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ORIGINAL ARTICLE

Dentistry

Arch Width and Arch Perimeter among Class I Normal Occlusion, Class II Division 1 and Class II Division 2 Malocclusions Using 3D Digital Model

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Abstract

Objective: This study aimed to compare the arch width and perimeter of the maxillary and mandibular arch in individuals with Class I normal occlusion, Class II Division 1 malocclusion (Class II/1), and Class II Division 2 malocclusion (Class II/2).

***Methods and Results*:** A total of 120 patients with a mean age of 14.5±1.1 years (range 13-16) were divided into three groups: Group 1 included 40 individuals with Class I normal occlusion, Group 2 included 40 patients with Class II/1, and Group 3 included 40 patients with Class II/2. The gender structure in all groups was the same. Measurements of intercanine width (ICW), interpremolar width (IPMW), intermolar width (IMW), and premolar width (PW) in the maxilla and mandible, and dental arch width (DAW) were performed using the Maestro 3D Studio program.

All mean maxillary and mandibular widths were higher in males than in females. This study showed that the maxillary ICW in Class II/1 was narrower than the ICW in Class I in males (31.6 mm vs. 33.9 mm), showing statistically significant differences *P*=0.030). In females, the maxillary IPMW in Class II/1 and Claas II/2 was significantly narrower than in Class I. (37.6 mm and 37.5 mm vs. 39.2 mm) (*P*=0.001). The IPMW in Class II/1 and Class II/2 in males had smaller values (38.1mm and 38.8mm) than Class I occlusion (39.9 mm) but did not show statistically significant differences (*P*=0.085). The perimeter of the maxillary arch in Class II/1 was smaller than in Class I, but larger than in Class II/2 (71.7 mm, 75.0 mm, and 73.3 mm, respectively, in females (*P*=0.003) and 76.7 mm, 78.4 mm, and 75.6 mm, respectively, in males, while we did not obtain a statistically significant difference (*P*=0.395). Intercanine, interpremolar, premolar, and intermolar widths were larger in the maxilla than in the mandible. In the mandible, we obtained a statistically significant difference only in the IPMW of the female gender classes (32,6 mm for Class 1, 32.4 mm for Class II/1 and 31.5 mm for Class II/2, *P*=0.031). According to gender, we obtained a statistically significant difference only in the mandible ICW in Class I occlusion (24.9 mm in females and 26.0 mm in males, *P*=0.018).

Conclusion: For each gender, the width and perimeter of the dental arch should be adjusted for each malocclusion. (**International Journal of Biomedicine. 2025;15(1):177-182.**)

Keywords: dental arch • arch perimeter • arch width • Angle's malocclusions

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Abbreviations

Class II/2, Class II Division 2 malocclusion; **Class II/1**, Class II Division 1 malocclusion; **DA**, dental arch; **DAW**, dental arch width; **ICW**, intercanine width; **IPMW**, interpremolar width; **IMW**, intermolar width; **MC**, malocclusion class; **PW**, premolar width.

Introduction

The dimensions of the dental arch (DA) are significant factors in the diagnostic and treatment planning in orthodontics, as they affect dental aesthetics, available space, and the stability of the dentition. Differences in the DA dimensions are observed between different groups of Angle's malocclusions.[1] The DA dimensions are important for orthodontists, prosthodontists, oral and maxillofacial surgeons, and anthropologists. The dimensions of the arches, especially the width and length of DAs, will help a lot in the diagnosis, planning, and therapeutic treatment.[2] Considerable variation occurs in DAW between different malocclusion groups.[3]

Dental arch differs among individuals because a DA is influenced by the environment, nutrition, genetics, race, and sex.[4] According to the literature, the width between the canines in the upper jaw is greater than between the canines in the lower jaw. Additionally, it is often seen that males have a higher ICW than females.[5] Muthaq et al.[6] showed no statistically significant differences in the IMW and ICW among the five malocclusion groups (Class I, Class II/1, Class II/2, Class III, and Class II subdivision). Furthermore, a study by Patel et al. showed that the average ICW in Class II/2 was also greater than in Class II/1.[4]

The formation and development of the DA is a continuous and complicated biological process. The arch undergoes 3D alterations in its width, length, and height. Due to variations in age, the measurements for each parameter may undergo alterations.[7] Bishara et al.[8] measured the perimeter and width of the mandibular and maxillary DAs between Class II/1 and normal occlusion, which showed no significant difference in ICW between the mandible and maxilla.

Based on the literature, the maxillary ICW is larger than the mandibular ICW, and commonly, the male ICW is larger than the female.[5] Therefore, due to the impact on tooth stability, aesthetics, and space availability, the assessment of ICW is crucial for accurate diagnosis and treatment planning in any orthodontic case.[9]

According to several studies, there is a positive correlation between the perimeter of the DA and the ICW and IMW, showing that these types of dimensions of the DAs act as guides in diagnosing and planning orthodontic therapy.[10,11]

In recent years, with the advancement of digital technology, it has become possible for digital models in orthodontics to significantly impact treatment planning, as they enable the creation of virtual configurations and the personalized fabrication of aligners and braces. Also, digital 3D models eliminate the need for physical storage space and the risk of damage or breakage.[12] Digital planning in digital models is essential, ultimately facilitating the correct formulation of a treatment.[13]

This study aimed to compare the arch width and perimeter of the maxillary and mandibular arch in individuals with Class I normal occlusion, Class II/1, and Class II/2. Also, the DAW and maxillary and mandibular perimeter between males and females of the Kosovo population will be compared using 3D digital models.

Materials and Methods

A total of 120 patients with a mean age of 14.5±1.1 years (range 13-16) were divided into three groups: Group 1 included 40 individuals with Class I normal occlusion, Group 2 included 40 patients with Class II/1, and Group 3 included 40 patients with Class II/2. The gender structure in all groups was the same (Table 1).

Table 1.
General characteristics of the patients with different malocclusions.

	Class I	Class II/1	Class II/2	Total
Sex, n (%)				
F	24 (60.0)	24 (60.0)	24 (60.0)	72 (60.0)
M	16 (40.0)	16 (40.0)	16 (40.0)	48 (40.0)
Age (years)				
Mean ± SD	14.5 ± 1.0	14.3 ±1.2	14.7 ± 1.2	14.5 ± 1.1
Rank	13-16	13-16	13-16	13-16

Inclusion criteria: the presence of teeth from the first molar of one side to the first molar of the other side, as well as symmetry in both DAs. Exclusion criteria: plaster models must not have porosity, patients who have a broken or broken tooth, patients with congenital defects, patients who previously had orthodontic treatments incised, or transposed teeth, presence of air bubbles, cracked or broken plaster, patients with anomalies in the size or shape of the teeth, patients with interproximal caries or restorations that may affect the measurements.

In the first step of the work, an alginate impression was made on both DAs, which were sent to the laboratory to form plaster models. These plaster models were then scanned for 5 seconds with a 3D scanner, creating the 3D digital models (Deluxe model; Open Technology, Italy).

The necessary points for each measurement were determined by two expert operators, and the software program enabled the automatic calculation of millimeters on the spot.

In the digital models, measurements were made of the ICW, IPMW, PW, and IMW in the maxilla, and the same widths were also measured in the mandible. The ICW was measured as the distance between the cusp tips of the canines. The IPMW was measured as the distance between the buccal cusps of the first premolar. The PW was measured as the distance between the buccal cusps of the second premolars. The IMW was measured as the distance between the mesiobuccal cusps of the first molars. These measurements were performed using the Maestro 3D Studio program (Figure 1).

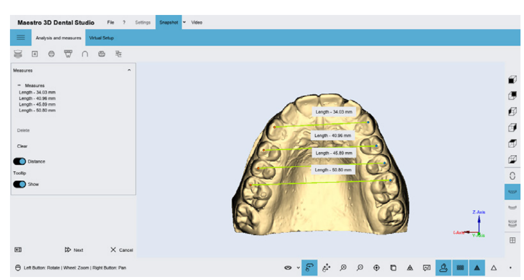

Fig. 1 *Digital measurement of arch width in maxilla. Maestro 3D Dental Studio software.*

For arch perimeter, the curve was drawn from the mesial side of the first permanent molar to the mesial side of the first permanent molar on the other side, thus passing through the tops of the cusps of the premolars and canines and the incisal edges of the incisors in the maxilla and mandible (Figure 2).

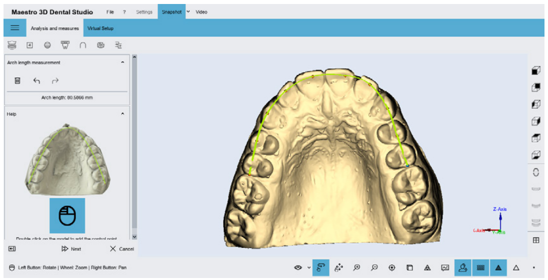

Fig.2. *Digital measurement of arch perimeter. Maestro 3D Dental Studio software.*

Statistical analysis was performed using the statistical software package SPSS version 20.0 (SPSS Inc, Armonk, NY: IBM Corp). For the descriptive analysis, results are presented as mean (M) ± standard deviation (SD). The normality of distribution of continuous variables was tested using the Shapiro-Wilk test. For data with normal distribution, inter-group comparisons were performed using Student's T-test. For nonparametric data, inter-group comparisons were performed using the Mann-Whitney U Test. Multiple comparisons were performed with one-way ANOVA and a post-hoc Tukey HSD test or Kruskal-Wallis H-test. The value of $P<0.05$ was considered significant.

Ethical Considerations

The study protocol was reviewed and approved by the Ethics Committee of the University Dentistry Clinical Center of Kosovo (Protocol # 4068, 07.17.2020). Written informed consent was obtained from all the participants.

Results

We found statistically significant differences in maxillary and mandibular arch widths according to gender. All mean maxillary and mandibular widths were higher in males than in females (Table 2).

We also obtained a statistically significant difference in the ICW in the maxilla between the male malocclusion classes (MCs), while we did not obtain a statistically significant difference according to gender for each MC. A statistically significant difference in the IPMW in the maxilla between the female MCs was found ($P<0.001$). At the same time, we did not obtain a statistically significant difference between genders for each MC (Table 3).

We obtained a statistically significant difference in the PW in the maxilla between the female MCs ($P<0.001$), while according to gender for each MC, we obtained a statistically significant difference only in Class II/2 ($P=0.01$). We did not find a statistically significant difference in the IMW in the maxilla between the MCs of both genders, while according to gender for each MC, we obtained a statistically significant difference only in Classe I ($P=0.016$) and Class II/2 ($P=0.032$).

Table 2.

Comparison of maxillary (Max) and mandibular (Mand) arch widths and perimeter by gender

	Female		Male		P-value	Test
	Mean	SD	Mean	SD		
ICW (Max)	32.0	2	33.0	2.4	0.015	T=2.46
IPMW (Max)	38.1	1.8	39.0	2.4	0.031	T=2.17
PW (Max)	43.5	1.8	44.8	2.8	0.005	U'=2256.0
IMW (Max)	48.5	2.1	49.7	2.8	0.028	U'=2137.0
Arch Perimeter (Max)	75.2	4.0	77.2	4.4	0.015	U'=2183.0
ICW (Mand)	25.0	1.7	25.9	1.8	0.012	T=2.54
IPMW (Mand)	32.2	1.7	33.0	2.3	0.016	U'=2175.0
PW (Mand)	37.7	1.7	38.4	2.6	0.021	U'=2159.0
IMW (Mand)	45.7	1.6	46.5	2.6	0.017	U'=2174.0
Arch Perimeter (Mand)	63.8	3.2	65.9	3.7	0.011	U'=2204.0

Table 3.

Comparison of maxillary arch widths according to malocclusion classes and gender

	Class	Female	Male	*P*-value	Test
		Mean±SD	Mean±SD		
ICW	I	32.9±1.6	33.9±2.0	0.132	U'=247
	II/1	31.6±1.8	31.6±2.1	0.649	U'=209
	II/2	31.6±2.3	33.6	0.016	U'=280
P-value		*P*=0.140	*P*=0.030		
Test		KW=3.93	KW=6.99		
IPMW	I	39.2±1.8	39.9±2.4	0.189	U'=240
	II/1	37.6±1.7	38.1±1.6	0.412	T=0.828
	II/2	37.5±1.4	38.8±2.8	0.384	U'=224.0
P-value		*P*=0.001	*P*=0.085		
Test		KW=13.9	F=2.61		
PW	I	44.5±1.4	45.5±2.5	0.114	T=1.62
	II/1	42.9±2.3	43.9±2.0	0.071	U'=258
	II/2	42.9±1.1	45.0±3.5	0.01	T=2.67
P-value		*P*=0.001	*P*=0.265		
Test		KW=14.7	F=1.37		
IMW	I	49.3±1.5	50.7±1.9	0.016	T=2.51
	II/1	48.1±2.9	48.5±2.3	0.649	T=0.458
	II/2	48.0±1.5	49.8±3.5	0.032	T=2.22
P-value		*P*=0.054	*P*=0.069		
Test		KW=5.82	KW=5.33		
Arch Perimeter	I	75.0±2.6	78.4±4.1	0.003	T=3.203
	II/1	71.7±4.6	76.7±4.9	0.755	T=0.315
	II/2	73.3±3.6	75.6±4.0	0.017	U'=279
P-value		*P*=0.003	*P*=0.395		
Test		F=6.43	KW=1.86		

There was a statistically significant difference in the perimeter of the maxillary arch between the classes in the female gender (*P*=0.003), while according to gender for each MC, we obtained a statistically significant difference only in Classe I (*P*=0.003) and Class II/2 (*P*=0.017) (Table 3). The perimeter of the maxillary arch in Class II/1 was smaller than in Class I, but larger than in Class II/2 (71.7 mm, 75.0 mm, and 73.3 mm, respectively, in females (*P*=0.003) and 76.7 mm, 78.4 mm, and 75.6 mm, respectively, in males, while we did not obtain a statistically significant difference (*P*=0.395)

Intercanine, interpremolar, premolar, and intermolar widths were larger in the maxilla than in the mandible. Meanwhile, in the mandible, we obtained a statistically significant difference only in the IPMW of the female gender classes (P=0.031). According to gender, we obtained a statistically significant difference in the mandible ICW in Class I occlusion (*P*=0.018) (Table 4).

Table 4.
Comparison of mandible arch widths according to malocclusion classes and gender.

	Class	Female	Male	*P*-value	Test
		Mean±SD	Mean±SD		
ICW	I	24.9±1.5	26.0±1.1	0.018	T=2.48
	II/1	25.6±1.2	26.0±2.0	0.486	T=0.702
	II/2	24.6±2.1	25.6±2.2	0.309	U'=238.0
P-value		*P*=0.190	*P*=0.889		
Test		KW=3.32	KW=0.24		
IPMW	I	32.6±1.6	33.6±1.6	0.089	U'=254
	II/1	32.4±2.2	33.3±2.4	0.481	U'=218
	II/2	31.5±1.1	32.1±2.7	0.155	U'=244.0
P-value		*P*=0.031	*P*=0.731		
Test		KW=6.96	KW=0.63		
PW	I	38.1±1.1	38.7±1.5	0.125	U'=248
	II/1	37.8±2.2	38.8±2.0	0.144	T=1.49
	II/2	37.1±1.3	37.6±3.7	0.535	T=0.625
P-value		*P*=0.108	*P*=0.732		
Test		KW=4.44	KW=0.62		
IMW	I	45.9±1.9	46.1±2.8	0.866	T=0.169
	II/1	45.6±3.1	46.8±2.0	0.534	U'=215
	II/2	45.6±2.0	46.5±2.9	0.327	U'=228.0
P-value		*P*=0.805	*P*=0.707		
Test		KW=0.43	F=0.349		
Arch Perimeter	I	63.5±3.0	65.6±3.5	0.252	U'=234
	II/1	64.3±3.8	66.2±4.1	0.300	U'=230
	II/2	63.6±2.7	65.9±3.8	0.032	T=2.22
P-value		*P*=0.812	*P*=0.954		
Test		KW=0.416	KW=0.094		

Discussion

A comprehensive assessment of the analyses conducted on the study models is necessary to rectify a malocclusion or anomaly and receive appropriate orthodontic treatment. Unquestionably, the primary objective of orthodontic treatment is to cure malocclusions and realign the teeth inside the DAs to enhance the aesthetics and functionality of the DA. Recently, the trend in orthodontics has been the digitization of study models.

This study showed that the maxillary ICW in Class II/1 was narrower than the ICW in Class I in males (31.6 mm vs. 33.9 mm), showing statistically significant differences *P*=0.030). In females, the maxillary IPMW in Class II/1 and Claas II/2 was significantly narrower than in Class I. (37.6 mm and 37.5 mm vs. 39.2 mm) (*P*=0.001). The IPMW in Class II/1 and Class II/2 in males had smaller values (38.1mm and 38.8mm) than Class I occlusion (39.9 mm) but did not show statistically significant differences (*P*=0.085).

The digitization of study models has been a recent development in orthodontics. Many studies have seen the utility of digital methods and software programs for orthodontic use by making orthodontic measurements easier and more accurate.[14,15]

The digital model analysis allows the 3D evaluation of DAs by enlarging them without changing their dimensions; it also facilitates the storage of data and their distribution between professionals, allowing us to have a more accurate analysis of orthodontic planning and treatment.[16,17]

Marwa et al.[18] compared the dimensions of the DAs in Class II/1 and Class II/2 against Class I using 3D digital models and showed significant statistical significance where the maxillary IPMW in Class II/1 and Class II/2 was smaller than the IPMW in Class I occlusion, while the maxillary IMW in Class II/1 was significantly narrower than the IMW in Class II/2 and Class I, but without showing significant statistical significance. In our study, we observed that the intercanine, interpremolar, and premolar width in the maxilla, according to MCs, was greater in Class I occlusion compared to the width in Class II/1 and Class II/2 with a significant difference, while the maxillary IMW was also greater in Class I. We did not obtain a significant difference between the measurements in Class II/1 and ClassII/2 which were performed on the digitized models. Some studies investigated the transverse morphology and growth of Class II/1 and Class II/2 compared with Class I.[19-21] According to Uysal et al.,[22] when comparing maxillary and mandibular widths between Class I and Class II/2, all mandibular widths were significantly narrower in Class II/2 patients than in Class I patients. To further elaborate on this, our study shows that intercanine, interpremolar, premolar, and intermolar widths are significantly larger in Class I than the widths of Class II/1 and Class II/2, and this shows a statistically significant difference in ICW and IPMW.

Considerable variations occur in DAW among different malocclusion groups. Also, in the study, the maxillary ICW of Class I showed a significant difference greater than that of the maxillary ICW of Class II/1 and Class II/2. These findings are consistent with other studies.[4,19,23] Sayin and Turkkahraman [24] detected that the maxillary IMW was narrower in Class II/1 than the normal sample. Ahmed et al. stated that the maxillary ICW was significantly decreased in Class II/1 and Class II/2; on the other hand, the maxillary and mandibular ICW and IMW were increased in Class II/2.

The influence of environment, nutrition, genetics, gender, and race are related to the changes in the DAs of each individual.[4,25] The impact of sexual dimorphism on the width of the DAs is clearly shown by the study conducted by Moshabab and Haider,[26] where their results report that the width of the DAs was greater in males than in females. Our study also found such results, showing that all maxilla widths in Class I versus Class II were greater in males than females, with a significant difference.

The scientific literature, especially regarding sexual dimorphism, shows that the maxillary ICW is greater than the mandibular ICW and greater in males than females.[5]

That the arch length is one of the most crucial parameters[27] for space analysis is shown by the results of Shafique et al.,[28] in that the arch perimeter greatly affects the position of the teeth in the DA, so reducing the DA perimeter leads to increased arch length discrepancies, resulting in crowding. However, since the arch widths and lengths vary, according to the available literature, careful evaluation for correct treatment and planning is needed.[29]

Omnia et al.[30] studied the relationship between the arch circumference and intercanine and intermolar widths in patients aged 13–16. They showed that this relationship between these parameters guides the diagnosis and planning of orthodontic treatment. According to a study on DA morphology by Buschang et al.,[20] females with Class II/1 had narrower and longer DAs than those with Class II/1 and Class I normal occlusion. However, our study shows that the DA circumference in Class II/1 is smaller than that of Class I but larger than that of Class II/2 (71.7 mm in females and 76.7 mm in males). Such results were also found in the research of Al-Khateeb and Abu Alhaija [29] in children aged 13-15 years in the Jordanian population, where the perimeter of the maxillary arch was significantly longer in Class II/1 than in Class II/2. Petrovic et al.[31] used digital models, and their results showed better levels of agreement in the width of the maxillary arch perimeter to its length. Better agreement was found for the IMW than for the ICW.

To maintain oral health, it is essential to compare the width and perimeter of DA before the start of any orthodontic treatment. Ultimately, accurate measurements improve the functionality and appearance of tooth structure by helping orthodontists make diagnoses, plans, and treatments, especially when using 3D digital technology. Our research suggests that 3D-scanned digital models can be a reliable substitute for conventional plaster models. For the first time in Kosovo, this study compares the width and perimeter of DAs in Class I, Class II/1, and Class II/2 and analyzes these measurements by gender using digital measurements.

The limitations of our study include the limited number of patients and the study's design; we also suggest a larger study size and the inclusion of other parameters such as tooth size, DA shape, and palate depth.

In conclusion, due to the differences observed in DAs and to have a good occlusion, we suggest that before and during any orthodontic treatment, we consider adjusting the width and perimeter of the DAs according to gender. The reduction in width in malocclusions is associated with a shorter perimeter of the DAs. This shows a relationship between the width and length of the arch, where a narrower DA affects the reduction of the total space.

Competing Interests

The authors declare that they have no competing interests.

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