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Relationship between tooth size discrepancies and malocclusion

Kristina Lopatiene, Aiste Dumbravaite

SUMMARY

The main goal in comprehensive orthodontic treatment is to obtain optimal final occlusion, overbite and overjet. Tooth size discrepancies of the maxillary and mandibular arches is an important factor for achieving this goal. The aim of this study was to determine the relationship between the Bolton overall and anterior ratio and the relationship between first molars according to the Angle classification, and the size of overjet and overbite. The study sample consisted of 181 pretreatment dental casts with fully erupted and complete permanent dentitions from first molar to first molar, which were selected randomly. The evaluation of the Bolton anterior ratio showed that anterior ratio ranged between 66.038% and 96.907%, mean value – 77.889±4.296. The lowest mean value of the Bolton anterior ratio was in Angle Class II, and the highest – in Angle Class III, but this difference was not statistically significant. The evaluation of the Bolton overall ratio showed that the overall ratio ranged between 85.648% and 98.907%, mean value – 92.735±2.489. The lowest mean value of the Bolton overall ratio was in Angle Class II, and the highest – in Angle Class III, but this difference was not statistically significant. Moderate correlation was detected between the Bolton overall ratio and overjet ($r=-0.45$, $p<0.001$) The evaluation of the relationship between the Bolton overall ratio and overbite showed that a statistically reliable weak correlation ($r=0.18$, $p<0.001$). The evaluation of the Bolton ratio is clinically important and affects the planning of orthodontic treatment.

Key words: Bolton's ratio, tooth size discrepancy, malocclusion, overbite, overjet.

INTRODUCTION

The main goal in comprehensive orthodontic treatment is to obtain optimal final occlusion, overbite and overjet. It has been found that tooth size discrepancies of the maxillary and mandibular arches is an important factor for achieving this goal [1,2,3]. Ideal occlusion is impossible in the presence of tooth size discrepancy [4, 5]. On the other hand, differing tooth sizes may be one of the important factors causing malocclusion [3]. A number of researchers, such as Bolton, Black, Ballard, Neff and Lundstrom, evaluated this relationship of the widths of the upper and lower teeth [6].

Neff (1949) found that the ratio of anterior teeth size is mathematically related to overbite, determined the coefficient of the anterior teeth [7]. Lundstrom (1955) studied the tooth size ratio between maxillary and mandibular anterior teeth, which he called "the anterior index"[8]. Gilpatric (1923) found that the sum of the mesiodistal widths of all maxillary teeth exceeds the mandibular teeth by 8-12 mm, and the greater this value, the greater the overbite [4]. Bolton (1958, 1962), comparing the sums of maxillary and mandibular mesiodistal tooth size, determined the ideal tooth size ratio between the mesiodistal width of overall and the anterior teeth [9]. This Bolton analysis influenced examination of orthodontic patient and planning of orthodontic treatment, and is still used to this day [6]. Bolton's analysis of overall and anterior teeth is the most frequently used analysis in both clinical orthodontics and scientific studies when evaluating the correspondence between maxillary and mandibular mesiodistal width of teeth.

In recent studies, researchers evaluated the relationship between the correspondence of maxillary and mandibular mesiodistal tooth size and Angle Class I, II, and III malocclusions, overjet, and overbite. According to literature, the results of these studies were contradictory. Akyalcin in his study evaluating the re-

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lationship between the Bolton ratio and overjet, found a statistically significant relationship between the Bolton overall ratio and the size of overjet [3]. The results of studies evaluating the relationship between Angle Class I, II, and III malocclusions and the Bolton ratio are rather contradictory. The majority of studies failed to find any statistically significant difference between the relationships of the first permanent molars according to Angle's classification, and the value of the Bolton ratio.

The aim of this study was to determine the relationship between the Bolton overall ratio (BOR) and the Bolton anterior ratio (BAR) and the relationship between first molars according to the Angle's classification, and the size of overjet and overbite.

MATERIAL AND METHODS

During this study, it was analyzed 181 patient models prior to orthodontic treatment. Subjects for this study were randomly selected from 1195 patients treated at Kaunas University of Medicine Clinic of Orthodontics. Patients were between 12 and 16 years of age. All models had the following characteristics:

1) these were good quality models;

2) these were models with complete permanent occlusion and fully erupted all first molars;

3) the teeth had no evident loss of mesiodistal crown width due to dental caries, crown fracture, pathological wear, or congenital defects;

4) the dental arches had no crown or bridge prostheses;

5) the dental crowns had no anomalies in tooth size, shape, or number.

During the study, it was evaluated the following:

The relationship between the first permanent maxillary and mandibular molars was evaluated using Angle classification: Class I – the anterior buccal cusp of the maxillary first molar occludes in the buccal groove of the mandibular first permanent molar; Class II – the anterior buccal cusp of the maxillary first permanent molar is located anteriorly with relation to the buccal groove of the mandibular first molar; Class III – the anterior buccal cusp of the maxillary first permanent molar is located posteriorly with relation to the buccal groove of the mandibular first molar [1, 2, 3, 4, 10].

Overbite (OB) – the distance at which the crowns of upper central incisors overlap the crowns of lower central incisors, measured using vernier calipers, with ±0.1 mm accuracy. According to the techniques proposed by Proffit, overbite was differentiated into four groups: OB=0-2 mm, 3-4 mm, 5-7 mm, and over 7 mm [3, 11].

Overjet (OJ) – the distance between the edge of the upper central incisor and the labial surface of the lower central incisor, measured in parallel with the occlusal plane. Overjet was measured using vernier calipers, with ±0.1 mm accuracy, and was distributed into four groups according to Proffit: 0-3.5 mm, 3.5-6 mm, 6-9 mm, and over 9 mm [3, 11].

Mesiodistal width of tooth – the mesiodistal width of permanent maxillary and mandibular incisors, canines, premolars, and first molars, measured between anatomical medial and distal contact points in parallel with the occlusal plane [1, 2, 3, 4, 5, 6, 10, 12, 13, 14]. Measurements were preformed using vernier calipers, with ±0.1 mm accuracy.

During the model analysis, measurements were performed using the vernier calipers "Münchner Design" manufactured by the company "Dentaurum". The accuracy of measurements was ±0.1 mm. In order to evaluate the accuracy of measurements, we randomly selected diagnostic models of 30 children and repeatedly performed all measurements. There were no statistically significant differences in the obtained results.

The Bolton ratio – we evaluated the correspondence between the maxillary and mandibular mesiodistal tooth width, calculating the Bolton anterior and Bolton overall ratio. The ratio was calculated for 6 and 12 teeth, and the calculation was performed using the following formulas [1, 2, 3, 4, 5, 6, 10, 12, 13, 14]:

Anterior ratio (%) –

$$\frac{\text{The sum of mesiodistal width of 6 lower teeth (33-43)}}{\text{The sum of mesiodistal width of 6 upper teeth (13-23)}} \times 100$$

Overall ratio (%) –

$$\frac{\text{The sum of mesiodistal width of 12 lower teeth (36-46)}}{\text{The sum of mesiodistal width of 12 upper teeth (16-26)}} \times 100$$

According to the overall ratio proposed by Bolton in 1958 (the ratio between the tooth size of 12 upper and 12 lower teeth (norm – 91.3±1.91%), the subjects were distributed into three groups [4, 13]:

1. Low Overall Bolton Index (BL) (<89.39%).

2. Normal Overall Bolton Index (BN) (89.3-93.21%).

3. High Overall Bolton Index (BH) (>93.21%).

Statistical data analysis was performed using SPSS 13.0 (Statistical Package for Social Sciences) software package.

RESULTS

In this study, we examined 59 (32.6%) boys and 122 (67.4%) girls.

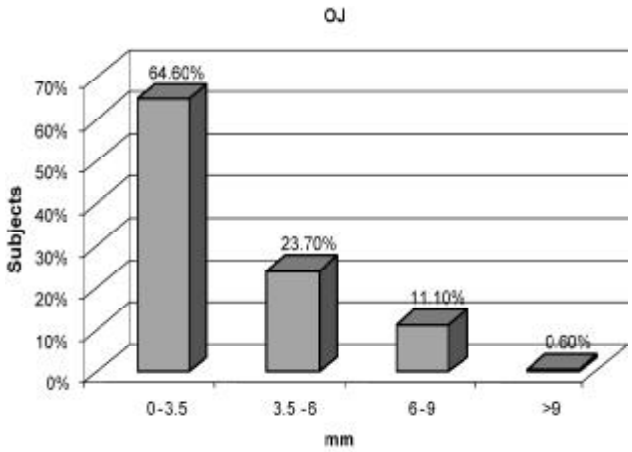

Fig. 1. The distribution of overjet in the studied group.
*Negative OJ was detected in 2 patients.

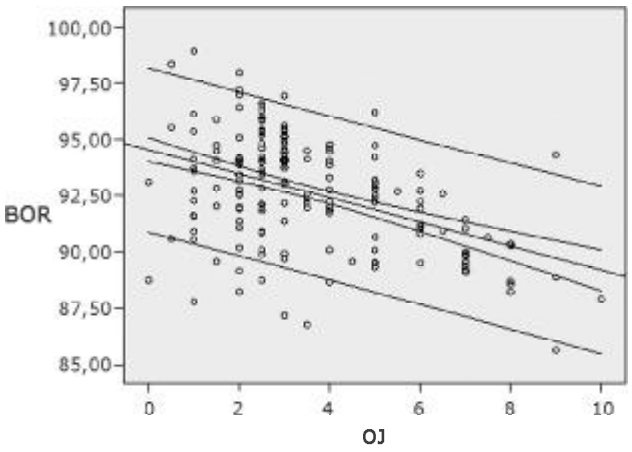

Fig. 2. The relationship between the Bolton overall ratio (BOR) and overjet (OJ).
The reliability level of confidence intervals was P=0.95. The dotted line indicates the prognosis interval and the continuous line – the confidence interval of the mean prognosticated values. Although the prognosticated values in both cases coincide, their confidence intervals differ. The confidence interval of the mean value is narrower (shown as a continuous line).

During model analysis, when evaluating the relationship between first permanent maxillary and mandibular molars according to Angle classification, Angle Class I was found in 71 (39.2%) patients, Angle Class II – in 91 (50.3%), and Angle Class III – in 19 (10.5%) patients (Table 1).

The evaluation of Bolton anterior ratio showed that the anterior ratio ranged between 66.038% and 96.907%, mean value – 77.889±4.296. The lowest mean value of the Bolton anterior ratio was in Angle Class II, and the highest – in Angle Class III, but this difference was not statistically significant (Table 2).

The evaluation of the Bolton overall ratio showed that the overall ratio ranged between 85.648% and 98.907%, mean value – 92.735±2.489. The lowest mean value of the Bolton overall ratio was in Angle Class II, and the highest – in Angle Class III, but this difference was not statistically significant (Table 3).

With respect to the normal Bolton overall ratio (91.3 ± 1.91%), the subjects were distributed into three groups:

1. Low Bolton overall ratio (BL) (<89.39%) was found in 17 patients with wider maxillary teeth.
2. Normal Bolton overall ratio (BN) (89.3 - 93.21 %) was found in 85 patients.
3. High Bolton overall ratio (BH) (>93.21%) was found in 79 patients with wider mandibular teeth (Table 4).

The evaluation of overjet (OJ) showed that it ranged between 0 to 10 mm, the mean value being 3.5±2.04

Table 1. The distribution of the studied patients according to sex and malocclusion

Relationship between the first permanent molars according to Angle's classification	Number of males	Number of females	Total:
Class I	19	52	71
Class II	33	58	91
Class III	7	12	19

Table 2. The Bolton anterior ratio in different malocclusion

Relationship between the first permanent molars according to Angle's classification	n	Mean	Standard deviation	Standard error	Lowest value	Highest value
Class I	71	78.075	3.820	.453	69.811	96.907
Class II	91	77.703	4.697	.492	66.038	95.833
Class III	19	78.084	4.135	.949	66.087	85.057
Total:	181	77.889	4.296	.319	66.038	96.907

Table 3. Bolton overall ratio in different malocclusion

Relationship between the first permanent molars according to Angle's classification	n	Mean	Standard deviation	Standard error	Lowest value	Highest value
Class I	71	92.937	2.396	.284	86.802	98.907
Class II	91	92.506	2.546	.267	85.648	96.429
Class III	19	93.083	2.579	.592	88.679	98.343
Total:	181	92.735	2.489	.185	85.648	98.907

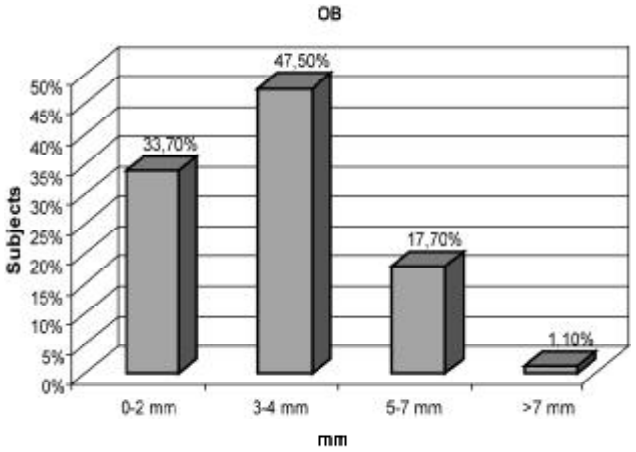

Fig. 3. The distribution of overbite (OB) in the studied group

mm. Negative OJ was detected in 2 (1.09%) patients. Normal OJ – 0 to 3.5 mm – was found in 117 (64.6%) patients, increased OJ was found in 64 (35.4%) patients: 3.5-6 mm OJ was found in 43 (23.7%) patients, and 6-9 mm OJ – in 20 (11.1%) patients, while OJ exceeding 9 mm was detected in 1 (0.6%) patient (Fig. 1).

Moderate correlation was detected between the Bolton overall ratio and overjet (Pearson's correlation coefficient r=-0.45, p<0.001) (Fig. 2). A linear regression model was created, allowing for prognosticating overall ratio values according to OJ values. The obtained regression model was statistically reliably adjusted to the findings (F= 45.334, p<0.001). The linear regression equation was the following:

$$\text{The Bolton overall ratio} = 94.633 - 0.551 \times OJ$$

The zero hypothesis on the coefficients being equal to zero was ruled out, both coefficients were statistically reliable (p<0.001), and their confidence intervals were the following: the free member (93.98 ÷ 95.29), and OJ-related coefficient (-0.712 ÷ -0.389). The meaning of the OJ-related coefficient was the following: when OJ *increased* by 1 mm, the Bolton overall ratio *decreased* by 0.551 %. It is noteworthy that changes in OJ entailed alteration in the Bolton overall ratio value. This linear regression equation shows that knowing the value of one member (OJ) it is possible to determine the value of other (BOR).

The evaluation of overbite (OB) showed that it ranged between 0 and 8.5 mm, the mean value being 3.35±1.41. Normal OB – between 0 and 2 mm – was found in 61 (33.7%) patients, increased OB was found in 120 (66.3%) patients : 3-4 mm OB – in 86 (47.5%) patients, and 5-7 mm OB – in 32 (17.7%) patients, and OB greater than 7 mm was detected in 2 (1.1%) patients (Fig. 3).

Table 4. The distribution of the Bolton overall ratio according to malocclusion

Malocclusion	BL		BN		BH		Total
	n	%	n	%	n	%	n
Class I	5	7.04	33	46.48	33	46.48	71
Class II	10	10.99	46	50.55	35	38.46	91
Class III	2	10.53	6	31.58	11	57.89	19

The evaluation of the relationship between the Bolton overall ratio and overbite showed that a statistically reliable weak correlation (Pearson's correlation coefficient r=0.18, p<0.001). According to the form, a direct correlation was found, and according to the direction – a positive (direct) correlation was detected. In the presence of a positive relationship, increasing values of one determinant (OB), the values of the other determinant (BOR) increased as well.

DISCUSSION

The aim of our study was to determine the relationship between the Bolton overall and anterior ratio and the relationship between first molars according to the Angle classification, and the size of overjet and overbite and to compare obtained results with other studies. The importance of tooth size discrepancies in orthodontic diagnosis has been widely reported in the literature and accepted by the orthodontic community because the relationship between the upper and lower anterior and posterior dentitions is related to orthodontic finishing excellence [2, 15, 16]. A proper balance should exist between the mesiodistal tooth size of the maxillary and mandibular arches to ensure proper interdigitation, overbite and overjet at the completion of orthodontic treatment. During this study, we evaluated how the ratio between maxillary and mandibular mesiodistal width of the teeth is related to the relationship between first permanent molars according to Angle classification [10, 17].

The comparison of our findings with data presented in literature showed that a part of studies detected a relationship between the Bolton overall ratio and overjet. According to some studies, the Bolton overall ratio is statistically significantly related to the degree of overjet in case of Angle Class I, and with the degree of overbite and the degree of angulation of maxillary incisors (p<0.01) – in case of Angle Class II. The study showed that when the Bolton overall ratio decreased (increased), overjet and overbite increased (decreased) [3]. In the presence of Class I relationship between the first permanent molars, a decreased Bolton overall ratio indicates that the sum of the maxillary tooth size is greater than the sum of the mandibular tooth size, i.e. the upper teeth are wider than the lower teeth [13, 16, 18], which may increase overjet. In the presence of an increased Bolton overall ratio, when the sum of the mandibular tooth size is greater than the sum of the maxillary tooth size, the

L1-GoGn angle increases respectively, the relationship between the first permanent molars corresponding to Class II. Besides, wider lower teeth lead to an increase in the inclination of the upper incisors (U1-SN) and a decrease in overbite. This is possible in the presence of the functioning dentoalveolar compensation mechanism that plays the main role in ensuring a better function [3, 17, 19].

According to the findings of our study, a moderate correlation exists between the Bolton overall ratio and overjet (Pearson's correlation coefficient r=-0.45, $p<0.001$) in case of all study sample. The evaluation of the relationship between the value of the Bolton overall ratio and overbite showed a statistically reliable weak correlation (r=0.18) in case of all study sample. The obtained results agree with those presented in literature on the correlation between the Bolton overall ratio and overjet.

The results of scientific studies on the correlation of the relationship between the first permanent molars according to Angle classification with the value of the Bolton ratio are controversial. Some scientists – such as Basarana, Crossby and Alexander, Qiong and Jiuxiang, and Susan. Al-Khateeba – found no statistically significant difference between the relationship of the first permanent molars according to Angle classification and the value of the Bolton ratio. According to the findings of these studies, the value of the Bolton ratio was unrelated to relationships between the first permanent molars according to Angle classification [1, 2, 4, 10]. Several scientists did find a correlation between the value of the Bolton ratio and relationships between the first permanent molars according to Angle classification. Sperry et al. (1977) studied the relationships between the first permanent molars according to Angle classification (Class I, II, III) and the value of the Bolton ratio. According to the findings of their study, the value of the Bolton overall ratio was statistically significantly greater in patients in whom the relationship between the first permanent molars corresponded to Class III, and their lower teeth wee larger. These scientists stated that the evaluation of the Bolton ratio is one of the diagnostic procedures for the detection of mandibular prognathia [2, 3, 4, 10, 20, 21]. Fattahi et al. in their study also found that the value of the Bolton overall ratio was statistically significantly greater in patients in whom the relationship between the first permanent molars corresponded to Class III. The mean value of the Bolton anterior ratio in the presence of Class III relationship between the first permanent molars was statistically significantly greater than in the presence of Class II relationship. No statistically significant difference was found when comparing Class I and Class III relationship between the first permanent molars and the value of the Bolton ratio [4]. Lavelle et al., and Araujo and Souki obtained similar results [2, 3, 4]. Nie and Lin, and Smith concluded that in patients with Class III relationship between the first permanent molars, the Bolton anterior ratio was typically higher than in patients with Class I or Class II relationship. A discrepancy between the sizes of the upper and the lower teeth may be an important factor contributing to the development of malocclusion [2, 3, 4].

The results of our study have been corroborated by the majority of studies analyzing the correlation between the value of the Bolton ratio and the relationship between the first permanent molars according to Angle classification. Our study did not detect any significant correlation between the value of the Bolton ratio and the relationship between the first permanent molars according to Angle classification.

CONCLUSIONS

1. Statistically significant relationship between the Bolton overall ratio and size of overjet was detected. A moderate correlation was found between the Bolton overall ratio and overjet (r=-0.45, $p<0.001$).

2. A regression model was created, allowing for the prognostication of the Bolton overall ratio values according to the overjet values. A 1-mm increase in overjet resulted in a 0.551% decrease in the Bolton ratio.

3. The comparison of overall and anterior Bolton ratio revealed no statistically significant difference between Angle Class I, II, and III.

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