Original Article

Tooth Size Discrepancies and Arch Parameters among Different Malocclusions in a Jordanian Sample

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Abstract: The objectives of this study were to determine the mean mesiodistal tooth width of the dentition, Bolton anterior and overall ratios, arch length, and arch width in the different malocclusions in a Jordanian sample. The mesiodistal tooth width, arch width, and length were measured on a total of 140 orthodontic models of school students aged 13–15 years of different occlusal relationships (Class I, Class II division 1, Class II division 2, and Class III malocclusions). Anterior and overall Bolton ratios were calculated. The mean and standard deviation were calculated. Student's *t*-test and analysis of variance were used for the statistical analysis. The results show that (1) females have smaller teeth than males; (2) Class III malocclusion showed larger teeth than the rest of the other occlusal categories; (3) no statistically significant differences were found in Bolton ratios between the different malocclusions; (4) Class II division 1 showed the narrowest maxillary arch compared with the other types of malocclusion; (5) the mandibular intercanine width was significantly larger in Class III group than in Class II division 1 and Class II division 2 groups; (6) the maxillary arch was significantly longer in Class II division 1 than in Class II division 2; and (7) the mandibular arch of both Class II categories was significantly shorter than Class III malocclusion group. In conclusion, tooth size differences were found between right and left sides, between females and males, and between the different malocclusions. Arch width and length also showed differences among the different malocclusions. (*Angle Orthod* 2006;76: 459–465.)

Key Words: Tooth size; Arch width; Arch length, Bolton ratio

INTRODUCTION

Mesiodistal tooth width has an anthropological significance because it provides valuable information on human evolution with its technological and dietary changes.[1] On a clinical level, mesiodistal tooth width is correlated to the arch alignment and large teeth are associated with crowded dental arches.[2–4] Moreover, a relation has been noted between tooth size and third molar eruption and impaction.[5]

Differences in tooth size have been associated with different ethnic backgrounds and malocclusions.[6–8] A comparative study between Jordanians, Iraqi, Yemenites, and Caucasians reported that Jordanians and Iraqi had larger teeth than the other populations.[9] The latter study, however, did not discuss the differences in tooth size between different malocclusions.

Correct tooth size relationship between maxillary and mandibular teeth is an important factor to achieve a proper occlusal interdigitation during the final stages of orthodontic treatment.[10,11] Several methods have been described to evaluate interarch tooth size relationship such as Kesling's diagnostic setup,[12] Neff's anterior coefficient,[10,13] and Bolton's ratios for the six anterior teeth, and the overall ratio for the 12 teeth.[11,14]

Many factors such as heredity, growth of the bone, eruption and inclination of the teeth, external influences, function, and ethnic background would affect the size and shape of the dental arches.[15–18] Several studies were carried out on arch width and transverse craniofacial development to evaluate changes due to growth, treatment, and relapse.[19–22] Some studies investigated the transverse morphology and growth of Class II division 1 and Class II division 2 compared

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TABLE 1. Distribution of Subjects According to Sex and Malocclusion Group

Classification of Malocclusion	Number of Females	Number of Males	Total
Class I	21	13	34
Class II division 1	21	11	33
Class II division 2	18	19	37
Class III	15	21	36

with Class I.[23–25] Very few studies, however, included the four types of anteroposterior occlusion groups in their comparisons.[26,27]

The aims of this study were to determine: the mean mesiodistal tooth width, the anterior and overall Bolton ratios, the arch length, and arch width in the different malocclusions in a Jordanian sample.

MATERIALS AND METHODS

A total of 140 sets of alginate impressions were obtained from students (age range 13–15 years) with different malocclusions (Class I, Class II division 1, Class II division 2, and Class III malocclusions). The distribution of subjects according to sex and malocclusion group is shown in Table 1. The impressions were poured in the same day by an orthodontic technician. The inclusion criteria for the subjects were as follows.

1. Complete permanent dentition with no caries, proximal restorations, attrition, or dental anomalies.
2. All teeth fully erupted to the occlusal plane.
3. No previous or ongoing orthodontic treatment.
4. No transverse discrepancies such as crossbite or scissors bite.

The mesiodistal tooth width from first molar to first molar was measured on the orthodontic models by Dr. Al-Khateeb. The readings were obtained by measuring the greatest distance between the contact points on proximal surfaces using a vernier gauge caliper (Munchner, Munich, Germany). In addition, the arch length and arch width between canines, premolars, and first molars in both arches were measured. The arch width between each tooth and its analog on the contralateral was measured at three points: the distance between the buccal cusp on the right side to the buccal cusp on the left side, distance between the central fossa to central fossa, and the distance between the lingual cusp to the lingual cusp. For the first molars, the measurements were made from the mesiobuccal and mesiolingual cusps to the mesiobuccal and mesiolingual cusps of the contralateral molar, respectively.

To calculate the measurement error, 20 casts were remeasured after two weeks of the initial measurement. The method error was calculated as recommended by Dahlberg[28] and Houston.[29] The Dahlberg error was 0.29 mm for the mesiodistal tooth width, 0.19 mm for arch length, and 0.27 mm for the arch width. The Houston's coefficient of reliability was 0.93.

Tooth size ratio between upper and lower teeth was calculated as described by Bolton:[11]

Anterior ratio

= [(Sum of mesiodistal width of mandibular six anterior teeth) ÷ (Sum of mesiodistal width of maxillary six anterior teeth)] × 100%

Overall ratio

= [(Sum of mesiodistal width of mandibular 12 teeth) ÷ (Sum of mesiodistal width of maxillary 12 teeth)] × 100%

Statistical analysis

The mean and standard deviation for each tooth in the different groups of malocclusion were calculated. Mesiodistal tooth width comparisons between right and left sides and between females and males were made for each tooth using Student's *t*-test. Analysis of variance was used to determine whether significant differences existed between the groups. The compared variables were mesiodistal tooth widths, the sum of the six anterior teeth in both arches, the sum of the 12 teeth in both arches, the Bolton's anterior and overall ratios, the arch length, the intercanine width, interpremolars, and intermolar widths from all the measured points. Least significant difference was used to identify which of the groups is different.

RESULTS

The means and standard deviations (M ± SD) of the mesiodistal widths of the 12 teeth (first molar to first molar) in the maxillary and mandibular arches within different malocclusion groups are shown in Table 2. Table 3 shows the mean and standard deviations (M ± SD) of anterior and overall Bolton ratios in the different malocclusion groups. The maxillary and mandibular intercanine, interpremolars, and intermolar widths and arch length (Mean ± SD) for the four occlusal patterns are shown in Table 4.

Right to left side comparisons

The maxillary right first molar was significantly larger than the left one ($P < .01$). Both maxillary left lateral incisors and mandibular left canines were larger than their contralateral teeth ($P < .05$ and $P < .01$, respec-

TABLE 2. Mean and Standard Deviation of (M ± SD) Mesiodistal Tooth Width in the Different Malocclusion Groups (measurements are in mm)

Arch	Tooth	Class I Malocclusion	Class II Division 1	Class II Division 2	Class III Malocclusion	Total
Maxillary arch	Central incisor	9.51 ± 0.51	9.75 ± 0.65	9.30 ± 0.69	9.72 ± 0.73	9.57 ± 0.67
	Lateral incisor	7.23 ± 0.50	7.45 ± 0.61	7.33 ± 0.66	7.40 ± 0.74	7.35 ± 0.63
	Canine	8.47 ± 0.73	8.44 ± 0.40	8.44 ± 0.62	8.65 ± 0.78	8.50 ± 0.65
	1st premolar	7.71 ± 0.57	7.66 ± 0.46	7.59 ± 0.57	7.70 ± 0.55	7.66 ± 0.54
	2nd premolar	7.11 ± 0.40	7.16 ± 0.55	7.24 ± 0.61	7.45 ± 0.86	7.24 ± 0.64
	1st molar	11.24 ± 0.53	11.25 ± 0.65	11.16 ± 0.53	11.45 ± 0.70	11.28 ± 0.61
Mandibular arch	Central incisor	5.84 ± 0.32	5.91 ± 0.43	5.77 ± 0.41	5.91 ± 0.37	5.86 ± 0.39
	Lateral incisor	6.35 ± 0.46	6.49 ± 0.49	6.37 ± 0.52	6.54 ± 0.46	6.43 ± 0.49
	Canine	7.53 ± 0.46	7.48 ± 0.49	7.48 ± 0.50	7.76 ± 0.59	6.57 ± 0.52
	1st premolar	7.89 ± 0.66	7.65 ± 0.50	7.63 ± 0.53	7.86 ± 0.59	7.75 ± 0.58
	2nd premolar	7.75 ± 0.56	7.84 ± 1.01	7.64 ± 0.79	7.79 ± 0.80	7.76 ± 0.80
	1st molar	11.47 ± 0.65	11.61 ± 0.67	11.56 ± 0.75	12.05 ± 0.59	11.74 ± 0.69

TABLE 3. Mean and Standard Deviation (M ± SD) of Anterior and Overall Bolton Ratios in the Different Malocclusion Groups in Percent (%)

	Class I Malocclusion	Class II Division 1	Class II Division 2	Class III Malocclusion	Total
Anterior ratio	78.3 ± 3.08	77.6 ± 3.79	78.2 ± 3.51	78.4 ± 3.64	78.2 ± 3.49
Overall ratio	91.9 ± 2.33	90.9 ± 2.89	91.0 ± 2.55	91.5 ± 3.15	91.3 ± 2.75

TABLE 4. Mean and Standard Deviation (M ± SD) of Arch Length and Width in the Different Malocclusion Groups. Measurements are in mm[a]

Arch	Tooth	Class I Malocclusion	Class II Division 1	Class II Division 2	Class III Malocclusion	Total
Maxillary arch	Intercanine width	34.68 ± 1.84	34.02 ± 2.65	34.61 ± 2.08	34.76 ± 2.98	34.51 ± 3.28
	1st premolar					
	DBC	42.66 ± 2.50	40.20 ± 3.19	41.97 ± 2.32	42.38 ± 3.92	41.77 ± 3.25
	DCF	36.84 ± 2.36	34.48 ± 2.95	36.68 ± 2.44	36.47 ± 2.94	36.09 ± 2.93
	DLC	32.04 ± 2.43	29.86 ± 3.16	31.54 ± 2.32	31.42 ± 2.81	31.17 ± 2.90
	2nd premolar					
	DBC	47.59 ± 2.38	45.77 ± 3.24	47.58 ± 3.13	47.46 ± 3.66	47.07 ± 3.26
	DCF	41.68 ± 2.39	40.06 ± 3.00	41.68 ± 2.79	41.67 ± 3.46	41.24 ± 3.06
	DLC	36.87 ± 2.59	35.31 ± 3.05	36.36 ± 2.74	36.64 ± 3.46	36.26 ± 3.07
	1st molar					
	DBC	54.03 ± 2.35	52.14 ± 3.13	53.54 ± 2.68	54.22 ± 3.35	53.48 ± 3.00
	DCF	47.56 ± 2.19	45.98 ± 3.06	47.36 ± 3.29	47.54 ± 3.75	47.10 ± 3.20
	DLC	42.49 ± 2.50	41.05 ± 2.86	41.47 ± 2.58	42.29 ± 3.23	41.80 ± 2.86
	Arch length	39.26 ± 2.26	40.44 ± 2.50	38.68 ± 3.11	39.36 ± 2.67	39.39 ± 2.71
Mandibular arch	Intercanine width	27.03 ± 1.62	26.47 ± 1.80	26.74 ± 1.88	27.92 ± 2.66	27.05 ± 2.09
	1st premolar					
	DBC	36.03 ± 2.35	34.48 ± 2.68	35.27 ± 2.06	35.82 ± 2.47	35.43 ± 2.43
	DCF	32.50 ± 2.17	31.02 ± 2.79	31.76 ± 2.04	32.15 ± 2.24	31.88 ± 2.34
	DLC	29.34 ± 2.16	27.84 ± 3.16	28.69 ± 2.06	28.93 ± 2.32	28.72 ± 2.46
	2nd premolar					
	DBC	41.56 ± 2.86	40.34 ± 3.19	40.81 ± 2.87	42.46 ± 3.55	41.27 ± 3.23
	DCF	37.32 ± 2.39	36.28 ± 3.13	36.46 ± 2.75	37.82 ± 3.00	37.03 ± 3.09
	DLC	32.93 ± 2.39	32.03 ± 3.29	32.36 ± 2.62	33.44 ± 3.10	32.67 ± 2.90
	1st molar					
	DBC	48.21 ± 2.44	46.53 ± 3.58	47.42 ± 2.68	48.57 ± 3.24	48.21 ± 2.44
	DCF	42.47 ± 2.42	41.64 ± 2.72	41.86 ± 2.58	42.71 ± 2.94	42.51 ± 2.69
	DLC	36.32 ± 2.32	35.56 ± 2.70	35.85 ± 2.47	36.49 ± 2.96	36.04 ± 2.63
	Arch length	33.19 ± 1.80	32.31 ± 2.22	32.88 ± 2.05	33.58 ± 2.18	33.00 ± 2.09

[a] DBC indicates distance between the buccal cusp on the right side to the buccal cusp on the left side; DCF, distance between the central fossa to central fossa; DLC, the distance between the lingual cusp to the lingual cusp.

TABLE 5. Differences in the Mesiodistal Tooth Width in the Different Malocclusion Groups. Measurements are in mm

Arch	Tooth	Class I/ Class II Division 1	Class I/ Class II Division 2	Class I/ Class III	Class II Division 1/Class II Division 2	Class II Division 1/Class III	Class II Division 2/Class III
Maxillary arch	Central incisor	0.24	0.20	0.22	0.47**	—	0.42**
	Lateral incisor	0.22	0.10	0.17	0.11	—	—
	Canine	—	—	0.18	—	0.21	0.21
	1st premolar	—	0.12	—	—	—	0.11
	2nd premolar	—	0.13	0.33*	—	0.29	0.21
	1st molar	—	—	0.20	—	0.20	0.29*
Mandibular arch	Central incisor	—	—	—	0.14	—	0.14
	Lateral incisor	0.14	—	0.19	0.12	—	0.17
	Canine	—	—	0.24	—	0.28*	0.28*
	1st premolar	0.23	0.25	—	—	0.20	0.22
	2nd premolar	—	0.11	—	0.19	—	0.15
	1st molar	0.13	0.18	0.31	—	0.44**	0.49**

* $P < .05$.
** $P < .01$.

tively). For the rest of the teeth, there was no significant difference between the right and the left sides.

Female to male comparisons

Significant tooth size differences were found between males and females. In Class I malocclusion group, the lower canine was significantly smaller in females than in males ($P < .01$). In Class II division 1 malocclusions, the maxillary first molar and mandibular canine ($P < .1$), and the sum of maxillary 12 teeth ($P < .05$) were significantly smaller in females than in males.

In Class II division 2 malocclusions, the maxillary central incisors and canines, mandibular first premolar and canine, the sum of maxillary six anterior teeth, and the sum of mandibular 12 teeth were significantly smaller in females than in males ($P < .05$). In Class III malocclusions, several teeth were significantly smaller in females than in males. These teeth were the maxillary first molar and mandibular second premolar ($P < .01$), mandibular first molar and canine ($P < .05$), and the sum of maxillary and mandibular 12 teeth ($P < .05$ and $P < .01$, respectively).

The maxillary intercanine width was significantly smaller in females than in males ($P < .01$). There was a tendency toward shorter maxillary and mandibular arches in females than in males, but it did not reach a significant level.

Comparisons between the different malocclusion groups

Tooth size. The differences in mesiodistal tooth widths between the different malocclusion groups are shown in Table 5. In Class III malocclusion, the maxillary first molar was significantly larger than the maxillary first molar in Class II division 2 malocclusions ($P < .05$). The maxillary second premolar in Class III malocclusions was significantly larger than that in Class I malocclusions ($P < .05$). The maxillary central incisors in Class III and Class II division 1 malocclusions were significantly larger than the maxillary central incisors in Class II division 2 ($P < .01$). The mandibular first molar in Class III malocclusions was significantly larger than that in Class II division 1 and Class II division 2 malocclusions ($P < .01$). The mandibular canine in Class III malocclusions was significantly larger than the mandibular canine in Class II division 1 and Class II division 2 malocclusions ($P < .05$).

Bolton ratios. There were no statistically significant differences in the Bolton anterior and overall ratios between the different occlusal categories or between the different sexes.

Arch width. The maxillary interpremolar and intermolar widths in Class II division 1 malocclusions were significantly smaller than those in the other malocclusion groups from all the measured points, ie, between buccal cusps, between central fossae, and between the palatal cusps. All differences in arch widths between different malocclusion groups at the different measured points and the level of significance are shown in Table 6. No differences were found in the maxillary intercanine width.

In the mandibular arch, the intercanine width in Class II division 1 and Class II division 2 was significantly smaller than that in Class III malocclusion group. The first premolar interarch width in Class II division 1 was smaller than that in Class I and Class III malocclusions. At the second premolar region, both the Class II division 1, and Class II division 2 were narrower than Class III malocclusion. The intermolar width in Class II division 1 was significantly smaller than that in Class III.

Arch length. The maxillary arch length in Class II

Table 6. The differences between arch lengths and widths at different teeth in the different malocclusion groups. Measurements are in mm

Arch	Tooth	Class I/ Class II div I	Class I/ Class II div 2	Class I/ Class III	Class II div I/ Class II div 2	Class II div 1/ Class III	Class II div 2/ Class III
Maxillary arch	Inter-canine width	0.66	—	—	0.59	0.75	0.16
	1st premolar						
	DBC	2.46***	0.69	0.29	1.77*	2.17*	−0.40
	DCF	2.35***	0.16	0.37	2.19*	1.99*	0.20
	DLC	2.18***	0.50	0.63	1.68*	1.56*	0.12
	2nd premolar						
	DBC	1.82*	—	0.13	1.82*	1.69*	0.12
	DCF	1.61*	—	—	1.61*	1.60*	—
	DLC	1.56*	0.50	0.23	1.05	1.33	0.27
	1st molar						
	DBC	1.89**	0.44	0.19	1.40*	2.08**	0.68
	DCF	1.57*	0.19	—	1.38	1.56*	0.18
	DLC	1.44*	1.01	0.19	0.43	1.24	0.82
	Arch length	1.17	0.59	—	1.76**	1.08	0.69
Mandibular arch	Inter-canine width	0.56	0.29	0.89	0.27	1.45**	1.17*
	1st premolar						
	DBC	1.55**	0.76	0.21	0.79	1.34*	0.55
	DCF	1.48**	0.74	0.35	0.74	1.14*	0.40
	DLC	1.49*	0.65	0.41	0.85	1.09	0.24
	2nd premolar						
	DBC	1.22	0.75	0.90	0.47	2.11**	1.65*
	DCF	1.04	0.86	0.50	0.18	1.54*	1.36*
	DLC	0.90	0.56	0.52	0.33	1.41*	1.08
	1st molar						
	DBC	1.67*	0.79	0.36	0.89	2.04**	1.15
	DCF	0.83	0.61	0.24	0.22	1.07	0.84
	DLC	0.76	0.47	0.16	0.29	0.92	0.63
	Arch length	0.88	0.31	0.39	0.57	1.27*	0.70

* $P < .05$
** $P < .01$
*** $P < .001$

division 2 malocclusion was significantly shorter than that of Class II division 1 ($P < .01$), Table 6.

In the mandible, Class II division 1 malocclusions showed a significantly shorter arch length than the Class III malocclusions.

DISCUSSION

In this study, the mesiodistal tooth size, Bolton ratio, arch width, and arch length were compared in Class I, Class II division 1, Class II division 2, and Class III in a Jordanian sample.

A significant right to left side tooth size discrepancy was found in some of the teeth in both upper and lower arches. Ballard,[30] found that in 90% of his sample there was a right to left discrepancy and concluded that asymmetry in tooth size is the rule, not the exception.

The significant difference in tooth size between females and males found in this study confirms previous results published on the Jordanian population.[9] In both the studies, the main tooth size difference between the two sexes was demonstrated in the canines, molars, and the sum of the tooth widths in both arches. Moreover, the sexual dimorphism in tooth dimensions was shown in other studies for different populations.[6,31] However, differences between females and males were shown not to be systematic across all teeth.[32,33]

In this study, the Bolton ratio between the different malocclusions showed no significant differences. This finding was in agreement with earlier studies on some other populations.[8] However, other studies showed a tendency toward larger Bolton ratio for class III malocclusion than the other malocclusions in the Chinese population.[34,35] The difference in the results between this study and the other investigations might be attributed to the sample size, method of analysis, sample size, and large standard deviation found in this study. Moreover, maxillary and mandibular first molars, maxillary central incisors, and mandibular canines in Class III malocclusion were larger than those in the other malocclusion groups. The increase in both upper and lower tooth dimensions might have compensated for any significant increase in Bolton ratio.

In this study, no difference was found in the maxillary intercanine width in the investigated groups. Several studies have reported similar results.[36–38] On the other hand, a study by Staley et al[23] reported a larger intercanine width in the normal occlusion than that in Class II division 1, whereas Sayin and Turkkahraman[38] reported a larger intercanine width in Class II division 1 than that in Class I occlusion. In this study, Class III malocclusions showed a larger intercanine width than both Class II division 1 and Class II division 2, which might indicate a restricted growth in this region in Class II malocclusion.

The maxillary interpremolar and intermolar widths in Class II division 1 were significantly smaller than that in the other malocclusion groups. Similar results were reported for Class II division 1 when compared with Class I and Class II division 2.[23,25] However, Frhlich[36] found no significant difference in the arch width of Class I and Class II. The mandibular arch in Class III malocclusion was wider than the Class II division 1 along all the posterior teeth. The Class I malocclusions, however, were wider than the Class II division 1 malocclusions mainly at the first premolar region. The studies by Buschang et al[24] and Lux et al[25] reported a wider mandibular arch in Class I than Class II malocclusion. The studies by Nojima et al[26] and Kook et al[27] compared Class I, Class II, and Class III malocclusions in different populations. However, no differences were made between the different occlusal categories within the same population.

The maxillary arch length in Class II division 1 was significantly larger than Class II division 2, which is an expected result, considering the proclination of the maxillary central incisors in Class II division 1 compared with Class II division 2. In the mandibular arch, both Class II division 1 and Class II division 2 were shorter than Class III malocclusion group. This can be attributed to the increased growth potential of mandible in Class III patients.[39,40]

CONCLUSIONS

- There were differences in tooth size between right and left sides confirming the presence of asymmetry between the two sides.
- Females showed a tendency of having smaller teeth than males.
- Class III malocclusion showed a tendency toward larger teeth than the other occlusal categories.
- No statistically significant differences were found in the Bolton ratios for the six anterior teeth and the 12 teeth within the different malocclusions in the Jordanian sample.
- Class II division 1 showed the narrowest maxillary arch compared with the other types of malocclusion.
- The mandibular intercanine width was significantly larger in Class III group than in Class II division 1 and Class II division 2 groups. No differences in the maxillary intercanine width were found among the different groups.
- The maxillary arch was significantly longer in Class II division 1 than in Class II division 2. The mandibular arch of both Class II categories was significantly shorter than Class III malocclusion group.

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