Original Article

Assessing the accuracy of two posterior tooth-size discrepancy prediction methods based on virtual occlusal setups

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ABSTRACT

Objective: To assess accuracy of the Bolton and Johnson/Bailey (JB) analyses in identifying clinically significant posterior tooth-size discrepancies using virtually constructed occlusal setups.

Materials and Methods: Virtual models and cone-beam computed tomography data sets from 30 patients were utilized to construct 60 (two per patient) virtual posterior occlusal setups. Observed discrepancies in cusp-embrasure relationships were compared to estimated posterior interarch tooth-size discrepancies (ITSDs) calculated via Bolton and JB posterior analyses. Clinical significance for discrepancies was established at $>$1 mm from ideal cusp-embrasure relationships in accordance with current American Board of Orthodontics methodology. Data within groups were normally distributed, thus comparisons were completed via paired *t*-tests. Paired nominal data were analyzed utilizing McNemar's test, and simple linear regression was used to model the relationship of predicted to observed discrepancies.

Results: McNemar's test revealed significant differences ($P \leq .05$) between the Bolton and JB groups' frequencies in matching the virtual setups correctly. JB predictions matched 100% (right) and 97% (left) setups; whereas, Bolton predictions matched only 23% (right and left) setups. A positive correlation was observed between JB predictions and cusp-embrasure discrepancies, demonstrating that average posterior discrepancy values increased 0.28 mm for every 1 mm predicted via the JB analysis.

Conclusions: The JB analysis correctly characterized, but overestimated, the degree of posterior ITSDs corresponding to a clinically significant discrepancy in the virtual setups. Algebraically calculated posterior ITSDs based on the Overall and Anterior Bolton ratios were not accurate predictors of discrepancies observed in the virtual setups. Both Bolton and JB demonstrated weaknesses that limit precise identification of clinically significant ITSDs. (*Angle Orthod.* 2020;90:239–246.)

KEY WORDS: Posterior tooth-size; Tooth-size prediction; Virtual set-ups

INTRODUCTION

A primary goal of orthodontic treatment is to achieve a functional occlusion of posterior teeth.[1] Although this is achievable in most cases, an ideal posterior occlusion can be difficult to establish in the presence of an interarch tooth-size discrepancy (ITSD). Defined as a degree of disproportion among sizes of individual teeth,[2] an ITSD can exist in the anterior or posterior regions. However, minimal research has addressed posterior ITSDs and whether established methods are accurate in identifying significant discrepancies in the final posterior occlusion.[3]

Past researchers have described posterior tooth-size relationships, beginning with G.V. Black.[4] As represented in Table 1, subsequent reports by Lundstrom,[5] Ballard,[6] and Bolton[7] described a larger combined width of the mandibular posterior teeth compared with the corresponding maxillary teeth and were useful in describing the normal "difference" between these segments. However, since the Bolton ratios were based on a sample of excellent occlusions, his report defined the degree of "difference" that

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Table 1. Mean Mesiodistal Posterior (First Premolar, Second Premolar, and First Molar) Tooth Widths (mm) Reported by Black,[4] Lundstrom,[5] Ballard,[6] and Bolton[7]

Researcher	Black		Lundstrom		Ballard		Bolton	
Arch	Mx	Mn	Mx	Mn	Mx	Mn	Mx	Mn
First Premolar	7.2	6.9	Not reported	Not reported	7.27	7.36	7.04	7.15
Second Premolar	6.8	7.1	Not reported	Not reported	7.14	7.50	6.84	7.27
First Molar	10.7	11.2	Not reported	Not reported	10.98	11.17	10.4	11.14
Total	24.7	25.2	Not reported	Not reported	25.41	26.03	24.28	25.56
Mx/Mn Ratio	0.98 (Mx 98% of Mn)		0.95 (Mx 95% of Mn)		0.98 (Mx 98% of Mn)		0.95 (Mx 95% of Mn)	
Mn/Mx Ratio	1.02 (Mn = Mx + 2%)		1.05 (Mn = Mx + 5%)		1.02 (Mn = Mx + 2%)		1.05 (Mn = Mx + 5%)	

* Lundstrom did not report the individual tooth widths that comprised the posterior segments, only the interarch ratio. Mx = Maxillary; Mn = Mandibular.

constituted a "discrepancy." Prior to his study, an altered-cast or "Kesling" setup was employed by orthodontists to model the expected occlusion.[8]

Bolton's study used 55 excellent cases, 44 of which had received orthodontic treatment, to calculate ratios for use as treatment planning targets. By establishing mandibular to maxillary (Man/Max) ratios for the Anterior and Overall segments, orthodontists could better predict excellent results. Bolton did not define a posterior ratio; however, a recent report estimated it to be 106.2, using three methods of determination.[3] Bolton also visually analyzed the buccal relationships and, as illustrated in Figure 1, he subdivided the posterior arch into occluding units. As reported,[9,10] when an overall discrepancy existed and the buccal analysis revealed the expected 1:1 relationships, an anterior discrepancy would be concluded. The Bolton analysis provided advancement in the ability to analyze potential discrepancies prior to orthodontic treatment; however, limitations were reported regarding applicability to all races, genders, various population groups, and malocclusion types.[11–18]

Recently the Johnson/Bailey (JB) analysis was presented.[19] This report established ratios (Max/Man) for Overall, Posterior-Right, and Left and Anterior Segments (Figure 2) and, as illustrated in Figure 3, used different reference points compared with the Bolton method. Functional segments were expected to relate in a 1:1 relationship; however, when the JB was used to assess the 141 untreated excellent occlusions in the Andrews sample, maxillary exceeded mandibular in all segments (Overall = 1.06 $\pm$ 0.03, Anterior = 1.03 $\pm$ 0.03, Posterior = 1.10 $\pm$ 0.04). The Posterior ratios ranged from 0.98 to 1.23, demonstrating that the maxillary posterior functional segments exceeded the mandibular segments in the majority of the sample.

By using virtual setups and digital techniques with measurement accuracy comparable to traditional Vernier calipers,[20] this study compared the accuracy of the Bolton and JB methods in predicting posterior

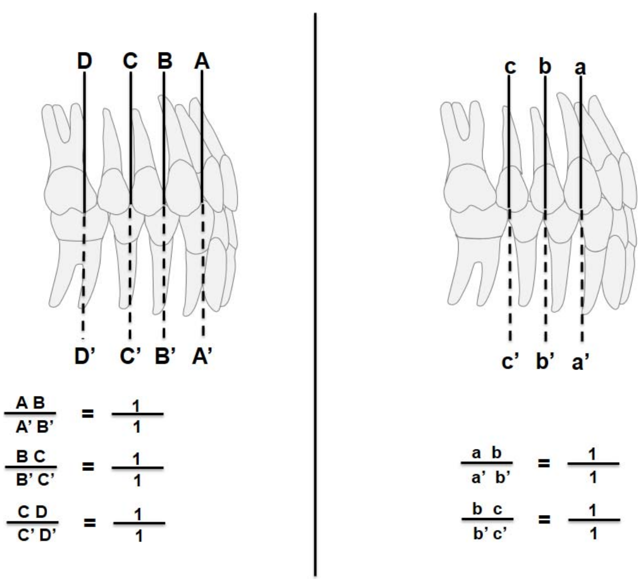

Figure 1. Representation of posterior occluding units used by Bolton.[7]

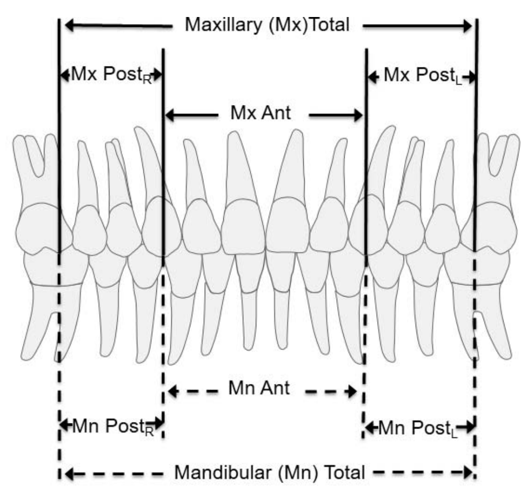

Figure 2. Representation of arch segments used in the Johnson/Bailey Analysis.[19]

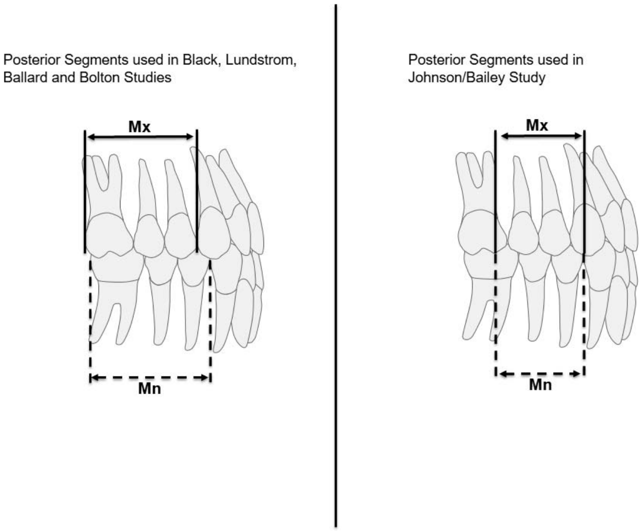

Figure 3. Representation of the different arch segments used by GV Black,[4] Lundstrom,[5] Ballard, and Bolton,[6,7] compared with Johnson/Bailey.[19]

ITSDs that result in clinically significant posterior discrepancies.

MATERIALS AND METHODS

This study was approved by the Wilford Hall Ambulatory Surgical Center Institutional Review Board and used pretreatment records of 30 de-identified Caucasian patients (19 male, 11 female) with a mean age of 16 years, 6 months. Since many patients demonstrated severe crowding, both casts and matched cone-beam computed tomography (CBCT) scans were analyzed to describe the standard measurement error and records were managed according to the following criteria:

- Casts were digitized using a 3Shape R700 digital scanner (3Shape North America, Warren, N.J.), with reported accuracy to within 60 microns.[21]
- CBCT data sets were acquired within 1 month of the casts, using an i-CAT FLX (Imaging Sciences International, Hatsfield, PA), set at a 23 cm $\times$ 17 cm field of view, and 0.3 mm voxel size.
- All casts included 28 fully-erupted teeth (second molar to second molar).
- Cases were excluded that demonstrated restorations, obvious tooth anomalies, or documented shape alterations.

3Shape OrthoAnalyzer 2013 software (3Shape North America) was used by the author, experienced in the use of virtual setups and American Board of Orthodontics (ABO) measurement methods, to virtually segment casts with minimal variability. Bolton ratios were calculated for each patient, based on previously published formulas[9,10] and tooth-size excesses or deficiencies were identified. The predicted posterior relationships were calculated by subtracting the Anterior from the Overall measurements to predict the relative Posterior excess or deficiency (bilaterally combined).

JB ratios were calculated for both right and left sides by dividing the maxillary posterior segment by the mandibular posterior segment. As reported by Bailey,[19] ratios between the segments in the JB analysis that exceeded 1.00 indicated a maxillary excess.

Dolphin Imaging 3D, Version 11.8, viewing software (Dolphin Imaging & Management Solutions, Chatsworth, Calif) was also used to measure the individual teeth in each data set. Following establishment of a standardized viewing protocol, all measurements were acquired at 1 voxel resolution, with sagittal, coronal, and axial planes set to correspond with the anatomy of each individual tooth.

Within the 3Shape OrthoAnalyzer Virtual Setup module, a "best-fit" posterior occlusion was established bilaterally for each case following a standardized protocol:

- The incisors were removed from each cast to prevent collisions with the canines.
- The mandibular teeth were leveled and aligned with no Curve of Spee. Transversely, the Curve of Wilson was flattened with $<$1 mm differential in buccal and lingual cusp height. The Collision Mapping feature was used to confirm ideal interproximal contacts without overlap of teeth.
- A Class I molar position was established by seating the palatal cusp of the maxillary first molar in the central fossa of the mandibular first molar, then rotating the first molar to align the mesiobuccal cusp with the buccal groove of the mandibular first molar. The maxillary teeth were then positioned ideally and the Collision Mapping feature was used to ensure ideal interproximal contacts.

As illustrated in Figure 4, 0-Point was established at the ideal Class I molar position and the cusps of the second premolar, first premolar, and canine were designated as Points 1, 2, and 3 progressing mesially. This construct for measurement was used to correspond with current ABO Objective Grading System (ABO OGS) methodology.[22] The definition of a "clinically significant" discrepancy was also selected to correspond with ABO OGS methods and measurements $\leq$ 1 mm from ideal were defined as acceptable and measurements $>$ 1 mm were unacceptable.

Virtual models of the 30 subjects were used to generate 60 (30 right and 30 left) virtual posterior occlusal setups. Both Bolton and JB predictions were compared to these 60 matched setups and a McNe-

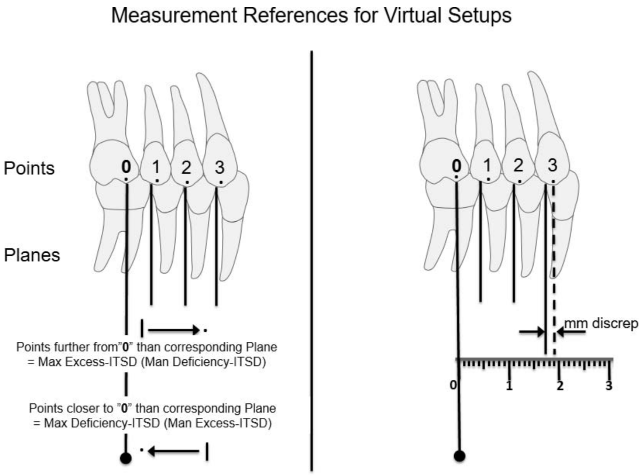

Figure 4. Representation of the Points of reference and positioning of Reference Planes.

mar's test was used to test the two proportions of prediction agreement with the virtual setups. A sample size of 60 matched pairs was determined to achieve greater than 80% power using a two-sided McNemar's test with an alpha level of 0.05. To determine the standard error of the CBCT and Virtual Cast measurement methods, the test-retest method was used to compare five cases (170 measurements) for each method with the level of significance set at $P \leq .05$.

RESULTS

Tables 2 and 3 represent the results of the Bolton and JB analyses in this study with mean ratios falling within 1 standard deviation of the patients in the original Bolton and JB studies.

The CBCT method demonstrated a mean error of 0.22 mm ± 0.07 mm (0.11 mm mean error of two landmarks per tooth) and the Virtual Cast method demonstrated an error of 0.30 mm ± 0.12 mm (0.15 mm mean error of two landmarks). Comparison of these means was statistically significant ($P = .0023$); however, it was determined to be clinically insignificant for either method. Overall differences between the two methods revealed a 2.0% difference (reduction of 0.07 mm per tooth surface for a 7 mm wide tooth) when measurements were obtained on the Virtual Casts compared with the CBCT.

The discrepancy designation (maxillary excess or deficiency) for each Bolton and JB analysis was compared to the observed discrepancy in each virtual setup. Using a McNemar's test to analyze the paired proportions of each method and the virtual setups revealed that both right and left JB predictions were statistically different from the Bolton results ($P <$ .0001). As represented in Table 4, the JB right and left Posterior prediction designations agreed with the virtual setups in 100% of the right and 97% of the left sides. In comparison, 23% of the Bolton predictions agreed with the discrepancies.

Due to the high level of agreement between the JB predictions and the Virtual setups, the quantitative predictions and setups were compared statistically and revealed significant differences for both right and left sides ($P < .0001$ for both). Comparisons were also completed between the JB predictions and the average discrepancy on each side, also demonstrating statistically significant differences on the right ($P = .002$) and left ($P = .003$) sides.

As represented in Figure 5, the mean setup discrepancies in each of the three measurement areas were calculated and revealed that the maxillary second premolar region demonstrated the greatest discrepancy from the ideal, bilaterally.

A simple linear regression was conducted to analyze the relationship of the average posterior discrepancy based on the JB predictions. A significant regression was found ($F[1, 58] = 13.997$, $P = .001$, with an R^2 of .194), indicating that approximately 19% of the variation in the average posterior cusp-embrasure discrepancy could be explained by the JB prediction. This relationship was modeled (Figure 6) to reveal that the average posterior discrepancy observed in a Virtual Setup = 0.28(JB prediction) + 0.59. According to this prediction model, the average posterior discrepancy increased 0.28 mm for each 1mm of discrepancy predicted via the JB posterior analysis.

DISCUSSION

The results of this study demonstrated the need to appreciate what information is actually revealed from the Bolton and JB analyses that can guide treatment planning decisions for individual patients. A Bolton analysis demonstrates how the tooth-size ratios of an

Table 2. Mean Bolton Relationships and Estimated Posterior ITSDs[a]

Group	Bolton Overall (SD)	Bolton Anterior (SD)	Est. Posterior ITSD (SD)
CBCT Datasets	92.3 (1.2)	78.2 (2.0)	-0.45mm (1.15)
Virtual Casts	93.2 (2.0)	78.6 (3.2)	-1.12mm (1.35)
Original Bolton Study	91.3 (1.91)	77.2 (1.65)	Defined as the Standard (Excellent Occlusion)

[a] CBCT indicates cone-beam computed tomography; ITSD, interarch tooth-size discrepancies; SD, standard deviation.
* (-) value indicates relative Maxillary Deficiency (Mandibular Excess); Combined right and left posterior segments with symmetry assumed.

Table 3. Mean Johnson/Bailey (J/B) Relationships and Standard Deviations (SD)

Groups	J/B Overall Ratios	J/B Posterior Left Ratio / Estimated ITSD Relative to Maxilla	J/B Posterior Right Ratio / Estimated ITSD Relative to Maxilla
CBCT Datasets	1.07 (0.02)	1.08 (0.05) / 1.60 mm (0.96)	1.06 (0.04) / 1.14 mm (0.83)
Virtual Casts	1.07 (0.03)	1.07 (0.05) / 1.39 mm (0.89)	1.07 (0.03) / 1.43 mm (0.63)
Original J/B Study	1.06 (0.03)	1.10 (0.04) / Not described	1.10 (0.04) / Not described

* (+) value indicates relative Maxillary excess (Mandibular deficiency).

individual patient compare to the ratios that existed in Bolton's sample. Therefore, when analyzing the results of this study with comparisons based on these normative ratios, it is useful to appreciate two aspects: first, an understanding of the posterior tooth-sizes and ratios of the patients in the Bolton study, since these were considered to be consistent with an ideal and, second, the actual quality of the posterior occlusions in the Bolton study that were judged to be excellent.

By using the normative Bolton Overall and Anterior ratios, it is possible to algebraically calculate his Posterior ratio at 1.054 (Man/Max); however this ratio conflicts with a recent report estimating it to be 106.2 based on three methods of determination.[3] Bolton's ratio can also be determined from the actual tooth measurements reported in his original thesis,[7] which demonstrated the most accurate ratio of 1.05 from his original data. Although his actual posterior ratio of 1.05 closely approximated the posterior ratio observed in

Table 4. Data for Virtual Set-up Discrepancies and ITSD Predictions[a]

Patient	Rt. Virtual Set-up Discrep (mm)	Rt. Virtual Average Discrep (mm)	Agreement with Rt. J/B Prediction (mm)	Lft Virtual Set-up Discrep (mm)	Lft. Virtual Average Discrep (mm)	Agreement with Left J/B Prediction (mm)	Agreement with Bolton Prediction, Discrepancy Divided Equally Rt. (mm) Lft.
1	4.22	1.41	YES (1.5)	1.24	0.41	YES (0.46)	**NO** (-2.85 / 2) **NO**
2	4.94	1.65	YES (2.23)	4.27	1.42	YES (0.83)	**NO** (-1.31 / 2) **NO**
3	2.06	0.69	YES (1.25)	2.52	0.84	YES (1.66)	**NO** (-0.88 / 2) **NO**
4	3.62	1.21	YES (1.35)	2.97	0.99	YES (2.09)	**NO** (-2.14 / 2) **NO**
5	1.1	0.37	YES (0.88)	2.51	0.84	YES (0.94)	**NO** (-2.75 / 2) **NO**
6	2.1	0.70	YES (1.83)	0.67	0.22	YES (0.98)	**NO** (-1.28 / 2) **NO**
7	3.7	1.23	YES (1.61)	1.72	0.57	YES (1.32)	**NO** (-2.05 / 2) **NO**
8	3.2	1.07	YES (2.12)	2.67	0.89	YES (2.24)	**NO** (-1.16 / 2) **NO**
9	2.77	0.92	YES (1.61)	3.59	1.20	YES (2.37)	**NO** (-0.01 / 2) **NO**
10	0.08	0.27	YES (0.27)	2.13	0.71	YES (0.01)	YES (0.81 / 2) YES
11	0.88	0.29	YES (0.75)	1.26	0.42	YES (0.63)	**NO** (-3.49 / 2) **NO**
12	3.44	1.15	YES (1.19)	2.96	0.99	YES (0.12)	**NO** (-2.44 / 2) **NO**
13	5.45	1.82	YES (1.49)	3.68	1.23	YES (0.67)	**NO** (-2.30 / 2) **NO**
14	3.18	1.06	YES (2.57)	4.25	1.42	YES (2.21)	YES (0.53 / 2) YES
15	6.27	2.09	YES (2.19)	5.34	1.78	YES (2.80)	YES (0.76 / 2) YES
16	6.2	2.07	YES (1.94)	2.56	0.85	YES (1.81)	**NO** (-0.20 / 2) **NO**
17	2.04	0.68	YES (1.63)	1.15	0.38	YES (2.28)	YES (0.76 / 2) YES
18	3.44	1.15	YES (0.23)	4.03	1.34	YES (1.56)	**NO** (-1.81 / 2) **NO**
19	3.00	1.00	YES (0.89)	3.71	1.24	YES (1.99)	**NO** (-0.52 / 2) **NO**
20	1.03	0.34	YES (1.04)	3.73	1.24	YES (0.63)	**NO** (-2.19 / 2) **NO**
21	2.37	0.79	YES (1.67)	2.73	0.91	YES (0.70)	**NO** (-1.71 / 2) **NO**
22	3.6	1.20	YES (0.90)	4.45	1.48	YES (1.28)	**NO** (-2.34 / 2) **NO**
23	0.85	0.28	YES (1.20)	1.7	0.57	YES (0.93)	**NO** (-1.31 / 2) **NO**
24	1.22	0.41	YES (1.73)	1.84	0.61	YES (2.29)	YES (0.14 / 2) YES
25	0.94	0.31	YES (0.41)	0.00	0.00	**NO** (0.10)	**NO** (-2.76 / 2) **NO**
26	2.19	0.73	YES (2.43)	5.2	1.73	YES (2.57)	YES (1.17 / 2) YES
27	3.31	1.10	YES (1.49)	3.3	1.10	YES (0.61)	**NO** (-1.58 / 2) **NO**
28	3.41	1.14	YES (0.99)	4.01	1.34	YES (1.06)	**NO** (-0.58 / 2) **NO**
29	4.39	1.46	YES (1.02)	4.97	1.66	YES (2.27)	**NO** (-0.74 / 2) **NO**
30	3.88	1.29	YES (2.51)	4.37	1.46	YES (3.13)	YES (2.11 / 2) YES
MEAN	**2.93 mm**	**0.98 mm**	**1.43 mm**	**2.84 mm**	**0.95 mm**	**1.4 mm**	**-1.12 mm**
SD	**1.65**	**0.55**	**0.63**	**1.67**	**0.56**	**0.89**	**1.32**
%			**100% Agree**			**97% Agree**	**23% Agreement 23%**

[a] ITSD indicates interarch tooth-size discrepancies; J/B, Johnson/Bailey; Rt, right; Lft, left; Bold items indicate disagreement between predicted discrepancy value and virtual set-up discrepancy value.

* (-) value indicates relative Maxillary Deficiency (Mandibular Excess).

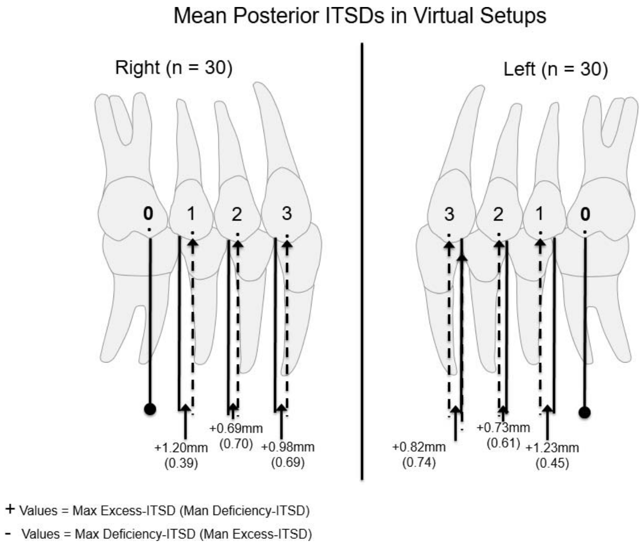

Figure 5. Graphic representation of the Mean (SD) discrepancies recorded in the virtual setups.

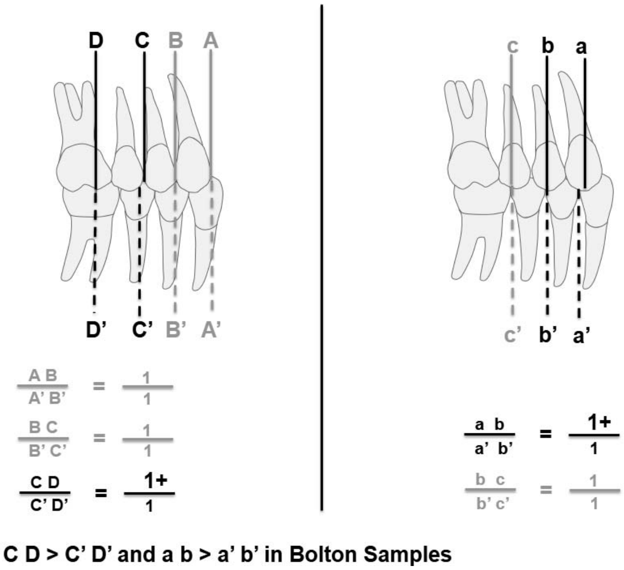

Figure 7. Illustration of buccal segment relationships reported in the Bolton thesis.[7]

this present study (1.06), it demonstrated less combined mandibular tooth width compared with that observed in the current study. Therefore, it was not surprising that 77% of the cases in the present study demonstrated mandibular tooth-size excess based on the Bolton analysis.

Additionally, the ABO OGS was not used for the Bolton study and an objective measurement of cusp-embrasure relationships was not conducted, as in the present study. However, Bolton did measure the discrepancies of the individual occluding segments (Figure 7) that comprised the posterior arch segments. He determined that the ratios of corresponding maxillary and mandibular occluding segments demonstrated 1:1 relationships, with two exceptions. The segment CD demonstrated an average difference of 0.75 mm relative to C'D' (clinically insignificant by ABO OGS standards) and segment ab demonstrated an average difference of 1.5 mm relative to a'b' (clinically significant by ABO OGS standards).[7] Therefore, the Bolton cases exhibited clinically significant posterior discrepancies (maxillary excess) when judged by current standards, discrepancies that compare closely to the current study (Figure 8). However, more importantly, it highlighted that a Bolton analysis can demonstrate mandibular posterior excess when the posterior occlusion exhibits maxillary posterior excess based on cusp-embrasure relationships.

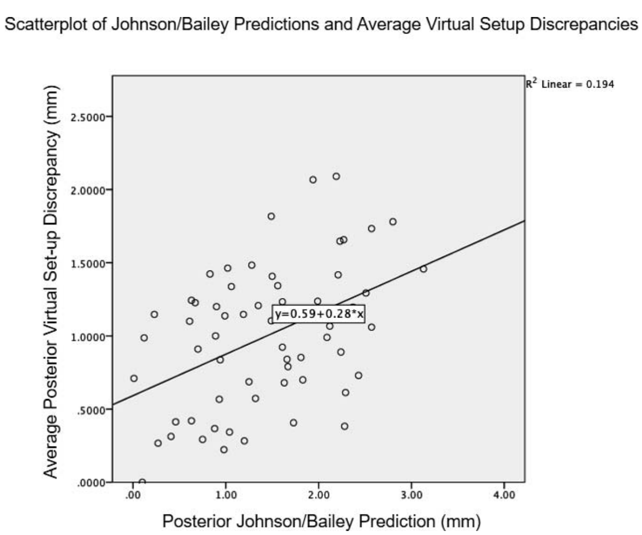

Figure 6. Scatterplot of Johnson/Bailey Predictions relative to Average Virtual Setup Discrepancies (current study).

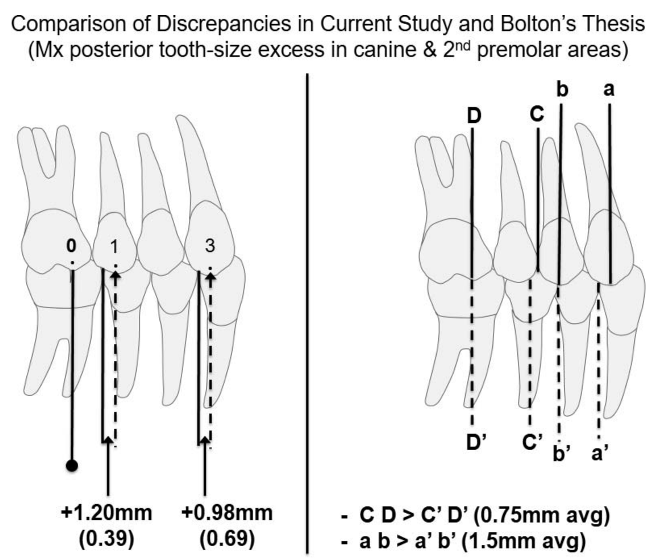

Figure 8. Comparison of buccal segment discrepancies reported in Bolton thesis[7] to the Current Study.

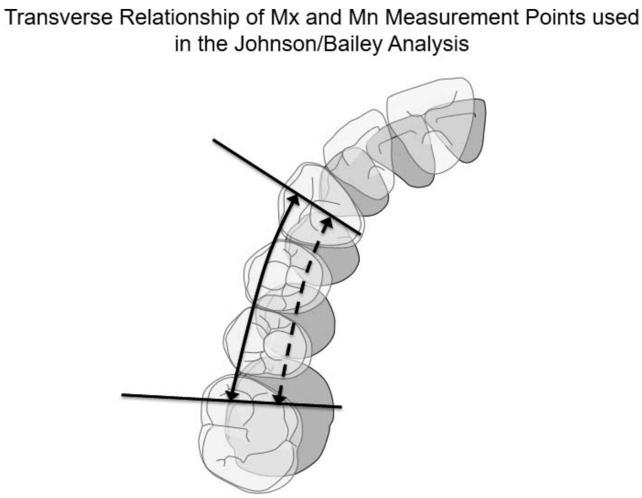

Figure 9. Illustration of buccolingual positioning of the measured segments in the JB Analysis (current study).

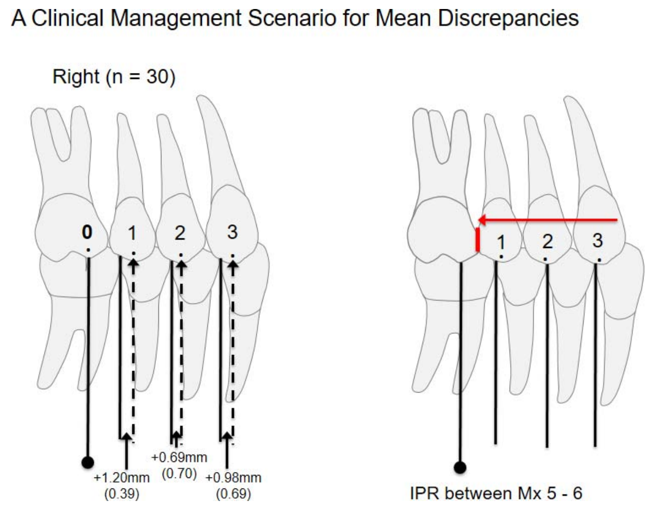

Figure 10. One clinical management scenario to address the mean discrepancies observed in this study.

When the JB Analysis was used, 100% (right) and 97% (left) occlusal segments indicated maxillary excess. As illustrated in Figure 9, although the normative ratio was described in the study[19] as approximating 1:1, due to the positioning of mandibular tooth landmarks lingual to the corresponding maxillary landmarks and curvature of the arch, the combined maxillary segment width should exceed the mandibular. This effect should be more amplified as facial cusp thickness increases, resulting in a broader arch form in the canine-first molar region relative to the mandibular interproximal contact areas. This was represented in the current study with mean right and left posterior JB ratios of 1.07 $\pm$ 0.03 and 1.07 $\pm$ 0.05, falling within 1 SD of the original JB study findings (1.10 $\pm$ 0.04).

The JB prediction of a discrepancy and the demonstration of a discrepancy via the setups agreed for nearly all patients. However, a comparison of the predicted discrepancy values (mm) and total discrepancy scores revealed statistically significant differences. Using Figure 10 as reference, further analysis demonstrated that measurement in each of the scoring areas can be influenced by a more distal discrepancy. For example, a 1.5 mm discrepancy at Point 1, if corrected with interproximal reduction, would result in all teeth mesial to Point 1 shifting distally, thereby correcting multiple discrepant areas. To account for this phenomenon and to allow for a more accurate comparison to a clinically unacceptable occlusal discrepancy ($>$1 mm in at least one scoring area), the averages of the discrepancy scores were calculated in each case. Comparison to these values also revealed statistically significant differences ($P = .003$ for the left; .002 for the right). Although a positive correlation was observed between these two variables, a Pearson correlation and simple regression analysis demonstrated that the JB prediction only accounted for 19% of the variation observed in the Setups, indicating that factors such as buccolingual cusp thickness, arch form, tooth shapes, measurement error, bias in the measurement method, or other variables contributed to the discrepancies as well.

These average discrepancy values were used to determine the prevalence of clinically significant posterior discrepancies in the setups and demonstrated that 31 of the 60 setups demonstrated an average discrepancy $>$1 mm, indicating at least one clinically significant cusp-embrasure discrepancy in over 50% of the setups. These 31 cases exhibited a mean JB posterior ratio of 1.08 $\pm$ 0.03, 1% percent above the mean for the study, again demonstrating the positive relationship between an increase in maxillary tooth-size excess and clinically significant posterior discrepancies.

Although the JB analysis demonstrated a high level of agreement with the type of discrepancy that would exist in the virtual occlusal setups, it was limited in resolution to the offending posterior segment and did not provide detection to the level of the offending tooth or teeth. Therefore, development of a virtual setup process to incorporate Bolton's original methodology of visually analyzing occluding segments may be of value for future studies, as demonstrated for other applications.[23–25]

This study demonstrated that both the Bolton and JB analyses have weaknesses that impact their utility in predicting posterior tooth-size discrepancies that adversely affect posterior cusp-embrasure relationships. If only a regional discrepancy is identified via either of these two analyses, then imprecise management could actually normalize the tooth-size ratio, but move cusp and embrasure relationships further from optimal positions.

CONCLUSIONS

Within the parameters of this study, the following conclusions can be offered:

- Use of an algebraically-calculated Posterior ratio based on the Bolton Overall and Anterior ratios is not accurate in identifying posterior ITSDs that adversely impact ideal posterior cusp-embrasure relationships.
- When defining a clinically significant discrepancy in posterior occlusal relationships as >1 mm, a Johnson/Bailey Posterior Ratio $\geq 1.08 \pm 0.03$ (Max/Man) is a useful clinical guide to the presence of one or more discrepant cusp-embrasure areas.
- Increases in the degree of maxillary posterior excess, predicted via the Johnson/Bailey analysis, are positively correlated with increases in the degree of posterior occlusal discrepancies.
- Although positively correlated, only 19% of the variability in average posterior cusp-embrasure discrepancies can be explained by the JB posterior prediction. Therefore, a virtual setup would assist in identifying the specific location of posterior discrepancies and better guide the clinician in making clinical decisions regarding precise management.

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