

Reliability of clinical crown center to predict marginal ridge leveling

Sérgio Estelita Barros^a; Denise Ficht^b; Guilherme Janson^c; Kelly Chiqueto^d; Eduardo Ferreira^a

ABSTRACT

Objective: To evaluate the null hypothesis that there is no difference between the vertical compensation necessary to level the clinical crown centers and that required to level the marginal ridges.

Materials and Methods: Initial dental casts selected from 200 patients that met the selection criteria were included. The vertical position of the clinical crown center (VPCC) and marginal ridge (VPMR) of posterior teeth were measured in both arches using a digital height gauge with 0.01mm precision. The vertical discrepancy between the clinical crown centers (VDCC) and marginal ridges (VDMR) of adjacent posterior teeth were calculated and compared. The significance level was set at $P < .05$.

Results: In general, vertical discrepancies between VDCC and VDMR were statistically significant ($P < .05$). Clinically significant differences were observed between the maxillary second premolar and first molar and between the mandibular molars. The VPCC was significantly and positively correlated with patient age.

Conclusions: Differences between VDCC and VDMR showed that the VPCC may not be an accurate predictor of marginal ridge leveling because the vertical compensation necessary to level the VPCCs is not similar to that required to level the marginal ridges, requiring caution in its utilization, mainly in teenagers. (*Angle Orthod.* 2017;87:556–562)

KEY WORDS: Tooth leveling; Bracket position; Clinical crown center; Marginal ridge

INTRODUCTION

The preadjusted appliance was designed to produce adequate tooth positioning without compensatory archwire bends. However, the concept that totally preadjusted appliances can treat malocclusions without any need for wire bending has not been scientifically supported.^{1–5} Bracket height can play an

important role in improving the clinical performance of preadjusted appliances, because vertical deviations smaller than 1 mm can be sufficient to produce significant clinical changes in torque, in-out, and marginal ridge leveling.^{5,6} The latter is a known objective of orthodontic treatment, and deviations greater than 0.5mm are negatively scored by the grading system of the American Board of Orthodontics (ABO).^{6–8} Poor leveling of the marginal ridge was the third greatest cause of lost points in 32 cases presented to the ABO.⁹

Using the incisal edge or cusp tip as an anatomical reference to measure bracket height has been common among orthodontists, as well as the use of the clinical crown center as a predefined vertical bracket position. Although the human eye can be quite accurate at locating the center of a clearly visible object,¹⁰ clinical conditions such as partially erupted teeth, gingivitis, crown morphology deviations, and lingual or palatal tooth displacement can impair accurate visualization of the clinical crown center.¹¹ Previous investigations have demonstrated that bracket position by the measurement method was more accurate than clinical crown center identification.² However, a more recent study has shown that the

^a Professor, Department of Orthodontics, Faculty of Dentistry, Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil.

^b Postgraduate Student, Department of Orthodontics, Faculty of Dentistry, Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil.

^c Professor and Head, Department of Orthodontics, Bauru Dental School, University of São Paulo, Bauru, SP, Brazil.

^d Professor, Department of Orthodontics, School of Dentistry, São Leopoldo Mandic, São Paulo, SP, Brazil.

Corresponding author: Dr Sérgio Estelita Barros, Department of Orthodontics, Faculty of Dentistry, Federal University of Rio Grande do Sul, Rua Ramiro Barcelos, 2492, Bairro Santana, Porto Alegre, RS - 90035-003, Brazil (e-mail: sergioestelita@yahoo.com.br)

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measurement method can also produce unleveled marginal ridges.⁴ Furthermore, there are many prescriptions for vertical bracket placement,^{11–14} but paradoxically, there is a lack of scientific studies to support them. In some cases, the prescriptions are sourced from individual clinical perceptions or based on data retrieved from dental anatomy books.^{5,11} On the other hand, the use of the clinical crown center for bracket placement seems to be a more streamlined clinical procedure, which can reduce chair time.

In order to shed some light on this issue, the aim of this study was to evaluate the reliability of the clinical crown center to predict marginal ridge leveling by comparing the vertical compensation necessary to level the clinical crown centers vs that required to level the marginal ridges.

MATERIALS AND METHODS

The sample size was calculated using values of α (type I error) and β (type II error) at 5% and 20%, respectively, and the value of the variance of measurements σ^2 (standard deviation) was based on a previous study.¹⁵ The minimum difference to be detected between marginal ridges and clinical crown center of adjacent teeth was 0.1 mm. Based on these parameters, a sample with at least 392 units in each dental group was required. The sample was obtained from a pool of 1430 subjects comprising the files of the Department of Orthodontics at Federal University of Rio Grande do Sul and the Orthodontic Service of the Military Polyclinic at Porto Alegre. The sample was a consecutive series of patients recruited from two centers. Total records of both centers had to be evaluated and all the eligible patients were selected in order to satisfy the sample size calculation for this retrospective cross-sectional study.

Sample selection was based on the following inclusion criteria: good-quality initial dental casts, initial panoramic and intraoral radiographs and photographs, permanent dentition with all teeth including second molars, molars and premolars in occlusion, good gingival and periodontal health as evaluated on intraoral photographs and radiographs, and no history of occlusal adjustment or parafunctional habits associated with occlusal wear. Exclusion criteria were extreme tooth malposition precluding dental cast measurement; extensive dental restorations involving cusp tip or marginal ridge; and dental anomalies of size, shape, or structure. Radiographs, photographs, and clinical records had to be included because the dental casts alone were not enough to demonstrate the fulfillment of all selection criteria.

Based on sampling calculation and selection criteria, 200 pairs of initial dental casts were selected. The

mean age of patients was 15.96 years (± 3.87), and gender distribution was similar (98 females—49%, and 102 males—51%). The sample was composed of maxillary and mandibular posterior teeth of both sides, summing 16 posterior teeth in each pair of dental casts. Thus, 3200 posterior teeth containing 400 units of each dental group (first premolars to second molars of maxillary and mandibular arches) were measured. The mean between right and left measurements was calculated for each dental group. Dental cast position was standardized with the aid of a parallelometer, whereas tooth measurements were performed using a digital height gauge with 0.01 mm precision (Mitutoyo America, series 570-312, Aurora, Ill; Figure 1).

First, the dental casts were fitted on a ball-joint base, which allowed an adjustable dental cast position (Figure 1). Landmarks used to standardize and measure the dental casts are shown in Figure 2. Before measuring each tooth, the long axis of the clinical crown, defined as a line passing through the buccal cusp tip (point A) and the deepest point of the buccal gingival margin (Point B), was aligned with the vertical rod of an L-shaped accessory attached to a parallelometer (Figures 2 and 3). Sequentially, the marginal ridge plane,¹⁶ defined by the buccal (point C) and lingual (point D) limits of the marginal ridge, was positioned parallel to the horizontal rod of the L-shaped accessory, keeping the previous adjustment for the long axis of the clinical crown (Figures 2 and 3). Thus, measurement of each tooth took place in a standardized and replicable position regarding the mesiodistal and buccolingual angulation of the tooth crown.

After standardization of dental cast position, the ball-joint base was locked and transferred to the digital height gauge with the dental cast in position and the following measurements were made: (1) vertical position of the mesial and distal marginal ridge of each tooth (VPMR), vertical distance between point A and the midpoint of the marginal ridge (point E, located between the buccal and lingual cusps; Figure 4); and (2) clinical crown height—vertical distance between points A and B; Figure 5).¹⁷ The middle of the clinical crown height was taken as the vertical position of the clinical crown center (VPCC).

The difference between the VPMR of adjacent marginal ridges was named vertical discrepancy between marginal ridges (VDMR), and it represents the degree of vertical compensation required to achieve leveling of these ridges. The difference between the VPCC of adjacent teeth was named vertical discrepancy between clinical crown centers (VDCC), and it represents the degree of vertical compensation required to level the clinical crown centers of the posterior teeth. Thus, the focus of this study was to evaluate the null hypothesis that there is



Figure 1. Instruments used in this study. Standardization of the dental cast position was obtained using an L-shaped accessory attached to a parallelometer. Tooth measurements were performed with a digital height gauge with 0.01-mm precision.

no difference between the vertical compensation necessary to level the clinical crown centers (VDCC) and that required to level the marginal ridges (VDMR, the gold standard). To analyze the study error, 40 of the 200 pairs of dental casts that composed this sample were randomly selected. The variables VPMR and VPCC were remeasured after 2 months by the same examiner (DF) following the previously described procedures. The agreement between the repeated measurements of each variable was evaluated using the method described by Bland and Altman.¹⁸

Statistical Analyses

Initially, descriptive statistics for all dental cast measurements were calculated. Data were tested for normality using the Shapiro-Wilks test. Normal distribution of data supported the use of parametric statistical tests to compare the variables.

Comparisons between VDMR and VDCC were performed by the *t*-test. The patient's age was correlated with the VPMR and VPCC using Pearson's correlation test.

Statistical analyses were performed with Statistica software (Statistica for Windows, version 7.0, Statsoft, Inc, Tulsa, Okla). Results were considered statistically

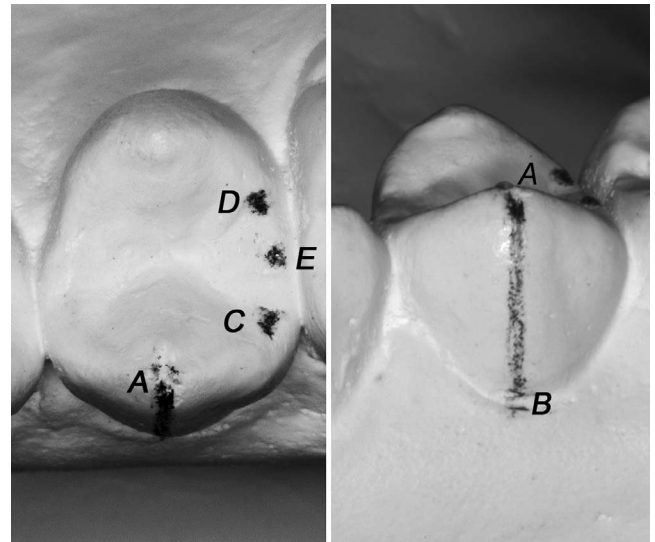


Figure 2. Landmarks. (A, B) Buccal cusp tip and the deepest point of the buccal gingival margin, which define the long axis of the clinical crown. (C, D) Buccal and lingual limits of the marginal ridge, which define the marginal ridge plane. (E) Midpoint of the marginal ridge located between the buccal and lingual cusps.

significant at $P < .05$. Vertical discrepancies between adjacent posterior teeth were considered clinically significant according to the threshold of 0.5mm proposed by the American Board of Orthodontics objective grading system (ABO-OGS).⁶

RESULTS

Using the Bland-Altman agreement approach, the measurements showed a bias smaller than or equal to 0.1. The VPMR of the maxillary right second molar was the dental cast measurement with the greatest bias (0.1 mm), whereas the other measurements had biases ranging from 0.01 to 0.09.

The null hypothesis was rejected. Except for the mandibular premolars, the VDMR was significantly different from that observed between the clinical crown centers of adjacent posterior teeth (VDCC; Table 1). Clinically relevant differences (>0.5 mm)⁶ between VDMR and VDCC were observed between the maxillary second premolars and the first molars and between the mandibular molars (Table 1).

In general, the VPMR was not significantly correlated with the patient's age, and correlation coefficient values were negligible (Table 2). Conversely, most teeth showed statistically significant correlation between the VPCC and patient's age (Table 3). The coefficient values indicated a moderate and positive correlation (mean *r* of 0.35) between the VPCC and patient's age (Table 3).

The mean VDMR (Table 4) was used to suggest differential values for vertical bracket position aiming at

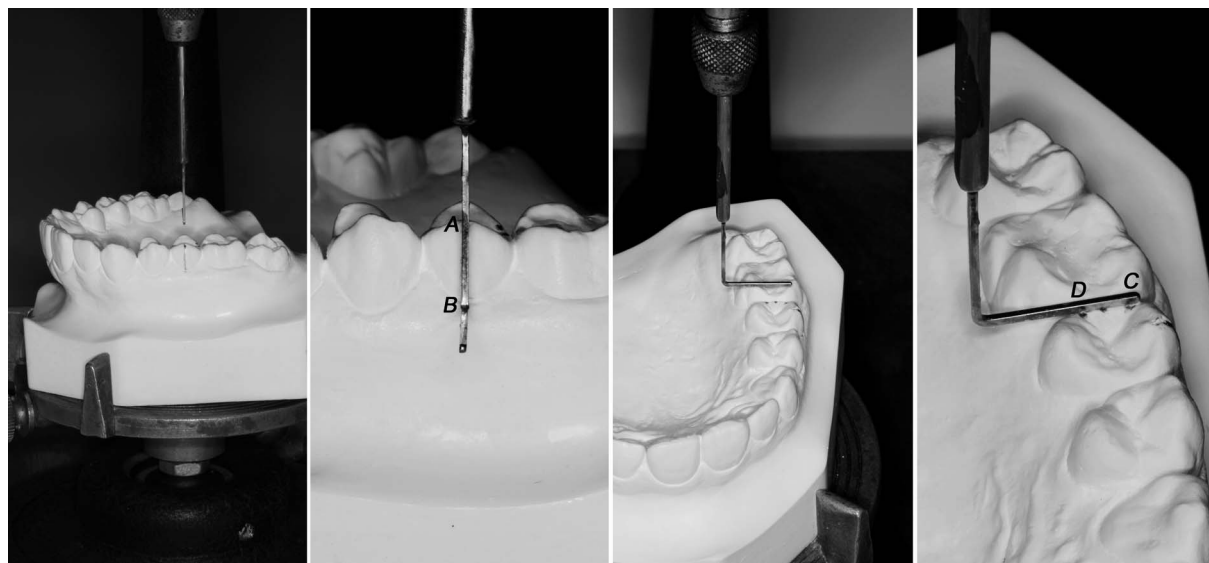


Figure 3. Standardization of dental cast position using an adjustable ball-joint base. Before measurement of each tooth, the long axis of the clinical crown was aligned to the vertical rod, whereas the marginal ridge plane was positioned parallel to the horizontal rod of an L-shaped accessory attached to a parallelometer. Thus, measurements were performed using a standardized mesiodistal and buccolingual angulation of the tooth crown.

marginal ridge leveling (Table 4). The most relevant vertical compensations for bracket position from a clinical standpoint were found between premolars and between second premolars and first molars in both arches.

DISCUSSION

The accuracy of digital height gauge associated with a standardized measurement protocol produced reliable dental cast measurements according to the outcomes of study error. Although the dental casts were carefully selected and tooth measurements were

reliable, it should be highlighted that the retrospective nature of this study does not control factors that may have produced a distorted impression or cusp tip wear due to dental cast smoothing and polishing or due to daily handling. Considering that most individuals with good-to-excellent occlusions have marginal ridges within 0.5 mm of the same level,¹⁹ this acceptable threshold for marginal ridge leveling, as suggested by the ABO-OGS index,⁶ was deemed as a reasonable limit for clinical significance in this study.⁴

The clinical crown center has been accepted as a predefined reference for vertical bracket position based

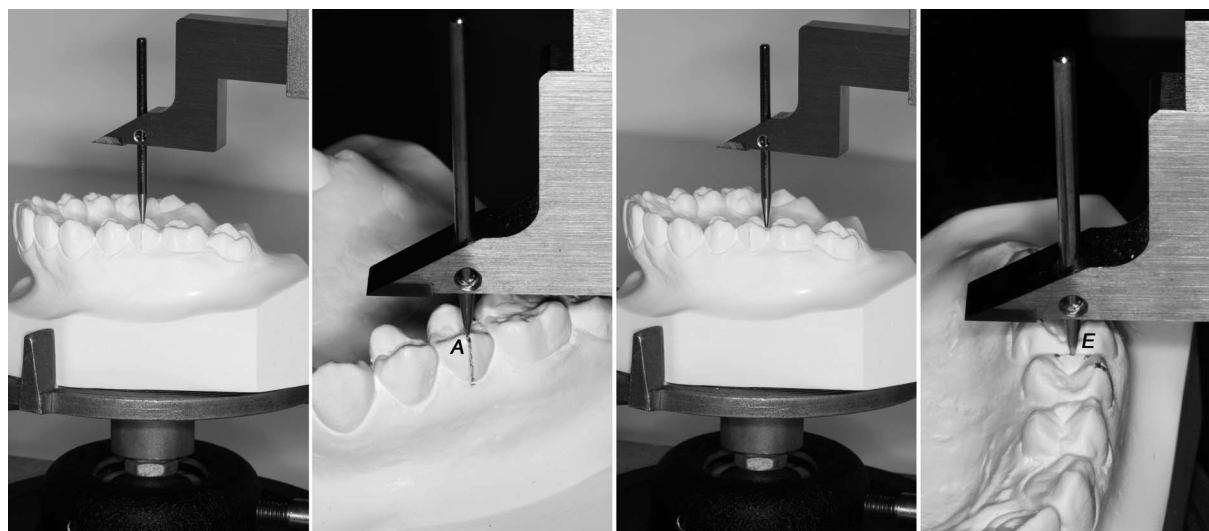


Figure 4. Measuring the vertical position of the marginal ridge (VPMR)—linear distance between the cusp tip (point A) and the midpoint of the marginal ridge located between the buccal and lingual cusps (point E).

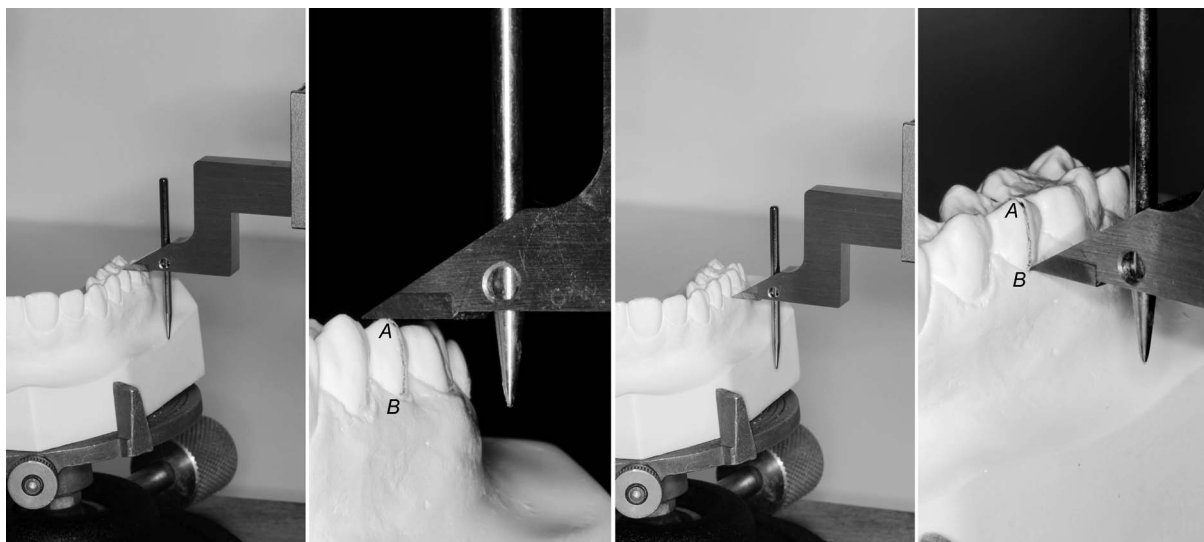


Figure 5. Measuring the clinical crown height—distance between the cusp tip (point A) and the deepest point of the gingival margin (point B), which was used to calculate the vertical position of the clinical crown center (VPCC).

on the premise that there is equivalence between the leveling of marginal ridges and clinical crown centers.^{10,20} However, when the vertical discrepancies of adjacent marginal ridges and clinical crown centers were compared, it became evident that they are not equivalent (Table 1). Thus, it seems clear that the clinical crown center is not a reliable reference to accurately predict marginal ridge leveling. This conclusion has been supported by other authors, suggesting that bracket bonding guided by measuring the distance from the incisal edge or cusp tip may result in improved vertical bracket position.^{1,2,11,21} However, it must be considered that the difference between marginal ridge and the VDCC exceeded the 0.5mm threshold only between the maxillary second premolar and the first molar and between the mandibular molars (Table 1). Thus, although the clinical crown center is not so accurate to predict marginal ridge leveling, in most cases it would be able to produce tolerable results.

Table 1. Vertical Discrepancy Between Adjacent Marginal Ridges and Clinical Crown Centers of Adjacent Posterior Teeth (*T*-Test)

Variables		VDCC ^a , mm		VDMR ^b , mm		<i>P</i> *
		Mean	SD	Mean	SD	
1st PM–2nd PM	Mx	0.57	0.23	0.72	0.35	<.001
2nd PM–1st M		0.22	0.28	0.78	0.34	<.001
1st M–2nd M		0.38	0.31	0.23	0.39	<.001
1st PM–2nd PM	Md	0.55	0.23	0.60	0.37	.099
2nd PM–1st M		0.44	0.25	0.74	0.37	<.001
1st M–2nd M		0.28	0.28	–0.23	0.35	<.001

^a VDCC indicates vertical discrepancy between clinical crown centers of adjacent posterior teeth.

^b VDMR indicates vertical discrepancy between adjacent marginal ridges;

PM indicates premolar; M, molar; Mx, maxilla; Md, mandible.

* Statistically significant at *P* < .05.

The correlation between the VPCC and patient age was notoriously more expressive than that found for the marginal ridge (Tables 2 and 3). This finding can help explain the nonequivalence between vertical discrepancies obtained from these landmarks (Table 1). In fact, it has been demonstrated that the clinical crown length of permanent teeth continues to increase significantly throughout the teen years (12–19), corresponding to the age range of this sample.²² This developmental change directly affects the VPCC (Table 3), while the VPMR–cusp tip difference is not significantly affected if the patient has no parafunctional habit associated with tooth attrition (Table 2). It can be speculated that age and the occlusal development stage influenced the results. The most significant vertical discrepancies between clinical crown center

Table 2. Correlation Between Vertical Positioning of the Marginal Ridge and Patient's Age

Variables		<i>R</i>	<i>P</i> *
1st PM VPMR-D ^a	Mx	–0.05	.425
2nd PM VPMR-M ^b		0.06	.362
2nd PM VPMR-D		0.04	.484
1st M VPMR-M		0.11	.119
1st M VPMR-D		–0.15	.026
2nd M VPMR-M		0.03	.598
1st PM VPMR-D	Md	0.09	.202
2nd PM VPMR-M		0.14	.055
2nd PM VPMR-D		0.13	.063
1st M VPMR-M		0.02	.692
1st M VPMR-D		0.12	.079
2nd M VPMR-M		–0.02	.697

^a VPMR-D indicates vertical positioning of distal marginal ridge.

^b VPMR-M indicates vertical positioning of mesial marginal ridge; PM indicates premolar; M, molar; Mx, maxilla; Md, mandible.

* Statistically significant at *P* < .05.

Table 3. Correlation Between Vertical Position of Clinical Crown Center (VPCC) and Patient's Age

Variables		R	P*
1st PM	Mx	0.35	<.001
2nd PM		0.38	<.001
1st M		0.33	<.001
2nd M		0.44	<.001
1st PM	Md	0.19	.007
2nd PM		0.30	<.001
1st M		0.34	<.001
2nd M		0.48	<.001

PM indicates premolar; M, molar; Mx, maxilla; Md, mandible.

* Statistically significant at $P < .05$.

and marginal ridge included the first molars, which begin their eruption around age 6, whereas the adjacent teeth erupt significantly later. Thus, it can be assumed from Table 1 that the expected increments in the clinical crown length of newly erupted teeth could progressively reduce the differences between VDMR and VDCC. Consequently, a greater reliability of the clinical crown center as a predictor of marginal ridge leveling could be expected toward adulthood. However, the cross-sectional nature of this research may not be the most reliable study design to evaluate changes through time.

Clinical Implications

Direct bonding on the clinical crown center without using a bracket height gauge is the simplest clinical procedure for bracket bonding and probably the most used in daily practice.²³ However, this procedure must be used with caution when performed on posterior teeth in the early permanent dentition because its reliability to predict marginal ridge leveling can be influenced by the dental development stage, besides the dentogingival features and the eyeballing accuracy of the professional. Thus, use of the clinical crown center for vertical bracket positioning should be reserved for more ideal conditions, wherein patient maturation is already achieved (young adults), the clinical crown is completely exposed, gingival level and contour are not compromised by inflammation or extreme tooth malposition, and crown shape is not anomalous. When clinical conditions are not ideal for clinical crown center visualization and the professional is less experienced, the differential bonding values obtained from this study can be applied with the aid of a bracket height gauge to obtain more accurate posterior leveling (Table 4). Nowadays there are many prescriptions for vertical bracket placement, but paradoxically there is a lack of well-designed scientific studies to support them. The values suggested in this study are supported by an adequate study design applied to a generous sample size. However, due to the well-known inter- and intraindividual variability of

Table 4. Differential Values Suggested for Vertical Bracket Positioning Based on the Values of Vertical Discrepancy Between Adjacent Marginal Ridges (VDMR) Obtained From This Study

Variables	1st PM	2nd PM	1st M	2nd M
Maxilla	X ^a	X-0.7	X-1.5	X-1.7
Mandible	X	X-0.6	X-1.3	X-1.1

PM indicates premolar; M, molar.

^a X - Vertical height for bracket bonding

tooth shape and size, some orthodontists are critical of using bracket-placement charts.^{16, 21}

If the professional preference is not to use bracket-placement charts, then individualized bracket positioning¹⁶ to align the occlusal edge of the bracket pad with an imaginary line drawn from the mesial and distal heights of contour (rather than the clinical crown center) might produce vertical compensations closer to the gold standard assumed in this study. In this way, the landmarks would be not be influenced by the previously mentioned variables. However, further studies are necessary to evaluate this assumption.

CONCLUSIONS

- The clinical crown center was not an accurate predictor of marginal ridge leveling.
- Patient age is an additional factor influencing the reliability of using the clinical crown center to predict marginal ridge leveling.

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