# Comparison of the mandibular dental and basal arch forms in adults and children with Class I and Class II malocclusions

**Deepak Gupta,[a] R. Matthew Miner,[b] Kazuhito Arai,[c] and Leslie A. Will[d]**
*Ann Arbor, Mich, Boston, Mass, and Tokyo, Japan*

**Introduction:** The mandibular arch form at the levels of both the application point of the orthodontic bracket and the basal bone in adults and children with Class I malocclusion and Class II Division 1 malocclusion was investigated. **Methods:** One hundred thirteen pretreatment mandibular casts were scanned to generate a 3-dimensional computer model of each cast. The casts were divided into Class I and Class II Division 1 malocclusion groups, and were further divided into adults (age, ≥25 years) and children (age, ≤18 years). Two reference points, FA and WALA, were assigned for each tooth. The FA and WALA arch forms were compared, and the distances between corresponding points and intercanine and intermolar widths were analyzed. **Results:** The mandibular intercanine FA point widths were significantly greater in the Class II Division 1 malocclusion group than in the Class I malocclusion group ($P < 0.05$) and were also significantly greater in the Class I adults than in the Class I children ($P < 0.05$). Both the canine FA and WALA point distances and the molar FA and WALA point distances were moderately to highly correlated ($R^2 > 0.55$) and highly significant ($P < 0.001$) for all groups. The FA and WALA curves for all groups had individual differences, especially in the premolar and molar areas. **Conclusions:** The Class II Division 1 mandible is essentially the same as the Class I mandible with respect to basal bone and dental arch dimensions. WALA points can be used to predict individual dental arch forms in adults and children. Dental and basal arch forms were not significantly different between adolescents and adults. (Am J Orthod Dentofacial Orthop 2010;138:10.e1-10.e8)

The size and shape of the dental arches have considerable implications for orthodontic diagnosis and treatment planning.[1] An important goal of orthodontic treatment is to establish a dental arch form that is in harmony with the underlying, supporting basal bone. Studies to date that investigated the relationship between the dental arch form and the basal bone arch form used different methods for defining these arch forms, with conflicting results.[2-5]

In 1925, Lundstrom[6] coined the term "apical base" to refer to the junction of the alveolar and basal bones of the maxilla and the mandible near the apices of the teeth. He believed that the movement of teeth with mechanical force to achieve normal occlusion is not necessarily accompanied by growth of the apical base. He further postulated that this disharmony between the position of the teeth and the supporting bone led to an occlusion that cannot be maintained. Seventy-five years later, Andrews and Andrews[7] defined what they called the WALA ridge as the band of keratinized soft tissue directly adjacent to the mucogingival junction. The WALA ridge served as a clinically observable structure representing the apical base described by Lundstrom.[6] Andrews and Andrews[7] assigned points to the midfacial axes of the teeth (FA points) to define the dental arch form and then defined the basal arch form by assigning corresponding points along the WALA ridge that were directly beneath the FA points. Using this method, they could investigate the arch form of the basal bone and the arch form characterized by the sites of the orthodontic brackets.

Studies of differences in the transverse dimensions of the mandibular arch form in subjects with different classes of occlusion commonly assess intercanine and intermolar widths. However, many of these studies have obtained conflicting results regarding the transverse dimensions of the mandibular arch. Staley et al[5] compared arch widths of subjects with normal occlusion

[a]Student in Graduate Orthodontics, University of Michigan, Ann Arbor, Mich.
[b]Associate clinical professor, School of Dental Medicine, Tufts University, Boston, Mass; private practice, Dedham, Mass.
[c]Associate professor and chair, Department of Orthodontics, Nippon Dental University, Tokyo, Japan.
[d]Chair and Anthony A. Gianelly professor, Department of Orthodontics and Dentofacial Orthopedics, Goldman School of Dental Medicine, Boston University, Boston, Mass.
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Reprint requests to: Leslie A. Will, Department of Orthodontics and Dentofacial Orthopedics, Boston University Goldman School of Dental Medicine, 100 E Newton St, Room 104, Boston, MA 02118; e-mail, willla@bu.edu.
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with those with Class II Division 1 malocclusion using canine and molar cusp tips as landmarks. They reported no differences in mandibular intercanine widths between the 2 groups, although male subjects with normal occlusion had significantly larger mandibular intermolar widths than did male subjects with Class II Division 1 malocclusion. Sayin and Turkkahraman[4] compared the mandibular dental casts of Class I subjects with those of Class II Division 1 malocclusion subjects. Cusp tips were used as landmarks for the canines, premolars, and molars. They found no significant difference in interpremolar and intermolar widths. However, they found mandibular intercanine widths to be significantly larger in the Class II Division 1 group than in the Class I ideal occlusion group. Uysal et al[8] compared arch widths of subjects with normal occlusion, Class II Division 1 malocclusion, and Class II Division 2 malocclusion. They also reported significantly greater mandibular intercanine widths in the Class II Division 1 group compared with the normal occlusion group. Frohlich[3] compared mandibular intercanine and intermolar widths of children with Class II malocclusion with children with normal occlusion and found no significant difference in either intercanine or intermolar width between the 2 groups. Al-Khateeb and Alhaija[2] compared tooth sizes, arch widths, and arch lengths of malocclusion patients with Class I, Class II Division 1, Class II Division 2, and Class III with all patients 13 to 15 years of age. Arch widths were assessed by using buccal and lingual cusp tips as well as the central fossae as landmarks for the molars and premolars and the cusp tips for the canines. They reported no significant differences in mandibular intercanine widths or arch lengths between Class I and Class II Division 1 malocclusions. However, they reported that the first premolar interarch width in the Class II Division 1 malocclusion group was significantly smaller than in the Class I malocclusion group.

These inconsistent findings might be attributed to differences in inclusion criteria used for the study samples, such as age or severity of malocclusion. Additionally, a wide range of anatomic landmarks has been used for the measurements. Consequently, significantly different results have been obtained when applying these different measurement methods to the same dental casts.

Recently, Ronay et al[9] compared the FA and WALA points derived from arches using 3-dimensional (3D) computer models of mandibular casts from 35 Class I malocclusion patients. They found a highly significant correlation of WALA and FA point widths in the canine and molar areas, showing that the practitioner could estimate the FA-derived arch form from the WALA-derived arch form for a patient. They also concluded that FA and WALA arch forms are highly individualized and therefore cannot be defined by 1 generalized formula. Ball et al,[10] using methods identical to those of Ronay et al,[9] investigated the arch forms derived from WALA and FA in 35 Class II Division 1 malocclusion patients and made similar conclusions.

It is likely that mandibular remodeling and growth of the jaws can change the relationship between the dental and basal arches. Further studies comparing the dental and basal arch forms in adolescents vs adults and other classes of malocclusion would help to determine whether the findings of Ronay et al[9] and Ball et al[10] apply to patients of different ages and different types of malocclusion. In this study, we compared the mandibular arch form at both the level of the clinically relevant application points of the orthodontic bracket (FA points) and the level of the underlying anatomic structure of the basal bone (WALA points) in adults and children with Class I and Class II Division 1 malocclusions.

## MATERIAL AND METHODS

Sixty-three pretreatment mandibular casts from patients with Class I malocclusion (mean age, 23.17 ± 12.02 years) and 58 pretreatment mandibular casts from patients classified as Class II Division 1 (mean age, 22.24 ± 11.97 years) were selected from a sample of 750 patients for this study. Portions of the data collected by Ronay et al[9] and Ball et al[10] were used for the Class I and Class II Division 1 samples, respectively. Both groups were further divided into adults (age, ≥25 years) and children (age, ≤18 years). The Class I group included 31 adults (mean age, 34.09 ± 7.32 years) and 32 children (mean age, 12.6 ± 1.56 years). The Class II Division 1 group included 28 adults (mean age, 33.31 ± 7.44 years) and 30 children (mean age, 11.17 ± 0.99 years). Previous studies found few difference between the sexes, and therefore the data were combined.[11,12] The sample size for each group was calculated based on an alpha significance level of 0.05 and a beta of 0.1 to achieve 90% power. The ad-hoc power analysis showed that 25 patients in each group were needed. Subjects were selected to participate in the study by visual inspection of dental casts and review of treatment records. Inclusion criteria for the Class I malocclusion group required patients to be skeletal and dental Class I with an ANB angle of 0° to 4°, and have Class I molar and canine relationships. To be included in the Class II Division 1 malocclusion group, patients were required to be skeletal and dental Class II with an ANB angle of >4°, and have Class II molar and canine relationships. Additional inclusion criteria for both groups were fully developed permanent dentitions from first

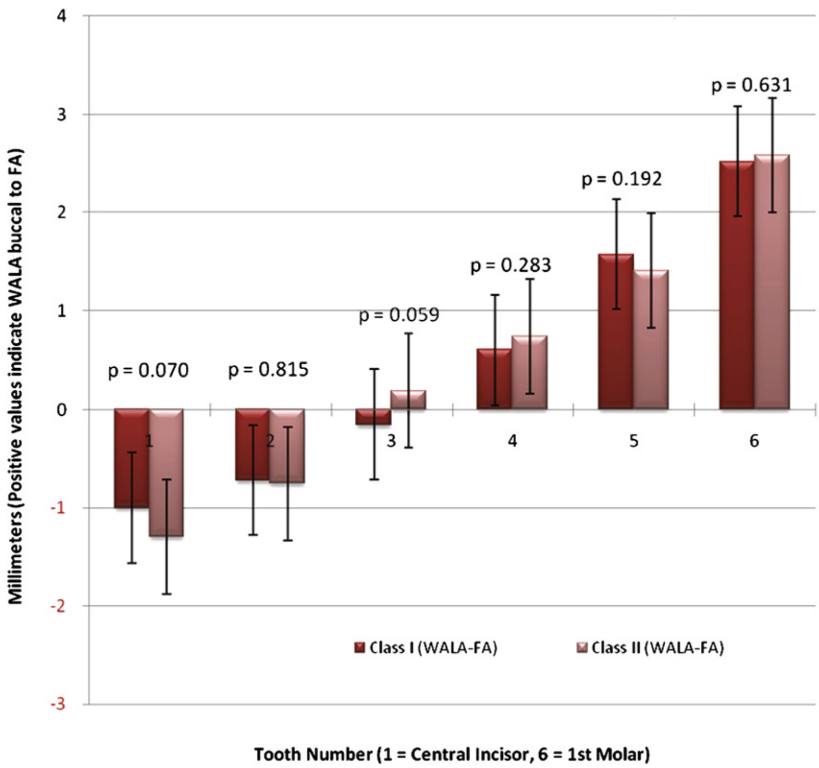


**Fig 1.** Mean distances between FA and WALA points for Class I and Class II Division 1 groups, with standard deviations and *P* values.

molar to first molar with no crossbites; no prosthetic crowns, large restorations, or gingival defects; and minimal crowding or spacing, with no tooth size-arch length discrepancy greater than 2 mm. Second molars were excluded from consideration because of the inability to ensure complete eruption in patients of all ages. Also, casts with unidentifiable mucogingival junctions were excluded from the sample. Approval for this study was granted by Harvard Medical School and Tufts University School of Dental Medicine.

Three-dimensional computer models of the dental casts were generated with a laser scanning unit. The setup consisted of a computer-assisted noncontact high-definition 3D scanning system including a laser-scanning unit (Dental Plaster Model Shape Scanning System, Surflacer model VMS-100f UNISN, Osaka, Japan), computer-aided-design software program (Dent-Merge, version 5.0, UNISN) and a dental cast analyzing software (Surfacer version 9.0, Imageware, Structural Dynamics Research Corporation, Milford, OH). This system was used to create and edit 3D digital models of the dental casts and identify anatomic landmarks for arch-form characterization. Ball et al[10] described the accuracy and performance characteristics of this system in a previous study.

The laser-scanning unit had 4 main components: a slit-ray laser projector, 2 sets of video cameras, 2 x-y object tables and an r-table to measure the circumference of the object. The mandibular dental casts were scanned at 3 angles in the frontal and sagittal planes. Each dental cast required 60 to 80 minutes to be scanned. Scanned images, including about 90,000 sets of x, y, and z coordinates per cast, were captured by the computer software. The data from the coordinates of both the frontal and sagittal planes were then joined and manually corrected for scanning artifacts. Finally, a 3D model of the entire cast was generated by using the cast-analyzing software (Surfacer, Imageware, Structural Dynamics Research Corporation).

Using the Surfacer software, the anatomic reference points were subjectively identified by the primary author (D.G.). The reference points included the FA points and WALA points, defined below.

1. For all teeth except the molars, the FA point is defined as the most prominent part of the central lobe of the clinical crown or the midpoint of the facial axis of the clinical crown. The FA point for the first molars is the most prominent point of the clinical crown in line with the mesiobuccal groove

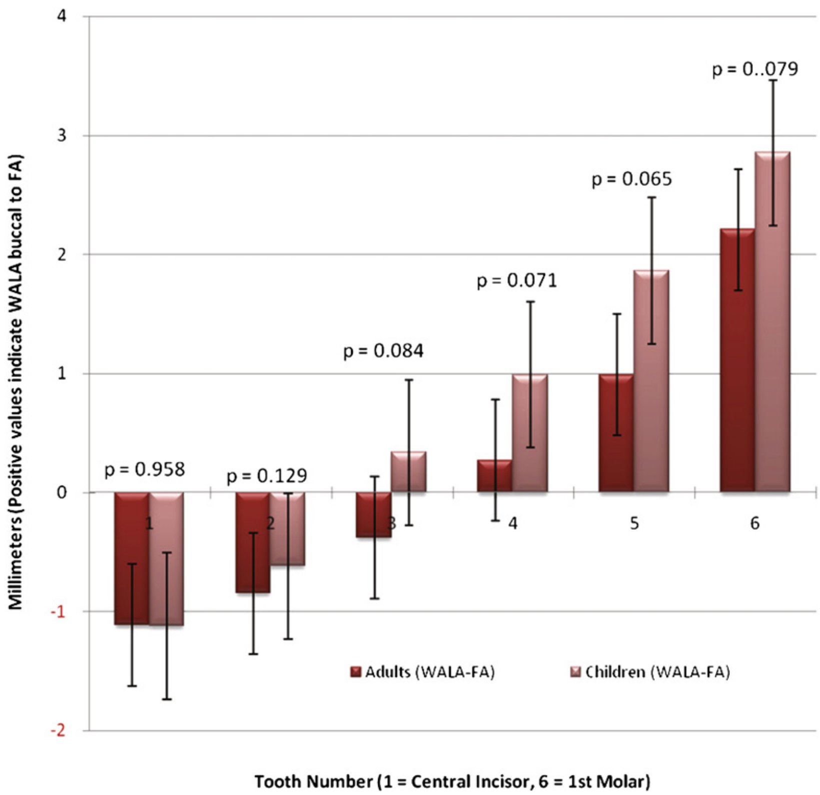


**Fig 2.** Mean distances between FA and WALA points for adults and children, with standard deviations and *P* values.

that separates the 2 large facial cusps. The FA point is the point on the crown where an orthodontic bracket would be placed for a fully preadjusted appliance system.[7]

2. The WALA point is defined as the point along the WALA ridge directly beneath the FA point of each tooth. The WALA ridge is a band of soft tissue immediately superior to the mandible's mucogingival junction. It is located at or nearly at the same vertical level as the horizontal center of rotation of the teeth in an arch.[7] The primary author was calibrated with Ball et al[10] and Ronay et al[9] to ensure that the points were selected in the same manner. To evaluate the reliability of landmark location, 10 mandibular dental casts were randomly selected from the sample. The FA and WALA points were determined twice by the primary author to evaluate intraoperator reliability, 2 weeks apart, on the right and left sides of the dental arch, totaling 120 teeth. Means and standard deviations of the 3D distance between 2 locations were calculated for reliability of landmark location. The same determination was made once by Ball et al[10] and Ronay et al[9] to evaluate interoperator reliability. The intraoperator and interoperator reliability values for the FA point were 0.27 mm (SD, 0.22 mm) and 0.49 mm (SD, 0.63 mm), respectively. The intraoperator and interoperator reliability values for the WALA point were 0.71 mm (SD, 0.42 mm) and 0.95 mm (SD, 0.75 mm), respectively.

Each set of points was digitized as x, y, and z coordinates with the Surfacer software. The sets of points were then exported into Excel software (version 2007, Microsoft, Redmond, Wash) with an ASCII format. A standard graph format was used to create graphs of both WALA and FA arch forms by connecting the individual FA and WALA point values by linear interpolation. Distances between the FA and WALA points for each tooth were then calculated. Mandibular intercanine and intermolar widths for the FA and WALA points were also calculated.

### Statistical analysis

The data were analyzed with the Excel software. Statistical analyses of the mean distances and standard deviations between FA and WALA points and a comparison of the mandibular intercanine and intermolar

**Table I.** Statistical comparisons of mean distances of FA and WALA canine and molar widths

| | FA canine width (mm) | FA molar width (mm) | WALA canine width (mm) | WALA molar width (mm) |
|---|---|---|---|---|
| Class I | 27.76 ]* | 51.37 ]NS | 28.75 ]NS | 56.22 ]NS |
| Class II | 28.46 | 50.56 | 28.49 | 55.27 |
| Class I adults | 27.87 ]NS | 51.67 ]NS | 28.2 ]NS | 55.7 ]NS |
| Class II adults | 27.93 | 50.92 | 27.58 | 54.86 |
| Class I children | 27.88 ]NS | 51.07 ]NS | 29.27 ]NS | 56.73 ]NS |
| Class II children | 28.49 | 50.23 | 29.35 | 55.64 |
| Class I adults | 27.87 ]NS | 51.67 ]NS | 28.2 ]* | 55.7 ]NS |
| Class I children | 27.88 | 51.07 | 29.27 | 56.73 |
| Class II adults | 27.93 ]NS | 50.92 ]NS | 27.58 ]NS | 54.86 ]NS |
| Class II children | 28.49 | 50.23 | 29.35 | 55.64 |

*NS*, Not significant.
**P* <0.05.

widths for all groups were performed with independent samples *t* tests. Linear regression and correlation analyses were also used to assess the correlation between FA and WALA point distances at the canine and molar areas for the groups.

## RESULTS

The mean distances and standard deviations between corresponding FA and WALA points for the Class I and Class II Division 1 malocclusion are shown in Figure 1, and similar data for adults and children are shown in Figure 2. The graphs illustrate that, for all groups, the FA points were located more lingually (positive values) in the premolar and molar areas in relation to the corresponding WALA points, and more buccally (negative values) in the area of the central and lateral incisors. The Class I malocclusion group had a negative mean distance at the canines, whereas the Class II Division 1 malocclusion group had a positive value. Similarly, the entire adult group had a negative mean distance at the canines, and the entire group of children had a positive value. An independent samples *t* test showed that no difference between the Class I and Class II Division 1 malocclusion groups, or between the adult and child groups, was statistically significant ($P < 0.05$).

Table I shows statistical comparisons of mean distances of FA and WALA canine and molar widths for adults and children with Class I and Class II Division 1 malocclusions. The independent samples *t* test was used to determine which differences between the groups were statistically significant. No significant differences were found between the WALA point widths or the FA point widths at the molars or canines, except that the mandibular intercanine FA point widths were significantly greater in the Class II Division 1 malocclusion group compared with the Class I malocclusion group ($P < 0.05$), and the mandibular intercanine WALA point widths were significantly greater in the Class I adult group compared with the Class I child group ($P < 0.05$).

**Table II.** Correlation between FA and WALA arch widths: coefficient of correlation ($R^2$)

| | Canine width ($R^2$) | Molar width ($R^2$) |
|---|---|---|
| Class I | 0.578* | 0.801* |
| Class II Division 1 | 0.77* | 0.687* |
| Adults | 0.713* | 0.785* |
| Children | 0.841* | 0.626* |

**P* <0.001.

Table II shows a positive correlation between canine FA and WALA point distances and between molar FA and WALA points for Class I, Class II, all adults, and all children. Scatter plots were generated for each group to show the distances between FA and WALA points at the canines and molars. A best-fit line for the data in each scatter plot was found by using linear regression with a coefficient of determination ($R^2$) and *P* values resulting from correlation analysis. The canine FA and WALA point distances and the molar FA and WALA point distances were highly significant ($P < 0.001$) for all groups, but the degrees of correlation differed. The canine FA and WALA widths were highly correlated for the adults as a group, the children as a group, and all Class II patients, but only moderately correlated for all Class I patients. Similarly, the molar FA and WALA widths were highly correlated for all adults and all Class I patients but only moderately correlated for all children and all Class II patients.

Superimpositions of the FA and WALA curves for the Class I malocclusion and the Class II Division 1 malocclusion samples are shown in Figures 3 and 4, respectively. Connection of the individual FA and WALA point values by linear interpolation was done to produce these graphs. To compare individual patients, the data were standardized by first translating the arch to place the midpoint between the FA points of the central incisors to the origin. The arch was then rotated to relocate the midpoint of the first molars to the y-axis. The curves show individual differences, especially in the premolar and molar areas, where the values describing these teeth were scattered.

## DISCUSSION

We found that intercanine dental widths were significantly greater in the Class II Division 1 group compared with the Class I malocclusion group when not separating adults from children. Occlusion of the mandibular teeth with a wider portion of the maxillary

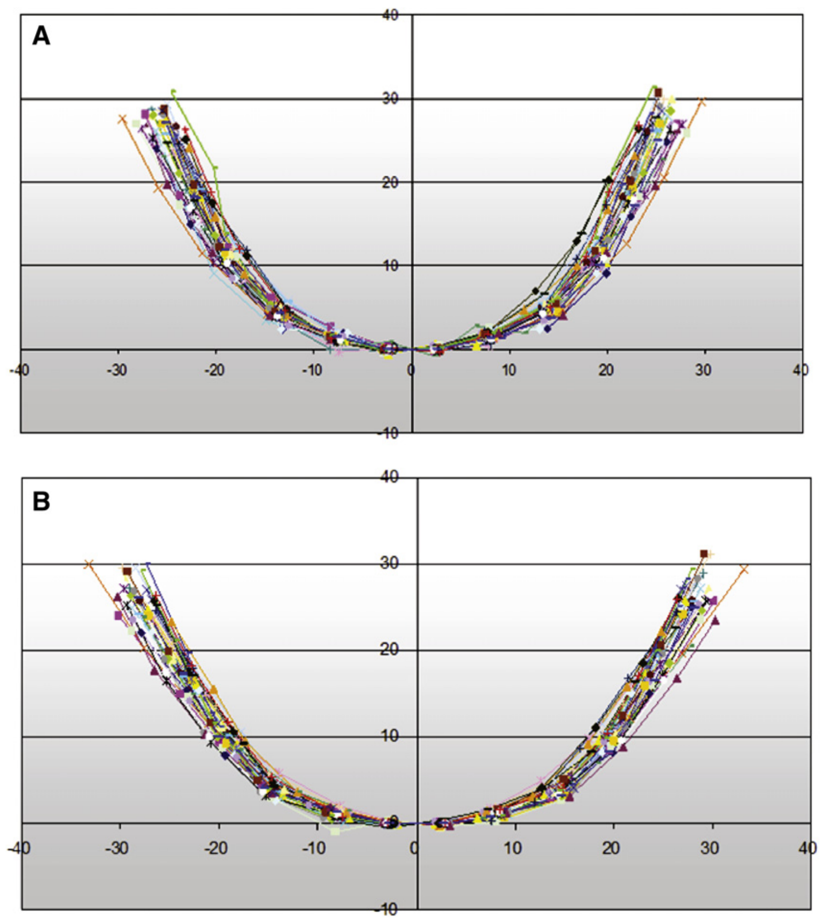


**Fig 3. A**, Superimposed FA curves for all Class I patients; **B**, superimposed WALA curves for all Class I patients.

arch might be the cause of this increase. However, the difference in the mean intercanine widths between the 2 groups was 0.7 mm, which is unlikely to be clinically significant. We also found no significant difference in the intermolar widths of the 2 groups. When the different age groups were considered separately, we found that Class II Division 1 children had a statistically significantly greater intercanine width compared with adults. Our results support those of Sayin and Turkkahraman[4] and Uysal et al[8] but differ from those of Frolich,[3] Staley et al,[5] and Al-Khateeb and Alhaija.[2]

The discrepancies in results between our study and those of Frolich[3] and Al-Khateeb and Alhaija[2] are resolved if we examine our data while considering patient age. Our data showed no significant differences in intercanine or intermolar widths when comparing Class II Division 1 children with Class I malocclusion children or when comparing Class II Division 1 adults with Class I malocclusion adults. These results are consistent with those of Frolich[3] and Al-Khateeb and Alhaija[2] that both used adolescent patient populations (<16 years of age). Because the Class II Division 1 samples used by Sayin and Turkkahraman[4] and Uysal et al[8] had mean ages of 16.07 ± 2.76 and 18.5 ± 2.9 years, respectively, and the Class I samples had mean ages of 19.17 ± 3.19 and 21.6 ± 2.6 years, respectively, a comparison of their results with ours by a nonage-based grouping is most reasonable, and thus our results are consistent with theirs.

Previous investigators measured the transverse dimensions of the alveolar bone using the mucogingival junction.[4,5,8] Sayin and Turkkahraman[4] used points on the mucogingival junction beneath the mandibular first molars to compare mandibular alveolar arch widths between Class I ideal occlusion and Class II Division 1 malocclusion patients. Their study cited no significant difference in maxillary and mandibular alveolar arch widths between the 2 groups. Similarly, Staley et al[5] used landmarks on the mucogingival junction beneath the first molars and found that male subjects with normal occlusion had a greater mandibular alveolar width

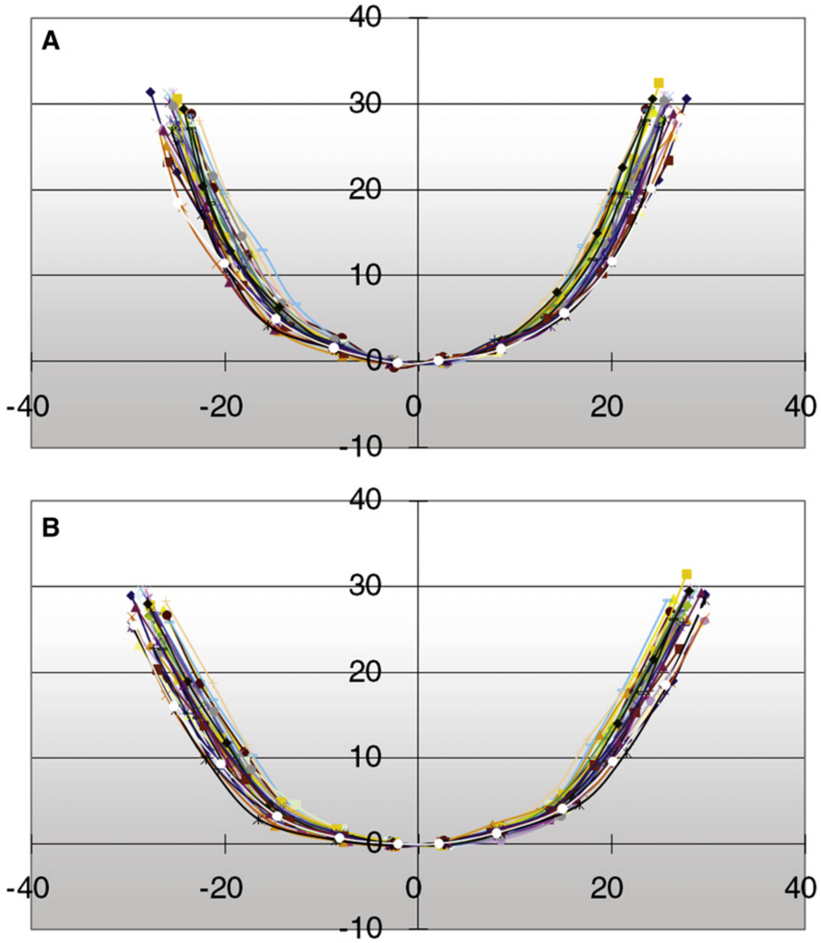


**Fig 4. A,** Superimposed FA curves for all Class II patients; **B,** superimposed WALA curves for all Class II patients.

than did those with Class II Division 1 malocclusion. In comparison, female subjects from both groups had similar mandibular alveolar widths. Uysal et al[8] used points along the mucogingival junction beneath the first molars, first premolars, and canines to determine mandibular alveolar arch widths. They found significantly narrower mandibular premolar and molar alveolar widths in the Class II Division 1 group compared with the normal occlusion sample. According to our findings, there was no statistically significant difference in canine and molar basal arch widths between the Class I and Class II Division 1 malocclusion patients with either age-based or nonage-based grouping.

In our study, no significant differences were found when comparing mean intercanine and intermolar widths of Class I children with Class I adults. However, as already stated, when comparing Class II Division 1 children with adults, the intercanine width was statistically significantly greater in children. Although the difference was statistically significant, it was small (1.26 mm) and not judged to be clinically significant. When the eta-square test was performed, it was found that only 0.18% of the variance in canine width was due to age. We therefore do not believe that canine width changes with age. Thus, with the exception of a small change in intercanine width, our data indicate that the dental and basal arch forms stay relatively stable in both Class I and Class II Division 1 subjects from adolescence to adulthood. This suggests that a person's adolescent WALA arch form could reliably be used to derive an archwire template for orthodontic treatment and result in a stable posttreatment arch form.

Correlation analysis demonstrated a highly statistically significant correlation between FA and WALA point widths in the canine and molar areas for the Class I and Class II Division 1 malocclusion patients. This is consistent with the results of Ronay et al[9] and Ball et al[10] for Class I and Class II Division 1 malocclusion patients, respectively. From this, it is reasonable to use anatomic landmarks of the basal arch form, such as the WALA points, as a template to produce the ideal clinical archwire blank form for a patient, particularly in the canine and molar areas. This could lead to more stable and predictable treatment outcomes, as they had concluded.

Our results, as well as those of Ronay et al[9] and Ball et al,[10] highlight the possibility of using the anatomy of the basal bone as a clinical guide to construct a stable dental arch form. In both studies, the arch form of the basal bone was approximated by using points along the WALA ridge, and both studies found a highly significant correlation between FA and WALA point distances in the canine and molar areas. Since the WALA ridge is a soft-tissue approximation of a hard-tissue structure, future work should explore new technologies that might enable us to locate other points or landmarks that are a better representation of the arch form of the basal bone and would therefore more accurately predict the ideal dental arch form. Three-dimensional imaging, such as cone-beam computed tomography, could be used to directly measure the basal bone rather than soft-tissue landmarks to approximate it.

## CONCLUSIONS

1. The Class II Division 1 mandible is essentially the same as the Class I mandible with respect to the basal bone and dental arch dimensions. Additionally, no significant difference was found between the 2 groups when the samples were grouped by age. Therefore, we do not recommend approaching Class II Division I patients as having a different pattern of mandibular arch form than Class I patients.
2. WALA points can be used to predict individual dental arch form in adults and children with Class I and Class II Division 1 malocclusions. Our results support those of Ronay et al[9] and Ball et al[10] for patients with Class I and Class II Division 1 malocclusions, respectively. Therefore, it is possible to use anatomic landmarks of the basal bone, such as WALA points, to predict optimal, individualized archwire sizes. Such an approach to orthodontic treatment should enable optimal dental arch stability, esthetics, and function.
3. The dental and basal arch forms stay relatively stable in both Class I and Class II Division 1 patients from adolescence to adulthood. No clinically significant differences were found when comparing mean intercanine and intermolar widths of Class I children with those of Class I adults. This suggests that a patient's adolescent WALA arch form could reliably be used for an archwire template for orthodontic treatment, and the result would be a stable posttreatment arch form.

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