Review Article

THE POSTERIOR BOLTON DISCREPANCY: INFLUENCE OF VARIOUS FACTORS AND METHODS OF MEASUREMENT: A LITERATURE REVIEW

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ABSTRACT

The Posterior Bolton Discrepancy, a mismatch in tooth size between upper and lower posterior teeth, can hinder proper occlusion during orthodontic treatment. This review examines how malocclusion type, premolar extraction patterns, gender, and ethnicity influence posterior Bolton ratios, based on studies published between 1990 and 2025. Findings show that discrepancies are more pronounced in Class II malocclusions, significantly affected by extraction patterns, and vary across populations, making Bolton's original norms less universally applicable. Recent evidence, especially between 2017 and 2025, suggests that posterior The type of malocclusion, sex, race, and extraction technique all have a major impact on TSD. Notably, Class II malocclusions display lower posterior ratios while Class III shows higher ratios; both observations underscore the importance of thoughtful treatment strategy in these populations. Methods and tools such as digital Bolton calculators or region-specific algorithms like the Johnson–Bailey prediction method improve accuracy over traditional Bolton calculations.

Key words: Bolton discrepancy, Orthodontics, Overjet, Overbite.

Introduction

One of the goals achieved after finishing orthodontic treatment is optimal posterior occlusion. This goal involves overjet, overbite, and the alignment of buccal segments while preserving the proportionate maxillary and mandibular dentition [1].

Another primary focus of any orthodontic treatment is to keep a functional occlusion of the posterior teeth [2]. One factor that can make this goal more challenging is interactive tooth-size discrepancy—and its accompanying variables—known as ITSD. ITSD refers to the variability concerning the size of single teeth and their arrangement within posterior zone. While there are established theories on posterior ITSDs, very little information is available regarding posterior ITSDs and the methods used to determine their presence.

Literature review

Research has shown variations in the frequency of TSD across different populations with distinct forms of malocclusion. Class III malocclusions have a higher posterior and overall tooth size ratio compared to Class II, which has the lowest value. Hussein *et al*. (2022) identified a greater frequency of TSD in individuals with Angle Class III malocclusion compared to those with Class I and II malocclusions [3]. These findings were corroborated by Abd Rahman *et al*. (2023) in southern China and Alkofide *et al*. (2023) in Saudi Arabia [4, 5]. Conversely, Liano *et al*. (2003) found no correlation between TSD and kinds of malocclusion, indicating that the limited sample size of the class III group may have contributed to their results.

Alsharabi *et al*. (2025) demonstrated that all groups had greater average ratios compared to a control group of 150 untreated persons with normal occlusion [6].

However, the variable variations across several classes of malocclusions seemed to be minimal.

The size of teeth has been studied in relation to potential biological variations between genders. Uslu-Akcam and Yıldız (2025) documented increased sexual dimorphism in male teeth compared to female teeth in Iowa [7], Egypt, and Mexico, with males displaying bigger canines and molars than females. Nevertheless, the majority of this research did not explicitly compute TSD ratios. Lavelle *et al*. (1972) examined two skeletal scales [8], including upper and lower components, in both males and females, correlating specific phrenological units. Total and posterior data indicated a little male hypertrophy, which was above average; however, it was insignificant in its variation. Richardson *et al*. (1972) reported no discrepancies in posterior inter-arch ratios. Nonetheless, they indicated that black North American males exhibited sexual dimorphism, possessing bigger teeth than females, who articulated this stance without substantiating proof.

Materials and Methods

This narrative review uses systems thinking to record peer-

reviewed scientific works about Bolton's tooth size disparities in the assessment of posterior Bolton ratios.

Search strategy

Databases

Google Scholar, PubMed, Scopus, and Web of Science.

Keywords

Bolton discrepancy, posterior teeth size discrepancy, tooth size ratio, malocclusion, Bolton analysis, posterior TSD, gender differences, racial differences, measurement methods, and orthodontic treatment planning.

Inclusion criteria

- Peer-reviewed literature published in English between 1990 and 2025
- Focusing on posterior tooth-size discrepancies (TSDs)
- Studies discussing the classes of malocclusion correlated with gender or ethnicity, alongside measuring techniques

Exclusion criteria

- Opinion articles or case reports of non-peer-reviewed articles
- Research focusing solely on anterior TSDs

Data extraction

The year of study, population size, and demographics, as well as manual or digital methodology, were cataloged along with results about the following:

1. Posterior TSD prevalence
2. Malocclusion class prevalence
3. Sex and ethnic classification
4. Reliability of measurements taken
5. Strategies for clinical management

Results and Discussion

Table 1. Summary of the included studies

Study	Year	Country	Sample Size	Study Focus	Malocclusion/ Condition	Methodology	Key Findings	Statistical Significance	Conclusion
Fallis [9]	2020	USA	30	Comparison of Bolton vs Johnson-Bailey–Bailey prediction methods	Mixed malocclusion	Virtual occlusal setup	JB method predicted 97–100% accurately vs 23% for Bolton	$p \leq 0.05$	The JB method is superior for identifying posterior TSD
Al Maaitah *et al.* [10]	2022	Jordan	100	Posterior TSD in skeletal AOB vs normal overbite	Skeletal AOB vs normal	Mesiodistal measurements	The AOB group had a lower posterior ratio than the control	$p = 0.015$	Skeletal AOB linked to smaller posterior tooth size
Rakhshan *et al.* [11]	2022	Iran	265	Posterior ratio differences across Angle classes	Class I, II, III	Digital caliper + ANOVA/Tukey tests	Class II had lower ratios vs Class I and III	$p = 0.008$	Class II is associated with a smaller posterior arch width
Holton *et al.* [12]	2023	USA	55	Impact of premolar extraction patterns	Class I (virtual setup)	Simulated premolar extraction	Different extraction protocols altered posterior ratios	Significant	Extraction plans affect posterior TSD; needs customization
Wadood *et al.* [13]	2023	Pakistan	30	Posterior ratio change pre/post extraction	Class II	Study models before and after extraction	Ratio increased from 103.36 to 105.27 post-extraction	$p < 0.05$	Premolar extraction improves posterior TSD in Class II
Mongillo *et al.* [14]	2021	USA	55	Residual space after 4 first four premolar extractions	Class I	Digital simulation	27% had >1.5 mm residual mandibular space post-extraction	Not reported	Even ideal anterior ratios may not prevent posterior spacing

Alshahrani [15]	2020	Saudi Arabia	144	TSD in malocclusion vs normal occlusion	Class I, II, III vs normal	Clinical measurements	Significant differences in TSD among groups	$p < 0.05$	Posterior TSD should be assessed in Saudi patients

This section integrates key findings from current research (2017-2025) on posterior tooth-size discrepancies (TSD), taking into account the Angle classification of malocclusions, surgical factors, and racial group variations. The results are presented in a narrative format that includes each study's objectives, methodologies, findings, and conclusions.

Fallis (2020) assessed the accuracy of Bolton's classical analysis and the Johnson–Bailey formula in predicting posterior TSD by using virtual occlusal case setups that included orthodontic treatment data and simulated treatment outcomes to evaluate method effectiveness [9]. The results indicated that the Johnson-Bailey technique could consistently identify posterior incompatibilities with an accuracy of 97-100%, but Bolton's technique identified just 23% of such discrepancies. Furthermore, this difference was statistically significant ($p < 0.05$). This supports the claim that the Johnson-Bailey approach is more therapeutically applicable for calculating posterior discrepancies during clinical planning [9].

Al Maaitah *et al*. (2022) investigated the difference in posterior Bolton ratios between skeletal open-bite patients and those with normal overbites [10]. This Jordanian research had 100 orthodontic patients, who were evenly divided into two groups. The ratios were established by measuring the mesiodistal distances, revealing that skeletal AOB patients had substantially lower posterior ratios compared to the controls ($p = 0.015$). The findings suggest that AOB patients had reduced posterior tooth mass, highlighting the need for individualized treatment strategies [10].

Rakhshan *et al*. (2022) examined posterior Bolton disparities between Class I, II, and III malocclusion groups within an Iranian population in a separate research conducted in Tehran [11]. The sample included 265 digital orthodontic models that were subjected to ANOVA and Tukey's post hoc analyses. The findings indicated that Class II patients had significantly decreased posterior Bolton ratios compared to Class I and Class III individuals (ANOVA $p = 0.008$). The findings indicate that Class 2 is characterized by a relative reduction in thyroid volume, resulting in a reduced tooth complex in the posterior mandible, as observed in the lateral view, which could compromise treatment objectives and occlusal harmony [11].

Holton *et al*. (2023) investigated the impact of several premolar extraction techniques on posterior Bolton ratios in class I malocclusions using virtual simulation technologies in the United States [12]. A clinical sample of 55 Class I orthodontic patients was examined both with and without simulated premolar extractions. The data revealed that the extraction of maxillary first and mandibular second premolars led to a more significant rise in the posterior Bolton ratio compared to non-extraction patients. This conclusion was statistically significant, emphasizing the influence of extraction options on the management of posterior TSD during orthodontic treatment [12].

Wadood *et al*. (2023) conducted a concurrent study in Pakistan on Class II malocclusion [13], with the objective of evaluating posterior Bolton ratios before and after bilateral first premolar extraction. The researchers used cast models and observed a significant increase in the posterior Bolton ratio after the excision of both first premolars ($p < 0.05$). Consequently, the findings indicate that extract space management effectively repositions teeth and enhances their proportionality in some circumstances [13].

Mongillo *et al*. (2021) performed a digital setup investigation to investigate spacing gap abnormalities in Class I patients with two excised first premolars [14]. Their results indicated that even among individuals with optimal posterior Bolton ratios, a significant percentage (27%) had excess mandibular separation above 1.5 mm during the post-extraction phase. This indicates that posterior TSD may occur independently of balanced posterior ratios, underscoring the need for distinct assessment of posterior segments [14].

Ultimately, Alshahrani (2020) examined the Bolton ratios in Saudi orthodontic patients categorized by different malocclusions. The sample included 144 patients from the southern part of Saudi Arabia, revealing significant disparities in total and posterior Bolton ratios across various malocclusion types when compared to norm occlusion controls ($p < 0.05$). He determined that posterior TSD is essential for diagnostic and brace design for Saudi patients [15].

The Recent Literature from 2017 to 2025 has provided insights into the evolving understanding of posterior tooth-size discrepancies (TSD), which continue to distinguish themselves from established norms. Convergence between these recent findings and earlier research reveals numerous persistent trends alongside new contradictions. The most recent research between 2017 and 2025 has developed new concepts about posterior tooth-size discrepancies (TSD), which continue to differ from the norm (Overall Ratio (12–12): 91.3% ± 1.91, Anterior Ratio (6–6): 77.2% ± 1.65). There are several persistent trends along with new

contradictions that converge these recent findings with earlier research.

According to Fallis (2020), the Johnson–Bailey (JB) posterior analysis detected 97–100% of clinically significant posterior tooth-size discrepancies (TSDs) versus only 23% with the traditional Bolton analysis [9]. This finding supports earlier work by Bailey *et al*. (2013), who introduced the JB method and noted it "provided more specific ratios utilizing more clinically relevant functional arch components" than Bolton's method. In other words, both Fallis and Bailey demonstrated that JB analysis better identifies posterior TSDs. While previous reviews, such as Anitha and Manohar (2024) [16] and O'Mahony *et al*. (2000), criticized standard Bolton ratios for their lack of precision in predicting interarch discrepancies, more recent research seems to agree that the Johnson–Bailey approach significantly outperforms Bolton's classical formula in predicting posterior discrepancies [17, 18].

Bolton ratios

Al Maaitah *et al*. (2022) observed that skeletal AOB patients had posterior Bolton ratios significantly lower than normal-bite controls (p=0.015) [10]. Still, they pointed out that these differences were less than one standard deviation of Bolton's norms and did not have strong clinical significance. Alshahrani (2020) reported no significant variation in Bolton ratios across different types of malocclusions [15], including AOB, in Southern Saudi patients. Alqahtani *et al*. (2023) also showed that Saudi Class I/II/III patient groups differed from Bolton's original values but did not differ from each other, which was previously documented. In conclusion, Al Maaitah's more negative posterior Bolton ratios in open-bite cases support these observations [10], suggesting any influences of open-bite on Bolton ratios are likely small and within the normal range of variation. No significant correlation was demonstrated between the degree of open bite and TSD, aligning with earlier findings that a pure posterior open bite is not a strong predictor of Bolton discrepancy [19, 20].

Class I/II/III malocclusion comparisons

In the Iranian population sample studied by Rakhshan *et al.* in 2022 [11], the Class II patients showed significantly lower posterior Bolton ratios when compared to Class I or III (ANOVA p=0.008). This indicates a relative decrease in the posterior tooth width of the mandible in Class II patients. In contrast, many previous studies have reported a posterior Bolton difference among the different classes of malocclusion. For example, Wedrychowska-Szulc *et al*. (2010) and other researchers such as Crosby and Alexander (1989) and O'Mahony *et al*. (2000) found no significant differences in Bolton ratios with Angle's Classification I, II, and III. Also, a Brazilian study confirmed that the type of malocclusion did not affect posterior Bolton's discrepancy. Alshahrani (2020) observed Saudi Class I, II, and III cohorts to have nearly the same posterior ratios [15]. The more recent findings of Rakhshan suggesting a Class II-specific posterior discrepancy are rather peculiar, considering the lack of evidence supporting such a claim from most past research. At the same time, other prior studies, like the one conducted by Wedrychowska-Szulc, noted the higher posterior mean ratios in Class III over Class II. The current report of Class II hypodontia is at odds with the historical view of minimal class-based effects; it probably reflects differences in population or sample [21-23]. To summarize, Rakhshan's findings contradict previous studies suggesting that class differences are insignificant, proposing that posterior Bolton TSD may vary by class in some ethnic groups and not others [24, 25].

Effects of premolar extraction on posterior ratios

The impact of premolar extraction on posterior Bolton ratios is receiving research attention. In Class I situations, Holton *et al*. (2023) reported an increment of ideal posterior Bolton ratio from 105.77% to 106.52% with the extraction of maxillary first and mandibular second premolars [12], a significant increase. Mongillo *et al*. (2021) also demonstrated that, under the circumstance of ideal posterior ratios [14], the first four premolar extractions resulted in some mandibular residual spacing in over a quarter of cases (27% of cases ≥1.5 mm). Wadood *et al*. (2023) also found that Class II patients with bilateral first-premolar extraction showed a significant increase in posterior ratio ($p<0.05$) [13]. This is in agreement with Endo *et al*. (2010), who noted that virtually any set of premolar extractions will decrease the posterior Bolton ratio in orthodontic patients, due to the disproportionate removal of maxillary and mandibular tooth mass. More simply, the prevailing notion is that the extraction of premolars changes the ratio of teeth, resulting in a more pronounced mandible dominance [26, 27].

The increases in posterior ratios noticed by Wadood and Holton reflect Endo's conclusions as well [12, 13]; for instance, Endo observed significant posterior ratio reductions after extracting both upper first and lower second premolars, which is consistent with Holton's observation of a raised posterior ratio (an upper first premolar extraction widens the upper arch). Also consistent is Wadood's observation that a marked increase in the posterior ratio occurs after the extraction of the first four premolars, correlating with their observation of a raised posterior ratio for that pattern. All in all, premolar extraction consistently reshapes interarch proportions, as was shown in recent and past studies. With four two-extraction methods, Holton and colleagues reported an average mandibular spacing of 1.1 to 1.3 mm. Mongillo's residual spaces have also been thoroughly characterized. Collectively, these results demonstrate that no one formula completely prevents posterior TSD and that careful planning of extraction patterns is necessary to maintain Bolton ratios [12, 13].

Differences in ethnicity and population

Examining Saudi patients, Alshahrani (2020) reported Bolton ratios with varying values across types of malocclusions and emphasized posterior TSD, possibly as a focal point in treatment. However, earlier research from Saudi Arabia focused on more homogeneous values. For instance, Alshahrani's 2020 Southern Saudi sample demonstrated no marked differences based on the presence of a specific malocclusion in posterior ratios [15].

A 2023 Saudi meta-analysis also found that Saudi Class I, II, and III groups all significantly deviated from Bolton's American norms, but did not differ from each other. Bolton's standards seem to be applicable only in cases of normal occlusion for Saudis, as all types of malocclusions appear to share a common ratio specific to Saudis (≈92.5% overall). This observation – that Arab orthodontic patients frequently possess greater mandibular tooth mass than Bolton's sample – has been noted in other studies involving non-Western populations. For example, in the recent study, Awawdeh *et al*. (2023) reported that most of the Saudi subjects had posterior ratios greater than Bolton's norms (Overall Ratio (12–12): 91.3% ± 1.91, Anterior Ratio (6–6): 77.2% ± 1.65). Similar ethnic variations have been described in other regions around the world. In conclusion, the results depicting Middle Eastern samples together with other studies demonstrate the existence of ethnic differences: Bolton's values were originally derived from ideal (norm) occlusions, whereas the diverse groups of regional malocclusions (Arab, Iranian, Pakistani, etc.) tend to possess unique characteristic Bolton ratios [28-31].

Limitations and recommendations

Despite the increased attention on posterior TSD, many studies still lack uniformity in the standardized definition and measurement of posterior ratios. These include back-calculations via Bolton's formula to direct measurements and virtual setups, resulting in varying degrees of accuracy among different studies. Moreover, most studies tend to have small or narrow demographic sample sizes, which reduces generalizability [32, 33].

Several studies do not fully examine treatment results during the timelines following decisions based on ratios. This highlights a gap in longitudinal multicenter trials that measure how initially set posterior TSD affects occlusion finishing, relapse patterns over time, and subsequent patient-reported outcomes. Additionally, distinguishing between dental and skeletal malocclusions contributing toward posterior discrepancy is infrequently done despite differences in approach toward their management.

Future studies should aim to develop population-specific Bolton standards. Both historical and contemporary studies show persistent ethnic and regional differences. This suggests that Bolton's original norms, based on a North American sample, tend to overgeneralize and could lead to inaccurate diagnoses in other populations. Therefore, cross-sectional studies on diverse racial groups to determine normative posterior tooth-size ratios defined for specific ethnic groups are necessary. This would facilitate better treatment strategies while minimizing the chances of overlooked tooth-size discrepancies in clinical work.

In addition, future research should incorporate and validate Johnson–Bailey and virtual occlusal setup methods as advanced digital diagnostic tools. These methods have shown greater accuracy than classical techniques for the detection of posterior TSDs. Their application in different classes of malocclusion and treatment methods needs to be tested through multicenter clinical trials to provide reliable data that would enhance global standards for TSD evaluation.

Conclusion

Research indicates that posterior tooth size discrepancies are critical to optimal occlusal relationships; however, they seem to be neglected in routine orthodontic assessments. Recent evidence, especially between 2017 and 2025, suggests that posterior TSD is significantly related to the type of malocclusion, sex, ethnicity, and extraction method used. Notably, Class II malocclusions display lower posterior ratios while Class III shows higher ratios; both observations underscore the importance of thoughtful treatment strategy in these populations. Methods and tools such as digital Bolton calculators or region-specific algorithms like the Johnson–Bailey prediction method improve accuracy over traditional Bolton calculations. Moreover, even region-related differences among Middle Eastern populations underscore the problem with using one-size-fits-all approaches in diverse orthodontic patient groups.

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