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An Evaluation of Mandibular Dental and Basal Arch Dimensions in Class I and Class II Division 1 Adult Syrian Patients using Cone-beam Computed Tomography

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ABSTRACT

Aim: The aim of this study is (1) to inspect any difference in mandibular arch widths between males and females in class I and class II division 1 (class II-1) malocclusions using cone-beam computed tomography (CBCT), (2) to compare the mandibular dental and basal widths between the two groups, and (3) to investigate any possible correlation between dental and basal arch widths in both groups.

Materials and methods: The CBCT images of 68 patients aged between 18 and 25 years consisted of 34 class I (17 males and 17 females) and 34 class II-1 (17 males and 17 females) who were recruited at the Department of Orthodontics, University of Damascus Dental School (Syria). Using on-demand three-dimensional (3D) on axial views, facial axis points for dental measurements and basal bone center (BBC) points for basal measurements were identified on lower canines and first molars. Dental and basal intercanine width (ICW) and intermolar width (IMW) were measured.

Results: Independent t-test showed a statistically significant difference between males and females in several variables in both groups and a statistically significant difference between class I and class II-1 groups in the basal ICW for both genders and in the dental ICW for females only ($p < 0.05$). In class I group, Pearson's correlation coefficients between dental and basal measurements showed a strong correlation in the IMW for both genders ($r \geq 0.73$; $p < 0.01$) and a moderate correlation in females' ICW ($r = 0.67$; $p < 0.01$). In the class II-1 group, a moderate correlation in females' IMW ($r = 0.67$; $p < 0.01$) was found.

Conclusion: Females compared with males had narrower dimensions. Class I patients had larger ICW than class II-1 patients in all measurements and had narrower IMW than class II-1 in most measurements for both genders. There were moderate-to-strong correlations between dental and basal dimensions. BBC points might be landmarks that accurately represent the basal bone arch.

Clinical significance: CBCT-based assessments of dental and basal arch dimensions provide a great opportunity to accurately evaluate these aspects, to enhance clinicians' decisions regarding proper tooth movements, and to achieve good dentoalveolar intra-arch harmony.

Keywords: Basal arch, Class I, Class II-1, Cone-beam computed tomography, Dental arch, Intercanine width, Intermolar width.

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INTRODUCTION

The transverse dimensions of the dental arches have significant effects on orthodontic diagnosis and treatment planning. They affect the amount of the available space for dental alignment, stability of the produced tooth movements, and the final esthetic outcome.[1] Several studies[1-5] have assessed dental arch dimensions using FA that were first proposed by Andrews.[6] Other studies have used tips of cusps as landmarks for linear measurements.[7,8] Lundström defined the "apical base" as the section of bone on which the teeth rest or attached, and refers to the junction of the alveolar and basal bones of the maxilla and mandible in the region of the apices of the teeth.[9] Downs[10] described the use of A and B points on lateral cephalometric images to determine the anterior border of maxillary and mandibular apical bases and their relationship to the anterior cranial bases. Howes[11] reported that the basal arch refers to the apical third of the alveolar bone. In the mandibular arch, he found that the basal arch was located on approximately 8 mm below the gingival margin. Rees[12] found that points positioned at 8 to 10 mm from gingival margins of the molars and incisors could be used as "reasonably accurate" landmarks for locating the supporting basal bone in both arches. Sergl et al[13] used the most concave contour of the buccal surfaces of the casts to measure the basal bone area. Andrews and Andrews[14] have proposed the WALA points on the alveolar ridge on casts to estimate the basal arch width. The WALA points may not provide an accurate representation of the basal bone because of soft tissue thicknesses that vary among the teeth above the underlying alveolar bone and this may affect the spatial positions of WALA points among patients.[15] In addition, the definition of the vertical position of the basal area of the alveolar process varies among clinicians.[16,17] The alveolar bone is more affected by orthodontic tooth movements than the corresponding basal bone.[18] Furthermore, the vertical location of WALA points does not mimic the real location of the basal bone as previously defined by Lundström.[9]

Recently, Bayome et al,[4] using CBCT images, proposed root center (RC) points in the assessment of basal arch width. They defined the basal arch as the horizontal band that passes through the centers of the roots at a vertical level located at the junction between the gingival and the middle-thirds of the mandibular canines which corresponded with the WALA point vertical level. The implementation of CBCT imaging in evaluating basal and dental arch dimensions was only shown in two recent papers.[4,5] However, neither studies evaluated class II-1 malocclusion nor did they actually measure the "basal arch" according to the old definition of the "apical base" by Lundström.[9] These two studies employed RC points to evaluate basal dimensions.

Thus, determination of the basal bone level is still a confusing matter because of the absence of an agreement among authors. Sticking to the old definition of the "apical base," the actual vertical basal bone level must be located on the apical part or dental roots. In this study, we propose a new approach to determine the basal bone on CBCT images and to evaluate apical base transverse dimensions between two different skeletal patterns of malocclusion without being affected by the thicknesses of the overlying soft tissues.

Several previous studies have shown that patients with class II-1 malocclusion have a narrower maxillary dental arch than those with class I normal or ideal occlusion[19-22] or class I malocclusion.[7] However, regarding mandibular transverse dimensions, they showed conflicting results. For this reason, the current study is focused on the mandibular arch to clarify the differences between class II-1 and class I malocclusion. The objectives of this CBCT-based cross-sectional study were (1) to evaluate any possible differences in mandibular arch width between males and females in skeletal class I and class II-1 malocclusion, (2) to compare the mandibular dental and basal widths between the two groups, and (3) to investigate any possible correlation between dental and basal arch widths in both groups.

MATERIALS AND METHODS

This was a cross-sectional CBCT-based study for analytic and comparative purposes and was accomplished at the Department of Orthodontics, University of Damascus Dental School (Syria). The sample size was calculated using the G*power 3.1.7 program.[23,24] The smallest difference requires detection of 1 mm, using 2-sample t-test, for a power of 80%, and a significance level of 5% (depending on a previous study).[2] The sample size was 64 images which were found to be required (32 per each group).

Ethical approval was obtained from the University of Damascus Dental School Local Ethics Committee, 06-2015 2732/SM. This research work was self-funded. Disproportionate multistratified random sampling with respect to sex and malocclusion class was employed. The CBCT records were obtained by checking 745 patients archived who visited the Department of Orthodontics at Damascus University from January 2012 to November 2016. The study sample consisted of 68 malocclusion patients divided into two groups (class I, class II-1). Each group consisted of 34 patients (class I: 17 males and 17 females; class II-1: 17 males and 17 females). The CBCT images were included according to the following criteria:

- Age between 18 and 25 years
- ANB angle = 2° ± 2 for skeletal class I[25]
- ANB angle > 4° for skeletal class II-1[25]
- Permanent dentition and fully erupted teeth (excluded third molars)
- Mild-to-moderate crowding or spacing
- No extracted, missing, cracked, or impacted teeth
- No dental restorations that altered tooth size, shape, or location of the midpoint of the clinical crown
- No prosthetic crowns
- No periodontal or periapical lesions

Cone-beam Computed Tomography Image Acquisition

All CBCT images were acquired by SCANORA 3D™ Device (Soredex, Tusula, Finland) with the following parameters: 15 mA, 85 kV, 15 seconds exposure time, and a large 75-mm × 145-mm field of view at a voxel size 0.25 mm.[3] The axial images were exported in digital imaging and communication in medicine format and imported into on-demand 3D™ software (CyberMed, Finland) for 3D volumetric rendering.

Cone-beam Computed Tomography Image Analysis

Head orientation in CBCT-generated cephalograms was first performed. The 3D intracranial reference planes orientation was achieved using three planes defined by at least three landmarks or two landmarks and a plane: axial, sagittal, and coronal planes. The axial plane was defined bilaterally by the right and left Porion and right and left Orbitale landmarks. The sagittal plane was defined by Nasion (Na), anterior nasal spine, and Basion landmarks. The coronal plane was defined bilaterally by Porion landmarks and perpendicular to the axial plane. In the sagittal, axial, and coronal views, the volume was rotated until the axial plane was oriented horizontally, and the sagittal and coronal planes were oriented vertically.[26] The skeletal class was evaluated depending on the ANB angle as shown in Figure 1.

To obtain repeatable standard sections, reorientation of each CBCT image was performed. The contact point between mandibular central incisors (MCI) edges was considered as the origin of three axes: Sagittal, axial, and coronal. The axes were rotated around the MCI point, so the axial plane coincided with occlusal plane that connected between the mesiobuccal cusp tip of mandibular first molars and the MCI point. The sagittal plane was determined by passing MCI and parallel or coincided with intermaxillary suture, which connects between anterior and posterior nasal spine. Finally, the coronal plane was perpendicular with previous planes (Fig. 2).[4]

For dental measurements, the referential occlusal plane was moved downward to the level of FA points of mandibular canines on the axial views on the CBCT images. They were measured between the FA points of the right and left mandibular canines and first molars (Fig. 3). For basal measurements, the same plane was moved downward at the vertical level of the junction between the middle-third and the apical third of the canine roots (Fig. 4). They were measured between BBC points that

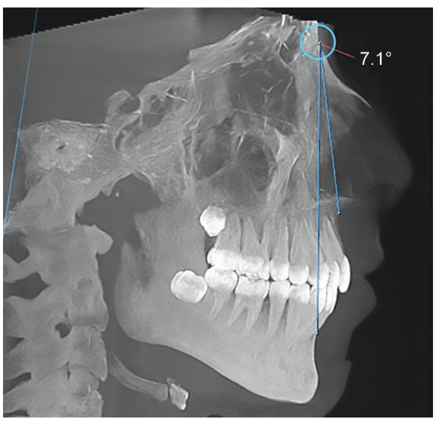

Fig. 1: ANB angle measured on lateral cephalometric image that was extracted from CBCT

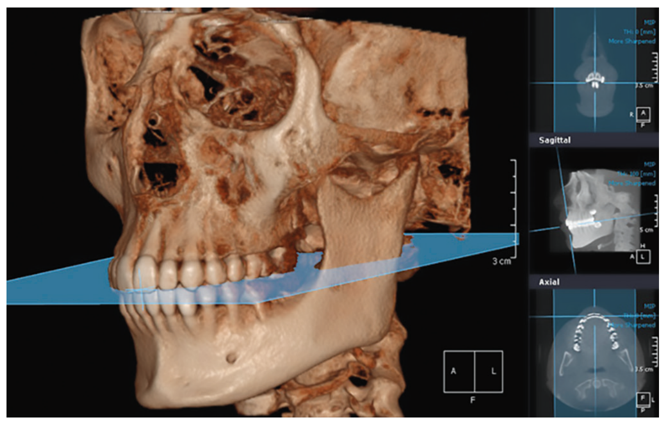

Fig. 2: Reorientation of three axes and definition of the referential occlusal plane

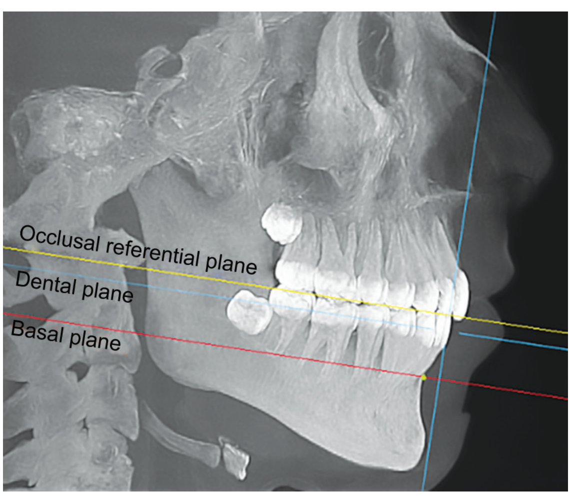

Fig. 3: Identification of planes: occlusal referential plane: yellow line, dental plane: blue line, basal plane: red line

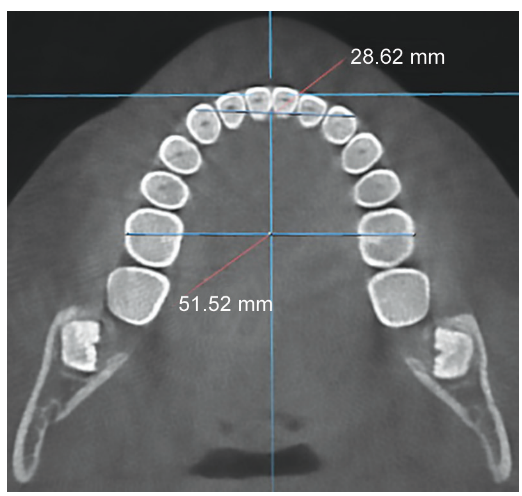

Fig. 4: Dental measurements on axial view

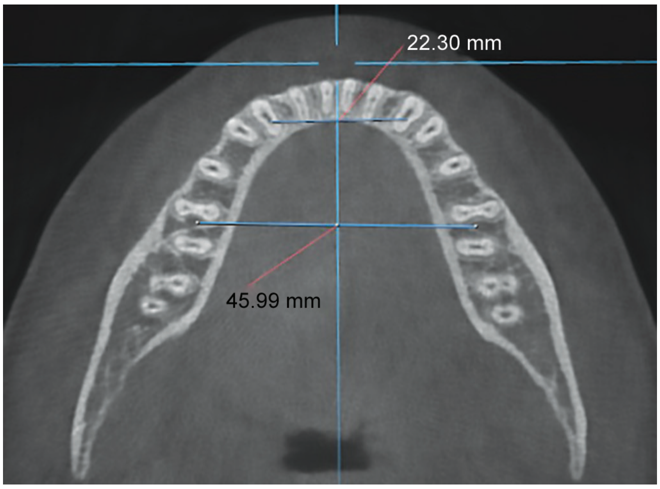

Fig. 5: Basal measurements on axial view

Table 1: Definitions of mandibular arch measurements

	Definition
FA points	The middle of the axis of the facial surface of each tooth on the CBCT images
BBC points	The middle distance between buccal and lingual cortical bone
Dental arch[a]	
ICW	The distance between the FA points of the right and left mandibular canines
IMW	The distance between the FA points of the right and left mandibular first molars
Basal arch[b]	
ICW	The distance between the BBC points of the right and left mandibular canines
IMW	The distance between the BBC points of the right and left of mandibular first molars

[a]Points were defined by previous authors[3,4]; [b]Points were defined by the authors

were located at the middle distance between buccal and lingual cortical bone of the mandibular canines and first molars (Fig. 5 and Table 1).

Statistical Analysis

All statistical analyses were performed using Statistical Package for the Social Sciences, version 22 (SPSS Inc., Chicago, Illinois, USA). Kolmogorov–Smirnov tests were applied to assess the normality of data distributions and were found normally distributed. Therefore, independent sample t-tests were applied to detect the significant differences between males and females and between class I group and class II-1 group variables. The significance level was set at 0.05. Pearson's correlation coefficients were calculated to evaluate any possible correlation between mandibular dental and basal ICW and IMW of each malocclusion class.

Error of the Method

Ten CBCT images were selected randomly and were remeasured after a month interval by the same principal researcher (L. A-H). To assess the systematic and random errors, paired t-tests were applied and showed no systematic error between the two occasions of measuring. Intraclass correlation coefficients (ICCs) were calculated which confirmed an excellent agreement between the two readings. The highest ICC value was 0.999 for dental IMW and the lowest ICC value was 0.992 for dental ICW measurement (Table 2).

RESULTS

The study sample consisted of 68 images divided into two groups: 34 images of skeletal class I with a mean ANB angle of 2.7 ± 0.95 and 34 images of skeletal class II-1 with a mean ANB angle of 6.2 ± 1.1. Females compared with males had statistically significant narrower dimensions in both groups (Table 3). A statistically significant difference was found between the two groups in the basal ICW for both genders ($p < 0.01$) and in the dental ICW for females only ($p < 0.05$ and Table 4). In the class I group, strong correlations were found between the dental and basal IMW for both genders (males: $r = 0.77$; females: $r = 0.73$; $p < 0.01$) and moderate correlations between the dental and basal ICW in the females group ($r = 0.67$; $p < 0.01$). In the class II-1 females group, a moderate correlation was found between the dental and basal IMW ($r = 0.67$; $p < 0.01$; Table 5).

DISCUSSION

This study aimed to compare mandibular dental and basal arch dimensions in class I and class II-1 adult Syrian sample using CBCT images to accurately determine the basal bone. To the best of our knowledge, this is the first study that chose the junction between the middle-third and apical-third of lower canines roots to avoid the possible uneven positions of teeth apices when locating the vertical level of the basal bone plane. In addition, the middle distance between the buccal and lingual cortical

Table 2: Assessment of the intraobserver reliability and error of the method (in mm)

	1st measurement	2nd measurement			
Variable	*Mean ± SD*	*Mean ± SD*	*ICC*	*Mean difference*	*p-value*[a]
Dental ICW	30.84 ± 2.02	30.86 ± 1.94	0.992	0.02	0.805
Dental IMW	51.33 ± 2.92	51.42 ± 2.84	0.999	0.07	0.173
Basal ICW	22.41 ± 2.15	22.54 ± 2.16	0.998	0.13	0.434
Basal IMW	45.63 ± 2.22	45.64 ± 2.22	0.998	0.04	0.423

SD: Standard deviation; [a]Comparison between repeated measurements using paired t-tests

Table 3: Gender comparisons of mandibular dental and basal measurements in the skeletal Class I and Class II-1 groups (n = 68)

	Class I (n = 34)			*Class II-1 (n = 34)*		
Group	*Males (n = 17)*	*Females (n = 17)*		*Males (n = 17)*	*Females (n = 17)*	
Gender	*Mean ± SD*	*Mean ± SD*	*p-value*	*Mean ± SD*	*Mean ± SD*	*p-value*
Dental						
ICW	31.03 ± 1.19	1.89 ± 29.89	0.0677	2.09 ± 30.93	2.33 ± 28.43	0.003**
IMW	54.33 ± 2.31	2.61 ± 50.87	0.001**	2.40 ± 54.38	2.58 ± 51.31	0.002**
Basal						
ICW	23.33 ± 2.00	2.23 ± 21.59	0.031*	2.34 ± 20.48	1.71 ± 19.87	0.385
IMW	47.20 ± 2.90	2.36 ± 45.40	0.061	3.54 ± 47.65	2.19 ± 44.28	0.002**

SD: Standard deviation; *Significant at $p < 0.05$; **Significant at $p < 0.01$; Independent sample t-test

Table 4: Descriptive statistics of the mandibular dental and basal ICW and IMW in the skeletal class I and skeletal class II-1 groups along with the results of significance testing

	Males (n = 34)			*Females (n = 34)*		
	Class I (n = 17)	*Class II-1 (n = 17)*		*Class I (n = 17)*	*Class II-1 (n = 17)*	
Gender	*Mean ± SD*	*Mean ± SD*	*p-value*	*Mean ± SD*	*Mean ± SD*	*p-value*
Dental						
ICW	31.03 ± 1.19	30.93 ± 2.09	0.883	29.89 ± 1.89	28.43 ± 2.33	0.028*
IMW	54.33 ± 2.31	54.38 ± 2.4	0.950	50.87 ± 2.61	51.31 ± 2.58	0.580
Basal						
ICW	23.33 ± 2	20.48 ± 2.34	0.003**	21.59 ± 2.23	19.87 ± 1.71	0.007**
IMW	47.2 ± 2.9	47.65 ± 3.54	0.730	45.4 ± 2.36	44.28 ± 2.19	0.115

SD: Standard deviation; *Significant at $p < 0.05$; **Significant at $p < 0.01$; Independent t-test

Table 5: Correlation coefficients between mandibular dental and basal measurements in the skeletal class I and class II-1 groups (n = 68)

	Class I (n = 34)				*Class II-1 (n = 34)*			
Class	*Dental*	*Basal*			*Dental*	*Basal*		
Type	*Mean ± SD*	*Mean ± SD*	*r*	*p-value*	*Mean ± SD*	*Mean ± SD*	*r*	*p-value*
Males (n = 17)								
ICW	31.03 ± 1.19	23.33 ± 2.00	0.356	0.256	30.93 ± 2.09	20.48 ± 2.34	0.280	0.360
IMW	54.33 ± 2.31	47.20 ± 2.90	0.774	0.003**	54.38 ± 2.40	47.65 ± 3.54	0.52	0.070
Females (n = 17)								
ICW	29.89 ± 1.89	21.59 ± 2.23	0.679	0.001**	28.43 ± 2.33	19.87 ± 1.71	0.086	0.712
IMW	50.87 ± 2.61	45.40 ± 2.36	0.737	0.001**	51.31 ± 2.58	44.28 ± 2.19	0.671	0.001**

SD: Standard deviation; **Significant at $p < 0.01$; r: Pearson's correlation coefficient

bone (BBC points) was used transversely on axial views for performing the apical base measurements.

Gender dimorphism in mandibular dental and basal arches dimensions was observed in the current study with males having significantly larger dimensions than females in almost all mandibular dimensions for class I and class II-1 patients. This may be due to the fact that after the age of 12 years, changes in arch widths continue to a larger extent in males.[27,28] The current findings agree with several studies[8,22,29] and disagree with others.[1] This may be related to the difference in ethnicity[30] or probably due to the different landmarks that have been used to assess the dental ICW that was located on the canines' cusp tips.[31,32]

When the skeletal class I and class II-1 dimensions were evaluated, there were some differences in the dental and basal arch dimensions. Dental ICW in females and basal ICW in both genders were significantly narrower in the class II-1 group compared with the class I group. This result may support Gianelly's assumption that the mandibular arch acts as a "narrow foot" that moves forward after the "shoe" is widened. It was postulated that the mandible in initial contact position in centric relation is in a distal position because the constricted maxilla is holding it back in that position.[33] Moreover, Coskuner and Ciger[34] showed that the mandibular dimensions significantly increased after treating class II division 1 or division 2 patients to achieve the ideal maxillary arch form. Our results differ from the study of Frohlich[35] and Al-Khateeb and Abu Alhaija,[7] which found no significant differences between dental ICW in class I and class II-1 groups, while Sayin and Turkkahraman[19] and Ball et al[2] found the mandibular dental ICW to be significantly larger in the class II-1 group compared with the class I group. Otherwise, the previous mentioned studies that evaluated the basal ICW depending on dental casts found that there was no significant difference between class I and class II-1 groups.[2,7,19,35] This conflicting result in the basal ICW may be due to the different vertical and transverse levels used in its assessment among these studies. The difference observed between Al-Khateeb and Abu Alhaija's study and the current one may be due to the different locations of landmarks that were used to assess the dental ICW. These landmarks were located on the canines' cusp tips compared with FA points of the current study, as well as the age of the sample with an age range of 13 to 15 years compared with the age range of 18 to 25 years in the current study. The differences between the results of the current study and those of Ball's study may be attributed to the difference in the mean age of the recruited patients, which was 11 to 15 years in his study compared with 18 to 25 years in the current study, as well as the diverse ethnicity of the patients between the two studies.

Correlation analysis in the class I group showed moderate-to-high significant correlations between dental and basal measurements in the canine and molar areas for females, and a highly significant correlation in the molar area for males. This agrees with the results of Ronay et al,[1] except for the canine area in males. The analysis in class II-1 patients revealed only a moderately significant correlation between dental and basal measurements in the molar area for females. This result is different from that of Ball et al[2] who found a highly significant correlation between dental and basal measurements in the canine and molar areas. The differences between our findings and their findings can be explained by the difference in the ethnicity of the included subjects[30] and the method of analyzing the basal bone. Ronay et al[1] and Ball et al[2] used WALA points that had the previously mentioned shortcoming of being unstable among different regions with different soft tissue thicknesses,[15] whereas in the current study, BBC points were used which may have served as more reliable landmarks for detecting and representing the actual basal bone in the vertical and transverse levels.

The CBCT images can provide a 3D view of maxillofacial bony structures, so we can accurately assess the basal bone and its spatial dimensions using BBC points, which might be considered reliable landmarks that represent to a great extent the basal bone arch and could be used in further CBCT-based research work to evaluate the basal characteristics of any type of malocclusion and treatment-induced changes. The current results of the correlation analysis may be useful for orthodontic clinicians for a better understanding of the spatial relationships between dental and basal arch dimensions in class I and class II-1 malocclusions and may help them to predict the ideal dental dimensions depending on the basal dimensions in each group.

It is recommended that a further investigation of dental and basal dimensions should be conducted taking into account different vertical growth patterns, the other types of malocclusions (i.e., the class II division 2 and class III malocclusion), gender dimorphism, age groups, severity of malocclusion, and the ethnicity of the recruited patients.

CONCLUSION

- Males had larger arch transverse dimensions than females in both groups, and gender dimorphism was observed in two of four widths in the class I group and in three of four widths in the class II-1 group.
- Mandibular dental and basal arch widths of class II-1 patients were smaller than those of class I patients in terms of basal ICW in both genders and dental ICW in the females group.
- BBC points are suggested as reliable landmarks for analyzing and evaluating the basal bone arch dimensions in malocclusion patients.

CLINICAL SIGNIFICANCE

The assessment of dental and basal arch dimensions is very important to achieve an ideal arch coordination when treating patients with class II or class I malocclusions. The current study revealed moderate-to-strong correlations between dental and basal dimensions in both groups of malocclusions and for several variables. The CBCT-based assessments provide a great opportunity to evaluate these dimensions to enrich the clinicians' decisions regarding the proper tooth movements.

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