showed that the anterior teeth explain most of the maxillary arch-form differences between the sexes in Class II Division 1. The upper- and lower-end ratios showed that, in the Class II Division 1 group, the obvious difference in maxillary arch shape was the smaller anterior maxillary lateral length in girls than in boys. For the mandibular arch, there was no significant sex difference in the Class II Division 1 malocclusion group.

The maxillary arch-form difference matrix between Class II Division 1 and normal occlusion is shown in Tables III and IV. The arch-shape difference between the 2 groups was significant regardless of sex ($P < .001$). Arch size was also different. The maxillary arch in the Class II Division 1 group was larger (2.7% for boys, 1.8% for girls) than in the normal-occlusion group. When the posterior teeth were deleted, the results showed that P values increased to .08 for the boys and .14 for the girls. This suggested that posterior teeth contributed most of the form difference regardless of sex. As described in previous studies,[6,12-14] we focused on the 2 ends of the matrix (largest and smallest ratios) to observe the form-difference matrix carefully. In the lower end of the matrix, it was mainly ratios of linear distance oriented across the posterior landmarks (1, 2, 3, 4, 11,

Table IV. Maxillary arch-form difference matrix between Class II Division I and normal occlusion in females sorted from lowest to highest ratios

Landmark	*Ratio**	*Landmark*	*Ratio*	*Landmark*	*Ratio*	*Landmark*	*Ratio*
11–12	0.944	2–8	0.967	2–6	0.983	3–10	1.026
7–8	0.946	2–5	0.967	4–7	0.985	1–11	1.026
2–3	0.946	1–7	0.967	7–11	0.986	6–11	1.027
3–4	0.947	9–12	0.967	3–6	0.991	4–14	1.028
2–4	0.950	8–9	0.968	7–10	0.992	6–10	1.030
8–12	0.953	6–7	0.968	1–2	0.993	1–12	1.030
8–14	0.954	1–5	0.968	5–14	1.004	3–14	1.033
10–11	0.954	9–10	0.969	13–14	1.004	2–11	1.034
8–13	0.955	9–13	0.969	6–14	1.007	1–14	1.034
11–13	0.957	9–14	0.970	1–9	1.009	4–10	1.035
10–12	0.957	3–8	0.970	7–9	1.010	4–12	1.036
1–4	0.958	2–7	0.970	5–12	1.010	2–12	1.036
12–13	0.958	3–5	0.970	4–6	1.011	3–12	1.036
8–11	0.958	12–14	0.972	5–13	1.011	4–13	1.037
10–13	0.961	7–14	0.973	1–10	1.013	3–11	1.037
5–8	0.963	3–7	0.974	6–13	1.014	2–14	1.038
1–3	0.963	6–8	0.974	5–10	1.015	4–9	1.038
1–8	0.963	9–11	0.975	6–12	1.016	1–13	1.039
11–14	0.964	7–12	0.977	2–9	1.017	3–13	1.041
8–10	0.964	7–13	0.977	5–11	1.018	4–11	1.042
10–14	0.964	4–8	0.979	2–10	1.020	2–13	1.044
5–6	0.966	1–6	0.981	5–9	1.023	6–9	1.044
5–7	0.966	4–5	0.982	3–9	1.025		

$T_1 = 1.106$; $M_1 = 0.982$; $P_1 < .001$.
$T_2 = 1.101$; $M_2 = 0.982$; $P_2 < .001$.
$T_3 = 1.069$; $M_3 = 0.968$; $P_3 = .14$.
T_2, M_2, P_2: EDMA when deleting posterior teeth; T_3, M_3, P_3: EDMA when deleting anterior teeth.
*Mean distance between 2 landmarks in maxillary arch of female normal-occlusion subjects divided by corresponding distance of female Class II Division 1 subjects.

12, 13, and 14) on the 2 sides of the arch. This suggested that a narrower maxillary arch width in the Class II Division 1 group was an obvious characteristic regardless of sex. When the upper end of the form-difference matrix was studied, most smaller ratios were linear distances from landmarks in the same side of arch.

In the mandibular arch, shown in Table V (females omitted), the size in the Class II Division 1 group was slightly larger (0.6% in girls, 0.7% in boys) than in the normal-occlusion group, but the shape difference was not significantly different ($P = .28$ for boys, $P = .11$ for girls).

DISCUSSION

In the EDMA study of Ferrario et al,[14] they demonstrated that the dental-arch form difference between healthy men and women with sound dentition is in size, but not in shape. This study showed similar results for subjects with normal occlusions. In our previous study,[18] a mathematical interpolation (second-order conic curve including ellipses, parabolas, and hyperbolas) of the same subject's arch produced similar eccentric ratios (a variant reflecting arch shape) for the sexes and showed a larger arch circumference in males than females. This also suggested that the arch form between the sexes was different in normal occlusion, but with a size discrepancy more than a shape difference. In addition, in this study, for the maxillary arches of the Class II Division 1 group, there were arch-form differences by sex in both size and shape. Considering the above factors, we compared the arch forms of the Class II Division 1 and normal-occlusion groups with the sexes separated.

In this study, the 3-dimensional coordinate of landmarks in dental arch-form was identified by the YM-2115 three dimension measure machine, and each landmark was projected to the standard plane. This method overcame the problem of magnification and distortion errors associated with photographic techniques in previous studies.[12-15] It seemed reasonable that the accuracy had been increased.

In this study, we showed that arch sizes in the Class II Division 1 group were greater than in the

Table V. Mandibular arch-form difference matrix between Class II Division 1 and normal occlusion in males sorted from lowest to highest ratios

Landmark	*Ratio**	*Landmark*	*Ratio*	*Landmark*	*Ratio*	*Landmark*	*Ratio*
6–7	0.925	10–12	0.979	2–9	0.994	3–10	1.009
4–5	0.933	8–14	0.983	4–6	0.994	2–10	1.010
7–8	0.935	12–14	0.983	9–14	0.995	4–11	1.010
11–12	0.935	11–14	0.983	10–13	0.995	6–14	1.010
8–9	0.946	2–3	0.984	1–9	0.996	6–13	1.010
6–8	0.948	8–13	0.984	3–6	0.997	1–10	1.011
7–9	0.962	2–5	0.985	9–13	0.998	5–13	1.014
13–14	0.963	6–9	0.986	9–11	0.998	3–12	1.014
4–7	0.964	7–14	0.986	3–4	0.999	5–14	1.014
4–8	0.966	7–13	0.986	1–4	0.999	4–10	1.015
3–7	0.968	10–11	0.986	9–10	0.999	5–10	1.015
3–8	0.968	7–10	0.986	1–6	1.000	2–12	1.015
3–5	0.970	1–5	0.987	2–6	1.000	4–12	1.017
5–8	0.971	1–2	0.988	5–6	1.001	1–12	1.019
5–7	0.973	8–10	0.988	6–11	1.002	3–13	1.022
2–8	0.975	11–13	0.989	2–4	1.002	2–13	1.024
8–12	0.975	9–12	0.989	6–12	1.004	4–13	1.024
2–7	0.975	1–3	0.989	3–11	1.005	3–14	1.026
7–12	0.978	12–13	0.990	5–11	1.006	4–14	1.026
1–8	0.978	3–9	0.990	2–11	1.006	1–13	1.028
1–7	0.978	10–14	0.991	5–12	1.008	2–14	1.029
7–11	0.978	4–9	0.992	6–10	1.008	1–14	1.034
8–11	0.978	5–9	0.993	1–11	1.009		

$T_1 = 1.118$; $M_1 = 0.993$; $P_1 = .28$.
*Mean distance between 2 landmarks in mandibular arch of male normal-occlusion subjects divided by corresponding distance of male Class II Division 1 subjects.

normal-occlusion group (1.8%-2.7% in the maxillary arch, 0.6%-0.7% in the mandibular arch). The results in the mandible agreed with those in the study of Buschang et al[5]: Class II Division 1 >Class I >Class Division 2. But, for the maxillary arch, they reported that Class I >Class II Division 1 >Class II Division 2. Moreover, that study demonstrated only that the Class II Division 1 group had longer and narrower maxillary arches than the Class II Division 2 group, and there was no characteristic arch-shape difference between Class II Division 1 and Class I malocclusions. The difference in results between that study and ours can be explained as follows.

First, in that study, Class I included malocclusion subjects, whereas Class I included only normal occlusions in this study. Second, occlusal type was not mentioned in that study; this might have affected sample selection. For example, some skeletal Class II malocclusions can be converted to dental Class I malocclusions by forward movement of the permanent first molar because of premature loss of the deciduous second molar, so the Class I group might contain skeletal Class I and Class II patients. Similarly, the Class II group might include some Class I patients. In our study, skeletal type was considered, and, to simplify this study, the subjects were selected by the criterion of occlusal type coinciding with skeletal type. Third, the analysis method of that study was different from ours (multivariate principal component analyses v EDMA). Racial difference might also be a factor.

In this study, by using EDMA, arch size and shape were considered simultaneously, and the major areas that explain most differences can be found. We obtained the following results between Class II Division 1 and normal occlusion: maxillary arch forms including size and shape were different regardless of sex, and the posterior landmarks contributed the most to form differences. Moreover, it demonstrated that a narrower posterior arch width was the most important factor. On the other hand, mandibular arch form between the groups showed no significant difference, although arch sizes are slightly larger in Class II Division 1 subjects. This partly agreed with a comparison study of arch widths in adults with normal occlusions and Class II Division 1 malocclusions by Staley et al.[19] They measured intercanine and intermolar widths on the models. They concluded that Class II Division 1 subjects had narrower maxillary molar and canine widths than normal-occlusion subjects, and only male Class II Division 1 subjects had narrower mandibular molar widths than normal-occlusion subjects.

We also showed that maxillary canine and molar widths in Class II Division 1 subjects were narrower than in normal-occlusion subjects regardless of sex. This can be deduced by the ratios between corresponding landmarks—eg, the ratios of molar width were 1.044 in females and 1.053 in males, whereas the ratios of canine width were 1.015 in females and 1.042 in males. In the mandibular arch, the ratios of canine width were 0.998 in females and 1.015 in males whose values were close to 1; the ratios of molar width were 1.037 in females and 1.024 in males. Thus, we obtained a different conclusion from Staley's study, in that only female Class II Division 1 subjects had relatively narrower mandibular molar widths than normal-occlusion subjects. This could be related to the differences in sample selection and racial composition.

In the upper end of ratios (ie, lower ratios) in the male maxillary arch-form difference matrix, the ratios of distance between landmarks 4 and 5, and 10 and 11 (ie, cusp of canine to first premolar) were the smallest (0.912 and 0.930, respectively). This means that the distance in cusp of canine to premolar was larger in the Class II Division 1 group than in the normal-occlusion group. Moreover, other ratios of distance between landmarks on the same arch side were also at the upper end of the matrix. This suggests that maxillary arch forms in male Class II Division 1 subjects tended to be conic.

For the female maxillary arch-form difference matrix, the ratios of distance between landmarks similar to the male matrix were at the upper end of the matrix, but the values of these ratios were larger than in males. Thus, the female maxillary arch form in Class II Division 1 was narrower and longer than that for female normal occlusion, but the difference was less obvious between the Class II Division 1 and the normal-occlusion male groups. This can be explained by the sexual dimorphism in the maxillary arch of Class II Division 1 subjects. As shown in Table II, males generally have longer anterior lengths than females.

It is well documented that, after age 13 years, arch length decreases as age increases; the amount of decrease varies in different reports, but few changes with age have been reported for arch width.[20-22] In this study, the results have more clinical relevance: narrower maxillary posterior arch width is an important factor of arch-form difference between Class II Division 1 and normal-occlusion patients. Staley et al[19] hypothesized that, during eruption, the maxillary posterior teeth of Class II Division 1 subjects compensate for the increased buccal overjet (resulting from the anteroposterior displacement of the jaws) by palatal movement into better interdigitation with the mandibular teeth. Many Class II subjects (92%) in this study had good buccolingual posterior interdigitation in centric occlusion; this finding supports the tooth compensation hypothesis of Staley et al.[19]

CONCLUSIONS

Arch forms were compared between 60 normal-occlusion subjects and 60 Class II Division 1 subjects with EDMA. The results showed that arch forms in maxillary Class II Division 1 subjects significantly differed from subjects with normal occlusions in both size and shape regardless of sex, and posterior areas contribute most to the arch-form difference. Although the size of maxillary Class II Division 1 was larger than that of normal occlusion, the narrower maxillary posterior arch width in Class II Division 1 was an important factor for the arch-form difference compared with normal occlusion. But, for the mandible, there was no significant arch-form difference, although arch size in the Class II Division 1 group was slightly larger than that in normal occlusion. This suggests that expanding the maxillary posterior arch width might be an important way to decrease the arch-form difference between Class II Division 1 and normal-occlusion subjects, and to harmonize the maxillary and mandibular arch forms.

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