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Correlation Between Facial Forms and Bolton Ratios in Class I and Class II Malocclusions

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ABSTRACT

Background and Objective: Facial morphology and dental arch dimensions coordination are fundamental aspects of orthodontic diagnosis and treatment planning. Tooth-size discrepancies, as quantified by anterior and overall Bolton ratios, may vary with facial form and malocclusion classification. Aim: To evaluate the correlation between facial forms (as measured by facial index) with anterior and overall Bolton ratios in Class I and Class II malocclusion subjects in Erbil city, using three-dimensional facial and intraoral digital scans.

Methods: The cross-sectional study included 128 participants divided by sex (males: 64, females: 64), malocclusion class (Class I: 64, Class II: 64), and facial form based on facial index thresholds (24 euryprosopic, 27 mesoprosopic, 77 leptoprosopic). Facial scans provided measurements of facial height (nasion–gnathion) and bizygomatic width, which were used to calculate the facial index. Digital intraoral scans were used to calculate anterior and overall Bolton ratios. Normality was assessed with the Shapiro–Wilk test. Group differences were analyzed using the Kruskal–Wallis and Mann–Whitney U tests, and associations were evaluated using Spearman correlation.

Results: No correlation was found between facial index and either anterior or overall Bolton ratios (P>0.05). However, anterior Bolton ratios differed significantly among facial form types (P=0.009), with pairwise analysis showing higher values in mesoprosopic forms compared to euryprosopic forms. No significant differences were found between Class I and Class II groups.

Conclusions: These findings indicate that although facial index does not predict anterior or overall Bolton ratios across malocclusion classes, differences in anterior ratios among facial types may still occur. Clinically, this emphasizes that Bolton ratio assessment should always be performed individually, rather than inferred from facial form or malocclusion type, to ensure precise diagnosis and treatment planning.

Keywords: Facial Forms; Bolton Ratio; Malocclusion; 3D Facial Scanning; Intraoral Scanning

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INTRODUCTION

Malocclusion is the most frequent dental problem and a public health concern due to its high prevalence and impact on function, aesthetics, and quality of life.[1] Class I malocclusion is the most common, followed by Class II, which demands an accurate appreciation of dental and skeletal coordination for successful orthodontic treatment.[2,3]

Differences in mesiodistal tooth width between the maxillary and mandibular teeth constitute an important diagnostic problem in orthodontics because they may prevent the establishment of proper intercuspation and finishing.[4,5] The Bolton analysis is a well-established technique that enables the estimation of these deviations by assessing the ratio of anterior to overall tooth sizes, allowing clinicians to recognize changes in proportion that can compromise tooth alignment and occlusion.[1,6]

The faces can be described in terms of the facial index (FI), which is expressed as the ratio of vertical (facial height which is measured from nasion (n), the midpoint of the frontonasal suture, to gnathion (gn), the lowest point on the mandibular border) to transverse (facial width measured as the bizygomatic breadth, the distance between the right and left zygion which is the most lateral points of the zygomatic arches) face size multiplied by 100 that is divided into leptoprosopic (long and narrow, FI ≥ 90), mesoprosopic (medium proportioned, FI 85–89.9), and euryprosopic (broad and short, FI < 85) types as defined by Farkas 1994.[7,8] These morphological differences are a critical part in orthodontic diagnosis, as they affect the severity and pattern of malocclusion, space analysis, crowding, and overbite and overjet relationships.[9,10]

Despite the clinical significance of Bolton tooth-size discrepancies, research exploring their association with facial form remains limited, particularly within Middle Eastern populations.[11] There is evidence of differences in anthropometric measurements across regions, which may affect facial form and dental characteristics, underscoring the importance of using locally derived findings.[12]

The development of three-dimensional (3D) scanning technology has revolutionized orthodontic diagnostics, as it now enables the provision of non-invasive, accurate, and reproducible measurements of skeletal and soft tissue.[13,14] 3D facial and intraoral scanners enable a comprehensive evaluation of facial form without any inconvenience, as well as an accurate determination of tooth widths, which is necessary for Bolton analysis.[14,15] These virtual tools provide full diagnosis and individualized treatment planning in contemporary orthodontics.[16]

METHODS

This cross-sectional observational study included 128 participants aged 20–25 years. The sample size was calculated using G*Power 3.1 based on a medium effect size (0.5), alpha level of 0.05, statistical power of 80%, and two-tailed testing for comparison between malocclusion groups. The sample was balanced by sex and dental classification, with 32 males and 32 females in each malocclusion group (Class I and Class II), resulting in four equal subgroups. Inclusion criteria required permanent dentition, dental Class I or Class II malocclusion verified clinically according to Angle's molar classification, and no previous orthodontic treatment or craniofacial anomalies. Class II subjects included Division I, Division II, and subdivision cases. Participants with missing teeth (except third molars) or heavy restoration, prosthesis, attrition, or craniofacial syndromes were excluded.[17]

Participants were classified according to Angle's molar classification into Class I and Class II groups. A non-probability consecutive sampling method was used for recruitment; therefore, no randomization was applied. An equal number of males and females were included in each group to ensure balanced representation.

Ethical approval was obtained from the Scientific Research Ethical Committee of Hawler Medical University, College of Dentistry (Reference No. HMUD,2425153; date 26/10/2024), in accordance with the Declaration of Helsinki.

Intraoral scans were obtained using a TRIOS 5 (3Shape, Denmark) intraoral scanner to produce precise digital models of both maxillary and mandibular arches.

Bolton analysis was performed using OrthoAnalyzer software, version 2022 (3Shape A/S, Denmark), which automatically segments the teeth and measures mesiodistal tooth widths to calculate anterior and overall Bolton ratios as shown in Figure 1. The anterior ratio was calculated as the sum of the mesiodistal widths of the six mandibu-

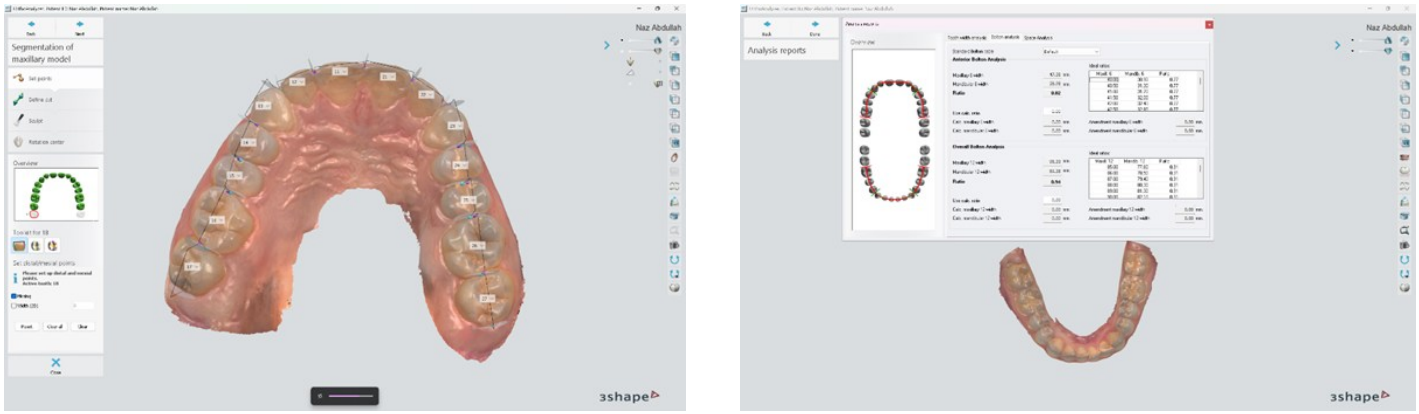

Figure 1. Digital model preparation (a) automatic teeth segmentation. (b) Bolton ratios report

lar anterior teeth divided by the sum of the six maxillary anterior teeth, multiplied by 100. The overall ratio was similarly derived using twelve teeth per arch.[1,6]

Three-dimensional facial scans were performed using the MetiSmile face scanner, version 1.5 (Shining 3D, Hangzhou, China), under consistent room lighting conditions and with the participant in a natural head position. Scanning was performed following the manufacturer's protocol. Each scan captured the entire facial surface, enabling measurement of nasion-to-gnathion vertical facial height and bizygomatic width. Data were processed using Metron Track software (Shining 3D, Hangzhou, China) to align, analyze, and export facial measurements as shown in Figure 2. The facial index was calculated as facial height divided by facial width multiplied by 100.7 Based on this index, participants were classified into leptoprosopic (FI > 90), mesoprosopic (85 ≤ FI ≤ 89.9), or euryprosopic (FI < 85) groups.[18]

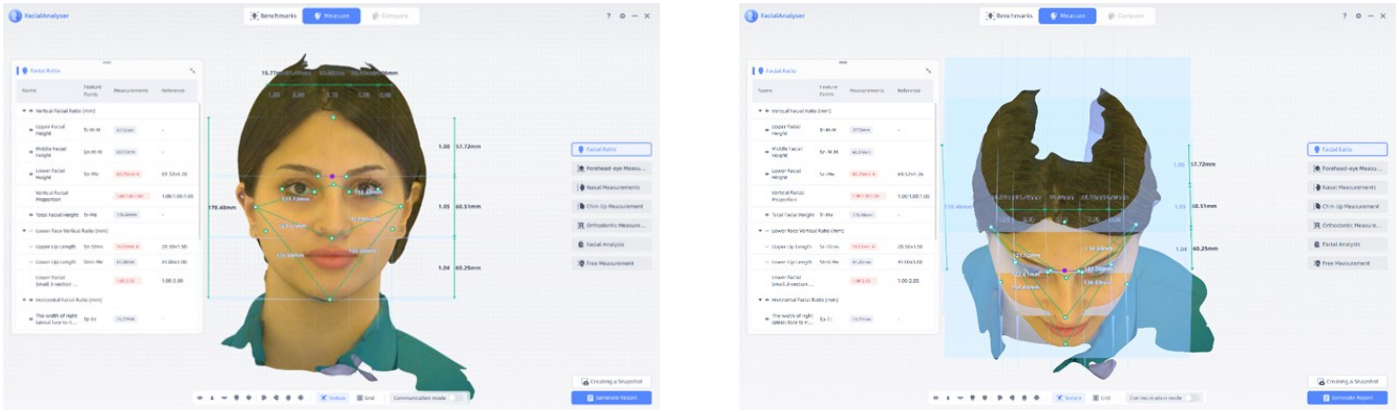

Figure 2. Automatic anthropometric landmarks are identified with linear measurements (a) frontal view, (b) viewing from above.

Statistical analysis was performed using IBM SPSS Statistics (version 25). Normality of distributions was assessed using the Shapiro-Wilk test. Since the data were not normally distributed ($p < 0.05$), non-parametric statistical methods were used. Kruskal-Wallis tests followed by pairwise Mann-Whitney U comparisons with Bonferroni correction, in addition to Spearman's correlation analysis, were used to evaluate relationships among facial form classification, Bolton ratios, and malocclusion type. Statistical significance was set at $p < 0.05$. No missing data were identified, and all participants had complete records available for analysis.

RESULTS

Table 1 shows descriptive statistics for Bolton Ratios (Anterior and Overall), and Facial Measurements (Nasion to Gnathion (mm) and Bizygomatic Breadth (mm)). The mean Anterior Bolton Ratio was 79.62% (SD = 1.98), and the Overall Bolton Ratio was 91.91% (SD = 1.96). The Facial Form

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Index had a mean of 91.20 (SD = 9.25). The relatively large standard deviations in facial height, bizygomatic breadth, and facial index likely reflect both biological variability and technical aspects of 3D scanning. Natural head position is reproducible but allows small deviations that influence vertical and transverse measures.[19] Moreover, comparative studies of 3D scanners show region-dependent differences, with midline landmarks more stable than lateral areas.[20] These factors explain the dispersion without undermining the reliability of our findings.

Table 1. Descriptive Statistics for Bolton Ratios and Facial Measurements

	N	Minimum	Maximum	Mean	Std. Deviation
Anterior Bolton Ratio (%)	128	72.00	86.00	79.62	1.98
Overall Bolton Ratio (%)	128	82.00	97.00	91.91	1.96
Nasion to Gnathion (mm)	128	82.05	140.23	111.43	12.27
Bizygomatic Breadth (mm)	128	96.91	148.97	122.53	10.72
Facial Form Index (%)	128	64.05	125.83	91.20	9.25

Table 2 presents the Spearman correlation coefficients among the Anterior Bolton Ratio. A statistically significant moderate positive correlation was observed between Anterior and Overall Bolton Ratios ($r = 0.345$, $p < 0.001$), indicating that higher anterior ratios tend to associate with higher overall ratios. In contrast, neither Anterior Bolton Ratio ($r = 0.047$, $p = 0.601$) nor Overall Bolton Ratio ($r = 0.061$, $p = 0.497$) showed significant correlations with Facial Form Index. These results suggest that tooth-size discrepancies, as measured by Bolton ratios, vary independently from the vertical-to-transverse facial proportions in this sample. Because the variables were not normally distributed, median and interquartile range values were also reviewed during analysis and showed patterns consistent with the reported mean values.

Table 2. Spearman's rho Correlation Between Facial Form Index and Bolton Ratios

Variables		Anterior Bolton Ratio (%)	Overall Bolton Ratio (%)	Facial Form Index (%)
Anterior Bolton Ratio (%)	Correlation Coefficient	1.000	0.345**	0.047
	p-value	.	0.001	0.601
Overall Bolton Ratio (%)	Correlation Coefficient	0.345**	1.000	0.061
	p-value	<0.001	.	0.497
Facial Form Index (%)	Correlation Coefficient	0.047	0.061	1.000
	p-value	0.601	0.497	.

A comparison of Bolton Ratios between Class I and Class II. Mann-Whitney U tests revealed no statistically significant differences in Anterior ($U = 1851.5$, p-value = 0.351) or Overall ($U = 1844.0$, p-value = 0.332) Bolton Ratios between Class 1 and Class 2 dental classifications, with both comparisons demonstrating small effect sizes ($r < 0.1$).

Figure 3 shows a comparison between the mean of Anterior and Overall Bolton Ratios across dental

classification. In both dental classes, the Overall Bolton ratio is greater than the Anterior Bolton ratio (92.13% vs 79.38%) in Class I and (91.71% vs 79.86%) in Class II, respectively.

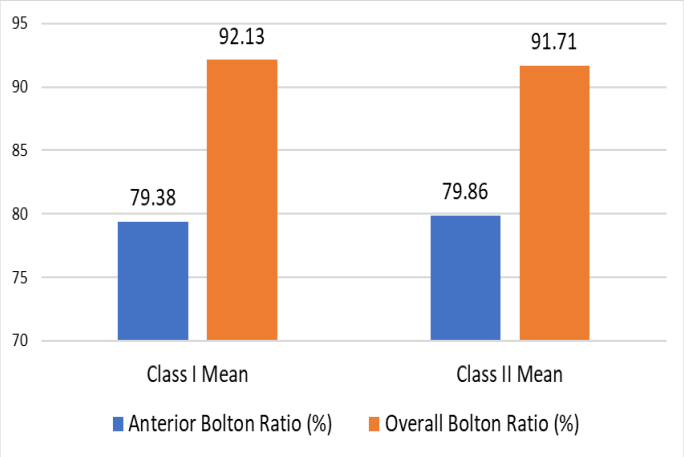

Figure 3. Comparison between the mean of Anterior and Overall Bolton Ratio across dental classification

DISCUSSION

The present study investigated whether facial form, as measured by the facial index, is associated with Bolton tooth-size ratios in individuals with Class I and Class II malocclusions. There was no direct correlation between facial index and anterior/overall Bolton ratios. The potential influence of dental classification was also examined on these ratios.

Although Class II malocclusion is often associated with an abnormality in jaw and tooth relationships, our results, mirroring those of several previous studies, showed no statistically significant difference in Bolton ratios between Class I and Class II subjects.[21,22] This supports the hypothesis that sagittal malocclusion type alone may not be a reliable predictor of tooth-size discrepancies.[23]

Additionally, the lack of correlation between facial index and Bolton ratios in the present study aligns with earlier findings by Azeem et al., who investigated the relationship between vertical facial types (mesofacial, dolichofacial, and brachyfacial) and Bolton tooth-size ratios.[11] Their results also further support the idea that tooth-size discrepancies may be largely independent of general facial morphology.[11]

Although these differences were not statistically significant, the lower anterior Bolton mean observed in Class II participants suggests minor variations that could still have clinical implications.[22] These small anterior discrepancies, if left unrecognized, could impact overjet correction or anterior alignment.[24] Therefore, even when statistical tests do not show strong associations, individualized tooth-size analysis remains essential for optimal treatment outcomes.[1]

Previous studies investigating the correlation between facial form and Bolton ratios have produced mixed results. For example, Azeem et al. found no statistically significant relationship between vertical facial types (mesofacial, dolichofacial, and brachyfacial) and either anterior or overall Bolton ratios, concluding that the two variables are not correlated. Similarly, several other studies have reported that variations in facial morphology do not consistently predict tooth-size discrepancies, as also reported by Vorloeper et al.[25] However, there remains a scarcity of studies assessing this relationship within specific malocclusion classes (e.g., Class I and Class II). Most existing research evaluates facial form or dental classification in isolation. Our findings, therefore, contribute to filling this gap by analyzing both factors concurrently.[11,25]

This study has certain limitations. The sample was limited to young adults aged 20–25 years, which may affect how generalizable the findings are to other age groups. Only Class I and Class II malocclusions were included; Class III and other malocclusion types were not examined. All participants were recruited from a single geographic area, which might reduce how applicable the results are elsewhere. Lastly, the cross-sectional design prevents the assessment of changes over time.

Future studies could include a broader age range, multi-center samples, and more types of malocclusions, including Class III, to improve representativeness and statistical power. Using longitudinal designs and advanced 3D analysis methods may also help explain how facial proportions relate to dental morphology across different populations.

CONCLUSION

The findings of this study showed no significant correlation between facial form and either anterior or overall Bolton ratios. Likewise, no meaningful differences were observed between Class I and Class II malocclusions. These results indicate that variations in tooth size are largely independent of facial morphology and dental classification, emphasizing that clinicians should not rely solely on facial type or malocclusion class when assessing

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tooth-size discrepancies. Individualized Bolton analysis remains essential for accurate diagnosis and treatment planning.

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Conflict of Interest

The authors declare no conflicts of interest.

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