Original Article

Reliability of an indirect bone-probing method for diagnosis of labial bone crest level of the mandibular anterior teeth

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ABSTRACT

Objectives: To evaluate the null hypothesis that there would be no difference between the labial bone crest level of the mandibular anterior teeth evaluated with an indirect bone-probing method (IBP) and cone-beam computed tomography (CBCT).

Materials and Methods: Twenty-nine adult patients with a mean age of 32.15 ± 8.75 years were enrolled. An IBP based on indirect tactile perception was used to determine the labial bone crest level of the mandibular anterior teeth clinically. Bone crest perception degree, gingival thickness, and patient discomfort during IBP were also recorded. CBCT scans were used to evaluate the level and thickness of the labial bone crest. IBP and CBCT methods were compared statistically. The significance level was set at 5%.

Results: There was a significant difference between the labial bone crest level diagnosed by IBP and CBCT. However, the difference was not clinically significant. IBP and CBCT measurements were significantly and strongly correlated ($R = 0.74$). Thinner gingival tissue was associated with a higher perception of bone crest. Only two patients reported mild to moderate discomfort during IBP.

Conclusions: IBP allowed the labial bone crest level to be determined with acceptable clinical accuracy, especially in patients with thinner gingival tissue. (*Angle Orthod.* 2022;92:333–339.)

KEY WORDS: Bone crest; Indirect probing; Diagnosis; Periodontal status

INTRODUCTION

Tooth movement, especially in the labio-lingual direction, can produce unwanted and irreversible changes to the height of the alveolar bone crest and gingival insertion.[1,2] The risk of orthodontic treatment causing damage to the periodontium may vary according to some initial clinical conditions, such as the presence, height, and thickness of the alveolar bone; the gingival biotype; the presence of gingival inflammation; as well as factors related to orthodontic mechanics, including the type of tooth movement, the intensity of orthodontic load, and the amount of tooth movement required.[3–5]

Dehiscence and fenestration have a high prevalence and are a common finding before orthodontic treatment, especially in the mandibular anterior teeth labial periodontium.[6] Therefore, this area of known vulnerability requires careful pretreatment evaluation to identify bone dehiscence,[6] which could lead to gingival recession, especially when proclination and/or derotation of the mandibular anterior teeth is planned.[1,2] Some types of tooth movement can produce or increase the severity of pretreatment bone dehiscence, encouraging the development of gingival recession during or after treatment, especially if aggravated by other predisposing factors.

Because bone dehiscence cannot be diagnosed with a clinical examination or by conventional (two-dimensional) radiographs, cone-beam computed tomography (CBCT) has been considered the noninvasive gold standard method for diagnosing bone defects, such as dehiscence and fenestration.[7] However, there is no consensus on the routine use of CBCT in orthodontic practice. The use of larger voxel sizes can reduce the

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Accepted: December 2021. Submitted: July 2021.
Published Online: January 31, 2022

radiation dose delivered to the patient, but the lower resolution of the radiographic image may compromise the evaluation of bone defects.[8] Alternatively, an invasive probing method has already been proposed to evaluate bone crest height and dehiscence.[9,10] However, a noninvasive and nonionizing method has not been previously proposed or tested for the clinical detection of the presence and level of the labial bone crest of the mandibular anterior teeth.

Thus, the objective of this study was to evaluate the accuracy of an innovative probing method, indirect bone probing (IBP), which uses a specially designed probe to perceive the presence and level of the labial bone crest of the mandibular anterior teeth. Therefore, this study tested the null hypothesis that there would be no difference between the labial bone crest level of the mandibular anterior teeth evaluated with CBCT and IBP.

MATERIALS AND METHODS

This cross-sectional observational study was focused on the diagnostic accuracy of radiographic (CBCT) and clinical (IBP) methods for determining the presence and level of the labial bone crest of the mandibular anterior teeth. This research was approved by the institutional review board of the Faculty of Dentistry, Federal University of Rio Grande do Sul, under protocol number 4.194.434.

Patients were selected based on the sample size calculation and the following criteria: adult patients regardless of their sagittal malocclusions (class I, II, or III), absence of active periodontal disease, and mild to moderate mandibular anterior crowding. The procedures involved in this research were explained to each patient, and informed consent was obtained before patient recruitment. Twenty-nine patients (18 female, 11 male) with a mean age of 32.15 $\pm$ 8.75 years were consecutively selected and enrolled in this study. Considering that one patient had agenesis of mandibular lateral incisors, 172 mandibular anterior teeth were evaluated in this study.

The Device

A newly designed clinical probe was developed from a conventional periodontal probe by changing its working end to an atraumatic shape. The working end is made with a 0.6-mm stainless-steel wire and has a semicircular ("U")–shaped working end, with 2.5-mm length and 1.5-mm diameter (Figure 1). It was specially designed to detect the presence of the alveolar bone crest based on the indirect tactile perception of the unevenness between the surfaces of the tooth root and alveolar bone (bone crest), which was called IBP. Thus, the instrument shank was bent to allow it to be parallel to the alveolar process and labial vestibule during the indirect probing procedure, so that the working end and handle of the probe were positioned at about 45° and 60° to the probing surface, respectively (Figures 1 and 2). This design increases the efficiency of the indirect probing process, since the 45° position allows the working end of the probe to simultaneously slide and press the labial bone plate surface, benefiting the indirect tactile perception (Figure 2).

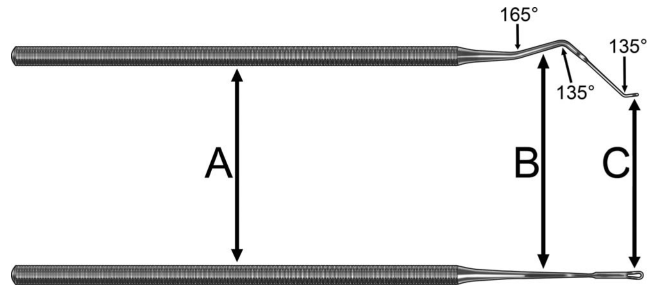

Figure 1. Indirect bone probe. (A) Handle. (B) Shank. (C) Semicircular ("U")–shaped working end.

Clinical Evaluation

The periodontal examination was performed by a previously calibrated operator (Dr Calvi). To ensure patient comfort during the IBP exam, 10% lidocaine topical anesthetic spray was applied over the region to be examined.

The working end of the probe was positioned on the outer surface of the marginal gingiva on the labial side of the evaluated tooth. Then, the working end was slid apically over the soft tissue covering the labial aspect of the tooth root and alveolar bone, applying gentle pressure against the gingiva (Figure 2). After, this same sliding procedure was performed in a coronal direction, following the long axis of the tooth. When necessary, this procedure was repeated sequentially until the indirect tactile perception of the operator was able to detect the presence of an unevenness between the surfaces of the tooth root and the alveolar bone, which corresponded to the beginning of the alveolar bone on the central axis of the tooth (labial bone crest). The site where the labial bone crest was perceived was marked on the alveolar-gingival mucosa using a marker pencil. To determine the bone crest level in relation to the tooth, the distance between the bone crest point marked on the soft tissue and the midpoint of the incisal edge or cusp tip was measured, following the long axis of the tooth (Figure 3A). The clinical crown height was determined by the distance between the midpoint of the incisal edge or cusp tip and the deepest point in the concavity of the labial gingival contour (Figure 3B).

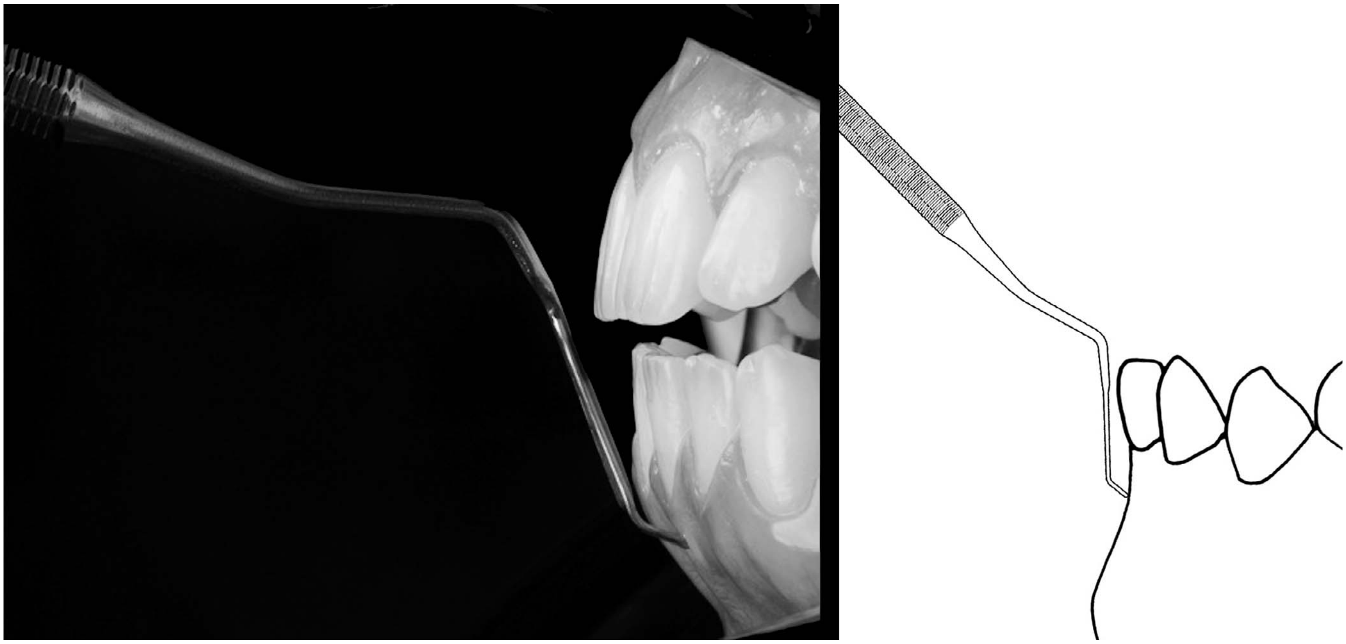

Figure 2. Indirect bone probe in position for clinical examination. The probe is vertically slid and slightly pressed against the gingiva and labial bone plate, such that bone crest can be perceived by indirect tactile perception.

The bone crest level in relation to the free gingival margin was determined by the difference between the values obtained for the variables bone crest level in relation to the tooth (Figure 3A) and clinical crown height (Figure 3B). This calculation allowed determination of the degree of bone dehiscence in the sample, based on a normal value of about 3 mm.[11] The measurements were performed for all mandibular anterior teeth using a dry-tip digital compass with 0.1-mm precision (Precision digital compass, Igaging, Dongguan, China; Figure 3C).

The degree of difficulty in perceiving the labial bone crest of the mandibular anterior teeth was scored using an ordinal scale: score 1, high bone perception; score 2, moderate bone perception; score 3, low bone perception; score 4, absent bone perception.

The gingival thickness of the mandibular anterior teeth of each patient was classified as thin or thick if the periodontal probe was visible or not after its placement in the labial gingival sulcus.[12] The degree of patient discomfort during IBP was evaluated by a numerical verbal scale (0 to 10) as *no pain* (0), *weak pain* (1 to 3), *moderate pain* (4 to 6), *severe pain* (7 to 9), or *unbearable pain* (10).[13]

Tomographic and Cephalometric Evaluation

A pretreatment CBCT scan was taken of each patient using the same machine (Orthopantomograph; Kavo, Instrumentarium Dental, Tuusula, Finland) using the following settings: 90 kVp, 10 mA, exposure time of 6.15 seconds, voxel size of 0.089 mm, and 61 × 41-mm field of view (FOV). Images were converted to DICOM format and imported into OnDemand3D software (Cybermed Inc., Seoul, Korea), which was used to measure the labial bone crest level, clinical crown height, and labial bone plate thickness. To avoid any bias of the clinical examination in the radiographic evaluation, the examiner (Dr Calvi) was blinded to patient information. The three-dimensional orientation of the mandibular segmental images, before measurement, was standardized using reference points and planes located on the teeth. In this way, the coronal and sagittal planes were aligned along the long axis of the tooth of interest, while the axial plane was oriented through the mesial and distal contact points.[14] The labial bone crest level and clinical crown height were measured using the same clinical landmarks (Figure 4A,B). The level of the bone crest in relation to the gingival margin was obtained by the same arithmetic calculation method applied to the corresponding clinical variable. In addition, the labial bone plate thickness was also determined as in Figure 4C.

Pretreatment lateral headfilms were digitized, and a customized cephalometric analysis was used to determine the cephalometric characteristics of the sample. Cephalometric evaluation was performed by a single examiner (Dr Chiqueto), who was blinded to patient identification. The data were analyzed with Radiocef Studio 2 software (Radiomemory, Belo Horizonte, Brazil). Lateral headfilms were obtained using the same x-ray machine (Orthopantomograph; Kavo, Instrumentarium Dental), which produced an

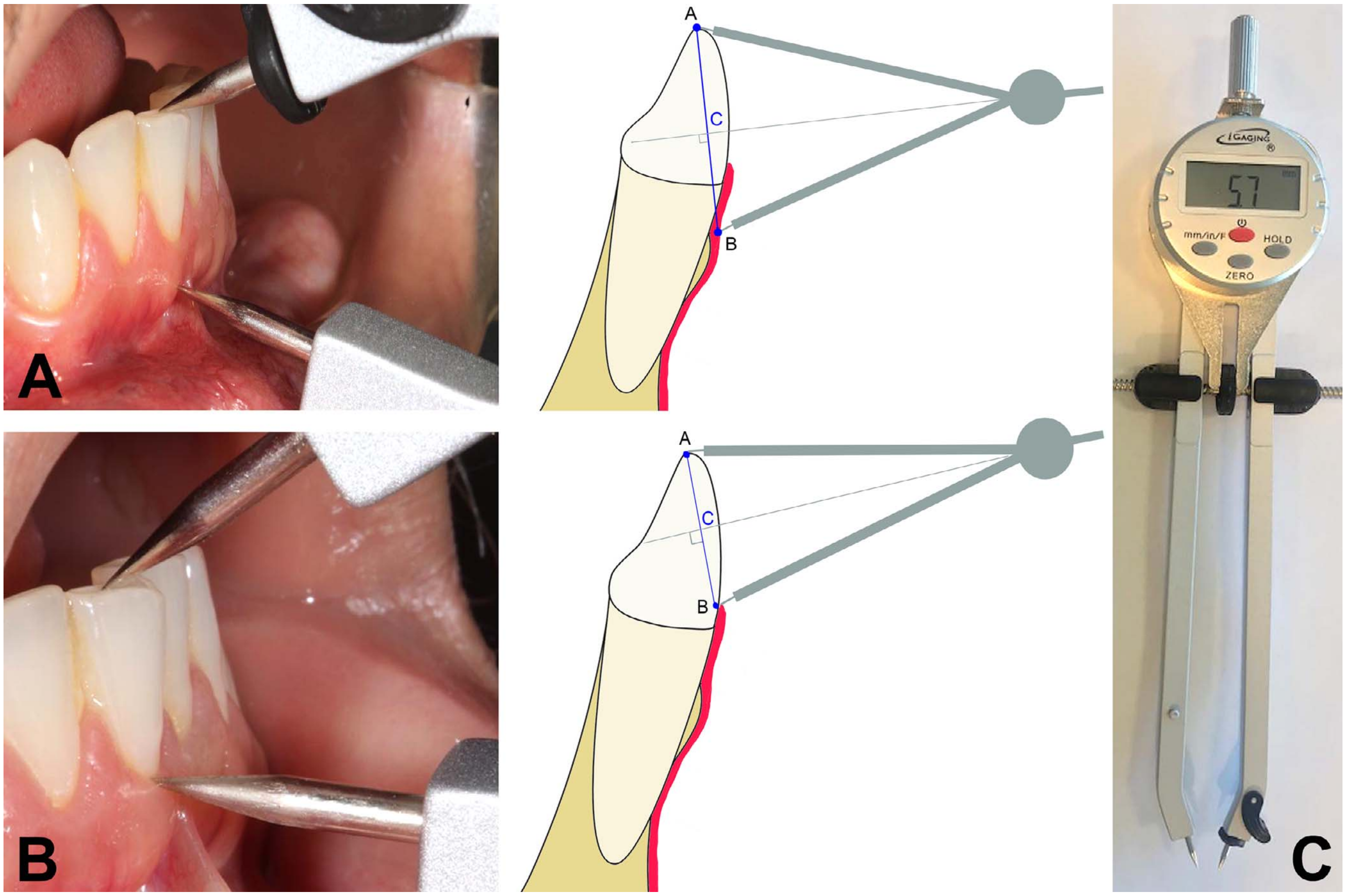

Figure 3. Measurement of the clinical variables. (A) Measurement of the bone crest level in relation to the incisal edge represented by the distance (C) between the incisal edge (A) and the gingival mark recorded by the IBP procedure (B). (B) Measurement of the clinical crown height, represented by the distance (C) between the incisal edge (A) and the deepest point in the concavity of the gingival contour (B). (C) Dry-tip digital compass used for clinical measurements (Precision digital compass, Igaging, 35-CD28, Dongguan, China).

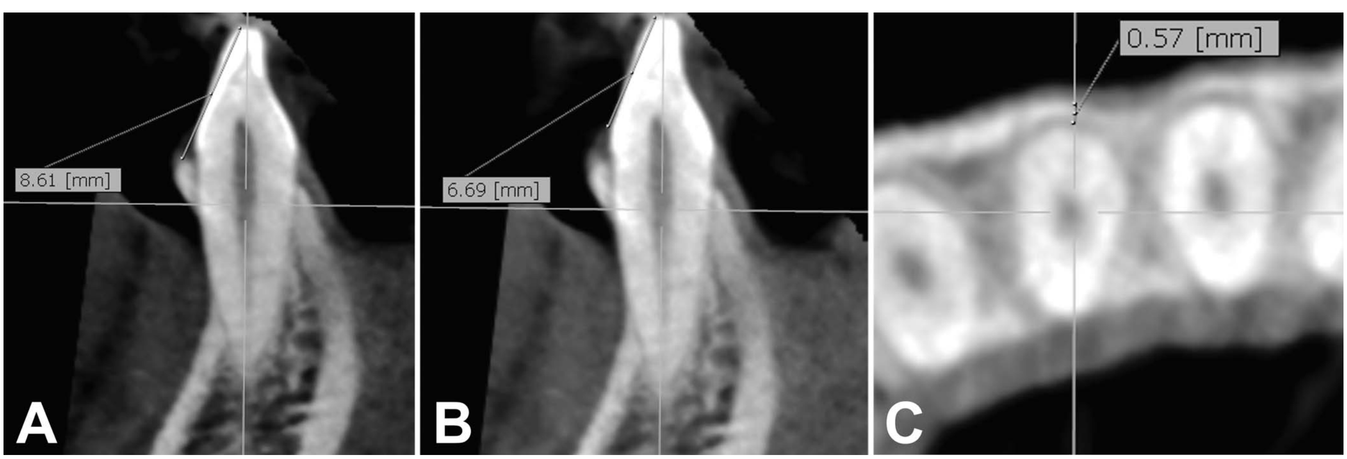

Figure 4. Measurement of the radiographic variables. (A) Distance between the midpoint of the incisal edge and the labial bone crest measured in the sagittal plane and over the long axis of the tooth to determine the labial bone crest level. (B) Distance between the midpoint of the incisal edge and the gingival margin measured in the sagittal plane and over the long axis of the tooth to determine the clinical crown height. (C) Distance between the labial surface of the tooth root and the labial surface of the bone plate measured in the axial plane, at an axial cut height of 0.5 mm below the bone crest, to determine labial bone plate thickness.

Table 1. Sample Distribution and Characteristics

Variable	Mean (N = 29)	SD
Age, y	32.15	8.75
Sex, n (%)		
Male	11 (37.93)	
Female	18 (62.07)	
Cephalometric characteristic		
ANB, °	1.78	2.09
FH.MP, °	23.19	4.57
SN.GoGn, °	31.32	5.94
NSGn, °	67.16	3.88
1.NB, °	25.80	6.58
Md1.MP, °	92.74	5.69

image magnification of 15%. This enlargement was corrected on the cephalometric software to match a 0% magnification factor.

To evaluate the error of the method, 10 CT scans and lateral headfilms were randomly selected and analyzed by the same examiner after a period of 2 weeks. The intraclass correlation coefficient (ICC) was used to assess intraexaminer reliability and reproducibility for all radiographic measurements.

Statistical Analysis

The ICC indicated that the measurement reliability and reproducibility degree ranged from excellent to good (ICC, 0.993–0.831). Descriptive statistics were carried out for clinical and radiographic continuous variables. Nominal and ordinal categorical variables were evaluated using chi-square tests. According to the results of the Shapiro-Wilk normality tests, nonparametric tests were selected for statistical analysis. Clinical and radiographic variables were compared and their correlation investigated by Wilcoxon and Spearman tests, respectively. All statistical tests were carried out using Statistica software (version 7.0, StatSoft Inc, Tulsa, Okla), adopting a significance level of 5%.

RESULTS

In general, adult orthodontic patients evaluated in this study showed a balanced sagittal and vertical skeletal pattern and well-positioned mandibular incisors (Table 1).

Labial bone crest levels measured in relation to the incisal edge or cusp tip between clinical and radiographic methods showed a slight difference, but the mean difference of 0.45 mm was not considered clinically significant (Table 2). The labial bone crest level measured in relation to the gingival margin was similar between the clinical and radiographic methods (Table 2). In addition, clinical and radiographic measurements performed to evaluate the labial bone crest level in relation to the incisal edge or cusp tip were significantly and strongly correlated ($R = 0.74$; Table 3).

Table 3. Correlation Between Clinical and Radiographic Evaluation of Bone Crest Level

	Clinical × Radiographic	
Variable	*R*	*P*
Bone crest to incisal edge (n = 163)	0.740	<.001*

* Statistically significant at $P < .05$.

Gingival thickness was associated with the ability of the examiner to perceive the bone crest. The labial bone crest of the mandibular anterior teeth was detected in 95% of all teeth evaluated. Thinner gingival tissue prevented the occurrence of cases with a low degree of perception. In contrast, thicker gingival tissue was associated with poorer perception of the bone crest, including nine teeth (5%) in which the bone crest could not be detected (Table 4).

The thickness of the labial bone plate was not correlated with the ability of the examiner to perceive the labial bone crest level. Although weak, there was a significant and positive correlation between gingival and bone thickness (Table 5).

The distance between the gingival margin and labial bone crest exceeded the normal range (3 mm), especially in the fourth quartile (Table 6). Only two patients reported mild sensitivity during the IBP exam, whereas the others reported no discomfort.

DISCUSSION

It is known that adult patients are more vulnerable to eventual periodontal damage associated with orthodontic treatment. The mean age of the sample in this study was consistent with that age at which adults have great interest in seeking orthodontic treatment (Table 1). The cephalometric features showed the presence of a balanced facial pattern and well-positioned mandibular incisors (Table 1). These general characteristics of the sample were consistent with the selection criteria adopted, since a specific skeletal pattern or malocclu-

Table 2. Comparison Between Clinical and Radiographic Evaluation of Bone Crest Level

	Clinical Measurement		Radiographic Measurement		
Variable	Mean	SD	Mean	SD	*P*
Bone crest to incisal edge (n = 163)	11.90	1.82	12.38	2.43	.002*
Bone crest to gingival margin (n = 159)	3.53	1.29	3.49	1.76	.288

* Statistically significant at $P < .05$.

Table 4. Relationship Between Gingival Thickness and Bone Crest Perception

Variable	Gingival Thickness, n (%)		
	Thin	Thick	*P*
Bone crest perception (n = 172)			
High	24 (60.00)	48 (36.36)	<.001*
Moderate	16 (40.00)	42 (31.82)	
Low	0 (0)	33 (25.00)	
Absent	0 (0)	9 (6.82)	

* Statistically significant at $P < .05$.

sion was not prioritized. This allowed the evaluation of the IBP method in unrestricted clinical conditions. A small sample reduction in this study was due to tooth agenesis (two teeth), nondetected bone crest by IBP (nine teeth), and nonvisualized gingival margin on CBCT (four teeth).

The labial bone crest level in relation to the incisal edge and cusp tip was about 0.45 mm more occlusally positioned in the clinical evaluation than in the radiographic evaluation (Table 2). This difference was not considered clinically significant and might be associated with the thickness of the gingival tissue pressed against the bone crest during the IBP process, which displaced the indirect tactile perception of the operator to a slightly more occlusal point. In addition to the negligible clinical impact of this difference, clinical and radiographic methods were significantly and strongly correlated ($R = 0.74$; Table 3). This reinforced the assumption that the main reason for this small difference was the systematic influence of overlapping gingival tissue during the IBP process rather than a systematic inaccuracy of the operator's perception in determining the bone crest level.

The bone crest level in relation to the gingival margin showed no statistically or clinically significant difference between the methods of clinical and radiographic diagnosis (Table 2). Although invasive bone-probing methods can accurately evaluate the labial bone crest level, their invasive characteristic requires local anesthetic infiltration, besides damaging the junctional epithelium and gingival conjunctive insertions.[9,10] Considering the risk of gingival recession due to more apical reinsertion during the healing process of the injured epithelium,[15] the transgingival probing technique should be considered with caution, especially in a periodontium area weakened by bone dehiscence. Currently, CBCT is the only noninvasive orthodontic pretreatment exam that is considered accurate for detecting bone dehiscence and fenestrations of the alveolar bone.[16] However, this pretreatment assessment is not routinely requested by many orthodontists because of its higher cost, complexity, and radiation dose delivered to the patient.[17] Considering the results of this study, the IBP represents an accurate,

Table 5. Influence of Bone Thickness (Radiographic) on Bone Crest Perception and Gingival Thickness (Clinical)

Variable	Bone Thickness	
	R	*P*
Bone crest perception (n = 172)	−0.034	.657
Gingival thickness (n = 172)	0.243	.001*

* Statistically significant at $P < .05$.

noninvasive, and nonionizing method of evaluating the labial bone crest level of the mandibular anterior teeth before orthodontic treatment.

The success rate for indirect perception of the bone crest level was 95% for the total sample and was even higher in patients with thinner and less fibrous gingival tissue (100%). The lowest indirect perception degree of the bone crest level was reported for 25% of the teeth covered with thick gingival tissue (Table 4). This may have contributed to reduce the mean accuracy of the IBP method in determining the bone crest level. It seems quite reasonable to assume that the accuracy of a bone-probing method involving the indirect tactile perception of the operator would be influenced by the thickness of the soft tissue covering the bone surface. Another factor that could influence the operator's perception is the thickness of the labial bone plate at the level of the bone crest. However, this variable had no significant influence on operator perception (Table 5). The reason for this may have been because the thickness of the labial bone plate was significantly and positively correlated with the gingival thickness (Table 5).[18] Considering that gingival thickness significantly influenced the operator's perception to detect the bone crest level, thicker gingival tissue could have totally or partially nullified the benefit that a thicker bone plate could bring to its perception. On the other hand, a less fibrous and thin gingival tissue could be more efficiently compressed, benefitting indirect tactile perception, even when bone thickness is thin. Thus, the labial bone crest level could be evaluated in the orthodontic pretreatment phase without the need for invasive or ionizing exams, especially in patients with thinner gingival tissue.

More than a quarter of the untreated adult patients in this sample showed an increased distance between the gingival margin and the labial bone crest in the pretreatment phase, exceeding the normal value of 3 mm (Table 6).[11] This discrepancy between the levels of the gingival margin and the bone crest characterized the occurrence of bone dehiscence, which represents an increased risk of gingival recession during orthodontic treatment.[1,4,11] It is known that gingival recession is always accompanied by alveolar bone dehiscence, but the opposite is not always true, making preexisting bone dehiscence a clinically undetectable risk factor for gingival recession during orthodontic treatment.[1,6,11,15]

Table 6. Values at the 25th, 50th, and 75th Percentiles of Bone Crest Level in Relation to the Gingival Margin

			Percentile		
Variable	Mean	SD	25th Lower Quartile	50th Median	75th Upper Quartile
Bone crest to gingival margin	3.49	1.69	2.54	3.02	3.86

Thus, IBP performed in the pretreatment stage can be considered a simple, comfortable, low-cost, noninvasive, nonionizing, and accurate procedure, which can have a beneficial application in the diagnosis of preexisting bone dehiscence. As a result, the risk of gingival recession during and after orthodontic treatment could be reduced as a result of conscious and careful planning of orthodontic treatment, especially in areas at risk, such as the labial periodontium of the mandibular anterior teeth. Rapid maxillary expansion is another common clinical procedure that moves teeth in the buccal direction, bringing periodontal risk, especially for premolars. However, the reliability of IBP involving other areas of the dental arch with thicker gingival tissue, as well as in younger patients, and with more raters, still needs to be evaluated. Although the indirect bone probe is not yet commercially available, essential information for instrument construction was provided in this study, allowing its immediate clinical application and reproduction.

CONCLUSIONS

- Indirect bone probing (IBP) allowed the labial bone crest level to be determined with acceptable clinical accuracy, especially in patients with thinner and more delicate gingival tissue;
- This very simple, noninvasive, and nonionizing clinical examination can be used routinely to reduce the need for CBCT to evaluate the labial bone plate level that covers the labial root aspect of the mandibular anterior teeth, assisting in orthodontic treatment planning.

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