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Original Research

Evaluation and Comparison of Intermaxillary Tooth Size Discrepancy among Class I, Class II Division 1, and Class III Subjects Using Bolton's Analysis: An *in vitro* Study

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Abstract:
Aim: The aim of the present study was to evaluation and comparison of intermaxillary tooth size discrepancy among Class I, Class II division 1, and Class III subjects using Bolton's analysis.
Materials and Methods: The pre-treatment casts were selected from the records of patients attending the Department of Orthodontics of Meenakshi Ammal Dental College, Chennai. The sample consists of 180 pre-treatment casts with both sexes evenly distributed with 60 casts in each type of malocclusion, i.e., Class I, Class II div 1, and Class III malocclusion. The sample was selected according to angles classification. All patients were Indian nationals, between the age group of 12 to 20 years and Bolton's analysis done on all the casts.
Results: Statistically no significant difference in all types of malocclusion except anterior Bolton's discrepancy in Class III.
Conclusion: Mean Bolton's anterior ratio for angles Class III subjects was significantly greater than for Class I and Class II subjects. When Bolton's overall ratio was compared there was no statistically significant difference among Class I, Class II div 1, and Class III malocclusions.

Key Words: Angle's classification of malocclusions (Class I, Class II, and Class III), Bolton's analysis, pre-treatment casts

Introduction

One of the goals in comprehensive orthodontic treatment is to obtain a best possible functional and esthetic result for the patient at the end of the treatment. There are many factors that influence the attainability of this goal, one of which is a tooth size discrepancy. A tooth size discrepancy is defined as a disproportion among the sizes of individual teeth.[1] Tooth size discrepancy represents a valid diagnostic tool that allows for an effective prediction of treatment outcomes and may also limit the necessity for diagnostic setups for complex cases.

In order to achieve a good occlusion with the correct overbite and overjet, the maxillary and mandibular teeth must be proportional in size. The Mesiodistal widths of teeth were first formally investigated by Black.[2]

Over the years, many investigators have attempted to quantify this relationship. It was Gilpatric,[3] calculated that the total mesiodistal tooth diameters in the maxillary arch exceeded that in the mandibular arch by 8-12 mm.

Later Neff,[4,5] developed the "anterior coefficient," a method to compare the widths of the anterior teeth in opposing arches. He concluded, "That everything else being normal an orthodontic or non-orthodontic arch will settle to the degree of overbite indicated by the anterior coefficient.

Lundstrom,[6] showed a large biologic dispersion in the tooth width ratio, and said it was great enough to have an impact on the final tooth position, teeth alignment, and overbite and overjet relationships in a large number of patients.

The best-known study of tooth size disharmony in relation to treatment of malocclusion was by Bolton in 1958.[7] He computed the specific ratios of the mesiodistal widths that must exist between maxillary and mandibular teeth from both canine-canine and first molar-first molar so as to obtain optimum occlusion.

Bolton evaluated 55 cases with "excellent" occlusions, 44 had been treated orthodontically without extractions and 11 were untreated. The following ratios were established by Bolton[7]:

Overall ratio = 91.3% the standard deviation (SD) was 1.91%
Anterior ratio = 77.2% the SD was 1.65%

In a subsequent paper,[8] Bolton expanded on the clinical application of his tooth size analysis. Bolton's SD from his original sample (> 1SD) have been used to determine the need for reduction of tooth tissue by interdental stripping or the addition of tooth tissue by restorative techniques. John,[9] replicated Bolton study in Class I dentitions and reported similar results.

There is good evidence that populations differ with respect to inter-arch tooth size relationships because differences in tooth sizes are not systematic. For example, blacks have larger maxillary canines, premolars, and first molars than whites even though there are no differences for the maxillary central or lateral incisors.[10]

Moreover, tooth size differences between males and females are not systematic across all teeth.[11] Because population and gender differences in maxillary tooth size are not the same as the differences in mandibular tooth size, different inter-arch relationships might be expected.[11]

The dental literature has many studies comparing tooth size discrepancies and malocclusion in different ethnic groups. However, there is a lack of sex and angle classification specificity in these studies, additional data are necessary to understand this association.

Thus, the present study was undertaken in an effort to determine if a difference does exist in tooth size ratios between the different malocclusion classes and to determine if any sexual dimorphism exists in a sample which is taken from Department of Orthodontics and Dentofacial Orthopedics, Meenakshi Ammal Dental College, Chennai.

Materials and Methods

The pre-treatment casts were selected from the records of patients attending the Department of Orthodontics of Meenakshi Ammal Dental College, Chennai. The sample consists of 180 pre-treatment casts with both sexes evenly distributed with 60 casts in each type of malocclusion, i.e., is Class I, Class II div 1, and Class III malocclusion. The sample was selected according to angles classification. All patients were Indian nationals, between the age group of 12-20 years. Sample selection done as per the following. Good quality pre-treatment models, all permanent teeth erupted and present from right first molar to left first molar and angles molar relation should be bilateral. No extraction or interproximal stripping performed. No severe mesiodistal and occlusal tooth abrasion. No restorative treatment. No history of orthodontic treatment. No residual crown or crown bridge restorations. Subjects with congenitally missing teeth, extracted teeth, questionable articulation, malformed teeth, broken or chipped teeth or carious lesion that could affect the mesiodistal crown width were not included in the sample.

The measurements were made directly on casts using a digital vernier caliper with an accuracy of 0.01 mm with fine tips to improve the access inter-proximally. All measurements were taken under natural light by one examiner. The measuring is done by placing caliper beaks from the buccal (labial) aspect, and held occlusally parallel to the long axis of tooth. The beaks were then closed until gently contact with the contact points of the tooth was felt.

Following measurements are taken:

From the pre-treatment models, the mesiodistal dimension of the teeth of 180 samples is taken. The widest points on the mesiodistal direction on each tooth are measured. All measurements are in millimeters.

The same investigator performed all measurements. For method error evaluation, 10 casts were selected at random, 2 weeks after the original measurements. The teeth were remeasured on these casts. The 1st and 2nd measurements were compared statistically. These measurements were recorded from first molar to first molar and subjected to Bolton's analysis

The Bolton's anterior ratio was calculated using the following formula:

$$\text{Anterior ratio} = \frac{\text{Sum of mandibular 6}}{\text{Sum of maxillary 6}} \times 100 = 77.2\%$$

Anterior ratio = 77.2% the SD was 1.65%
The data are classified as normal for Bolton's ratio within ± 1 SD (77.2 ± 1)
Anterior mandibular discrepancy (excess) if ratio is > 1 SD i.e., more than 78.2%.
Anterior maxillary discrepancy (excess) if ratio is < 1 SD i.e., <76.2%.
The overall ratio was calculated using the following formula.

$$\text{Overall ratio} = \frac{\text{Sum of mandibular 12}}{\text{Sum of maxillary 12}} \times 100 = 91.3\%$$

Overall ratio = 91.3% the SD was 1.91%
The data are classified as normal for Bolton's ratio within ± 1 SD (91.3 ± 1)
Overall mandibular discrepancy (excess) if the ratio is >1 SD, i.e., more than 92.3%.
Overall maxillary discrepancy (excess) if ratio is <1 SD i.e., < 90.3%.
Measurements that are obtained from 180 samples were subjected to statistical analysis.

Study I: Analysis of error in the sample

Study II: For all the samples mean and SD has to be calculated and compared among the three malocclusions as a function of gender.

Statistical analysis

The statistical analysis can be divided into 3 parts.

Study-1: The reliability of the data were assessed using student's paired *t*-test, Pearson's correlation coefficient and intraclass correlation coefficient.

Study-2: The mean Bolton's anterior and overall tooth size ratios of the sample were computed and compared as a function of angle classification as well as gender using student's independent *t*-test or one-way ANOVA followed by Tukey HSD procedure appropriately.

Results

The same investigator performed all measurements, and the reproducibility of the method was tested. A total of 10 individuals were selected randomly from the original sample, and measurements were repeated twice within 2-week period. No significant differences between the two sets of measurements ($P > 0.05$) (Table a-c) were found on testing using Student's paired *t*-test, Pearson's correlation coefficient and intraclass correlation coefficient.

Results from Table 1 shows that in Class I, mean anterior ratio for male (79.01 ± 2.37) was higher than females (77.89 ± 2.06). However, there was no statistically significant difference in mean anterior ratio between males and females with ($P = 0.06$). For Class-II, mean anterior ratio for male (77.45 ± 2.51) was lesser than females (78.55 ± 3.37). However, there was no statistically significant difference in mean anterior ratio between males and females with ($P = 0.16$). For Class-III, Mean anterior ratio for male (78.78 ± 2.41) was lesser than females (79.82 ± 3.67). However, there was no statistically significant difference in mean anterior ratio between males and females with ($P = 0.20$). No statistically significant difference in Bolton's anterior ratio between males and females of Class I, Class II div I, and Class III malocclusion.

Results from Table 2 shows that in Class I, mean overall ratio for male (92.02 + 2.21) was lesser than female (92.19 ±± 2.47). However, there was no statistically significant difference in mean overall ratio between male and female with ($P = 0.78$). For Class-II, mean overall ratio for male (91.14 ± 2.27) was lesser than female (91.47 ± 2.80). However, there was no statistically significant difference in mean overall ratio between males and females with (P = 0.62). For Class-III, mean overall ratio for male (91.87 ± 2.71) was higher than female (92.40 ± 2.52). However, there was no statistically significant difference in mean overall ratio between males and females with ($P = 0.95$). Inference is statistical and there is no significant difference in the overall ratio of males and females of Class I, Class II div I, and Class III malocclusion.

Table a: Comparison of mean values between repetition I and II to assess the reliability of the data.

Variable	Mean±SD			*P* value[@]
	Repetition-I	Repetition-II	Difference	
Anterior ratio	78.81±4.25	78.81±4.29	0.005±0.07	0.80 (NS)
Overall ratio	92.11±2.81	92.15±2.80	0.042±0.13	0.27 (NS)

[@]Students paired *t*-test was used to calculate the *P* value, SD: Standard deviation, NS: Non significant

Table b: Correlation analysis to assess the reliability of the data.

Variable	Correlation[$] coefficient (*r*)	*P* value
Anterior ratio	0.9999	< 0.0001 (Sig)
Overall ratio	0.9990	< 0.0001 (Sig)

[$]Pearson's correlation coefficient

Table c: Reliability analysis.

Variable	Intraclass correlation coefficient	*P* value
Anterior ratio	0.9999	< 0.0001 (Sig)
Overall ratio	0.9990	< 0.0001 (Sig)

Table 1: Comparison of Bolton's anterior ratio (mean) between males and females of Class I, Class II div 1, and Class III malocclusion.

Variable	Class	Sample (*n*)	Mean±SD (*n*=30)		*P* value*
			Male	Female	
Anterior ratio	Class I	60	79.01±2.37	77.89±2.06	0.06 (NS)
	Class II div 1	60	77.45±2.51	78.55±3.37	0.16 (NS)
	Class III	60	78.78±2.41	79.82±3.67	0.20 (NS)

SD: Standard deviation, NS: Non significant

Table 2: Comparison of Bolton's overall ratio (mean) between males and females of Class I, Class II div 1, and Class III malocclusion.

Variable	Class	Sample (*n*)	Mean±SD (*n*=30)		*P* value*
			Male	Female	
Overall ratio	Class I	60	92.02±2.21	92.19±2.47	0.78 (NS)
	Class II, div 1	60	91.14±2.27	91.47±2.80	0.62 (NS)
	Class III	60	92.44±3.41	92.40±2.52	0.95 (NS)

*Students independent *t*-test was used to calculate the *P* value, SD: Standard deviation, NS: Non significant

Table 3: Comparison of Bolton's anterior ratio (mean) between males and females as a function of gender.

Variable	Gender	Sample (*n*)	Mean±SD	*P* value*
Anterior ratio	Male	90	78.41±2.50	0.43 (NS)
	Female	90		
	Total	180	78.75±3.18	

*Students independent *t*-test was used to calculate the *P* value, SD: Standard deviation, NS: Non significant

Table 4: Comparison of Bolton's overall ratio (mean) between males and females as a function of gender.

Variable	Gender	Sample (*n*)	Mean±SD	*P* value*
Anterior ratio	Male	90	91.87±2.71	0.70 (NS)
	Female	90		
	Total	180	92.02±2.60	

*Students independent *t*-test was used to calculate the *P* value, SD: Standard deviation, NS: Non significant

Results from Table 3 shows that the mean anterior ratio for the whole male sample (78.41 ± 2.50) was lesser than females (78.75 ± 3.18). However, there was no statistically significant difference in mean anterior ratio between males and females. ($P = 0.43$) of the whole sample.

Results from Table 4 shows that the mean overall ratio for the whole male sample (91.87 ± 2.71) was greater than females (92.02 ± 2.60). However; there was no statistically significant difference in mean overall ratio between males and females. ($P = 0.70$) of the whole sample.

Results from Table 5 shows comparison of anterior Bolton's ratio (mean) of males among the malocclusions. For males, the mean anterior ratio in Class I (79.01 ± 2.37) was higher than Class II (77.45 ± 2.5) and it is statistically evident ($P < 0.05$). However, there is no statistically significant difference between males of Class II and Class III and also between Class III and Class I.

Results from Table 6 shows comparison of anterior Bolton's ratio (mean) of females among the malocclusions. For females, the mean anterior ratio in Class III (79.82 ± 3.7) was higher than Class I (77.89 ± 2.06) and it is statistically significant with ($P = 0.05$). However, there is no statistically significant difference between Class I and Class II and between Class II and Class III malocclusion.

The results from Table 7 shows that the mean overall ratio for males of Class III (92.44 ± 3.41) was higher than Class I (92.02 ± 2.21) which in turn higher than Class II (91.14 ± 2.27). However, there was no statistically significant difference in mean overall ratio among males of various malocclusions with (0.16).

The results from Table 8 shows the comparison of overall Bolton's ratio (mean) of females among the malocclusions. The mean overall ratio for females of Class III (92.40 ± 2.52) was higher than Class I (92.19 ± 2.47) which in turn higher than Class II (91.47 ± 2.80). However, there was no statistically significant difference in mean overall ratio among females of various malocclusions with (0.35).

The results from Table 9 shows the comparison of Bolton's anterior ratio (mean) between Class I, Class II div 1, and Class III malocclusion. The mean anterior ratio in Class III (79.30 ± 3.12) was higher than Class I (78.45 ± 2.27), which in turn higher than Class II (78.00 ± 2.99). However, statistically significant difference found only between Class III and Class II malocclusions ($P < 0.05$).

The results from Table 10 shows comparison of Bolton's overall ratio (mean) between Class I, Class II div 1, and Class III malocclusion. The mean overall ratio for Class III (92.42 ± 2.97) was higher than Class I (92.11 ± 2.33) which in turn higher than Class II (91.30 ± 2.53). However, there was no statistically significant difference in mean overall ratio among various malocclusions with ($P = 0.06$).

Discussion

It has been widely accepted that a correct maxillary and mandibular mesiodistal tooth size relationship is important to the achievement of proper occlusal interdigitation in the finishing stages of orthodontic treatment.

Though many authors like Neff,[4,5] Ballard,[12] and Lundstrom,[6] had attempted to quantify this relationship, it was Bolton,[7] in 1958 who computed the specific ratios of the mesiodistal widths that must exist between maxillary and mandibular teeth from both canine-canine and first molar-first molar so as to obtain optimum occlusion.

The intended purpose of tooth size discrepancy ratio as a diagnostic aid as said by Bolton is "to gain insight into the functional and esthetic outcome of a given case without the use of diagnostic set up."[7] Though till date diagnostic setup remains the golden standard for predicting interarch tooth size discrepancy, Bolton's analysis is the one which is being widely used due to the fact that, the measurements are easily and quickly made, making the analysis a practical diagnostic tool.

Tooth sizes have been analyzed mainly from two aspects, the difference between the genders and the difference between various occlusion categories, although several studies have attempted to show racial and ethnic differences in tooth size.[10,11] Bolton based his study upon a heterogeneous caucasian population sample and, hence, provides no information relating to other racial groups.[7] The importance of ethnicity in Bolton's studies have been stressed by the studies of Lavelle,[11] Smith *et al.*,[10] suggested that tooth size discrepancy differs between racial or ethnic groups. Also studies by Paredes *et al.*[13,14] and Uysal *et al.*,[15,16] Ta *et al.*,[17] suggested population specific Bolton standards are necessary for clinical assessments. On the other hand, studies by Nourallah *et al.*,[18] suggested that Bolton's interarch tooth size analysis can also be applicable to an Arabian or at least a Syrian population.

Studies of Savara and Lavelle,[11] shows male teeth on the average larger than female teeth and sexual dimorphism was evident predominantly in permanent canines, while incisors showed a minimum difference and premolars showed an intermediate

Table 5: Comparison of Anterior Bolton's ratio (mean) of males among the malocclusions.

Variable	Gender	Classes	Sample (*n*)	Mean±SD	*P* value	Significant# groups at 5% level
Anterior ratio	Male	Class I	30	79.01±2.37	0.03 (S)	I versus II
		Class II div I	30	77.45±2.51		
		Class III	30	78.78±2.41		

**One-way ANOVA was used to calculate the *P* value, #Multiple range test by Tukey HSD procedure was employed to identify the significant groups at 5% level, SD: Standard deviation, S: Significant

Table 6: Comparison of Anterior Bolton's ratio (mean) of females among the malocclusions.

Variable	Gender	Classes	Sample (*n*)	Mean±SD	*P* value	Significant# groups at 5% level
Anterior ratio	Female	Class I	30	77.89±2.06	0.05 (S)	III versus I
		Class II div I	30	78.55±3.37		
		Class III	30	79.82±3.67		

**One-way ANOVA was used to calculate the *P* value, #Multiple range test by Tukey HSD procedure was employed to identify the significant groups at 5% level, SD: Standard deviation, S: Significant

Table 7: Comparison of overall Bolton's ratio (mean) of males among the malocclusions.

Variable	Gender	Classes	Sample (*n*)	Mean±SD	*P* value	Significant# groups at 5% level
Overall ratio	Male	Class I	30	92.02±2.21	0.16 (NS)	Nil
		Class II div I	30	91.14±2.27		
		Class III	30	92.44±3.41		

**One-way ANOVA was used to calculate the *P* value, #Multiple range test by Tukey HSD procedure was employed to identify the significant groups at 5% level, SD: Standard deviation, NS: Non significant

Table 8: Comparison of overall Bolton's ratio (mean) of females among the malocclusions.

Variable	Gender	Classes	Sample (*n*)	Mean±SD	*P* value	Significant# groups at 5% level
Overall ratio	Female	Class I	30	92.19±2.47	0.35 (NS)	Nil
		Class II div I	30	91.47±2.80		
		Class III	30	92.40±2.52		

**One-way ANOVA was used to calculate the *P* value, #Multiple range test by Tukey HSD procedure was employed to identify the significant groups at 5% level, SD: Standard deviation, NS: Non significant

Table 9: Comparison of Bolton's anterior ratio (mean) between Class I, Class II div 1 and Class III malocclusion.

Variable	Classes	Sample (*n*)	Mean±SD	*P* value	Significant# groups at 5% level
Anterior ratio	Class I	60	78.45±2.27	0.04 (S)	III versus II
	Class II div I	60	78.00±2.99		
	Class III	60	79.30±3.12		

**One-way ANOVA was used to calculate the *P* value, #Multiple range test by Tukey HSD procedure was employed to identify the significant groups at 5% level, SD: Standard deviation, NS: Non significant

Table 10: Comparison of Bolton's overall ratio (mean) between Class I, Class II div 1, and Class III malocclusion.

Variable	Classes	Sample (*n*)	Mean±SD	*P* value	Significant# groups at 5% level
Overall ratio	Class I	60	92.11±2.33	0.06 (NS)	Nil
	Class II div I	60	91.30±2.53		
	Class III	60	92.42±2.97		

**One-way ANOVA was used to calculate the *P* value, #Multiple range test by Tukey HSD procedure was employed to identify the significant groups at 5% level, SD: Standard deviation, NS: Non significant

difference. Richardson and Malhotra,[19] found that the teeth of black North American males were larger than those of females for each type of tooth in both arches, but there were no differences in anterior or posterior interarch tooth size proportions. Al-Tamimi and Hashim,[20] also found no sexual dichotomy in Bolton ratios in a relatively small sample of 65 Saudi subjects. In contrast, Smith *et al.*,[10] found that males had larger Bolton's ratios than females. However, these differences were small being much < 1 SD from Bolton's sample.[7]

Bolton's ratio has been taken from a sample of perfect Class I occlusion.[7] The possible influence of different classes of malocclusion on Bolton's ratio was studied by various authors.[10,11,16,17,19,20-24]

Dental literature is replete with studies comparing tooth size discrepancy and malocclusion in different ethnic groups. However, there is a lack of gender and angle classification specificity in these studies, and additional data are necessary to understand this association.

The main objective of this study was to investigate the relationship between tooth size discrepancies and angles Class I, Class II div 1, and Class III malocclusions as a function

of gender on a sample of orthodontic patients who attended the Department of Orthodontics and Dentofacial Orthopedics of Meenakshi Ammal Dental College, Chennai.

The study was done to determine whether there are any differences in Bolton's anterior ratio and overall ratio among three malocclusion groups, i.e., Class I, Class II div 1, and Class III as a function of gender. The sample consisted of 180 pre-treatment casts with 60 samples in each class with both genders evenly distributed (30 males and 30 females in each class). The sample was selected according to angle's classification and angle's Class I, Class II div 1, Class III molar relation should be bilateral in order to avoid those molar relations caused by early loss of deciduous molars. All patients were Indian nationals, and between the ages of 13-20 years old. This young age group was chosen to minimize the alteration of mesiodistal tooth dimensions because of attrition, restoration, or caries.

Measurements were carried out using a digital vernier caliper (Yamayo) with an accuracy of 0.01 mm. Vernier was selected as a measuring tool because, it was proved to be the most accurate method for measuring mesiodistal width of tooth in models.

Bolton's ratio were compared in males and females of Class I, Class II div I, and Class III subjects, the results (Tables 1 and 2) showed that there is no statistically significant difference in the mean Bolton's anterior and overall ratio between males and females. When tooth size ratios were compared (Tables 3 and 4) as a function of sex among the whole sample, there was no significant difference between each group. These results are in agreement with studies of Richardson and Malhotra,[19] Nie and Lin,[23] Arauzo and Souki,[24] Alkafoide and Hashim,[25] Al-Tamimi and Hashim,[20] Basaran *et al*.,[26] and they found that there was no sexual dichotomy in Bolton's ratio. Richard son and Malhotra,[19] found that the teeth of black North American males were larger than those of females for each type of tooth in both arches, but there were no differences in anterior or posterior interarch tooth size proportions. It is important to note that the possibility of gender differences in tooth size discrepancies is different from differences in absolute tooth size. Lavelle,[11] showed that the total and anterior ratios were both greater in males than females. However, these sex differences were small, all being < 1%. Smith *et al*.,[10] found that males had larger ratios than females. However, these differences were small, being much < 1SD from Bolton's sample.

When comparison of anterior ratio among 30 males of Class I, Class II div 1, Class III malocclusion (Table 5) mean anterior ratio for Class I males significantly higher than Class II males ($P = 0.03$) while the rest of other combinations are insignificant. These results are in agreement with studies of Levellae[11] who found that mesiodistal crown dimensions for maxillary teeth were Class I (>) Class II div 1 (>) Class II div 2 (<) Class III and for mandibular teeth Class III (>) Class I (>) Class II div 1 (>) Class II div 2. Furthermore, when comparison among 30 females of Class I, Class II div 1, Class III malocclusion (Table 6) done the Bolton's anterior ratio for Class III is higher than Class I ($P = 0.05$) while other combinations are not statistically significant. Hence, these results are also in agreement with studies of Lavelle.[11] That means as a general trend, the Bolton's anterior discrepancy would be greater in Class III, and then comes Class I and finally Class II according to Lavelle.[11]

When comparison of overall ratio done in the same way (Tables 7 and 8) as discussed above, no statistical significance is found among the comparisons of various groups. Since there is no sexual dimorphism evident in mean anterior ratio and overall ratio samples of genders were pooled together in each class to form a single group with $n = 60$.

When comparison of mean anterior ratio and overall ratio were carried out among Class I, Class II div 1, and Class III malocclusion with 60 samples in each group, the results (Table 9) shows that the mean for the anterior Bolton ratio was statistically greater for the Class III sample than for the Class I and Class II samples ($P < 0.04$). These results are in agreement with studies of Levelle,[11] Nie and Lin,[23] Araujo and Souki,[24] Sperry *et al*.,[21] who also found in their studies that Class III patients demonstrate greater anterior tooth size discrepancy when compared with patients of Class II and Class I. Furthermore, when Class I and Class II div 1 samples compared with each other, they showed no significant differences. These results are in consistent with the results of Crosby and Alexander studies,[22] who also found no statistically significant differences when comparing Class I and Class II subjects. The suggested reasoning for this anterior discrepancy in Class III malocclusion is that the mesiodistal incisor tooth size of lateral incisor is smaller in Class III subjects or it may be due to accumulation of minor discrepancies of individual teeth in the maxilla. The data from above suggested that Class III patients demonstrate mandibular anterior tooth material excess and maxillary tooth material deficiency.[11] These results agree with studies done by Tuverson,[27] Redahan and Lagerstrom,[28] where mandibular tooth material excess.

Considering the Bolton's normality limits of ± 1 SD, which is presented by 77.2% ± 1.65%, only the Class III group in this study had a mean anterior Bolton ratio (79.30 ± 3.12) value outside of that limit.

The results from (Table 10) shows that even though the mean overall ratio for Class III is greater than Class II and Class I, statistically this difference is not evident ($P > 0.06$). These results are in partial agreement with studies of Uysal *et al*.,[15,16] Basaran *et al*.[26] and in disagreement with studies of Nie and Lin,[23] where overall ratio for Class III greater than Class II and Class I. Hence, it is evident that mandibular excess in Class III of this sample is probably due to mandibular anterior excess with mandibular overall excess has no significant role.

Summary and Conclusion

On the basis of the conditions of this investigation, the following summarizes the important issues of the study.

1. Significant sexual dimorphism for anterior and overall ratios did not exist when they were compared among malocclusions as a function of gender.
2. Mean Bolton's anterior ratio for angles Class III subjects was significantly greater than for Class I and Class II subjects.
3. When Bolton's overall ratio was compared there was no statistically significant difference among Class I, Class II div 1, and Class III malocclusions.

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