Analysis of Tooth Size Discrepancy (Bolton Index) among Patients of Orthodontic Clinic at Kaunas Medical University

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SUMMARY

The purpose of the study was to determine the total (TBI) and anterior (ABI) Bolton indexes among patients treated in the Clinic of Orthodontics at Kaunas University of Medicine, and to evaluate the clinical significance of the estimated tooth size discrepancies, the dependence of Bolton index on gender, teeth width variability, and to estimate the Bolton index changes that mostly have influence on teeth.

108 diagnostic models (37 boys and 71 girls) were examined. It was determined that in 62.3% of the cases (68 patients) normal total Bolton ratio was found (no tooth size discrepancies), 21.3% of patients (23 patients) - had wider upper than lower teeth, 15.7% (17 patients) – the opposite. Estimated ABI was normal in 48.1% (52 patients) of the cases, in 20.4% (22 patients) - upper front teeth appeared to be wider than lower front teeth, in 31.5% (34 patients) – the opposite. Significant tooth size discrepancies in both posterior and anterior segments were detected in 5.5% of examined patients ($91.3 - 3.86(2S) <= TBI <= 91.3 + 3.86(2S)$), in 18.5% - only in the anterior part of the dentition ($77.2 - 3.30(2S) <= ABI <= 77.2 + 3.30(2S)$). Both TBI and ABI values showed no dependence on patients' gender and occlusion. BI was mostly influenced by the width differences of the first permanent molars, upper central and lateral incisors.

Key words: Bolton index, tooth size discrepancy.

INTRODUCTION

The problems of tooth size and dental arch size discrepancy are well known in orthodontics. According to some investigators (C.L.B.Lavelle, D.A.Crosby) evaluation of tooth size discrepancy is of the same significance as the other orthodontic diagnostic tools, such as dental cast examination and x-ray analysis [1, 3].

Dental anatomy was the topic of particular interest in the early beginning of the 20th century. C.V.Black [2] described tooth size variations in 1902. C.W.Neff was the first to make an attempt to establish the influence of tooth size variation for interdigitation of dental arches in 1949; but the anterior teeth proportionality index, proposed by this author, was not widely accepted. There have been many attempts to introduce other tooth size discrepancy indexes, but most of them failed. Bolton Index (BI) has remained in the widest used for today. This index was described by W.A.Bolton [6] in 1958. Dental casts of 55 persons, whose occlusions were judged as perfect, have been selected in an original study and the generated equations were based on the measurements of these casts:

$$ABI = \frac{\sum_{i=31}^{33} dd_i + \sum_{i=41}^{43} dd_i}{\sum_{i=11}^{13} dd_i + \sum_{i=21}^{23} dd_i} * 100\% ,$$

$$TBI = \frac{\sum_{i=31}^{36} dd_i + \sum_{i=41}^{46} dd_i}{\sum_{i=11}^{16} dd_i + \sum_{i=21}^{26} dd_i} * 100\%$$

TBI – total Bolton index,
ABI – anterior Bolton index (calculated from the first molar to first molar in each arch)
dd – mesiodistal width of each tooth

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According to W.A.Bolton's conclusions, dental arches are proportional to each other when TBI is 91.3%±1.93 and/or ABI is 77.2±1.65. TBI is supposed to be ideal, if the sum of mesiodistal widths of maxillary teeth exceeds the mandibular one by 7.5 to 9.5 mm.

There has been a wide discussion and a substantial disagreement in orthodontic literature concerning many

aspects of BI. T.A.Stifter [7] is one of the first who has nearly got the same results after repeating Bolton's study in 1958. Nevertheless BI was strongly criticized for not taking into account the possible influence of racial and sexual dimorphism [1,8,10].

The aim of our investigation was to calculate ABI and TBI among the patients of the Orthodontic clinic at Kaunas University of Medicine, to evaluate the clinical significance of tooth size discrepancy, to assess the influence of sexual dimorphism on BI and to establish which teeth have the greatest influence on BI variation.

MATERIALS AND METHODS

In the Orthodontic clinic at Kaunas University of Medicine 108 diagnostic dental casts of patients (37 boys and 71 girls) that fulfill the following criteria have been selected for the study:

1.teeth 11-16, 21-26, 31-36, 41-46 were fully erupted;

2.teeth were not affected by significant size or form anomaly;

3.teeth were intact (no fillings, prosthetic restorations, carious or other hard tissue lesions).

Measurements were made directly on dental casts using "Minchner design Dental Vernier" ("Dentaurum") gauge. Measurements were made in accordance with the methodology described by R.C.Wheeler [12]. To determine BI sexual dimorphism, patients were divided into two groups according to gender. TBI, ABI values were calculated for each of them separately.

Statistical analysis was performed using SPSS® software (SPSS for Windows 2000, version 10.0, SPSS Inc., Chicago, Ill., USA). The mean ($\bar{x}$) and standard deviation (S) were used as descriptive values. Student's t-tests were used to compare the results and variation coefficient, which was implemented to ascertain teeth mostly differing by their width.

All measurements on dental casts were performed by three independent investigators (each measured 36 diagnostic casts, distribution of cases was randomized). No statistically significant intra-individual (p<0.01) or inter-individual (p<0.05) differences of the measurements were found.

RESULTS AND DISCUSSION

The calculated TBI and ABI values and the distribution of indexes are shown in Fig.1 and Fig.2. It was determined that in 62.3% (68 patients) of the cases patients had normal TBI (no tooth size discrepancies found), in 21.3% (23 patients) had wider upper than lower teeth, in 15.7% (17 patients) – the opposite.

The estimated ABI was normal in 48.1% (52 patients) of the cases, in 20.4% (22 patients) - upper front teeth appeared to be wider than lower front teeth, in 31.5% (34 patients) – the opposite.

Manifested teeth size discrepancies of various levels were found in 37% of the cases. Discrepancies in anterior segments were determined in 52% of the examined patients. From this data we may draw the assumption that tooth size discrepancy is more frequent in the anterior segments of dental arches. According to J.E.Freeman [13] and D.A.Crosby [3], tooth size discrepancy is clinically significant if 91.3-3.86(2S) <= TBI <= 91.3+3.86(2S) or/and 77.2-3.30(2S) <= ABI <= 77.2+3.30(2S). Clinically significant tooth size discrepancies in both posterior and anterior segments were detected in 5.5% of the examined patients in our sample, in 18.5% - only in the anterior part of the dentition. The comparisons of data derived from our and other studies are shown in Table I.

The percentage of the cases with clinically significant tooth size discrepancies in our investigation was found to be lower when comparing to other studies [3, 13]. In analogy with J.E.Freeman and D.A.Crosby, we detected that tooth size discrepancy problems are more frequent in the anterior segments. M.Heusdens [17] determines even a broader range for clinical insignificance of tooth size discrepancies: only extreme tooth size discrepancies 91.3-5.79(3S) <= TBI <= 91.3+5.79(3S) and/or 77.2-4.95(3S) <= ABI <= 77.2+4.95(3S) may influence treatment results. We have found only one case in our sample outside the range of 3S (TBI=84.7 %).

Descriptive values for TBI and ABI determined in our and other studies are shown in Table II and Table III. No statistically significant differences (p<0.05) in TBI and ABI values among the three investigation groups (Kaunas University of Medicine, W.A.Bolton and J.E.Freeman) were found. TBI and ABI variation

Table 1. *Percentage of clinically significant cases.*

BI value	Kaunas Medical University study	D.A.Crosby study	J.E.Freeman study
91,3-3,86(2S) <= BBI <= 91,3+3,86(2S)	5,5%	-	13,4%
77,2-3,30(2S) <= PBI <= 77,2+3,30(2S)	18,5%	22,9%	30,6%

Table 2. *TBI descriptive values.*

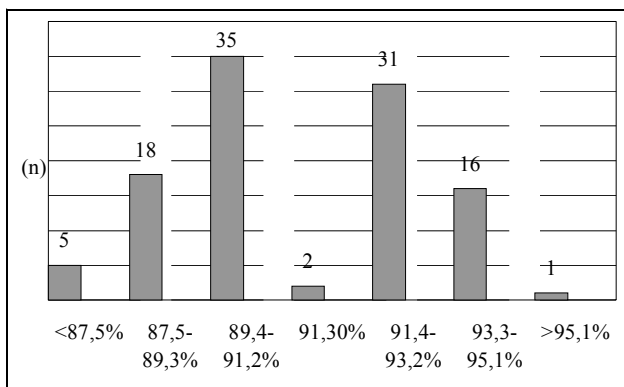|	Kaunas Medical University study	W.A.Bolton study	J.E.Freeman study
Sample size	108	55	157
Mean ($\bar{x}$)	90,98%	91,30%	91,40%
Median	91,09%	-	91,30%
Range	84,77%-95,33%	87,50%-94,80%	82,80%-99,40%
Standard deviation	2,06	1,91	2,57
Standard error of mean	0,25	0,26	0,21
Coefficient of variation	2,26%	2,09%	2,81%

Figure 1. TBI value distribution.
   Index value (%)
   91,3%- mean TBI value
   89,4-91,2% and 91,4-93,2% within 1S interval
   87,5-89,3%, 93,3-95,1% out of 1S , within 2S interval
   <87,5% and >95,1% out of 2S interval
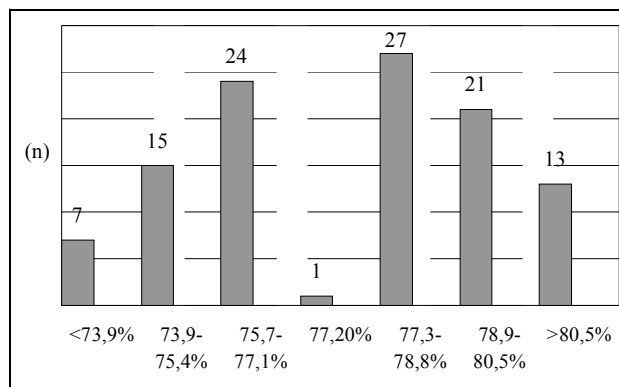   * S – Bolton's value for TBI in Table 3

Figure 2. ABI value distribution
   Index value (%)
   77,2%- mean ABI value
   75,5-77,1% and 77,3-78,8% within 1S interval
   73,9-75,4% and 78,9-80,5% out of 1S, within 2S interval
   <73,9%, >80,5% out of 2S interval
   * S – Bolton's value for ABI in Table 3

coefficients determined in our study are similar to W.A.Bolton's results. J.E.Freeman's data could have been influenced by some racial dimorphism, while all the patients selected for our and W.A.Bolton's studies were Caucasian type whites. On the contrary to the original studies [6,3], malocclusion type was not taken into account as criterion for case selection in our investigation, but the results (TBI, ABI values) allow us to suggest, that the type of malocclusion does not influence BI value [13].

The results of the study could be altered by sexual dimorphism (our sample included 65.7 % of females). Table IV illustrates TBI, ABI and arch length (sum of mesiodistal teeth widths) differences between genders. We found no statistically significant TBI and ABI differences between genders (p<0.05), but the sum of mesiodistal teeth widths differs significantly (p>0.05). Some other authors stated the same results [11,14,15,16]. According to W.A.Bolton, TBI is ideal if the sum of mesiodistal widths of 12 maxillary teeth (11-16, 21-26), and exceeds the mandibular one (31-36, 41-46) by 7.5 to 9.5 mm. We have calculated mean dental arch length for males and females and compared our results with S.Smith's data [8]. The results are shown in Fig. 3. S.Smith claims that the sum of
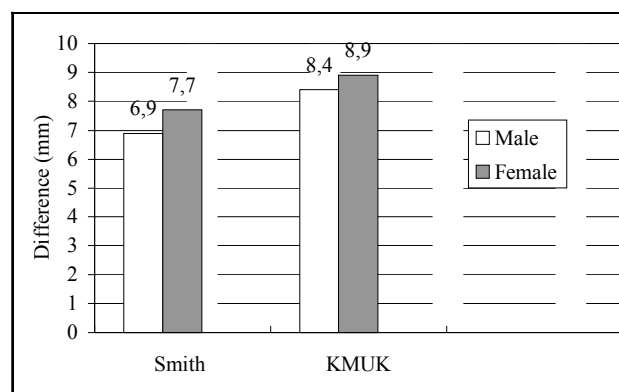

Figure 3. Maxillary and mandibular arch length differences.

maxillary teeth (11-16, 21-26) widths for males is less than 7.5 mm greater than the sum of mandibular (31-36, 41-46) teeth. That is why the author supported TBI validity for white females only, but not for males. Our results defend the original W.A.Bolton's statement.

BI values are dependent on teeth size variations. Teeth width variation coefficients are shown in Table V. In our study the highest variation coefficients were

Table 3. ABI descriptive values.

	Kaunas Medical University study	W.A.Bolton study	J.E.Freeman study
Sample size	108	55	157
Mean ($\bar{x}$)	77,59%	77,20%	77,80%
Median	77,51%	-	77,90%
Range	70,31%-83,98%	74,50%-80,40%	68,40%-87,90%
Standard deviation	2,56	1,65	3,07
Standard error of mean	0,25	0,22	0,25
Coefficient of variation	3,30%	2,14%	3,95%

Table 4. Influence of sexual dimorphism on TBI and ABI.

Gender	Number of cases	TBI mean ($\bar{x} \pm S$)	ABI mean ($\bar{x} \pm S$)	16-11, 26-21 mean of teeth width sum ($\bar{x} \pm S$)	36-31, 46-41 mean of teeth width sum ($\bar{x} \pm S$)
Female	71	90,7±2,14%	77,4±2,62%	95,9±4,55mm	87,0±4,42mm
Male	37	91,5±1,81%	78,0±2,40%	98,5±3,86mm	90,0±3,69mm
P	-	>0,05	>0,05	<0,05*	<0,05*

p –error probability, *p<0,05 – statistically significant difference

CONCLUSIONS

Table 5. Coefficients of teeth width variations.

Maxilla	0,30	0,29	0,26	0,19	0,22	0,32
Teeth	1	2	3	4	5	6
Mandible	0,13	0,20	0,26	0,22	0,22	0,39

found for the first molars, central and lateral maxillary incisors. These findings differ appreciably from S.S.Smith's, who found mandibular second bicuspids, maxillary lateral incisors and second bicuspids as most variable in width, results.

• Tooth size discrepancies of various levels manifested in 37.7% of the investigated cases. Discrepancies in anterior segments were detected in 51.9% of the cases. Clinically significant tooth size discrepancies in both posterior and anterior segments were found in 5.5% of the examined patients, in 18.5% - only in the anterior part of the dentition.

• TBI and ABI values showed no dependence on patients' gender and occlusion.

• BI was mostly influenced by the width differences of the first permanent molars, upper central and lateral incisors.

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