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DOI:

10.4103/jos.jos\_190\_21

# Impact of orthodontic correction of dental crowding with pre-molar extraction in the anterior mandible evaluated by cone-beam computed tomography

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Submitted: 25-Nov-2021

Revised: 07-May-2022

Accepted: 26-May-2022

Published: 13-Oct-2022

## Abstract

**INTRODUCTION:** To evaluate, by cone-beam computed tomography (CBCT), the change in thickness and height of the alveolar bone and interdental septum in the anterior mandible after orthodontic treatment for dental crowding using tooth extraction.

**MATERIAL AND METHODS:** The sample consisted of 48 mandibular incisors from adult patients who presented with Class I malocclusion and required orthodontic treatment with the extraction of mandibular premolars. CBCT images were taken before starting the treatment (T1) and three months after treatment (T2). The following measurements were evaluated: width and height of the alveolar bone and the interdental septum, the distance between the cemento-enamel junction and the bone ridges (F-CEJ-MBC and L-CEJ-MBC), as well as the vertical positioning and inclination of the incisor, using the Lingual Plane as the reference point. The paired Student's t-test and Pearson correlation were used with a significance level of 5%.

**RESULTS:** A significant increase was observed in the distance L-CEJ-MBC, which shows the appearance of bone dehiscence. The degree of dental crowding was not a risk factor for the development of dehiscence. The decrease in the incisor inclination and intrusion was related to the formation of dehiscence on the lingual surface.

**CONCLUSION:** The variation in the incisor's inclination and intrusion during the treatment of dental crowding using tooth extraction are related to the formation of bone dehiscence on its lingual surface.

## Keywords:

Bone resorption, computed tomography, tooth movement

## Introduction

Dental crowding is the most common malocclusion in patients worldwide and can be defined as a discrepancy between the size of the teeth and the length of the dental arch and/or positioning, which can result in misalignment, leading to abnormal contact between teeth.<sup>[1,2]</sup>

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During tooth movement in orthodontic treatment, the bone tissue surrounding the alveolar ridge is commonly reshaped according to the type of tooth movement.<sup>[3]</sup> The reduction in the volume of the alveolar bone, often to a minimal thickness or even non-existent, can be a complicating factor for orthodontic treatment.<sup>[3,4]</sup>

**How to cite this article:** Cardoso CA, Valerio CS, Carmelo JD, Rodrigues LG, Vespasiano Silva AI, Manzi FR. Impact of orthodontic correction of dental crowding with pre-molar extraction in the anterior mandible evaluated by cone-beam computed tomography. J Ophthalmic Sci 2022;11:47.

Therefore, the choice of the treatment plan should consider both bone morphology and tooth position. The observation of each patient's anatomical details, as well as the comprehension of the dental risks and damage to the adjacent tissue, enables one to recognize the limits of orthodontic treatment and to practice orthodontics more safely.<sup>[3]</sup> Hence, the structure and topography of the alveolar bone should be considered before planning the treatment and tooth movement, for which radiography and computed tomography (CT) exams are necessary.<sup>[5]</sup>

Tooth extractions are commonly performed during orthodontic treatment, most commonly extracting the first premolars. The choice of these teeth is justified by the intermediate positioning in the dental arch, which facilitates the correction of dental crowding, protrusion, and dentoalveolar retractions, as well as mid-line displacements.<sup>[6,7]</sup>

With the evolution of dental radiology, great interest in the cone-beam computed tomography (CBCT) has arisen, as it can perform an important function in the three-dimensional (3D) evaluation of defects, especially in the furcation region, as well as in bone and tooth morphology defects, which interfere directly in tooth treatment, planning, and prognosis.<sup>[8-10]</sup> Bone defects are often invisible in radiographic and clinical exams. These can only be identified through 3D exams, such as the CBCT.<sup>[9,11]</sup>

Few studies have evaluated the development of bone dehiscence as the consequence of orthodontic movement when using the CBCT exam.<sup>[8-10,12]</sup> In an attempt to prevent damage to the periodontal tissues, understanding the morphology of the vestibular and lingual bone plate can aid orthodontists in recommending or not the use of an orthodontic appliance in both treatment planning and the monitoring of the orthodontic mechanics. Therefore, the present study sought to evaluate if there is in fact, a significant change in the thickness and height of the alveolar ridge in the mandibular incisor and the interdental ridge in this region by means of a CBCT exam after orthodontic treatment for anterior-inferior dental crowding in cases treated with tooth extraction of the mandibular first premolars.

## Material and Methods

This research was approved by the Research Ethics Committee (logged under CAAE 30803614.3.0000.5137, protocol number 816.937). All participants of this study signed an informed consent form.

The sample calculation was performed using the Winpepi software (Jones and Bartlett Learning, Burlington, MA, USA), duly adjusted to be used in the sample

calculation. The Student's t-test, a test power of 80%, and a significance level (alpha) of 5% were applied for paired values. The estimated correlation of 0.7 was determined for the measurements taken before and after treatment. The bilateral paired Student's t-test was considered for this study, given that both differences, be they positive or negative, are important for this study. The sample calculation showed that the size of the sample to estimate the results should be between 13 and 23, considering the tooth as a sample unit. Thus, in this study, the sample consisted of 48 mandibular incisors from patients from the Orthodontics specialization course, which can be seen in the study design [Figure 1].

This study's participants were young adults (18 to 29 years of age) of both genders, with Class I malocclusion, according to Angle's classification, and a mesofacial biotype analyzed from cephalometric tracings. These individuals had been referred for orthodontic treatment of the mandibular arch through the extraction of their first pre-molars. They also presented anterior-inferior dental crowding and the need for implants in the upper molar region, which allowed for CBCT examination at the end of orthodontic treatment. All patients agreed to participate in this study.

Excluded from the sample were patients that presented: gingival recession in the mandibular incisor region; restoration in the cervical third of the incisors' crowns; spacing in the anterior region of the mandibular arch; a history of tooth extraction or the presence of agenesis in the mandibular incisor region; previous orthodontic treatment; a history of periodontal disease and/or periodontal treatment in the mandibular arch; bone or soft tissue lesions in the mandibular incisor region; and the use of tobacco, alcohol, or medications that affect one's bone metabolism.

Mandibular dental crowding was evaluated by means of the patients' Little's irregularity index,<sup>[13]</sup> performing the measurement of the linear distances from the points of anatomic contact of each mandibular incisor to the anatomical contact of the adjacent teeth in such a way that the sum of these five displacements represented the degree of anterior irregularity. Axial reconstruction of the CBCT was used to obtain Little's index.

The patients' initial CBCT images were taken before installing the orthodontic appliance (T1), while the final CBCT images were taken at least three months after having completed the orthodontic treatment (T2). The second tomography was justified because all selected patients needed third molar extraction. The measurements were taken from the CBCT images obtained during the two time periods of the study. The data were subsequently submitted for statistical analysis.

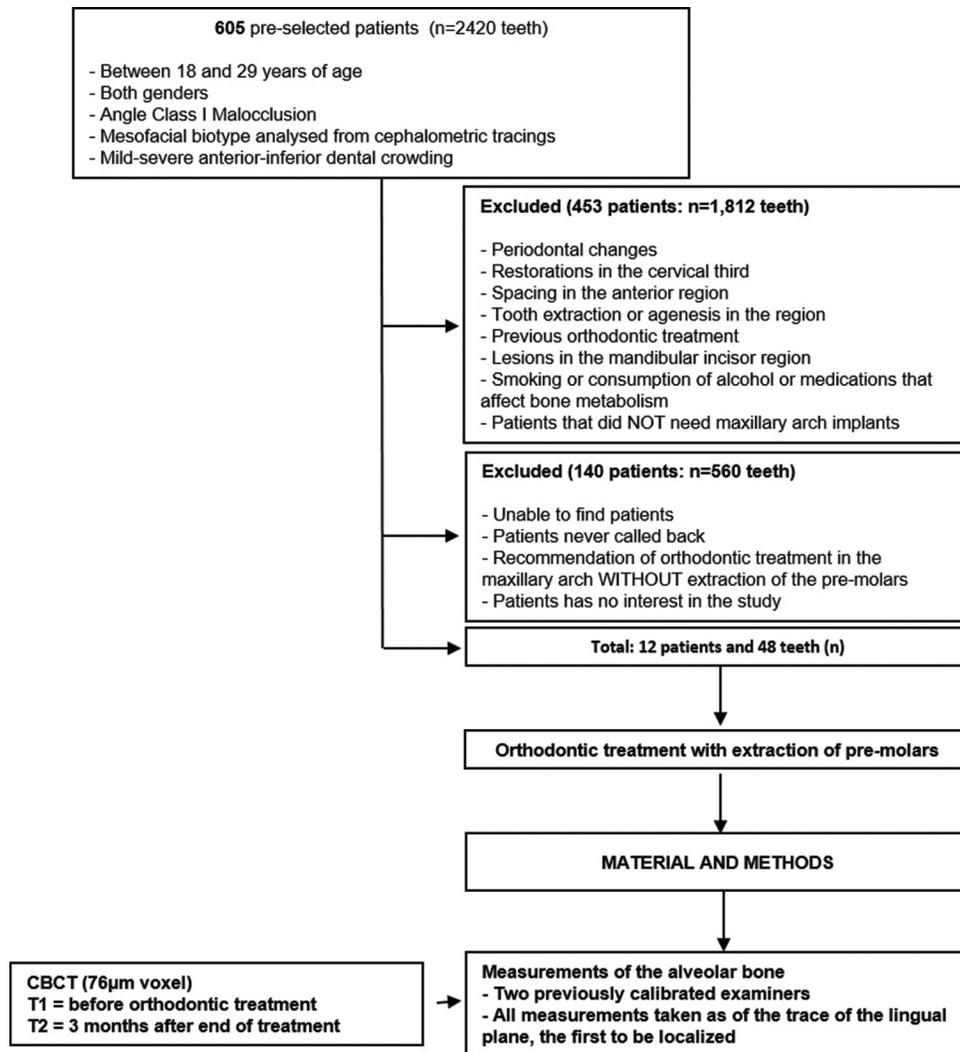


Figure 1: Flow diagram

The patients submitted to this study followed the following documentation protocol in T1 and T2: attainment of study models, intraoral and extraoral photographs, and full CBCT of the maxilla and mandible. The complete radiographic exam of the mouth and the panoramic radiograph were substituted by the CBCT with a smaller Field of View (FOV) (8 x 5 cm), thus guaranteeing the respect for the As Low As Reasonably Achievable (ALARA) principle, in which the patient was submitted to minimal exposure to radiation.

The CBCT exam was performed with the Kodak 9000 3D CBCT (East Kodak Company, Rochester, New York, USA), using the following exposure parameters: 74 KV, 10 mA, and an exposure time of 20 seconds. The thickness of the voxel used in this study corresponded to 76 µm or 0.076 mm. To obtain linear and angular measurements of CBCT scans, the Carestream 3D Imaging program (Kodak Dental Systems, Rochester, NY, USA) was used.

All patients were treated with fixed metal orthodontic appliances with a Roth prescription (Abzil, 3M Oral Care, São José do Rio Preto, Brazil), with a slot measuring 0.022 x 0.028 inches and continuous archwires (Morelli, Sorocaba, Brazil). After the maxillary Nance button and the mandibular lingual arch were placed, brackets were bonded to the premolars, canines, centrals, and laterals. The second molars received a bonded tube. Leveling and alignment were performed with round nickel-titanium wire (0.012 inches and 0.014 inches) and round stainless steel wire (0.016 inches and 0.018 inches). The canine retraction was initiated using round stainless-steel 0.018-inch wire. The retraction force was obtained with an elastomeric chain directly attached to the bracket (sliding mechanics). The force levels were set at 150 g. When canine retraction was completed, a stainless-steel 0.016 x 0.022-inch archwire was used to verticalize the canine roots. The incisor retraction was performed using stainless steel 0.018 x 0.025-inch archwire with T-loops. The finishing

archwires consisted of a rectangular stainless-steel 0.019 × 0.025-inch wire.

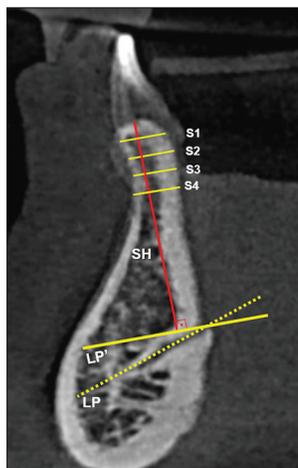
The measurements were taken by two radiologists who had been duly calibrated. The technical reliability of the measurements was based on the repetition of all of the measurements, with a minimum interval of one week between them to calculate the method's error. As regards the selection of images to acquire the measurement of the alveolar bone, the parasagittal reconstructions of the mandibular incisors passing through the center of the crown were selected, following the long dental axis. To acquire the measurements of the interdental bone septum, the parasagittal reconstruction was also positioned in the center of the interdental space.

### Measurement of the images

This study's measurements used the reference of the lingual canal and the lingual foramen to obtain the lingual plane, located in the median region of the mandible, as they are stable structures that do not change due to orthodontic treatment and present distinct cortical plates, according to Valerio *et al.*'s methodology.<sup>[14]</sup>

The following measurements were obtained in the CBCT images, according to Valerio *et al.*'s methodology.<sup>[14]</sup> [Table 1, Figures 2 and 3 (a,b)]:

1. Mandibular incisor inclination (IMPLA): The angle between the long axis of the incisor (MIH) and the lingual plane (LP);
2. Measurement of the distance between the pulp chamber roof and the lingual LP: This line, called the MIH line, was traced to assess the change in the vertical positioning of the mandibular incisor;
3. Measurements of the heights of the vestibular and lingual bone plates: taken as of the upper limit of



**Figure 2:** Cross-sectional CT slice in the region of the interdental bone ridge, indicating the acquired measurements of the interdental septum. Legend: Measurement of interdental septum height (SH). Measurement of interdental septum thicknesses S1, S2, S3, and S4, located at 3, 6, 9, and 12 mm below the bone crest, respectively. (LP) lingual plane. (LP') compensatory lingual plane

- the mandibular bone crest (MBC) in the direction of the LP, on the facial side (FH-MBC-LP), and on the lingual side (LH-MBC-LP);
4. Measurement of the distance between the cemento enamel junction (CEJ) and the bone crest, on the facial side (F-CEJ-MBC) and on the lingual side (L-CEJ-MBC);
5. Measurements of the thickness of the dental bone ridge: taken beginning at the intersection between the long axis of the incisor and the line that joins the vestibular and lingual CEJs (line CEJ-CEJ), at points located at 3, 6, 9, and 12 mm below the CEJ-CEJ line. The thickness of the dental bone ridge was identified by the letter (A), thus recording the thicknesses of A1, A2, A3, and A4, located at 3, 6, 9, and 12 mm below the CEJ-CEJ line, respectively;
6. Measurement of the height of the interdental bone ridge, mesial and distal to the mandibular incisor (SH\_M and SH\_D, respectively): beginning at the uppermost point of the ridge (bone crest), a

**Table 1: Abbreviation and description of the variables**

Abbreviation	Name
SHD	Bone Crest Height of the distal interdental septum
S1_D	Alveolar Ridge Thickness 1 Distal - interdental septum 3 mm below the bone crest
S2_D	Alveolar Ridge Thickness 2 Distal - interdental septum 6 mm below the bone crest
S3_D	Alveolar Ridge Thickness 3 Distal - interdental septum 9 mm below the bone crest
S4_D	Alveolar Ridge Thickness 4 Distal - interdental septum 12 mm below the bone crest
SH_M	Bone Crest Height Mesial interdental septum
S1_M	Alveolar Ridge Thickness 1 Mesial - interdental septum 3 mm below the bone crest
S2_M	Alveolar Ridge Thickness 2 Mesial - interdental septum 6 mm below the bone crest
S3_M	Alveolar Ridge Thickness 3 Mesial - interdental septum 9 mm below the bone crest
S4_M	Alveolar Ridge Thickness 4 Mesial - interdental septum 12 mm below the bone crest
F-CEJ-MBC	Facial CEJ to marginal bone crest - Distance from facial CEJ to facial marginal bone crest
L-CEJ-MBC	Lingual CEJ to marginal bone crest - Distance from lingual CEJ to lingual marginal bone crest
FH-MBC-LP	Facial height of alveolar ridge from marginal bone crest to lingual plane
LH-MBC-LP	Lingual height of alveolar ridge from marginal bone crest to lingual plane
A1	Facial lingual thickness of alveolar bone 3 mm below the CEJ line
A2	Facial lingual thickness of alveolar bone 6 mm below the CEJ line
A3	Facial lingual thickness of alveolar bone 9 mm below the CEJ line
A4	Facial lingual thickness of alveolar bone 12 mm below the CEJ line
MIH	Pulp chamber ceiling of the mandibular incisor to Lingual Plane
IMPLA	Mandibular incisor to Lingual Plane angle

perpendicular line was traced to the LP. In this line, the distance between the bone crest and the LP was measured, interdental septum height (SH);

- Measurement of the thickness of the interdental septum: the line traced to obtain the septum height (SH) was used as a reference. Beginning at the bone crest, moving in the direction of the LP, four points were marked to determine the thickness of the septum—points located at 3 mm (S1), 6 mm (S2), 9 mm (S3), and 12 mm (S4) below the bone crest.

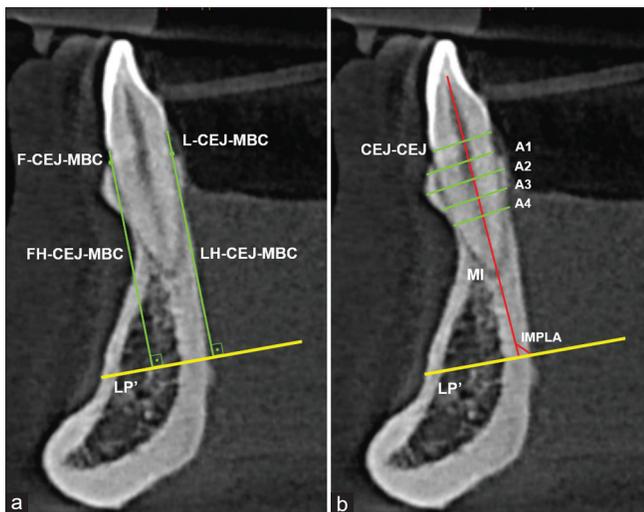
Both the height and thickness of the mesial interdental septum (SH\_M, S1\_M, S2\_M, S3\_M, and S4\_M), as well as the height and thickness of the distal interdental septum (S1\_D, S2\_D, S3\_D, and S4\_D) were evaluated.

The data obtained through the measurements were recorded, tabulated, and sent on for statistical analysis. For statistical analysis, the paired Student’s t-test and Pearson’s correlation were used. The significance level for the analysis of the results was set at 5%.

## Results

The statistical analysis was performed according to the evaluation of 48 mandibular incisors. The patients’ average at T1 was 22.71 ± 4.11 years, while the average treatment time was 32.43 ± 4.43 months.

The intra and inter-examiners’ agreement was excellent for the measurements of the alveolar bone and teeth,



**Figure 3:** (a, b) Cross sectional CT slice in the mandibular incisor region, indicating the acquired measurements of the alveolar bone and mandibular incisors. Legend: (LP') compensatory lingual plane. (a) (FH MBC LP) Vestibular bone plate height. (LH MBC LP) Lingual bone plate height. (F CEJ MBC) and (L CEJ MBC) are the distances of the CEJ to the bone crest on the vestibular and lingual surfaces, respectively. (b) (MI) Long axis of the incisor. (IMPLA) Angle between the LP' and the MI. (CEJ CEJ) Line that joins the vestibular and lingual CEJ. Lines A1, A2, A3, and A4, traced 3 mm, 6 mm, 9 mm, and 12 mm below the CEJ CEJ line, respectively

registering a result of 0.9961 and 0.9952, respectively. The intra and inter-examiners’ agreement concerning the measurements of the interdental septum regions was excellent, registering results of 0.9975 and 0.9963, respectively.

To assess whether or not there were significant differences between the two moments (T1 and T2), the paired Student’s t-test was used, comparing the same tooth [Table 2]. This study worked with the average of the evaluated measurements since these were evaluated twice at the same time. The difference in measurements between T1 and T2 was considered to be significant, with a 95% confidence interval (CI). It was observed that when the T value is positive, the measurement at T1 is less than that at T2, whereas when the T value is negative, the measurement at T1 is greater than that at T2. Hence, only the values of the changes in variables S3\_D, S4\_D, S3\_M, F-CEJ-MBC, A2, and A3 did not present statistically significant differences for the paired Student’s t-test.

## Pearson’s correlation

The correlations between the measurements were evaluated in two parts: comparing the measurements before and after and comparing the variation of a specific variable with the variations of the other during the T1 and T2 periods.

Evaluating the variation that occurred in the many variables between T1 and T2, a statistically significant positive correlation was found between the long axis of the mandibular incisor and the LP (IMPLA) and the

**Table 2: Statistic for the changes in variables**

Time Variable (T2-T1)	Average	Standard Deviation	n	P
Delta of SH_D	-1.33*	1.8139	48	0.001
Delta of S1_D	-0.68*	0.8218	48	<0.001
Delta of S2_D	-0.56*	0.8807	48	0.003
Delta of S3_D	-0.28	0.8906	48	0.109
Delta of S4_D	0.09	0.7094	48	0.519
Delta of SH_M	-1.76*	1.7180	48	<0.001
Delta of S1_M	-0.99*	0.6543	48	<0.001
Delta of S2_M	-0.76*	0.8432	48	<0.001
Delta of S3_M	-0.20	0.9860	48	0.293
Delta of S4_M	0.54*	0.9497	48	0.007
Delta of F-CEJ-MBC	0.20	0.6062	48	0.104
Delta of L-CEJ-MBC	1.28*	1.0672	48	<0.001
Delta of FH-CEJ-LP	-1.72*	1.6349	48	<0.001
Delta of LH-CEJ-LP	-3.38*	1.6287	48	<0.001
Delta of A1	-0.39*	0.3955	48	<0.001
Delta of A2	-0.18	0.5346	48	0.094
Delta of A3	0.14	0.7998	48	0.368
Delta of A4	0.42*	0.9573	48	0.032
Delta of MIH	-1.72*	1.6813	48	<0.001
Delta of IMPLA	-3.95*	5.5795	48	0.001

\*Significant (P ≤ 0.05)

variation in the LH-MBC-LP, L-CEJ-MBC, and MIH measurements. However, changes in the Little's Index presented no significant correlation with the variations in the variables MIH, LH-MBC-LP, FH-MBC-LP, F-CEJ-MBC, and L-CEJ-MBC [Table 3].

Observing the correlation between the MIH variation and the variation in the FH-MBC-LP, LH-MBC-LP, F-CEJ-MBC, L-CEJ-MBC, SH\_M, and SH\_D measurements, a statistically significant positive correlation was found among all of the aforementioned variables and MIH [Table 4].

Assessing the correlations between the variations in L-CEJ-MBC and F-CEJ-MBC with the variables FH-MBC-LP, LH-MBC-LP, SH\_D, SH\_M, IMPLA, and MIH, a statistically significant positive correlation was observed among all of the aforementioned variables, on both the vestibular and the lingual surfaces, not including the variations of FH-MBC-LP and IMPLA, which showed an increase in the F-CEJ-MBC measurement [Table 5].

**Table 3: Significant correlations occurred with the variations of IMPLA and Little's Index**

	Δ IMPLA		Δ Little's index	
	R	P	R	P
Δ FH- MBC-LP	0.369	0.054	0.176	0.370
Δ LH- MBC-LP	0.577	0.001*	-0.247	0.204
Δ F-CEJ-MBC	0.330	0.086	-0.332	0.084
Δ L-CEJ-MBC	0.539	0.003*	0.262	0.177
Δ MIH	0.421	0.026*	0.103	0.603

\*Significant correlation for  $P \leq 0.05$

**Table 4: Significant correlations associated with the variation that occurred in the vertical position (MIH) of the mandibular incisor**

	Δ MIH	
	R	P
Δ FH- MBC-LP	0.892*	<0.001
Δ LH- MBC-LP	0.750*	<0.001
Δ F-CEJ-MBC	0.626*	<0.001
Δ L-CEJ-MBC	0.625*	<0.001
Δ SH_M	0.924*	<0.001
Δ SH_D	0.864*	<0.001

\* Significant correlation for  $P \leq 0.05$

**Table 5: Correlations associated with variations in the L-CEJ-MBC and F-CEJ-MBC measurements**

	Δ L-CEJ-MBC		Δ F-CEJ-MBC	
	R	P	R	P
Δ FH- MBC-LP	0.629*	<0.001	0.361	0.059
Δ LH- MBC-LP	0.417*	0.027	0.519*	0.005
Δ SH_D	0.621*	<0.001	0.621*	<0.001
Δ SH_M	0.596*	0.001	0.455*	0.015
Δ IMPLA	0.539*	0.003	0.330	0.086
Δ MIH	0.625*	<0.001	0.626*	<0.001

\*Significant correlation for  $P \leq 0.05$

## Discussion

This study evaluated the change in the height and thickness of the alveolar bone in the region of the mandibular incisors in patients who presented anterior mandibular dental crowding and who were treated with orthodontics associated with tooth extraction of the mandibular first premolars.

The LP was used as a reference point to obtain the linear and angular measurements.<sup>[14]</sup> As the LP is traced over the lingual canal, because it is an easily identifiable structure and does not change with the treatment nor with minimal differences in the positioning of the patient's head when obtaining the CBCT images, the LP offers a new methodology with less probability of bias.

Prior studies adopted as first reference to evaluate mandibular incisors changes with orthodontic treatment, anatomical structures of the mandibular incisor that can modify with the treatment, such as dental inclination, root apex and root canal length. The use of these reference points has showed compromised results and lack of reproducibility.<sup>[10,12,15,16]</sup>

Future cross-sectional and longitudinal studies with the objective of evaluating dental and bone changes in the mandibular incisor region will be able to use the LP as a reference.

The trajectory of the lingual canal can vary when observed in the sagittal plane. In findings, 62% of the canals had a descending trajectory, 17.3% had only an anterior trajectory, while 20.7% presented an ascending trajectory.<sup>[17]</sup> In our study, all patients presented a descending trajectory of the lingual canal.

Even if an increase occurs in the measurements of the F-CEJ-MBC and L-CEJ-MBC variables, the paired Student's t-test showed that this change was statistically significant ( $P < 0.05$ ) only for the L-CEJ-MBC measurement, indicating a tendency toward bone dehiscence on the lingual surface after orthodontic treatment for dental crowding of the mandibular incisors with the extraction of the first premolars. Using Pearson's Correlation, it was found that the measurements used in this study were consistent since the great majority presented highly significant correlations.

Little's index did not present a statistically significant correlation with the variables that identify bone loss (F-CEJ-MBC, L-CEJ-MBC, FH- MBC-LP, and LH-MBC-LP), which showed that the degree of dental crowding is not a risk factor for the formation of dehiscence and bone fenestrations in patients treated with premolar extractions [Table 3]. These results can

be related to findings from Uysal.<sup>[15]</sup> These authors evaluated 125 CBCT images of mandibular incisors from individuals with Class I malocclusion, with an irregularity index, determining mild, moderate, and severe dental crowding. Significant relationships were found between the measurements of dental crowding of the mandibular incisor and the basal bone dimensions in female individuals, in such a way that the thickness of the cancellous bone of the symphysis and the thickness of the cancellous bone in the vestibular region up to the dental crest was less in patients with a greater index of irregularity. In the individual male group, the measurements of the symphysis and of the alveolar cancellous bone did not correlate with the degree of crowding.

A positive correlation was observed between the angle formed by the long axis of the mandibular incisor and the LP (IMPLA) and the following variables: MIH, LH-MBC-LP, and L-CEJ-MBC [Table 3]. This result illustrates that the retroclination of the tooth, considering the sagittal plane, acts directly in the bone loss of its lingual surface, increasing the probability of the formation of dehiscence and bone fenestration in this region. This correlation was also observed by Krishna *et al.*,<sup>[9]</sup> who evaluated the changes in the alveolar bone after the retraction of the maxillary and mandibular incisors in patients with dental biprotrusion, treated with the extraction of the premolars, using lateral cephalogram and CT image.<sup>[9]</sup> Some individuals presented dehiscence in the direction of the dental movement after the retraction of the incisors. As occurred in the present study, their study demonstrated that there was a reduction in the thickness of the alveolar bone in the direction of the dental movement, which exposes the patient to the risk of dehiscence.

For some authors who studied the variations in the marginal alveolar bone height in the mandibular incisor region due to orthodontic treatment without tooth extraction, despite the proclination of the incisors was not statistically correlated with the changes in the height of the facial alveolar bone, the distance from the facial CEJ to the facial marginal bone crest increased.<sup>[12,14]</sup> In this way, the alveolar bone loss occurred in the direction of tooth movement. Similarly, in this study, because of tooth extraction, the orthodontic movement occurred in the lingual direction, leading to retroinclination of the mandibular incisors and the statistically significant increase in the distance from the lingual CEJ to the lingual marginal bone crest, showing an alveolar bone loss in the direction of tooth movement and the formation of lingual bone dehiscence.

The distance between the pulp chamber roof of the mandibular incisor and the LP (MIH) was used to

evaluate the tooth's displacement in the vertical direction and identify the intrusion movement of the incisors. This measurement presented a positive correlation with the variables associated with bone height in both the interdental septum region and the alveolar regions [Table 4]. The significant correlation between the reduction of MIH with the concomitant reduction in the FH-MBC-LP, LH-MBC-LP, SH\_M, and SH\_D measurements, revealed that a bone reshaping occurs in both the vestibular and lingual bone plates, as well as in the mesial and distal bone septum, during dental retrusion and intrusion. Another important correlation was drawn between MIH and L-CEJ-MBC, as there was a strong and significant correlation between the two variables ( $r = 0.625$ ,  $P < 0.05$ ), which indicates that the dental intrusion can be a risk factor for bone dehiscence on the lingual side in patients with dental crowding treated with tooth extraction [Table 5].

The correlations between the variations of L-CEJ-MBC and F-CEJ-MBC with the FH-MBC-LP, LH-MBC-LP, SH\_D, SH\_M, IMPLA, and MIH variables were significant among all of the cited variables, both on the vestibular and the lingual surfaces, not including the variations of FH-MBC-LP and IMPLA on the vestibular surface [Table 5]. These correlations were more significant in the lingual cortical bone due to the retroclination movement of these teeth. During this movement, traction of the vestibular cortical bone occurs, which leads to the increase in bone tissue in the location, which is contrary to what happens in the lingual cortical bone, which undergoes pressure and resorption.

The present study identified that there was a significant increase in the L-CEJ-MBC distance and no significant change in the F-CEJ-MBC distance, illustrating the development of bone dehiscence on the lingual side during the retraction and retroclination movements of the mandibular incisors [Table 5]. Prior studies have also evaluated the effect of the increase in the proclination of the mandibular incisor and the formation of bone dehiscence<sup>[18-20]</sup>; however, few studies have evaluated the effect of the retroclination of the mandibular incisors in cases treated orthodontically with the extraction of premolars.<sup>[6,7]</sup>

Due to orthodontic indications, this study performed the extraction of the first pre-molars in all patients included in this study's sample. The information obtained in the results showed the tendency of the formation of bone dehiscence in the lingual bone plate, which is related to the retroclination and intrusion of the incisors, that is, a reduction in both IMPLA and in MIH variables. This study also verified that the degree of dental crowding was not a risk factor for the formation of this dehiscence. This may well have occurred due to the extractions of

the first premolars, which allowed for the dissolution of the dental crowding without provoking the proclination of the incisors. This information can help to determine the orthodontic plan treatment, mainly in adult periodontally compromised patients.

## Conclusion

In conclusion, there was a statistically significant increase in the L-CEJ-MBC distance, which illustrated the formation of bone dehiscence in the lingual aspect of alveolar bone after orthodontic treatment of anterior dental crowding with tooth extraction. The degree of dental crowding was not a risk factor for the development of vestibular or lingual bone dehiscence in the incisor; however, the reduction in mandibular incisor inclination and incisor intrusion is related to the formation of bone dehiscence on the lingual surface of the incisors.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published, and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

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