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Anterior and Overall Bolton ratios among Orthodontic Patients with Different Malocclusions

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Abstract

Objective: The aim of this study was to determine Bolton ratios in the Iranian orthodontically treated population of different malocclusions and compare these values among malocclusion groups and with Bolton reference values.

Methods: Bolton ratios of 210 subjects were investigated in three groups of Class I, II, and III skeletal patterns. The measurement of mesiodistal width of teeth was made on post-treatment dental models using a digital caliper. One-way analysis of variance and one-sample t-test were used to compare obtained anterior values and overall ratios among studied groups and with reference values, respectively. P-value<0.05 was considered as significant.

Results: The mean values of anterior ratio in total subjects were 76.77, and in the Class I skeletal pattern group was 76.51, which were significantly different from the reference value (p-value < 0.05). However, the differences in the mean anterior ratios of Class II and III groups and the mean overall ratios of three studied groups with reference values were not statistically significant. Furthermore, there was no significant difference between the anterior and overall Bolton ratios of the three studied groups (p-value>0.05).

Conclusion: Since the obtained Bolton ratios in Class II and III groups were not significantly different from reference values, these values are also applicable for mild skeletal malocclusions. However, the difference in mean anterior ratios of the total 210 subjects and Class I group with Bolton reference values could be caused by racial differences or several factors related to orthodontic treatment, which can be investigated in subsequent studies.

Keywords: Intermaxillary tooth size ratios, skeletal malocclusion, angle Classification, orthodontic camouflage treatment

1. Introduction

The goal of every orthodontist is to achieve the correct diagnosis and successful treatment of patients (1). The treatment success is defined by some factors, one of the most important of which is proper interdigitation of maxillary and mandibular teeth. For this purpose, it's essential to have an appropriate treatment plan and therapeutic techniques (2). Generally, the diagnostic data of orthodontics are collected from extraoral and intraoral examinations, photographs, radiographs, and diagnostic models (1). Dental models are one of the most vital tools for clinical decision-making and are also used to assess the symmetry of dental arches, space analysis, and evaluation of teeth size (1, 3, 4). Moreover, the proportionality of maxillary and mandibular teeth size is an essential requirement to achieve optimal occlusion (5-9). Therefore, the evaluation of teeth size is one of the key elements to predict the outcomes of orthodontic treatment (3).

For the first time, tooth size measurement was performed by GV Black. About a century ago, he designed tables of normal values of teeth size

(4). Bolton then measured the mesiodistal width of the mandibular and maxillary teeth in 55 samples with normal occlusion and presented the anterior and overall ratios, known as Bolton ratios. Samples of Bolton study consisted of 11 subjects with ideal occlusion, without orthodontic treatment, and 44 patients who underwent orthodontic treatment without extraction and reshaping of the teeth. The mean anterior and overall ratios obtained from Bolton's study were 77.2 ± 1.65 and 91.3 ± 1.91, respectively (5, 10). These values are still known worldwide as Bolton's reference values (2). However, it should be noted that several factors can affect tooth sizes and ratios. Several studies showed that teeth size depends on the race. So, it is recommended to use race-specific values of Bolton ratios for different populations (11-15). In this regard, Kachoei et al. studied Bolton ratios in schoolchildren of Tabriz, and no significant difference was observed between obtained and standard values of Bolton ratios (16). In the study of Mollabashi et al., which examined Bolton ratios on pre-treatment casts of orthodontic patients, the highest and lowest anterior and overall ratios, respectively, belonged to the "normal occlusion" and the "Class II Div 2" groups (17). In another study by Machado et al., conducted on pre-treatment casts of Portuguese subjects, mean values, standard deviations, and ranges of anterior and overall ratios were greater than those of Bolton's study. Indeed, not only the anterior ratio of Class I and Class II Div 2 groups but also the overall ratio of Class I and Class III groups were significantly different from Bolton's standard values (18). In this regard, Gaddam et al. studied Bolton ratios on pre-treatment casts of 100 subjects with Class I, Class II Div 1, Class II Div2, and Class III malocclusions. They showed that the anterior and overall ratios were not significantly different from Bolton's normal values (19). In addition, Akyalcın et al. studied the pre-treatment models of 152 Turkish subjects in three groups of Class I (n = 48), Class II (n = 60), and Class III (n = 44) malocclusions. The results showed that the mean anterior ratios of all groups were higher than Bolton standard values, yet the differences were not statistically significant (8). In another research, Lavelle et al. investigated dental models of 160 Caucasian subjects in three groups of skeletal and dental Class I, II, and III. The results demonstrated that maxillary teeth were smaller in the Class III group. On the other hand, the mandibular teeth of this group were larger, and hence, the Bolton discrepancy of the Class III group was higher than the two other groups. Therefore, they concluded that the teeth size could be a determining factor in malocclusion types (20).

Most of the mentioned researches investigated the teeth size ratios on pre-treatment casts of various malocclusions and reported the prevalence of TSD in each group. However, they did not address the proportions of acceptable occlusions resulting from orthodontic treatment. Since the standard values of anterior and overall ratios, provided by Bolton, are resulted from the assessment of subjects with ideal occlusion, the possibility of using these values for different malocclusion groups is questionable. Therefore, several authors have recommended that normal values of Bolton ratios should be specified for every malocclusion group (8, 9, 11, 18, 19).

The aim of this study was to determine the anterior and overall ratios in orthodontically treated patients of Class I, II, and III skeletal pattern groups, who have achieved excellent occlusion and the Class I canine relationship, and to compare the ideal ratios of the skeletal malocclusion groups with Bolton reference values.

2. Materials and Methods

This cross-sectional study was conducted on 210 sets (70 in each of three skeletal pattern groups) of post-treatment dental models and lateral cephalometric radiographs, chosen from records of Department of Orthodontics of Tabriz University of Medical Sciences, based on the following criteria.

Inclusion criteria

1. Patients with Class I, II, or III skeletal patterns who underwent orthodontic camouflage treatment and achieved acceptable occlusion, normal overjet, and overbite.
2. Post-treatment dental models with acceptable quality.
3. Eligible post-treatment Lateral cephalometric radiographs.
4. Patients with fully erupted anterior teeth of maxilla and mandible.
5. Patients without tooth extraction or with the extraction of two or four premolars.

Exclusion criteria

1. Patients who underwent orthognathic surgery.
2. Dental models of poor quality.
3. Interproximal caries of the anterior teeth damaged the surface integrity of enamel.
4. Morphologic anomalies of anterior teeth.

5. Severe wear on occlusal or interproximal surfaces.

ANB angle and wits appraisal were used to determine the Classification of subjects' skeletal patterns. The normal range of ANB is between 0 and 4 degrees, and the normal values of wits are 0 for females and -1 for males, which belong to the Class I skeletal pattern. The Class II and III patterns are defined by decreased and increased values of mentioned parameters, respectively. By manual tracing of post-treatment lateral cephalometric radiographs, the measurement of ANB angle and wits was performed, which is observable in Figure 1.

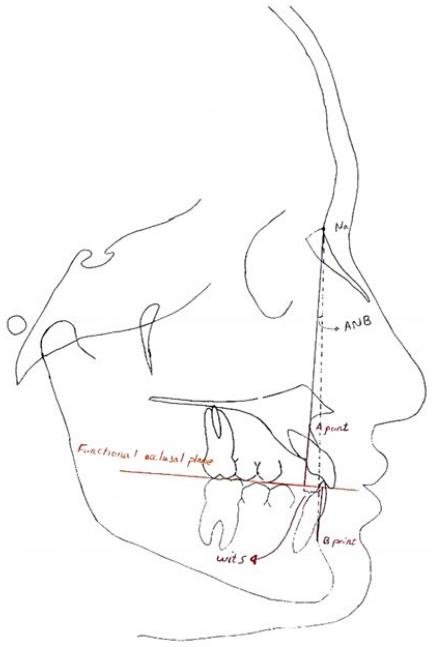

Figure 1. Measurement of ANB angle and wits using a manual tracing of lateral cephalograms.

The mesiodistal width of all teeth from the first molar to the first molar was measured at the level of interproximal contact points using a digital caliper accurate to 0.01 mm (as shown in Figure 2). All measurements were performed by the first author. Dental models and radiographs of 10 subjects were randomly selected to evaluate the Inter-examiner and Intra-Examiner Errors. At this stage, all measurements were repeated after eight weeks by the first and second authors (BK and TA). Then, the Intra-Class correlation coefficient was analyzed by comparing the data sets of each measurement

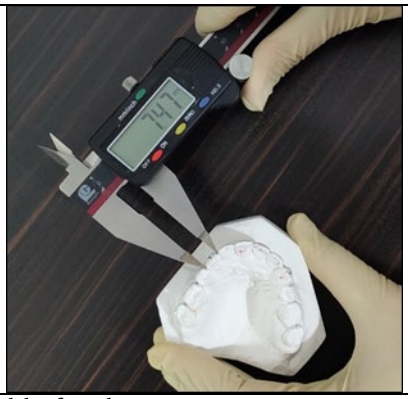

Figure 2. Measurement of mesiodistal width of teeth.

For non-extraction cases, Bolton anterior and overall ratios were calculated using the following formulae. It is worth mentioning that only the anterior ratio was calculated in the cases of tooth extraction or missing.

$$\frac{sum\ of\ 6\ mandibular\ anterior\ teeth\ (3\ to\ 3)}{sum\ of\ 6\ maxillary\ anterior\ teeth\ (3\ to\ 3)} \times 100 = Anterior\ Ratio$$

$$\frac{sum\ of\ 12\ mandibular\ anterior\ teeth\ (6\ to\ 6)}{sum\ of\ 12\ maxillary\ anterior\ teeth\ (6\ to\ 6)} \times 100 = Overall\ Ratio$$

The normality of obtained values of anterior and overall ratios of Class I, II, and III groups was analyzed by the Lilliefors-corrected Kolmogorov-Smirnov test. Subsequently, these values were compared with Bolton reference values using one way ANOVA. The differences of mean Bolton ratios among the three studied groups were analyzed using one-way ANOVA.

3. Results

This study was performed on 210 Iranian subjects (158 females and 52 males) with a mean age of 22.42 ± 3.54 years. According to Table 1, the Intra-Class correlation coefficient for intra-examiner and inter-examiner errors was in a range of 0.95 to 0.99, which indicates the high accuracy of the measurements.

Table 1. Intra-Class Correlation Coefficient of intra-examiner error and inter-examiner error

Variables	ICC of intra-examiner error	ICC inter-examiner error
Anterior Ratio	0.96	0.97
Overall ratio	0.98	0.97
ANB	0.95	0.91
wits	0.98	0.99

ICC: Intra Class Correlation Coefficient.

The results of the Kolmogorov-Smirnov test showed that Bolton anterior and overall ratios had normal distribution in each of Class I, II, and III groups (Table 2).

Table 2. the results of normality analysis using Lilliefors-corrected Kolmogorov-Smirnov test.

	Anterior Ratio (P-value)	Overall Ratio (P-value)
Class I	0.2	0.2
Class II	0.2	0.2
Class III	0.2	0.122

p-value: level of significance.

Table 3 shows the mean values of the anterior and overall Bolton ratios in each of Class I, II, and III skeletal pattern groups. The results of One-way ANOVA indicated that there was no significant difference between the anterior Bolton ratios of the three studied groups in the present study. Also, the comparison of the overall ratios of the three groups showed no significant difference (p-value = 0.35 and 0.51, respectively).

Table 3. The comparison of anterior and overall Bolton ratios among Class I, II, and III skeletal pattern groups, using One-way ANOVA.

		N	Mean	SD	P-value
Anterior Ratio	Class I	70	76.51	2.15	0.35
	Class II	70	77.08	2.43	
	Class III	70	76.73	2.42	
Overall Ratio	Class I	30	90.79	1.85	0.51
	Class II	14	91.51	1.89	
	Class III	27	90.49	3.64	

N: Number of subjects, SD: Standard deviation, p-value: level of significance

Table 4 represents the results of the One-Sample t-Test, which compares the obtained anterior and overall ratios with Bolton reference values. It can be seen that the mean (SD) of Bolton anterior ratio for the whole 210 subjects and Class I skeletal pattern group was 76.77 (2.34) and 76.51 (2.15), respectively, which were significantly different from Bolton reference value (p-value < 0.05). Indeed, this difference was not statistically significant in Class II and III skeletal pattern groups. However, the mean overall ratio of total subjects was 90.8, the difference of which with Bolton reference value (91.3) was not statistically significant. Also, there was no significant difference between the mean overall ratio of each studied group and the reference value.

Table 4. The comparison of anterior and overall ratios of three studied groups with Bolton reference values using One-Sample t-Test.

	Class	N	Mean	SD	p-value
Anterior Ratio	Class I	70	76.5105	2.15170	0.009
	Class II	70	77.0753	2.42922	0.669
	Class III	70	76.7273	2.42440	0.107
	Total	210	76.7710	2.33914	0.008
Overall Ratio	Class I	30	90.7859	1.84909	0.139
	Class II	14	91.5095	1.88513	0.684
	Class III	26	90.4901	3.64613	0.268
	Total	70	90.8208	2.65731	0.136

N: Number of subjects, SD: Standard deviation, p-value: level of significance

4. Discussion

The purpose of camouflage orthodontic treatments in Class II and III skeletal patterns is to achieve a Class I canine relationship, normal overbite and overjet, and proper interdigitation of the posterior teeth. To do so, the extraction of mandibular or maxillary premolars is unavoidable in most cases. As known, the alignment and esthetic of the anterior teeth are more important in camouflage treatments. On the other hand, most of the factors related to orthodontic treatment, including the inclination of the incisors, affect the anterior ratio generally (8, 21, 22). Therefore, the main focus of this study was on Bolton anterior ratio. Meanwhile, the overall ratio has been evaluated and reported as a secondary objective in non-extraction cases.

In the present study, the mean anterior ratio of all studied groups and the mean overall ratio of Class I and III groups were lower than Bolton standard values. However, the mean overall ratio of the Class II group was slightly higher than the mentioned reference value. Considering that the subjects of this study were collected from a different population and had undergone orthodontic treatment, observed differences can be attributed to racial diversity or the effect of several factors related to the orthodontic treatment, which can be examined in subsequent studies.

In this regard, Batool et al. studied 135 Pakistani subjects and showed that the mean anterior ratios of all studied groups were higher than Bolton reference values. The highest and lowest values were dedicated to Class I and II groups, the difference of which was statistically significant between the two groups. Also, the mean anterior ratio of total samples and Class II group were significantly different from reference values (1). Since the mentioned study and the present study were performed on two populations of almost different races, the diversity of their results is justifiable. On the other hand, the results of Batool's study are questionable because of unequal sample sizes of studied groups (37 in Class I, 60 in Class II, and 30 in Class III groups).

Furthermore, the study of Uysal et al. was performed on 150 subjects of normal occlusion and 560 subjects of four of Class I, Class II Div 1, Class II Div 2, and Class III malocclusion groups. They showed that the mean values of the anterior and overall ratios of all groups were higher than Bolton reference values, except for the mean overall ratio of the Class II Div 2 group. However, none of the differences were statistically significant (6). The results of Uysal's study are not comparable with the present study because it was conducted on the pre-treatment dental models of orthodontic patients.

In addition, Machado et al. studied 168 Portuguese subjects in five groups including, normal occlusion (29 subjects) and Class I (50 subjects), Class II Div 1 (23 subjects), Class II Div 2 (28 subjects), and Class III (38 subjects) malocclusions. The mean anterior and overall ratios of all studied groups were higher than Bolton reference values, amongst which the differences of the mean anterior ratio of normal occlusion, Class I and Class II Div 2 groups, and the overall ratio of Class I and Class III groups with Bolton reference values were statistically significant (18). Even though the mean anterior ratio was higher in the Machado study and was lower in the present study than Bolton reference value, which could be caused by racial differences, the results of the normal occlusion group were similar to the present study in terms of statistical significance. Nevertheless, since Machado studied the pre-treatment dental models, the results of the malocclusion groups cannot be compared with the results of this study.

Conclusion

Based on the results of this study, it can be concluded that:

- Bolton anterior and overall ratios of the Iranian orthodontically treated population

were lower than Bolton reference values, amongst which the highest and lowest values of the anterior ratio, respectively, belonged to Class II and Class I groups.
• Obtained Bolton ratios of Class II and III skeletal pattern groups were not significantly different from reference values. Therefore, these values are also applicable for mild skeletal malocclusions.
• The mean anterior ratios of the total 210 subjects and Class I group were significantly lower than Bolton's one, which could be affected by racial differences or several factors related to orthodontic treatment. These factors can be investigated in subsequent studies.

Conflicts of Interest

The authors declare that they have no conflicts of interest that could have influenced the work reported in this study.

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