Original Article

DOI: 10.7860/JCDR/2025/80058.21508

Dentistry Section

Evaluation of Bolton Anterior and Overall Tooth Size Discrepancy among Different Malocclusion Groups in Southern Indian Population: A Retrospective Study

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ABSTRACT

Introduction: Orthodontic treatment involves distinct phases, each with unique traits and challenges. In particular, the "Finishing" stage is renowned for the fine corrections needed to achieve optimal results. Discrepancies in tooth size contribute significantly to the difficulties encountered during this stage.

Aim: To assess differences in maxillary and mandibular tooth size discrepancies among different sagittal malocclusion groups in a South Indian population using the derived Bolton formula.

Materials and Methods: A retrospective study was conducted in the Department of Orthodontics at Karpaga Vinayaga Institute of Dental Sciences, Kanchipuram, Tamil Nadu, India, over three months, from July to September 2024. A total of 120 high-quality pretreatment orthodontic study models were selected. The inclusion criteria comprised patients aged 16 to 25 years with full permanent dentition up to the first molars in both arches. The models were categorised into three groups based on Angle's classification of anteroposterior malocclusion: Class I (n=40), Class II (n=40), and Class III (n=40). The mesiodistal width of each tooth up to the first molar on both sides was measured at the interproximal contact points using a digital caliper. Bolton's anterior and overall ratios were calculated using the measured values. Statistical analysis included one-way ANOVA to evaluate differences in mean Bolton ratios across groups, and the Chi-square test to assess the distribution of anterior and overall Bolton discrepancies among the malocclusion types. A p-value of <0.05 was considered statistically significant.

Results: The prevalence rate of tooth material discrepancies in the anterior region for Angle Class I and Class III groups was significantly greater than that for Class II groups. The mean overall and anterior ratios were not significantly different between the malocclusion groups (p=0.13 and p=0.72, respectively).

Conclusion: The present study indicated that Class I and Class III show an increased frequency of tooth material discrepancies compared with Class II.

Keywords: Anterior mandibular excess, Anterior maxillary excess, Bolton ratio, Dental arch, Occlusal analysis, Tooth material discrepancy

INTRODUCTION

Achieving ideal occlusion is a fundamental objective in orthodontic treatment. According to Andrews (1972), six keys to normal occlusion are essential for establishing optimal dental alignment and interarch relationships; the absence of any of these keys can result in poor occlusion [1]. Building upon this concept, McLaughlin later proposed a seventh key, emphasising the significance of coordinated tooth size. He highlighted that even with ideal tooth positioning, achieving perfect occlusion would be difficult if the mesiodistal widths of the maxillary and mandibular teeth were not properly proportioned [2].

Bolton further underscored the importance of tooth size compatibility between arches, introducing a formula to calculate the tooth size ratio and diagnose discrepancies between the maxillary and mandibular dentition [3]. Accurately identifying these discrepancies is critical, as mismatched tooth proportions can impact treatment planning, tooth alignment, and ultimately, the success of orthodontic finishing.

Despite this, differences in tooth size among various ethnic groups and malocclusion types are often overlooked during the early diagnostic stages. Such oversights may become evident later in treatment, particularly during the finishing phase, where occlusal and marginal finishing becomes more complex. Numerous studies have explored the relationship between tooth size discrepancies and malocclusion types, yielding mixed results. For example, Basaran G et al., investigated Bolton ratios in 300 individuals across five malocclusion groups (Class I, Class II, Class II Division 1, Class II Division 2, and Class III) and found no significant differences in tooth size ratios among the groups [4]. In contrast, Wedrychowska-Szulc B et al., in a study of 600 patients, reported statistically significant differences in anterior ratios between Class I and Class III malocclusions, as well as variations in total ratios across different groups [5]. Similarly, Shastri D et al., found that Class II malocclusions were associated with increased anterior ratios, although other ratios remained within established normative ranges [6].

While several populations have been studied in this context, there is a notable gap in research focusing on the South Indian population. Ethnic and regional variations in tooth size may influence interarch relationships and impact clinical decision-making. Therefore, the aim of the present study is to evaluate tooth size discrepancies among different sagittal malocclusion groups in the South Indian population, with a focus on assessing Bolton's anterior and total ratios.

MATERIALS AND METHODS

This retrospective study was conducted in the Department of Orthodontics at Karpaga Vinayaga Institute of Dental Sciences, Kanchipuram, Tamil Nadu, India, which was was carried out over a period of three months, starting in July 2024 and concluding in September 2024. The institutional ethical committee granted approval for this study with IEC number (KIDS/IEC/2024/IV/011). Informed consent was obtained from all individuals whose dental records and models were used in this study.

Sample size estimation: Sample size formula for One-way ANOVA:

$$n = \frac{2(Z_{\alpha/2} + Z_{\beta})^2 \cdot \alpha^2}{\Delta^2}$$

$$n = \frac{2(2.8)^2 \cdot 9}{(2)^2} = \frac{2 \cdot 7.84 \cdot 9}{4} = 35.28 \approx 36 \text{ per group}$$

Participants were classified into three malocclusion groups Class I (n=40), Class II (n=40), and Class III patients (n=40).

Inclusion criteria:

- High-quality pretreatment models;
- Full permanent dentition up to the first molars in both arches;
- Plaster dental models obtained from previously recorded, untreated cases archived in the departmental records;
- Models representing individuals from the Southern Indian population, as indicated in the study title;
- Only models from patients with no prior orthodontic treatment were included;
- Models must exhibit natural dentition with no Interproximal Reduction (IPR) or dental restorations (e.g., crowns, fillings, or prosthetic appliances). Clear and intact proximal contact points are required;
- Moderate spacing or crowding is permitted; digital or plaster models must be free from distortions, bubbles, or voids.

Exclusion criteria:

- Presence of large restorations, crowns, veneers, or prosthetic teeth that alter the natural mesiodistal width of teeth;
- Congenitally missing permanent teeth;
- Any missing permanent tooth (excluding third molars);
- Partially erupted or impacted teeth;
- Teeth with carious lesions or fractures that affect natural tooth dimensions;
- Severe occlusal or interproximal tooth wear; severe crowding is also excluded;
- Presence of supernumerary teeth or retained deciduous teeth.

Study Procedure

The Angle classification of occlusion was aligned with the skeletal classification, confirming consistency across all cases. Skeletal patterns were evaluated using Steiner's cephalometric analysis, with a primary focus on the ANB angle to classify skeletal relationships [4,5,7].

The greatest mesiodistal width of each tooth, up to the mesial margin of the first molar on both sides, was measured at the interproximal contact points on the proximal surfaces. The measurements included the following teeth in both the maxillary and mandibular arches: first and second premolars, canines, and central and lateral incisors. Measurements were conducted using a digital caliper (EKO Turbo, China) with a precision of ±0.01 mm to ensure high accuracy. The caliper was positioned perpendicular to the occlusal plane to minimise angulation errors.

Each tooth was measured twice by the same examiner, and the average of the two values was recorded. If discrepancies between the two measurements exceeded 0.1 mm, a third measurement was taken, and the final value was determined by averaging the two closest readings. This method helped to reduce intra-examiner variability and improve measurement consistency.

Bolton's analysis [3],

Anterior Bolton Ratio=(Sum of maxillary anterior teeth widths / Sum of mandibular anterior teeth widths)×100

Overall Bolton Ratio=(Sum of maxillary teeth widths / Sum of mandibular teeth widths)×100

STATISTICAL ANALYSIS

The data obtained from the tooth width measurements were recorded and analysed using International Business Machines - Statistical Package for the Social Sciences. (IBM SPSS) Statistics software version 21.0. Descriptive statistics, including mean and Standard Deviation (SD), were calculated for the anterior ratio and overall ratio of Bolton analysis. The data were assessed for normal distribution. One-way Analysis of Variance (ANOVA) was used to determine any significant differences in mean Bolton ratios between different groups. The Chi-square test was used to compare the distribution of anterior and overall Bolton ratios between groups. A p-value <0.05 was considered statistically significant. Confidence intervals (95% CI) were reported for all statistical comparisons.

RESULTS

The demographic data is presented in [Table/Fig-1]. [Table/Fig-2] demonstrate the mean and SD of malocclusion groups. The mean anterior ratio for Class I, II, and III is 77.2±2.7, 77.6±2.9, and 76.8±2.6, respectively. The mean overall ratio for Class I, II, and III is 91.8±3.0, 92.0±2.9, and 91.5±3.2, respectively.

Demographic data	Class I	Class II	Class III	Total
Sample size	40	40	40	120
Age (years)	18±1	17±2	17±1	17± 5
Gender				
Male	22	19	18	59
Female	18	21	22	61

[Table/Fig-1]: Baseline characteristics of patients.

Classification	Anterior ratio mean±SD	Overall ratio mean±SD
Class I	77.2±2.7	91.8±3.0
Class II	77.6±2.9	92.0±2.9
Class III	76.8±2.6	91.5±3.2

[Table/Fig-2]: Showing mean values, Standard Deviation (SD) of three malocclusion groups.

The data were classified as "normal" if the Bolton ratio was within ±1 SD and as a "discrepancy" if it was greater than or equal to ± 2 SD [7].

In [Table/Fig-3] the proportion of anterior tooth material differences that deviate from Bolton's means by more than one or two SD. The frequency of discrepancies varied depending on the Angle classification, with a Class III ratio of 73% and a Class I ratio of 64%, showing a tooth size discrepancy of ±2 SD compared to a Class II ratio of 52%.

Class	Outside 2SD <73.9	2SD 73.9-75.4	1SD 75.5-77.1	Mean 77.2	1SD 77.3-78.8	2SD 78.9-80.5	Outside 2SD >80.5
Class 1	0%	12%	28%	4%	4%	12%	40%
Class II	11%	11%	26%	0%	22%	15%	15%
Class III	4%	4%	19%	0%	8%	38%	27%

[Table/Fig-3]: The proportion of anterior tooth material differences that deviate from Bolton's means by more than one or two Standard Deviations (SD).

[Table/Fig-4] demonstrates the frequency of tooth size discrepancies that are one, two, or greater than two SDs from Bolton's mean for the overall ratio. The prevalence of discrepancies in the three malocclusion groups (Class I ratio of 48%, Class II ratio of 55%, and Class III ratio of 35%) did not differ when analysed by Angle classification.

Differences among various malocclusion groups: One-way ANOVA was used to determine any significant differences in mean Bolton ratios between different groups. Bolton's anterior and overall ratios for Class

Class	Outside 2SD <87.5	2SD 87.5-89.3	1SD 89.4-91.2	Mean 91.3	1SD 91.4-93.2	2SD 93.3-95.1	Outside 2SD >95.1
Class I	8%	20%	16%	4%	32%	8%	12%
Class II	0%	22%	15%	4%	26%	22%	11%
Class III	8%	4%	34%	4%	27%	23%	0%

[Table/Fig-4]: The proportion of posterior tooth material differences that deviate from Bolton's means by more than one or two Standard Deviations (SD).

I, Class II, and Class III malocclusions are shown in [Table/Fig-5,6]. The ANOVA test showed no statistically significant differences in Bolton's ratios among the malocclusion groups, with p-values of 0.139 for the anterior ratio and 0.72 for the overall ratio (p>0.05).

Comparison of anterior and overall ratios among different malocclusion groups: The Chi-square test was used to compare the distribution of anterior and overall Bolton ratios between groups. The values are shown in [Table/Fig-7,8]. The Chi-square test revealed no statistically significant differences in both anterior (p=0.077) and overall (p=0.87) ratio distributions among the three malocclusion groups (p>0.05).

Class	Mean	SD	f-value	p-value
Class I	77.2	2.7	2.00	0.139
Class II	77.6	2.9		
Class III	76.8	2.6		

[Table/Fig-5]: Bolton anterior ratio for different malocclusion groups. Significant level p<0.05 using ANOVA test

Class	Mean	SD	f-value	p-value
Class I	91.8	3.0	0.32	0.72
Class II	92.0	2.9		
Class III	91.5	3.2		

[Table/Fig-6]: Bolton overall ratio for different malocclusion groups. Significant level p<0.05 using ANOVA test

Anterior ratio	Class I	Class II	Class III	p-value	Chi-square value
Maxillary excess	19 (47.5%)	21 (52.5%)	15 (37.5%)	0.077	5.13
Mandibular excess	21 (52.5%)	19 (47.5%)	25 (62.5%)		

[Table/Fig-7]: Comparison of anterior ratios among different malocclusion groups. Significant level p<0.05 using Chi-square test; Values in parentheses represent percentage of distribution

Overall ratio	Class I	Class II	Class III	p-value	Chi-square value
Maxillary excess	20 (50%)	21 (52.5%)	22 (55%)	0.87	0.28
Mandibular excess	20 (50%)	19 (47.5%)	18 (45%)		

[Table/Fig-8]: Comparison of overall ratios among different malocclusion groups. Significant level p<0.05 using Chi-square test; Values in parentheses represent percentage of distribution

DISCUSSION

Orthodontic treatment is typically divided into distinct phases, each characterised by its own set of goals and challenges. The finishing phase, in particular, presents a significant clinical hurdle, as it often necessitates multiple refinements to achieve optimal occlusal relationships and aesthetic outcomes. This phase underscores the importance of meticulous diagnosis and treatment planning, where potential tooth size discrepancies should be identified early to facilitate precise and effective finishing.

Bolton was the first to emphasise the importance of assessing tooth size ratios, suggesting that deviations beyond one SD from the normative values warranted diagnostic attention [3]. Araujo E and Souki M expanded on this concept by analysing the Brazilian population and observing that Bolton discrepancies—defined using a ±2 SD threshold—were more frequently present in Class I and Class III malocclusion groups compared to Class II [7]. The present findings corroborate this study, with anterior discrepancies emerging as more common than total discrepancies, particularly in individuals with Class III and Class I malocclusions.

These observations are consistent with previous studies by Wedrychowska-Szulc B et al., and Nie Q and Lin J, both of which reported greater anterior tooth size discrepancies in Class III cases [5,8]. Such discrepancies often manifest as mandibular anterior tooth excess, suggesting that IPR or mandibular tooth extraction may be considered effective treatment strategies for managing Class III malocclusions. These results reinforce the clinical relevance of Bolton analysis as an integral component of diagnosis, treatment planning, and prognosis estimation in orthodontic practice [5].

Several studies have also explored the influence of sex and ethnicity on intermaxillary tooth size discrepancies [9-12]. Tooth size, much like other anthropometric traits, appears to vary across both sexes and different ethnic backgrounds. Research conducted in Chinese [13], Japanese [14], Spanish [15], and Iranian [16] populations has consistently demonstrated that tooth size discrepancies are often population-specific. A recent comparative study by Abd Rahman ANA et al., between Indian Malaysians and Chinese populations further confirmed this trend [17]. The current study contributes to this body of literature by examining Bolton discrepancies within a South Indian cohort, offering valuable population-specific insights.

For measurement purposes, digital calipers were used, following the methodology validated by Correia GD et al., who reported no significant differences in measurement sensitivity between digital and manual approaches [18]. Similar to the findings reported by Uysal T and Sari Z, the present analysis revealed no statistically significant differences in anterior or overall Bolton ratios among the various malocclusion types [19]. However, a noticeable trend of increased mandibular anterior excess was observed in Class III malocclusion, which, although not statistically significant, may have clinical relevance in individualised treatment planning.

In accordance with established literature [20-23], discrepancies greater than 2 SDs from the mean were considered clinically significant. This threshold enables clinicians to differentiate between minor variations and discrepancies that may require intervention.

Ultimately, while Bolton analysis serves as a useful diagnostic tool, comprehensive orthodontic treatment planning must extend beyond the evaluation of tooth size discrepancies alone. A rational, multifactorial approach—grounded in standardised assessment protocols—is essential for achieving optimal results. Evaluating tooth size variations in conjunction with other clinical parameters ensures a more holistic and effective treatment strategy [24].

Limitation(s)

Despite the use of precise instruments like digital calipers to measure tooth widths, the potential for human error remains a limitation in this study. Variability in measurements, whether stemming from technique or minor inconsistencies in tool handling, could affect the accuracy of the Bolton ratio calculations. Moreover, factors such as gender may influence the Bolton ratio, potentially impacting the generalisability of the findings. Additionally, the retrospective study design may limit the ability to identify clinically significant Bolton discrepancies across diverse patient populations. Future research incorporating larger, more diverse samples and prospective methodologies would enhance the validity and applicability of the results.

CONCLUSION(S)

The proportion of tooth size discrepancies exceeding two SDs was notably higher in individuals with Class III and Class I malocclusions

compared to those with Class II malocclusion in the South Indian population. However, no statistically significant differences were observed in the Bolton anterior and overall ratios among the different malocclusion groups. While Bolton analysis remains a valuable diagnostic tool in orthodontics, it is essential to recognise the influence of population-specific variations. Therefore, individualised treatment planning that considers unique dental characteristics is imperative for achieving optimal clinical outcomes.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: May 02, 2025
- Manual Googling: Jul 24, 2025
- iThenticate Software: Jul 26, 2025 (9%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. No

Date of Submission: **Apr 24, 2025**
Date of Peer Review: **May 18, 2025**
Date of Acceptance: **Jul 29, 2025**
Date of Publishing: **Sep 01, 2025**