Iran J Orthod. 2024 June; 19(1):e1152. doi:10.32592/ijorth.19.1.1152.
Published online 2024 June 1
Original Article **Open Access**

Evaluation of Bolton's Ratio in Normal Occlusion and Different Types of Malocclusion in Iranian Population

Iman Parisay [1], Fatemeh Mazhari [1], Roozbeh Rashed [2], Minoo Zohouryan [3], Bahareh Sanaee [3]*

[1] Professor, Department of Pediatrics, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran
[2] Orthodontist, Toronto, Canada
[3] Dentist, Department of Pediatrics, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran

*** Corresponding Author:** Bahareh Sanaee
Address: Department of Pediatrics, School of Dentistry, Azadi Square, Mashhad, Iran.
Email: snaeebahar@gmail.com

Received: 2024 March 29; **Revised:** 2024 May 01; **Accepted:** 2024 May 17

Abstract

Background: The Bolton analysis is commonly used by orthodontists. The Bolton ratios of different populations are significantly different from the standard values of Bolton. This study sought to examine the Bolton's anterior and overall ratios in various malocclusion types in Mashhad, Iran, in contrast to the Bolton's standards.
Methods: This descriptive-analytical study was conducted on 240 study models of patients (121 males and 119 females) in four groups (n= 60 cases) of normal occlusion, Class I, Class II, and Class III. The mesiodistal dimensions of the teeth were measured twice using a digital caliper. The anterior and overall ratios of Bolton were calculated. Statistical analysis was conducted utilizing SPSS 18.0.
Results: The mesiodistal width of the maxillary lateral incisors in normal occlusion cases was greater than that in Class I, Class II, and Class III malocclusions (P<0.05). Conversely, the mesiodistal width of the maxillary first and second premolars was the greatest in Class II and the smallest in Class III malocclusion (P<0.05). Correlation was not observed between dental ratios (anterior and overall) and gender or malocclusion groups (P>0.05). Furthermore, the anterior ratio was significantly higher than the Bolton's standard in Class I and III malocclusion groups (P<0.05). The normal occlusion group's overall ratio was significantly lower than the Bolton's original ratio (P<0.05).
Conclusion: Implementing the Bolton analysis in the population of Mashhad, Iran should be approached with caution.

Keywords: Tooth, Malocclusion, Orthodontics, Bolton's Ratio, Iran

Background

Mesiodistal tooth width is a crucial factor in orthodontic treatment planning (1). "Tooth size" has been introduced as the "seventh essential key" to achieve normal occlusion (2). Normal occlusion is an essential factor for proper articulation, mastication, and respiration (3). To achieve this goal, there should not be any tooth-size discrepancy amid the upper and lower arches (4).

Tooth size discrepancies can lead to various types of orthodontic problems. Large discrepancies in the mesiodistal widths of mandibular and maxillary anterior teeth, with greater maxillary teeth, can result in deep overbite, excessive overjet, and anterior crowding of the maxilla. Similarly, larger dimensions of mandibular teeth can lead to an edge-to-edge relationship of incisors, spacing of maxillary anterior teeth, crowding in the

anterior segment of the mandible, and inappropriate molar relationship (1, 5).

Tooth size varies among different races and genders (4, 6). Various methods and analyses are available to assess tooth size (7-10). Analyzing tooth size discrepancies prior to orthodontic treatment helps to determine the necessity of tooth extraction (4). The Bolton's analysis, developed by Bolton in 1958, is a commonly used method by orthodontists due to its accuracy, simplicity, and efficiency (4, 10, 11).

The Bolton ratios in various racial populations differ significantly from the standard values provided by Bolton (12, 13). This may arise from the fact that the Bolton's analysis is founded on the normal tooth size of the Caucasians (10). Therefore, its applicability in other populations requires verification. This study aimed to evaluate the anterior and overall Bolton ratios in different types of malocclusions in Mashhad, Iran in contrast to the Bolton's standards.

Methods

This cross-sectional study was implemented on study models of subjects treated in the Pediatric Department of the Dentistry Faculty of Mashhad University of Medical Sciences.

The sample size was calculated to be 240, with 60 models allocated to each group with a confidence interval of 95% and 80% power as derived from a study by Fattahi et al (14). A total of 180 pairs of study models from individuals aged 13-15 years, who had received treatment in the Pediatric Department of the Dentistry Faculty, Mashhad University of Medical Sciences, Mashhad, Iran, were randomly selected and divided into 3 groups as per the Angle classification:

Group 1 (n=60) with Class I malocclusion

Group 2 (n=60) with Class II malocclusion

Group 3 (n=60) with Class III malocclusion

The study models of the study by Talebi et al, (15) with normal occlusion were randomly selected for the fourth study group (n=60).

The models included in this study met the pre-specified criteria, which included the presence of each permanent teeth (excluding the permanent third molar), reaching the occlusal surface, and no signs of restoration, interproximal caries, attrition, or dental anomalies. Patients with a history of orthodontic treatment were not included in the study.

Mesiodistal widths of the first molars, first and second premolars, canine teeth, and incisor teeth of both jaws were measured by a single investigator using a digital Caliper (EKO Turbo, China) with an accuracy of ± 0.01 mm. Each tooth was measured twice to minimize errors. In cases where measurements differed, the mean value was recorded. The intra-examiner reliability was determined to be 0.2 mm. The anterior and overall ratios were calculated according to the Bolton's analysis as follows (10):

Anterior ratio: ∑ of widths of the lower six anterior teeth / ∑ widths of the upper six anterior teeth $\times 100$

Overall ratio: ∑ of widths of the lower 12 teeth / ∑ of widths of the upper 12 teeth $\times 100$

Statistical analysis:

Data were statistically analyzed with SPSS version 18.0 (SPSS Inc., Chicago, USA). The distribution of age and gender among the study groups was assessed using the Kruskal Wallis and Chi-square tests. One-way ANOVA and Tukey's post hoc test compared the mesiodistal widths of the teeth among the groups. Additionally, ANOVA compared the anterior and overall Bolton's ratios amid the groups. Independent sample t-test was utilized to find differences between males and females in the Bolton's ratio. Also, one-sample t-test was applied to compare the mean values of both anterior and overall Bolton's ratios of all groups with the Bolton's standard values. The threshold for statistical significance was established at $P<0.05$, and a 95% confidence interval was determined for all analyses.

Results

The samples for this study comprised of 240 Iranian individuals (121 males and 119 females), with 60 cases in each group. The Chi-square test showed no meaningful difference in sex distribution amid the study groups (P=0.415, Table 1). However, the Kruskal-Wallis test demonstrated a significant difference in age distribution among the study groups (P=0.001, Figure 1).

ANOVA revealed significant differences in the mesiodistal widths of the maxillary permanent lateral incisors, first premolars, and second premolars among the study groups (Table 2).

Table 3 compares the mesiodistal widths of the maxillary permanent lateral incisors, first premolars, and second premolars among the study groups. One-way ANOVA did not indicate any meaningful difference between the anterior (P=0.067) and overall (P= 0.05) ratios of the study groups (Table 4).

Independent sample t-test showed no significant difference in the anterior or overall

ratios between males and females within each study group (Table 5).

Table 6 compares both the Bolton's anterior and overall ratios observed in each group with standard values, which were defined as 77.2% ± 1.65% and 91.3% ± 1.91%, respectively.

Table 1. The comparison of distribution of gender in the study groups using Chi square test

Gender	Study groups				P-value
	Class III malocclusion Number (%)	Class II malocclusion Number (%)	Class I malocclusion Number (%)	Normal occlusion Number (%)	
Male	31(51.7)	31(51.7)	25(41.7)	34(56.7)	0.415
Female	29(48.3)	29(48.3)	35(58.3)	26(46.3)	
Total	60(100.0)	60(100.0)	60(100.0)	60(100.0)	

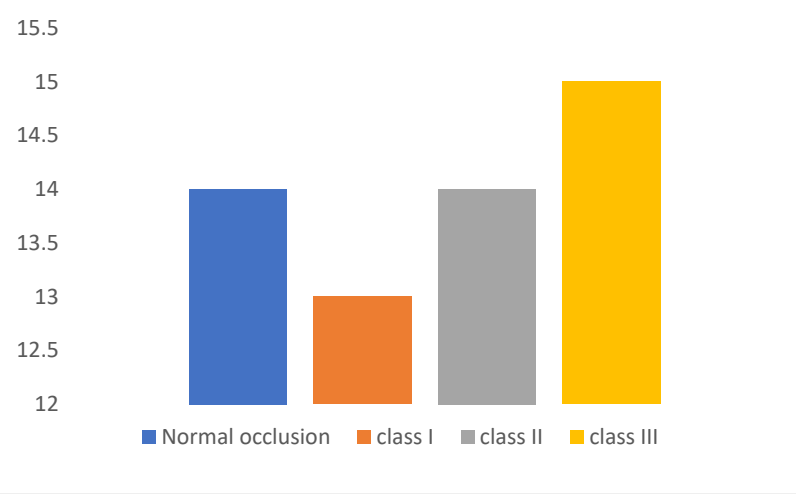

Figure 1. Distribution of age in the study groups

Table 2. The comparison of the mean and standard deviation of mesiodistal size of the teeth among groups using ANOVA

Tooth	Study groups				P-value
	Class III malocclusion Mean±SD	Class II malocclusion Mean±SD	Class I malocclusion Mean±SD	Normal occlusion Mean±SD	
Maxillary Central	8.41±0.62	8.41±0.53	8.53±0.54	8.56±0.57	**0.311**
Mandibular Central	5.37±0.43	5.28±0.38	5.42±0.34	5.38±0.36	**0.228**
Maxillary Lateral	6.74±0.61	6.63±0.69	6.82±0.54	7.05±0.71	***0.004**
Mandibular Lateral	5.87±0.53	5.75±0.31	5.94±0.41	5.86±0.39	**0.086**
Maxillary Canine	7.60±0.47	7.67±0.44	7.79±0.46	7.68±0.45	**0.143**
Mandibular Canine	6.64±0.58	6.71±0.50	6.81±0.49	6.71±0.46	**0.338**
Maxillary 1st premolar	6.85±0.39	7.13±0.37	7.05±0.36	7.05±0.41	***0.001**
Mandibular 1st premolar	6.85±0.53	7.03±0.44	7.04±0.38	7.05±0.42	**0.053**
Maxillary 2nd premolar	6.59±0.46	6.86±0.51	6.74±0.40	6.82±0.42	***0.009**
Mandibular 2nd premolar	7.11±0.51	7.25±0.45	7.20±0.54	7.16±0.47	**0.449**
Maxillary 1st molar	10.30±0.42	10.48±0.45	10.24±0.48	10.46±0.52	**0.166**
Mandibular 1st molar	10.84±0.76	10.94±0.64	10.98±0.65	10.85±0.63	**0.557**

*Significant at the level of P-value< 0.05.

Table 3. Comparison of the mesiodistal width of maxillary lateral incisors, and first and second premolars among the study groups using the Tukey's test

Tooth	Study groups Mean difference (P-value)					
	Class II vs. Class III	Class I vs. Class III	Class I vs. Class II	Normal occlusion vs. Class III	Normal occlusion vs. Class II	Normal occlusion vs. Class I
Maxillary lateral incisor	-0.112 (0.778)	0.08 (0.118)	0.192 (0.365)	0.310* (0.045)	0.422* (0.002)	0.230 (0.209)
Maxillary first premolar	0.280* (0.001)	0.197* (0.029)	-0.083 (0.643)	0.197* (0.029)	-0.833 (0.642)	-0.0001 (1.00)
Maxillary second premolar	0.262* (0.010)	0.144 (0.303)	-0.117 (0.491)	0.227* (0.033)	-0.034 (0.975)	0.082 (0.752)

*Significant at P<0.05.

Table 4. Comparison of anterior and overall Bolton's ratios among the study groups using one-way ANOVA

Variable	Study groups				P-value
	Class III malocclusion Mean±SD	Class II malocclusion Mean±SD	Class I malocclusion Mean±SD	Normal occlusion Mean±SD	
Anterior ratio	78.65±3.65	78.2±3.95	78.62±3.22	77.13±3.22	0.067
Overall ratio	91.3±1.91	91.09±3.11	91.69±3.21	90.32±2.27	0.050

Table 5. Comparison of anterior and overall Bolton's ratios between males and females in each study group using independent sample t-test

Study groups	Variable	Gender		P-value
		Female Mean±SD	Male Mean±SD	
Class III malocclusion	Anterior ratio	78.43±3.75	78.85±3.59	0.663
	Overall ratio	91.40±3.29	92.15±4.05	0.442
Class II malocclusion	Anterior ratio	78.44±4.09	77.99±3.87	0.664
	Overall ratio	91.41±3.83	90.78±2.27	0.438
Class I malocclusion	Anterior ratio	78.26±3.11	79.13±3.36	0.304
	Overall ratio	91.24±2.56	92.31±3.93	0.210
Normal occlusion	Anterior ratio	77.17±3.26	77.11±3.23	0.937
	Overall ratio	90.42±2.46	90.24±2.97	0.806

SD: Standard deviation

Table 6. Comparison of anterior and overall ratios of the study groups with Bolton's reference values using one-sample t-test

	Study groups			
	Class III malocclusion Mean±SD	Class II malocclusion Mean±SD	Class I malocclusion Mean±SD	Normal occlusion Mean±SD
Anterior ratio	78.65±3.65	78.2±3.95	78.62±3.22	77.13±3.22
P-value	0.007*	0.080	0.004*	0.885
Overall ratio	91.3±1.91	91.09±3.11	91.69±3.21	90.32±2.27
P-value	0.379	0.665	0.435	0.029*

*Significant at P<0.05 SD: Standard deviation

Discussion

Various methods and analyses have been developed to assess the size of maxillary and mandibular teeth so as to determine an ideal occlusion. Since such analyses have been designed for specific populations, their accuracy must be validated for use in other populations. This study aimed to evaluate the Bolton's ratios amid different types of malocclusions in the Iranian population of Mashhad, Iran.

In the current research, notable variations were observed between the groups under study in the mesiodistal widths of maxillary permanent lateral incisors, first premolars, and second premolars. The mesiodistal width of maxillary lateral incisors in normal occlusion cases was greater than that in Class I, Class II, and Class III malocclusions. Conversely, the mesiodistal width of the maxillary first and second premolars was the greatest in Class II and the smallest in Class III malocclusion. This finding could be related to the fact that maxillary teeth of Class II malocclusion cases tend to be larger than those in Class I and III malocclusions (13, 16). Nevertheless, the present study focused on the correlation between mesiodistal tooth dimensions and skeletal malocclusion. Rakhshan et al. (17) reported a statistically significant difference in buccolingual dimensions of mandibular central and lateral incisors, and maxillary lateral incisors among patients with Class I, II, and III skeletal malocclusions. Furthermore, they considered race and gender as influential factors for differences in tooth dimensions, emphasizing that the mesiodistal and buccolingual dimensions of the mandibular canine teeth exhibit the greatest difference between genders. This discrepancy was attributed to the considerable variation in the duration of amelogenesis of the mandibular canine teeth between males and females (17).

In the current research, the anterior ratio was significantly higher than the Bolton's standard in Class I and III malocclusion groups. The overall ratio of the normal occlusion group was significantly smaller in comparison to the original Bolton's values. Previous studies from different areas of the country have shown different results. Mollabashi et al.'s research (13) on the Iranian population stated that normal occlusion samples had greater dental ratios than the original Bolton values. However, Karimzadeh et al. (18) reported that the anterior ratio of Class I group in the Iranian population was lower than the Bolton's standard value. However, meaningful difference was not determined between the overall ratio of the groups and the Bolton's reference value. They concluded that the difference between dental ratios and Bolton's standard values was due to racial differences (18). Additionally, various studies from different countries have demonstrated that the Bolton's ratios of their study populations differed from the Bolton's standards (16, 19-21).

Mustafa and Abuaffan (19), Hussein et al, (20) and Lavelle (16) declared that the Bolton ratios could be inapplicable to their study populations. Mageet et al. (21) found a significant difference between dental ratios of patients with Class III malocclusion and the Bolton's standard values; however, the difference was insignificant in Class I and II groups. They suggested that the difference is probably due to differences in gender and race (21).

Generally, despite the importance and high diagnostic efficiency of the Bolton analysis, it is important to note that variables such as race, sex, width of anterior teeth, inter-incisal angle, and type of malocclusion are not considered in this analysis, and may pose inherent limitations to this analysis (22).

Using a digital caliper with an accuracy of 0.01 mm was one limitation of the present study. Employing more precise instruments to gauge tooth dimensions may enhance the accuracy of the

results. Also, by increasing the sample size and selecting more diverse samples from different areas of the country, a higher level of accuracy may be achieved.

Conclusion

The use of Bolton analysis in the population of Mashhad should be approached with caution.

References

1. Valentini LM, Fantasia E. Evaluation Of The Correlation Between Tooth Size-arch Length And Bone Dimension For The Correct Position Of Orthodontic Miniscrew: A Literature Review. WebMedCentral. 2019;10(6):WMC005587.
2. Andrews LF. The six keys to normal occlusion. Am J Orthod. 1972;62(3):296-309. PMID: 4505873 doi: 10.1016/s0002-9416(72)90268-0
3. Ackerman JL, Proffit WR, Sarver DM, Ackerman MB, Kean MR. Pitch, roll, and yaw: describing the spatial orientation of dentofacial traits. Am J Orthod Dentofacial Orthop. 2007;131(3):305-10. PMID: 17346584 doi: 10.1016/j.ajodo.2006.05.032
4. Jabri MA, Wu S, Zhang Y, Ma J, Wang L. A Review on Comparison of Tooth Size Discrepancies among Angle's Class I, II, and III Malocclusion: Is There a Significance?. J Contemp Dent Pract. 2019;20(8):994-9. PMID: 31797860 doi:10.5005/jp-journals-10024-2615
5. Lone IM, Zohud O, Midlej K, Awadi O, Masarwa S, Krohn S, et al. Narrating the Genetic Landscape of Human Class I Occlusion: A Perspective-Infused Review. J Pers Med. 2023;13(10):1465. PMID: 37888076 doi: 10.3390/jpm13101465
6. Abuhassan SM, Asiry MA. Intermaxillary tooth-size ratios in Saudis: A systematic review. JInt Oral Health. 2021;13(6):533. doi: 10.4103/jioh.jioh_40_21
7. Chandra D. A New Regression Equation For Prediction Of Width Of Unerupted Canine And Premolars Of Maxillary Arch In: Bbdcods. 2022.
8. Abaid S, Zafar S, Kruger E, Tennant M. Size estimation of unerupted canines and premolars using various independent variables: a systematic review. J Orofac Orthop. 2023;84(3):164-77. doi: 10.1007/s00056-022-00392-9
9. Eliewy Saloom J, Muslim Al Azzawi A, Nahidh M, Chaffat Auliawi Al-Mayahi S, Sahib Mahdi B. Predicting canine and premolar mesiodistal crown diameters using regression equations. Int J Dent. 2021;2021:1-5. doi: 10.1155/2021/9990417
10. Bolton WA. Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. Angle Orthod. 1958;28(3):113-30. doi: 10.1043/0003-3219(1958)028<0113:DITSAI>2.0.CO;2
11. Turtinen H, Sarja M, Hyvärinen J, Pirhonen P, Pesonen P, Pirttiniemi P, et al. Associations between Bolton ratio and overjet deviations in a Finnish adult population. Acta Odontol Scand. 2021;79(8):593-9. PMID: 33896362 doi: 10.1080/00016357.2021.1918348
12. Moon HR. Applicability of Bolton anterior and overall ratios for the Canadian Filipino population. [master's thesis]. Winnipeg, Manitoba: University of Manitoba. 2023.
13. Mollabashi V, Soltani MK, Moslemian N, Akhlaghian M, Akbarzadeh M, Samavat H, et al. Comparison of Bolton ratio in normal occlusion and different malocclusion groups in Iranian population. Int orthod. 2019;17(1):143-50. PMID: 30770330 doi:10.1016/j.ortho.2019.01.005
14. Fattahi HR, Pakshir HR, Hedayati Z. Comparison of tooth size discrepancies among different malocclusion groups. Eur J Orthod. 2006;28(5):491-5. PMID: 16763087 doi: 10.1093/ejo/cjl012
15. Talebi M, Parisay I, Sarraf A, Mazhari F. Regression equations for predicting the size of unerupted canines and premolars in an Iranian population: a pilot study. J Contemp Dent Pract. 2010;11(5):33-40. PMID: 20978722 doi: 10.5005/jcdp-11-5-33
16. Lavelle C. Maxillary and mandibular tooth size in different racial groups and in different occlusal categories. Am JOrthod. 1972;61(1):29-37. PMID: 4500185 doi: 10.1016/0002-9416(72)90173-x
17. Rakhshan V, Ghorbanyjavadpour F, Ashoori N. Buccolingual and Mesiodistal Dimensions of the Permanent Teeth, Their Diagnostic Value for Sex Identification, and Bolton Indices. Biomed Res Int. 2022;2022:8381436. PMID: 35187172 doi: 10.1155/2022/8381436
18. Karimzadeh B, Abdollahzadeh T, Eidi A, Kachoei M. Anterior and Overall Bolton ratios among Orthodontic Patients with Different Malocclusions. Iran J Orthod. 2021;16(2):1-7. doi: 10.22034/ijo.2022.546505.1025
19. Mustafa RA, Abuaffan AH. Bolton tooth size analysis in a sample of Sudanese adults. BrazDent Sci. 2021;24(2). doi: 10.14295/bds.2021.v24i2.2125
20. Hussein FA, Mohamed RE, El-Awady AA, Ali MM, Al-Khalifa HN, Abdallah KF, et al. Digital evaluation of Bolton's tooth size discrepancies among different malocclusions categories of Egyptian adolescent orthodontic population: A retrospective study. Int Orthod. 2022;20(3):100660. PMID: 35739004 doi: 10.1016/j.ortho.2022.100660
21. Mageet AO, Fanas ASA, Shaheen IK, Hadi KM, Abdelmagied MH. Variations of the Mesiodistal width of permanent teeth in a sample of patients attending Ajman University Dental College. Res J Pharm Technol. 2021;14(12):6565-72. doi: 10.52711/0974-360x.2021.01136
22. Hasija N, Bala M, Goyal V. Estimation of tooth size discrepancies among different malocclusion groups. Int J Clin Pediatr Dent. 2014;7(2):82. PMID: 25356005 doi: 10.5005/jp-journals-10005-1242.