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Association of Bolton Discrepancy with Arch form and Sagittal Molar Relationship

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ABSTRACT

Background: The Bolton analysis evaluates tooth size discrepancies to ensure optimal occlusion, with its influence across sagittal molar classes and arch forms remaining unclear.
Objective: To compare anterior and overall Bolton ratios across different sagittal molar classes (Class I, II, III) and arch forms (ovoid, square, tapered) in orthodontic patients aged 13 to 35 years
Materials and Methods: This cross-sectional comparative study was conducted on 90 cases, using consecutive, non-probability sampling techniques. Inclusion criteria included dental cases of both genders aged 13 to 35 years with all anterior permanent teeth erupted and in good quality study casts. Exclusion criteria included mesiodistal loss or excess of tooth material due to caries or restorations, prosthetic replacements of teeth, previous orthodontic treatment, or transverse discrepancies such as crossbite or scissors bite. Measurements of the mesiodistal width of twelve teeth in each arch were taken using a digital vernier caliper. ANOVA test was run to compare ratios among different classes and arch forms.
Results: The mean age of participants was 20.59±5.59 years. Gender distribution was 51.11% females and 48.89% males. The comparison of anterior and overall Bolton ratios among different sagittal molar classes revealed no significant differences: class I had ratios of 91.41±2.21 (overall) and 77.41±2.21 (anterior), class II had ratios of 91.54±2.37 (overall) and 77.54±2.37 (anterior), and class III had ratios of 91.79±1.69 (overall) and 77.79±1.69 (anterior). The comparison among different arch forms also showed no significant differences: ovoid arch form had ratios of 91.95±1.92 (overall) and 77.95±1.92 (anterior), square arch form had ratios of 91.35±2.41 (overall) and 77.35±2.41 (anterior), and tapered arch form had ratios of 91.12±1.79 (overall) and 77.12±1.79 (anterior).
Conclusion: Bolton discrepancy is not influenced by sagittal molar class or arch form, regardless of gender.
Keywords: Angle's classification, Arch forms, Bolton ratio, Dental discrepancies, Orthodontics, Sagittal molar classes.

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INTRODUCTION

Achieving normal occlusion, including proper overjet, overbite, interdigitation, and optimal aesthetics and function, requires a balanced mesiodistal dimension between the upper and lower teeth.[1] The intermaxillary tooth width ratio indicates that the upper dentition is typically 8-12 mm wider than the lower dentition.[2] Bolton's method, which quantifies tooth size discrepancies using the Overall Index (OI) and Anterior Index (AI), has become a key tool in orthodontics for evaluating and planning treatments to achieve balanced and functional occlusion.[3] Bolton introduced the Overall Index (OI) and Anterior Index (AI) to assess tooth size ratios in orthodontics. The OI compares the total widths of 12 mandibular to 12 maxillary teeth (typically around 91.3%), while the AI compares six lower to six upper anterior teeth (typically about 77.2%). Higher ratios indicate a Bolton discrepancy, suggesting larger mandibular teeth relative to the maxillary teeth.[4]

Bolton's ratios, based on a sample of 55 subjects with ideal occlusion, lack diversity in terms of gender and ethnic background.[5] Consequently, they may not be universally applicable across diverse populations and malocclusion cases. Research has shown variability in Bolton's indices among different ethnic groups, genders, and malocclusion types, highlighting the need for population-specific standards in orthodontics.[6]

Studies by various researchers have investigated the prevalence and impact of tooth-size discrepancies on occlusion across different malocclusion groups, genders, and ethnicities.[7] Findings consistently indicate a higher prevalence of tooth-size discrepancies in individuals with Class III malocclusion compared to Class I or Class II.[8] This trend has been observed in diverse populations, including southern Chinese and Saudi populations.[9] Moreover, individuals with malocclusion tend to exhibit significantly higher tooth-size ratios compared to those with untreated normal occlusions.

Recent studies have focused on objective analysis of dental arches, particularly through arch-width measurements, revealing correlations. Haralabakis et al. found that smaller teeth were associated with "wide" or "pointed" maxillary arches and "flat" mandibular arches.[10]

Understanding the association between Bolton discrepancy and dental arch form, as well as the sagittal molar relationship, is crucial in orthodontics. The arch

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form and the sagittal relationship between the upper and lower molars significantly influence overall occlusion and aesthetic outcomes. Tooth size discrepancies can lead to misalignments that complicate treatment planning and execution.

The objective of this study was to compare Bolton ratios among sagittal molar relations and various arch forms.

MATERIALS AND METHODS

This cross-sectional comparative study was conducted on 90 cases at Orthodontics, Bhitai Dental and Medical College, Mirpurkhas using Consecutive, non-probability sampling technique. Ethical approval was obtained from the institute (BMDC/R&D/ERC/2023-1, February 2, 2023). Informed consent was not required as this study was conducted with plaster models.

The calculation performed by the WHO calculator, considering the given parameters, utilized a mean and standard deviation (SD) of the anterior tooth size discrepancy set at 78.16±2.21.[11] With a confidence level of 95%, the calculations accounted for an absolute precision of 0.45 and a relative precision of 0.005. These parameters determined that a sample size of 90(30 in each class I, II and III) was appropriate for the study.

The inclusion criteria for the study were dental cases of both genders within the age range of 13 to 35 years. Participants were required to have all anterior permanent teeth erupted in both the upper and lower arches, with all teeth fully erupted to the occlusal plane. Additionally, good quality study casts were necessary for inclusion. The exclusion criteria was dental cases with mesiodistal loss or excess of tooth material resulting from caries or restorations, those with prosthetic replacements of teeth, a previous history of orthodontic treatment, or any transverse discrepancies such as crossbite or scissors bite.

The sagittal molar relation was assessed based on the Angle classification system. In Class I, the mesiobuccal cusp of the upper first molar occludes with the lower molar's buccal groove, indicating a proper alignment of the molars. Class II malocclusion is characterized by the mesiobuccal cusp of the upper first molar landing anterior to the lower molar's buccal groove, resulting in a distal relationship between the upper and lower teeth. Conversely, in Class III malocclusion, the mesiobuccal cusp of the upper first molar falls posterior to the lower molar's buccal groove, leading to a mesial relationship between the upper and lower teeth.

The classification of arch form involves categorizing it into three main types: ovoid, tapered, and square. An ovoid arch form is characterized by a smooth and rounded shape resembling an egg or an oval. This arch form typically exhibits a gentle curvature from the anterior to posterior region, with a well-rounded contour along the dental arch. In contrast, a tapered arch form is characterized by a gradual narrowing or tapering of the arch from the anterior to posterior region. This shape gives the arch a more pointed or triangular appearance, with the anterior teeth being wider than the posterior teeth. Lastly, a square arch form is characterized by a relatively straight or square shape with minimal tapering. The width of the dental arch remains consistent from the anterior to posterior region, resulting in a more box-like or square appearance.[11]

All the measurements were conducted by two experienced examiners to ensure accuracy and reliability. The mesiodistal width of twelve teeth in each arch was measured, from the first molar on one side to the first molar on the opposite side. These measurements were taken in millimeters using a digital vernier caliper with sharpened points, specifically the Mitu-Toyo brand from Japan.



Fig 01. Measurements of mesiodistal tooth widths

This tool was chosen for its precision and reliability, allowing the examiners to measure the greatest distance between the contact points on the proximal surfaces of each tooth.Bolton overall and anterior ratio was determined by the formula.

$$\text{Oveall} = \frac{\textit{sum of mandibular 6}}{\textit{sum og maxillary 6}} \text{ X } 100 = 91.3\% \pm 2 \text{ SD}$$

$$\text{Anterior} = \frac{\textit{sum of mandibular 12}}{\textit{sum og maxillary 12}} \text{ X } 100 = 77.2\% \pm 2 \text{ SD}$$

The data were analyzed using SPSS 23. Mean and standard deviation (SD) were computed for continuous data such as age, anterior, and overall Bolton ratios. Frequencies and percentages were calculated for gender and arch form. Anterior and overall Bolton ratios were compared among sagittal classes and arch forms using the ANOVA test. A p-value of ≤0.05 was set as the significance level.

RESULTS

The mean age was 20.59±5.59 years. Gender distribution revealed 51.11% females and 48.89% males. In terms of arch form, 45.56% exhibited an ovoid shape, 35.56% a square shape, and 18.89% a tapered shape. Regarding sagittal molar class, each class (I, II, III) was represented by 33.33% of the participants. (Table 01)

Table 02 presents a comparison of the anterior and overall Bolton ratio among different sagittal molar classes. For sagittal molar classes I, II, and III (with 30 participants each), the overall Bolton ratio was found to be 91.41 ± 2.21 (95% CI: 91, 92), 91.54 ± 2.37 (95% CI: 91, 92), and 91.79 ± 1.69 (95% CI: 91, 92) respectively. Similarly, the anterior Bolton ratio for sagittal molar classes I, II, and III was 77.41 ± 2.21 (95% CI: 77, 78), 77.54 ± 2.37 (95% CI: 77, 78), and 77.79 ± 1.69 (95% CI: 77, 78) respectively. No significant difference was found in the Bolton ratio among the sagittal molar classes (p=0.8).

Table 03 compares the anterior and overall Bolton ratio among different arch forms. For the ovoid arch form (with 41 participants), the overall Bolton ratio was 91.95 ± 1.92 (95% CI: 91, 93), and the anterior Bolton ratio was 77.95 ± 1.92 (95% CI: 77, 79). Among participants with a square arch form (32 individuals), the overall Bolton ratio was 91.35 ± 2.41 (95% CI: 90, 92), and the anterior Bolton ratio was 77.35 ± 2.41 (95% CI: 76, 78). For those with a tapered arch form (17 subjects), the overall Bolton ratio was 91.12 ± 1.79 (95% CI: 90, 92), and the anterior Bolton ratio was 77.12 ± 1.79 (95% CI: 76, 78). The difference for both the overall and anterior Bolton ratio was not significant (p=0.3).

Anterior and overall Bolton ratios among sagittal molar classes and arch forms in both genders were not statistically significant (p>0.05). (Fig 01 & 02)

Table 01. Distribution of age, gender, arch form and sagittal molar class

Characteristic	N=90*
Age (Years)	20.59 ± 5.59
Gender	
Female	46 (51.11)
Male	44 (48.89)
Arch Form	
Ovoid	41 (45.56)
Square	32 (35.56)
Tapered	17 (18.89)
Sagittal Molar Class	
I	30 (33.33)
II	30 (33.33)
III	30 (33.33)

* Mean ± SD; n (%)

Table 02. Comparison of anterior and overall Bolton ratio among sagittal molar classes

Bolton Ratio	Sagittal Molar Classes						P-value***
	I, N=30	**95% CI**	**II,** N=30	**95% CI**	**III,** N=30	**95% CI**	
Overall	91.41 ± 2.21	91, 92	91.54 ± 2.37	91, 92	91.79 ± 1.69	91, 92	0.8
Anterior	77.41 ± 2.21	77, 78	77.54 ± 2.37	77, 78	77.79 ± 1.69	77, 78	0.8

*Mean ± SD, **CI = Confidence Interval, ***One-way ANOVA

Table 03. Comparison of anterior and overall Bolton ratio among arch forms

Characteristic	Arch Form						P-value***
	Ovioid, N=41*	**95% CI**	**Square,** N=32*	**95% CI**	**Tapered,** N=17*	**95% CI**	
Overall	91.41 ± 2.21	91, 92	91.54 ± 2.37	91, 92	91.79 ± 1.69	91, 92	0.8
Anterior	77.41 ± 2.21	77, 78	77.54 ± 2.37	77, 78	77.79 ± 1.69	77, 78	0.8

*Mean ± SD, **CI = Confidence Interval, ***One-way ANOVA

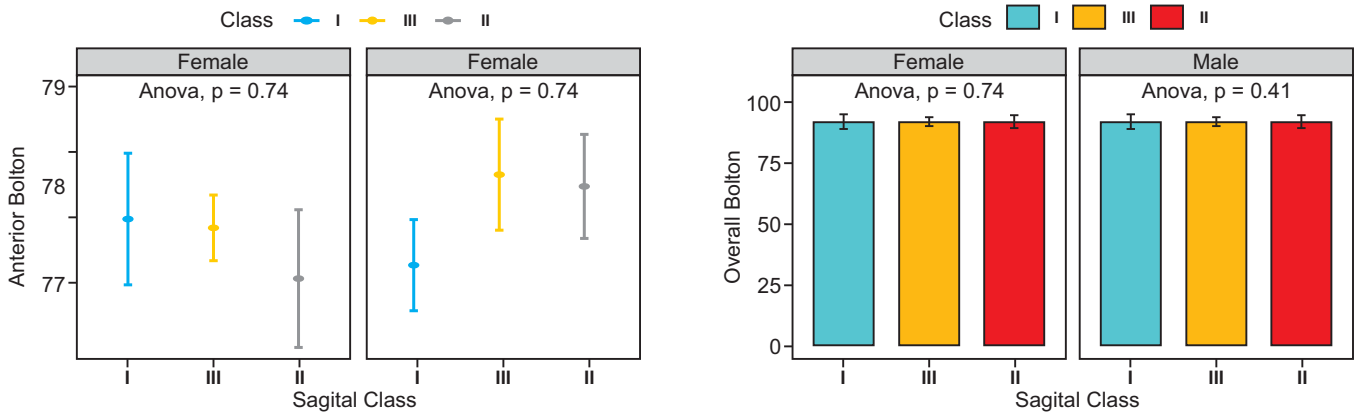


Fig 01. Anterior (upper panel) and overall (lower panel) ratio among sagittal molar classes

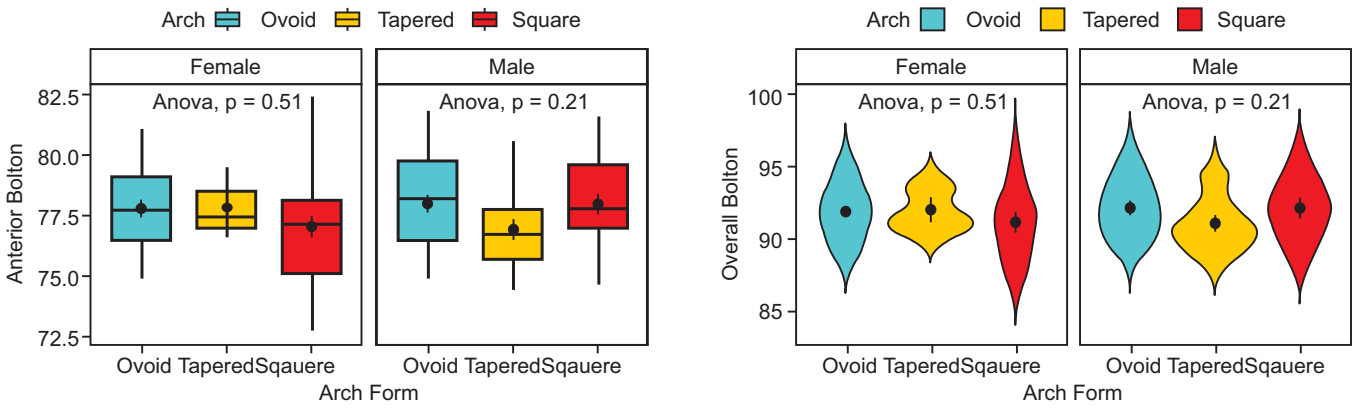


Fig 02. Anterior (upper panel) and overall (lower panel) ratio among arch forms

DISCUSSION

Our study found no significant differences among various classes of malocclusion. Alshahrani et al.[12] employed Autodesk® Meshmixer TM software for digital scanning of casts in their study involving 120 subjects, evenly distributed between genders and malocclusion classes. Their findings indicated no significant differences between genders or malocclusion types in Bolton ratios. However, malocclusion ratios were notably higher when compared to Bolton's original ratios. In another study by Omar et al,[13] involving 149 participants from Jeddah, digital calipers were utilized for measurements. Similar to Alshahrani et al., no significant differences were observed between genders or malocclusion types concerning Bolton ratios, although these ratios were significantly increased compared to Bolton's original values. Taibah[2] conducted a study in Jeddah with 84 participants diagnosed with open bite and 33 controls with ideal occlusion. Digital calipers were used for measurements. Their findings revealed no significant differences between control and open bite groups in terms of total overjet discrepancy (OI) and anterior overjet discrepancy (AI). However, OI showed a significant difference only between male and female subjects with open bite. Furthermore, no significant differences were noted compared to Bolton's study.[2] Additionally, Omar H investigated 70 individuals with normal occlusion in Jeddah, utilizing digital calipers for measurements.[13] They found no significant differences between genders or compared to Bolton's study.[14] Asiry and Hashim (2012) conducted a study in Riyadh involving 60 individuals with Class II div 1 malocclusion, again utilizing digital calipers. They found no significant differences between genders or when compared to Bolton's study, nor were there significant differences when compared to Class I normal occlusion.[15] Finally, Mullabashi employed Ortho-I software for digitally scanning casts in their study involving 160 participants from Jeddah.[16] No statistically significant differences were noted in overjet discrepancy (OI) and anterior overjet discrepancy (AI) among different occlusions or genders. No comparison was made with Bolton's study. Similarly another study in Iran comparing of Bolton ratio in normal occlusion and different malocclusion groups in the Iranian population did not found any significant difference.[16] Similarly, a study conducted in Peshawar, Pakistan also reported non-significant results.[17]

The current study found that the most common arch form was ovoid shape, followed by square shape, and the least common was tapered shape. Additionally, arch form was not associated with Bolton discrepancy. Similar findings were reported by a previous study.[11]

The study's strengths include a large, well-distributed sample size, precise measurements validated by experienced examiners, and robust statistical analysis. However, its cross-sectional design limits causal inference, reliance on plaster models may overlook natural variations, and exclusions reduce generalizability.

CONCLUSION

We found no significant differences in anterior and overall Bolton ratios among different sagittal molar classes or arch forms. The comparison among sagittal molar classes I, II, and III showed similar Bolton ratios. Different arch forms—ovoid, square, and tapered—revealed no significant variation in Bolton ratios.

Ethical Consideration

This study was approved by Institutional Review Board of Bhitai Dental and Medical College, Mirpurkhas, Pakistan.

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Conflict of Interest

Authors declared no conflict of interest.

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DATA SHARING STATEMENT: The data that support the findings of this study are available on request from the corresponding author. The data is not publicly available due to privacy or ethical restrictions.

AUTHORS' CONTRIBUTION

The following authors fulfill authorship criteria as per ICMJE guidelines;

Tariq, Khan SS: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.

Saleem F, Haider E: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.

Malik F: Analysis and interpretation of data, drafting the manuscript, final approval, agreed to be accountable for all the work.

Waqas: Analysis and interpretation of data, critical revision, final approval, agreed to be accountable for all the work.

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