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Research Article

Distribution of Tooth Size Discrepancies among Angle Classifications in a Dominican American Population, as Measured on Digital Models

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Abstract

Objective: To investigate the correlation between the anterior and overall tooth size ratios and the Angle Classification of malocclusion in a Dominican American population.

Materials and Methods: 180 orthodontic patients were divided into 3 malocclusion groups (Angle Class I, Class II and Class III). Each group was composed of 30 males and 30 females. The overall ratio of mandibular to maxillary teeth (first molar to first molar) and the anterior ratio of mandibular to maxillary canine to canine were measured using the OrthoCad^{tm} software measurement tool on digital models of all subjects. Statistical analysis of the data was done using SAS software. Means, Standard Deviations, standard error and range of the overall and anterior ratios were calculated separately for males and females in the three groups. To determine if there were significant differences due to gender, a student's t-test was used after testing for normality of the ratios for males and females in all malocclusion groups. A Wilcoxin Two-Sample Rank Sum test was used if the males and females in the groups were not normally distributed.

Results: There are no statistically significant differences in the anterior and overall tooth size ratios between male and female subjects in class I, Class II and Class III malocclusion. Class III anterior and overall ratios were significantly greater than the Bolton Mean with a higher prevalence of relative mandibular tooth size excess.

Conclusion: In a Dominican American population, different classifications of malocclusion do have an effect on anterior and overall tooth size ratios.

Keywords: *Tooth Size; Digital; Discrepancy; Classification; Dominican-American*

Introduction

In order to achieve a functional and esthetic occlusion, it is necessary to calculate the tooth size ratios of the entire dentition as well as the anterior tooth size ratio. Investigation of tooth size dates back to the time of G.V. Black [1] in 1902 and later Neff [2] in 1949. It culminated with the studies of Bolton [3,4] in 1958 and 1962, which established the mandibular to maxillary ratios of 77.2 for the anterior teeth and 91.3 for the entire dentition in a Caucasian sample. A study by Santoro., *et al*. [5] showed that in a Dominican American population, while there was not a significant difference in the ratio for the entire dentition as compared to the Bolton standard, there was a significant difference in the anterior ratio which was 78.1. They also found an overall tooth size discrepancy in 11% of their sample and an anterior discrepancy in 28% of their sample. The maxillary central and lateral incisors are the most variable teeth in size and shape. This could lead to difficulty in establishing an esthetic smile arc and failure to obtain good anterior coupling and an acceptable overbite and overjet relationship. Dominican Americans are among the fastest growing ethnic communities in the United States and have been shown in a previous study, to have a prevalence for tooth size discrepancy. In addition, a PubMed search, conducted in 2012 revealed no English references available regarding the association between Bolton's standards and malocclusion in a Dominican American population and none have been found since. Therefore, this study attempts to refine appropriate tooth size measurements for this population and determine the incidence in different malocclusion groups.

Genetic as well as environmental factors influence tooth size as reported in the twin studies by Osborne and Horowitz in 1958 and 1959 [6,7]. They showed close correlation in tooth size especially between monozygotic twins. Environmental variables may also

affect dental development. Teratogenicity, nutritional imbalance, and space limitation have the capacity to affect the form, size, number and shape of the permanent teeth. A number of studies [8-13] show that different racial and ethnic groupings have a significant difference from the Bolton standards and some studies [14,15] have indicated that there is a greater amount of tooth size discrepancy in patients with a Class III malocclusion.

Some studies have tested for sexual dimorphism in relation to tooth size and shape. A study by Mitsea., *et al*. [16] assessed the reliability of establishing gender identity using tooth size measurements for forensic purposes, however the results showed that there was an overall correct classification of only 72% and that there was a higher percentage of females correctly classified than males. They concluded that using the mesiodistal dimensions of teeth is not a reliable method for determining gender and that it should be used in combination with other identification methods. Horvath., *et al*. [17] studied the correlation between anterior tooth form and gender in a sample of 60 Caucasian males and 60 females. They determined that while there were significant differences in shape of the maxillary central incisor, lateral incisor and canine between males and females, the prediction of gender could not be made without tooth size measurements as well. They concluded that while tooth size accounts for part of the correlation, tooth shape is also gender specific.

Purpose of the Study

The aim of this study is to investigate the correlation between anterior and overall tooth size ratios and class I, class II and Class III malocclusion groups in a Dominican American population. The null hypothesis states that "there are no significant differences between anterior and overall tooth size discrepancy and Angle classification in a Dominican American population".

We attempted to answer the following questions:

1. Is there a correlation between the classification of malocclusion and tooth size ratio?
2. Is there a significant difference between the overall and anterior tooth size ratios of males and females?
3. Which Angle classification shows the greatest prevalence for tooth size discrepancy?
4. Is there a difference in the presence of maxillary and/or mandibular excess in the three malocclusion groups?
5. How does the anterior and overall tooth size ratio of Dominican American subjects differ from the Bolton Standard?

Materials and Methods

The sample for the study comprised the digital study casts produced by OrthoCAD^{tm} of 180 orthodontic patients from 12.9 to 18.6 years of age with a mean age of 15.7 years who were divided into three malocclusion groups: Angle Class I, Class II and Class III. All Class II and III cases were a full cusp Class II or III at least on one side and at least in an end on relationship on the opposite side. Class l cases had to have the Mesiobuccal cusp tip of the upper first molars occluding in the buccal groove of the lower first molars on both sides. We decided to use the Angle classification system utilized by the American Board of Orthodontics to determine qualification of cases for their clinical exam. As determined by Angle, this relates only to the relationship of the maxillary and mandibular first molars.

Method error

The method error was tested on the anterior and overall ratio of 30 cases by one observer. The first and second measurements were made two weeks apart. The Shapiro-Wilks test was used to determine if the differences between the first and second measurements were normally distributed. Paired t tests were done to determine significant differences between the first and second measurements.

Each group consisted of 60 subjects (30 males and 30 females). All subjects were undergoing orthodontic treatment in the postgraduate orthodontic clinic of the Columbia University College of Dental medicine. Alginate impressions were made of the maxillary and mandibular dental arches of each subject, immediately poured with white Type III Orthodontic stone and sent to OrthoCAD^{tm} for scanning.

Inclusion criteria of the sample:

1. Patient self-identified as Dominican American (or by parent in the case of minor children).
2. Correctly mounted digital cast.
3. All permanent teeth present and fully erupted from first molar to first molar in both arches.
4. No mesio-distal tooth structure loss or excess due to fracture, caries or restorations.

Exclusion criteria of the sample:

1. Incorrectly mounted or poor quality OrthoCad digital model.
2. Large restorations, abrasions, prosthetic replacements that could compromise the mesiodistal width.
3. tooth agenesis, tooth anomalies or extractions.

4. Digital cast showing gross anatomical dental abnormalities (e.g. Peg shape lateral).
5. Cases involving clefts of the lip and palate or other craniofacial syndromes.

The overall tooth size ratio of mandibular to maxillary teeth (first molar to first molar) and the anterior ratio of mandibular to maxillary canine to canine were measured using the OrthoCad software measurement tool on all digital casts. The OrthoCad digital caliper, with an accuracy of 0.1 mm. measured the greatest mesio-distal dimension of each tooth. The relative tooth size excess for both the overall dentition and the anterior teeth was also calculated.

Statistical analysis

Statistical analysis of the data was done using SAS software (Cary, North Carolina). Means, Standard Deviations, standard error and range of the overall and anterior ratios were calculated separately for males and females in the three groups. To determine if there were significant differences due to gender, a student's *t*-test was used after testing for normality of the ratios for males and females in all malocclusion groups. A Wilcoxin Two-Sample Rank Sum test was used if the males and females in the groups were not normally distributed.

Results

Measurement error and reliability

The Shapiro-Wilks test showed that differences in anterior ratio and overall ratio between the first and second measurements were normally distributed. The paired *t*-test indicated no significant differences between the first and second measurements of the 30 overall ratios at $P < 0.05$. The intraclass correlation coefficient was .99 for the overall ratio and .98 for the anterior ratio, indicating that measurements for both ratios are highly correlated and reliable (Table 1).

	N	Overall	Anterior
1st. measurement	30	0.90386	0.76348
2nd. measurement	30	0.90490	0.76496
T Test		P < 0.05	P < 0.05
Pearson Correlation		.99	.98

Table 1: *Error and reliability analysis.*

Malocclusion and gender analysis

No significant gender differences were found in the 3 malocclusion groups, so the data for all 60 subjects was pooled for each group (Table 2).

Anterior Ratio	Male (30 cases)			Range	Mean	Female (30 cases)	SE	Range	T-Test (Wilcoxon Rank Sum)
Class I	78.158	3.015	0.550	73.08-84.47	77.557	2.416	0.441	72.69-81.42	NS
Class II	77.428	2.038	0.372	73.61-83.75	77.601	1.937	0.354	73.82-82.62	(NS)
Class III	78.916	2.709	0.495	.7374-87.02	78.502	2.329	0.425	73.63-83.92	NS

Overall Ratio	Male (30 cases)				Female (30 cases)				
	Mean	SD	SE	Range	Mean	SD	SE	Range	T-Test (Wilcoxon Rank Sum)
Class I	91.487	2.260	0.413	87.24-95.60	91.476	1.721	0.314	87.36-95.74	NS
Class II	90.917	1.838	0.336	87.40-96.18	90.837	2.110	0.385	85.24-95.54	NS
Class III	92.543	1.798	0.328	89.00-98.49	91.862	1.852	0.338	88.48-95.26	(NS)

Table 2: *Comparison of anterior and overall ratios between Dominican American males and females.*

Malocclusion and tooth size ratios

The means of the anterior ratio in all 3 groups were not normally distributed so the non-parametric Kruskal-Wallis test was used for correlation. It showed (at $P < 0.05$) that malocclusion does affect anterior and overall tooth size. The mean anterior ratio was found to be greatest in the Class III group (78.70), followed by Class I (77.90) and Class II (77.50). Overall ratio was found to be greatest in the Class III group (92.20), followed by class I (91.50) and Class II (90.90) (Table 3).

Malocclusion and the Bolton Means

To compare the mean ratios of the malocclusion groups with the Bolton means, it was necessary to use the Wilcoxin Signed Rank Test for the class II group which was not normally distributed. Paired Student *t* tests were used for all other groups. Table 4 indicated that class III anterior and overall ratios were significantly different from the Bolton standard at the $P < 0.5$ level. There were no significant differences for the class I or class II groups.

Group	Mean	SD	SE	Range	Anova (Kruskal Wallis)
Ant. Rat.					
Class I	77.91	2.73	0.35	72.7-84.5	P < 0.05
Class II	77.50	1.97	0.25	73.6-83.8	P < 0.05
Class III	78.70	2.51	0.32	73.6-87.0	P < 0.05
Overall Rat.					
Class I	91.50	1.99	0.26	87.2-95.7	P < 0.05
Class II	90.90	1.96	0.25	85.2-96.2	P < 0.05
Class III	92.20	1.84	0.24	88.5-98.5	P < 0.05

Table 3: *Comparison of anterior and overall ratios of malocclusion groups.*

Group	Mean	SD	SE	Range	T-Test Wilcoxon
Ant. Bolton	77.20	1.65	0.22	74.5-80.4	
Class I	77.90	2.73	0.35	72.7-84.5	NS
Class II	77.50	1.97	0.25	73.6-83.8	NS
Class III	78.70	2.51	0.32	73.6-87.0	S at P < 0.05
Overall Bolton	91.30	1.91	0.26	87.5-94.8	
Class I	91.50	1.99	0.26	87.2-95.7	NS
Class II	90.90	1.99	0.25	85.2-96.2	NS
Class III	92.20	1.84	0.24	88.5-98.5	S at P < 0.05

Table 4: *Comparison of anterior and overall ratios with the Bolton Mean.*

Prevalence of tooth size discrepancy based on Bolton standard deviations

Anterior tooth size ratios outside of one standard deviation from the Bolton Standard were found in 79 subjects (43.89%) and overall tooth size ratios outside of one standard deviation were found in 50 subjects (27.78%) of the malocclusion sample respectively (Table 5). Anterior tooth size ratios outside of two standard deviations were found in 47 subjects (26.11%) and overall tooth size ratios outside of two standard deviations were found in 18 subjects (10.0%) of the malocclusion sample respectively (Table 6).

Tooth size discrepancy based on an absolute value of 1.5 mm

Anterior ratios outside of 1.5 mm were found in 29.44% of all the malocclusion subjects as indicated in table 7. Overall ratios outside of 1.5 mm were found in 48.88% of all malocclusion subjects. Based on the Chi-square test, we have statistically significant evidence to conclude that there was a difference in the distribution of subjects with anterior and overall ratios among the malocclusion classes.

N of subjects/(%)	< 75.54	75.55 - 78.85	> 78.86
Bolton ant. ratio	**Outside -1SD**	**Within + or – 1 SD**	**Outside + I SD**
Class I	12 (20)	29 (48.33)	19 (31.67)
Class II	11 (18.33)	40 (66.676)	9 (15)
Class III	4 (6.67)	32 (53.33)	24 (40)
Total	27 (15)	101 (56.11)	52 (28.89)
Bolton Overall ratio			
N of subjects/(%)	< 89.38	89.39-93.21	> 93.22
Class I	7 (11.67)	44 (73.33	9 (15)
Class II	12 (20)	44 (73.33)	4 (6.67)
Class III	4 (6.7)	42 (70)	14 (6.67)
Total	23 (12.78)	130 (72.22)	27 (15)

Table 5: *Prevalence of anterior and overall tooth size discrepancy based on Bolton's one standard deviation.*

Bolton ant. ratio	Outside -2 SD	Within + or – 2 SD	Outside + 2 SD
N of subjects/(%)	< 73.89	73.90 - 80.50	> 80.51
Class I	6 (10)	42 (70)	12 (20)
Class II	5 (8.33)	50 (83.33)	5 (8.30)
Class III	3 (5)	41 (68.33)	16 (26.67)
Total	14 (7.78)	133 (73.89)	33 (18.33)
Bolton Overall ratio			
N of subjects/ (%)	< 87.47	87.48-95.12	> 95.13
Class I	2 (3.33)	54 (90)	4 (6.7)
Class II	4 (6.67)	53 (88.33)	3 (5)
Class III	0 (0)	55 (91.67)	5 (8.33)

Table 6: *Prevalence of anterior and overall tooth size discrepancy based on Bolton's 2 standard deviations.*

Prevalence of tooth size discrepancy and malocclusion distribution

Prevalence and distribution of clinically significant anterior and overall tooth size discrepancy between the three-malocclusion groups were summarized in table 8. When using the parameter of absolute value to analyze the prevalence of anterior tooth size discrepancy, 29.44% of all malocclusion subjects were outside of 1.5 mm. The distribution of the 29.44% clinically significant anterior tooth size discrepancy within the three malocclusion groups was divided as follows: Class I (45.28%), Class II (18.86%) and Class

Anterior ratio	< -1.51	-1.51-0.00	0	0.01 - 1.50	> 1.51
Class I	8 (13.3%)	14 (23.33%)	5 (8.33 %)	17 28.33%)	16 (26.67%)
Class II	5 (8.33%)	16 (26.67%)	0 (0)	34 (56.67%)	5 (8.33%)
Class III	3 (5%)	10 (16.67%)	1 (1.67%)	30 (50%)	16 (26.67%)
Total	16 (8.89%)	40 (22.22%)	6 (3.33%)	81 (45%)	37 (20.56%)
Overall ratio	< -1.51	-1.51 - 0.00	0	0.01 - 1.50	> 1.51
Class I	15 (25%)	14 (23.33%)	0 (0)	13 (21.67%)	18 (30%)
Class II	17 28.33%	9 (31.67%)	3 (5%)	12 (20%)	9 (15%)
Class III	7 (11.67%)	9 (15%)	2 (3.33%)	20 (33.33%)	22 (36.67%)
Total	39 21.67%)	42 (23.33%	5 (2.78%)	45 (25%)	49 (27.22%)

Table 7: *Prevalence of anterior and overall tooth size discrepancy based on 1.5 mm absolute value.*

	> 1.5 mm		> 2 SD	
	Anterior	Overall	Anterior	Overall
Total	53/180 (29.44%)	88/180 (48.88%)	47/180 (26.11%)	18/180 (10.00%)
Class I	24/53 (45.23%)	33/88 (37.5%)	18/47 (38.29%)	6/18 (10 %)
Class II	10/53 (18.86%	26/88 (26.88%)	10/47 (21.27%)	7/18 (38.88%)
Class III	19/53 (35.84%)	29/88 (32.95%)	19/47 (40.42%)	5/18 (27.77%)

Table 8: *Summary of prevalence of tooth size discrepancy and malocclusion distribution.*

III (35.84%). Class II malocclusion group ratios were significantly lower than the Class I and Class III groups. The overall ratio outside of 1.5 mm constituted 48.88% of all the malocclusion subjects. The distribution between the three malocclusion class groups were Class I (37.5%), Class II (29.54%) and Class III (32.95%). The distributions of overall clinically significant tooth size discrepancy based on 1.5 mm of absolute value were not significantly different from each other between the three malocclusion groups. Table 9 shows a comparison of the current data to the Bolton standard and to the former study by Santoro., *et al*.

When using the parameter of two standard deviations outside of the Bolton mean to study the prevalence of anterior tooth size discrepancy, 26.11% of all malocclusion subjects satisfied the criteria. Within the 26.11%, the distribution between the malocclusion groups was: Class I (38%), Class II (21%) and Class III (41%). The Class II malocclusion group was significantly lower than the Class I and Class III groups. The overall ratio outside of two standard deviations of the Bolton mean constituted 10% of all the malocclusion subjects. The distribution of overall tooth size discrepancy

	Bolton's Values	Dominican American Santoro, 2000	Dominican American Current Data
Anterior Ratio			
Sample size	55	54	180
Mean	77.2	78.1	78.0
Range	74.5-80.4	71.4-86.6	72.7-87.0
Standard Deviation	1.65	2.87	2.46
Coefficient of Variation	2.12	3.68	3.16
+/- 2 Standard Deviation		28%	26 %
Overall Ratio			
Mean	91.3	91.3	91.5
Range	87.5-94.8	85.5-97.1	85.2-98.5
Standard Deviation	1.91	2.22	2
Coefficient of Variation	2.09	2.43	2.18
+/- 2 Standard Deviation		11%	10 %

Table 9: *Comparison summary to Bolton and Santoro's finding.*

between the three malocclusion groups were Class I (33.33%), Class II (38.88%) and Class III (27.77%). The distributions of the clinically significant overall tooth size discrepancy based on Bolton standards were not significantly different from each other error ratio.

Discussion

Comparison to Bolton analysis and Santoro., *et al*. findings

Our data were consistent with the values available from the Santoro., *et al*. [5] previous study both in anterior and overall ratio and prevalence of tooth size discrepancies. The overall ratio was found to be 91.5, slightly higher than 91.3 found in the previous study, and the anterior ratio was 78.0, slightly lower than 78.1 in the previous study. Both anterior and overall ratios are significantly different from the Bolton standards and should be applied when treating this population in order to attain optimal occlusal and overbite and overjet relationships. The frequency of overall tooth size discrepancies outside 2 standard deviations from the Bolton mean was 10%, slightly less than 11% found in the previous study, and the frequency outside of two standard deviations of the anterior ratio was 26%, slightly less than the previous finding of 28%. The difference in anterior and overall ratios was greatest in the Class III group as was the greatest amount of mandibular excess. This needs to be taken into consideration in planning for correction of anterior cross bites and may indicate the need for interproximal reduction.

Based upon the similarities in the population sample and inclusion criteria, it was not surprising that the results should be similar to the Santoro., *et al*. study. The minor difference between the two may be explained by the malocclusions that constitute the study sample and that the measurements were made on digital models in this study. The slight variation in results may be due to the specified number requirements of the subjects per malocclusion group and gender, 60 subjects per malocclusion group with 30 males and 30 females each. The distribution of the sample may not represent the natural prevalence of malocclusions that occur in this population and may be different from the Santoro., *et al*. sample. However, this study indicates that malocclusion does have an effect on and can influence tooth size ratio, and that the type of malocclusions that constitute the sample can affect the mean overall and anterior ratio.

The anterior ratio in this study is significantly higher than in Bolton's study which can also reflect the difference of the study population. The Bolton study comprised 55 Caucasian subjects with ideal occlusion whereas our study population comprised 180 Dominican American males and females equally divided into three malocclusion groups and by gender.

A higher incidence of tooth size discrepancy has been found consistently in other non-Caucasian populations. Many studies have shown that there are significantly different tooth size ratios among different racial groups. The anterior ratio of 78.0 in the current study compared to the Bolton finding of 77.2 was significantly higher. The explanation for this difference may be due to the population that constitutes the study sample. Bolton's study did not specify the gender of the subjects studied other than that they were Caucasians with excellent occlusion. It has been suggested that it was primarily a female population, whereas our current study's sample includes Dominican Americans who were equally distributed in gender and malocclusion groups. With regard to gender, there were no statistically significant differences in either anterior or overall ratios between males and females in any of the three malocclusion groups. Our findings are in agreement with other studies which analyzed different ethnicities. However, it is inconsistent with the study of Fattahi., *et al*. [14] which analyzed an Iranian population and found gender differences.

The finding of this study, that the largest tooth size ratios in Dominican Americans are found in the Class III group followed by the Class I and Class II groups respectively is in agreement with studies of other populations by Neil and Lin [15], Ta., *et al*. [18], Alkaid and Hashim [19], Araujo and Souki [20], Aysal and Sari [21], Endo [22], Al-Khateeb [23] and Johe., *et al* [24]. The studies of Fattahi., *et al*. [14], Strujic., *et al*. [25], Munjal., *et al*. [26], O'Mahoney [27] and Akyalcin., *et al*. [28] are in disagreement. However, this study does show that for a Dominican American population, tooth size discrepancy and malocclusion are strongly correlated and may cause or exacerbate malocclusion.

While reliability of measurements was good in this study, it might have been improved either by using PVS material for impressions or by intraoral scanning of the dentition and measurement of digital models using the MeshLab program. In this study, only Angle Classification, not patient skeletal pattern, was taken into consideration when assigning subjects to malocclusion groups. Future studies should investigate the relationship of skeletal discrepancy as well as occlusion on tooth size and compare the results with this study.

Conclusion

In a Dominican American population:

1. Different classifications of malocclusion do have an effect on anterior and overall tooth size ratios. Therefore, the null hypothesis is rejected.
2. There are no statistically significant differences in the anterior and overall tooth size ratios between male and female subjects in class I, Class II and Class III malocclusion.

3. Class III anterior overall, ratios were significantly greater from the Bolton Mean with a higher prevalence of relative mandibular tooth size excess.
4. Class I and class III malocclusions have significantly greater tooth size discrepancies than Class II malocclusion, based on 2 standard deviations from the Bolton Mean and 1.5 mm of absolute measurement.
5. More incidence of mandibular rather than maxillary excess occurred in Class I and Class III malocclusions.

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