Original Article

Cone beam computed tomography evaluation of distance from cementoenamel junction to alveolar crest before and after nonextraction orthodontic treatment

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ABSTRACT

Objective: To evaluate the distance between the cementoenamel junction and the alveolar bone crest before and after orthodontic treatment using cone beam computed tomography (CBCT).

Materials and Methods: The sample comprised 30 patients with Angle Class I malocclusion and mild to moderate crowding. The study database comprised dental CBCT scans obtained before and after orthodontic treatment. The distance between the cementoenamel junction to the bone crest of the buccal (n = 720) and lingual (n = 720) surfaces was measured in 24 teeth for each patient using a specific software tool (Xoran version 3.1.62). The Wilcoxon test was used for statistical analysis, and the level of significance was set at $P < .05$.

Results: The distance between the cementoenamel junction and the bone crest increased in 822 (57%) of the 1440 surfaces after orthodontic treatment. The buccal surface of the lower central incisors had the greatest frequency of increased distance (75%), and the lingual surface of lateral incisors had the lowest (40%). The distance between the cementoenamel junction and the alveolar bone crest was greater than 2 mm (alveolar bone dehiscence) in 162 (11%) of the 1440 surfaces before orthodontic treatment and in 279 (19%) after treatment.

Conclusion: The distance from the cementoenamel junction to the bone crest changed after orthodontic treatment; the distance was greater than 2 mm in 11% of the surfaces before treatment and in 19% after treatment. (*Angle Orthod.* 2016;86:543–549.)

KEY WORDS: Cone beam computed tomography; Alveolar bone loss; Orthodontics; Marginal bone level; Periodontium

INTRODUCTION

The distance between the cementoenamel junction and the bone crest, composed of junctional epithelium and connective tissue, is a biological parameter.[1] Increased distances from the cementoenamel junction to the bone crest may be indicative of alveolar bone dehiscence,[2–4] and Persson et al.[5] and Baysal et al.[6] adopted this classification when this distance is greater than 2 mm.

Alveolar bone dehiscence that results from orthodontic movement may be either not clinically evident or clearly identified as extensive gingival recession that compromises esthetics and tooth sensitivity.[7,8] The thicker the periodontium, the less likely that clinical changes will be found in the alveolar bone.[5,8] Size and position of the teeth, alveolar bone thickness, and orthodontic movement may affect the onset of dehiscence.[9,10] Movement direction, as well as frequency and magnitude of forces applied during orthodontic treatment, may also contribute to its occurrence.[2,5,7,8,11]

According to several authors,[2,12,13] the morphology of the lingual and buccal bone plates should be determined before orthodontic treatment using radiographs to carefully plan treatment and to avoid the

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Accepted: August 2015. Submitted: April 2015.
Published Online: September 17, 2015

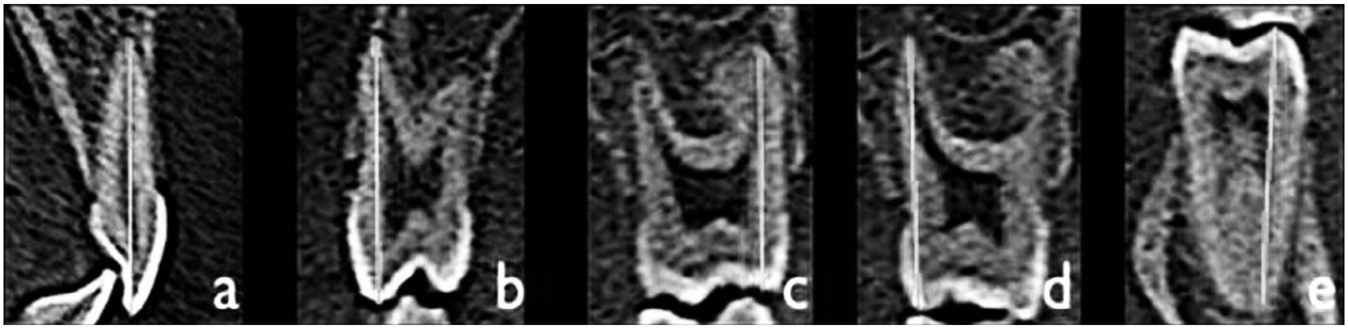

Figure 1. (a) CBCT sagittal view of single-rooted tooth. (b) Coronal view of two-rooted maxillary premolar. (c) Vestibular root of molar. (d) Lingual root of molar. (e) Mesial root of mandibular molar. Line = vertical dental axis (VDA).

appearance of alveolar bone dehiscence or to minimize its frequency.

Cone beam computed tomography (CBCT) emerged in the late 1990s as an appropriate technique to assess marginal bone changes. It provides images in which anatomical structures do not overlap, which ensures greater accuracy than two-dimensional radiographic images.[14–16]

CBCT also provides buccal and lingual views of teeth in high resolution using less radiation and at a lower cost than conventional and multislice CT.[2,4,5,8,16]

The high demand for orthodontic treatment in adult patients with periodontal disease has greatly stimulated research about periodontal health before treatment.[14,15] Alveolar bone dehiscence should be diagnosed before orthodontic treatment to minimize possible deterioration due to expansion, retraction, and buccolingual tooth inclination.[12,13,17,18]

Considering the limitations of two-dimensional radiographs in the evaluation of bone dehiscence and the lack of studies regarding the use of three-dimensional CBCT and the use of this technology to improve the diagnostic, this study measured the distance between the cementoenamel junction and the alveolar bone crest before and after orthodontic treatment using CBCT scans.

MATERIALS AND METHODS

A pilot study (n = 6) was used to calculate the sample size, and results indicated that at least 29 (n = 29.3) patients should be included to estimate the distance between the cementoenamel junction and the bone crest, at 95% confidence, maximum error of 0.42 mm, and a standard deviation of 1.16 mm for the mean treatment time of 22 months (SD = ±4.2). We included 30 patients to ensure greater certainty and reliability of our results.

Inclusion criteria were CBCT scans obtained before and after orthodontic treatment of individuals with Angle Class I malocclusion and mild to moderate crowding. CBCT scans were excluded if patients had mixed or deciduous dentition, periodontitis, traumatic dental injury, bruxism, missing teeth, orthopedic devices, or temporomandibular dysfunction. This retrospective study was approved by the Research Ethics Committee of the institution where it was conducted (Brazil Platform, Federal University of Goiás, Brazil, and case 024439/2014).

The buccal (n = 720) and lingual (n = 720) distances between the cementoenamel junction and the alveolar bone crest were measured on the CBCT images of teeth of 30 patients before and after orthodontic treatment. The surfaces of maxillary and mandibular central and lateral incisors, canines, first and second premolars, and first molars were measured. Images of maxillary and mandibular second and third molars were not included.

This retrospective study included images selected from a CBCT database of scans obtained before and after the orthodontic treatment. CBCT scans were taken using an i-CAT scanner (Imaging Sciences International, Hatfield, Penn) configured for 0.25-mm volumetric reconstruction, isometric voxel, 120-kVp tube voltage, field of view of 13 cm, and 3.8 mA tube current. The images were analyzed using the i-CAT scanner's own software (Xoran 3.1.62, Xoran Technologies, Ann Arbor, Mich).

Images were reformatted along with the length axis of the root in coronal and sagittal view to achieve an optimal visualization of the marginal bone in the coronal and sagittal view. To determine what slice to use for the measurement of the distance from the cementoenamel junction to the bone crest before orthodontic treatment in maxillary and mandibular central incisors and canines, we selected the sagittal section from the incisal edge (cusp tip) to the root apex and drew a straight line, called the vertical dental axis (VDA; Figure 1). For maxillary and mandibular posterior teeth, we selected the coronal section; for single-rooted premolars, VDA was determined according to two reference points, the tip of the buccal cusp and the root apex, and for two-rooted premolars, the tip of the

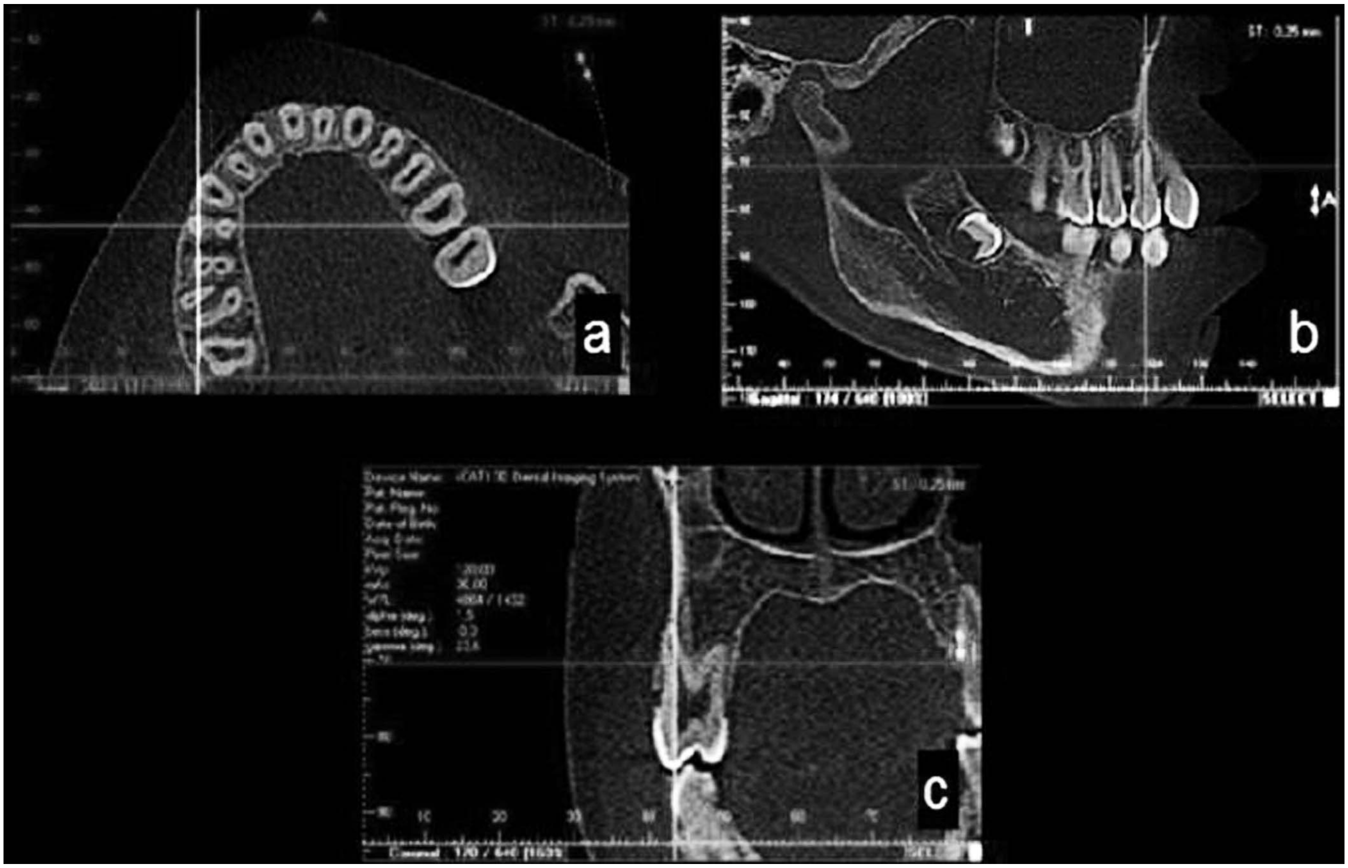

Figure 2. Multiplanar reconstruction of (a) axial and (b) sagittal (c) lines used in coronal axially guided navigation (AGN).

buccal cusp and the apex of the buccal root. For the buccal surface of the maxillary first molar, VDA was drawn from the mesiobuccal tip cusp to the apex of the mesiobuccal root, and for the lingual surface, from the tip of the lingual cusp to the apex of the lingual root. The reference points for molars were the mesial root and the tip of the mesiobuccal cusp (Figure 1).

The landmarks to measure the distance from the cementoenamel junction to the bone crest were buccal and lingual cementoenamel junction and the buccal and lingual alveolar bone crest. Axial-guided navigation (AGN) was used to locate these landmarks. This method was named AGN because measurements are made by moving the axial cursor on the sagittal or coronal multiplanar reconstructions guided by the axial multiplanar reconstruction (Figure 2).[19]

During AGN, the axial line in the coronal or sagittal section determines the measurement point at the alveolar bone crest, confirmed in the axial section and marked with the cursor. Then again, the movement of the axial line defines the measurement point at the cementoenamel junction, confirmed in the axial section. A Xoran 3.1.62 tool (Xoran Technologies) was used to draw a vertical line between the two points, and this line was measured (Figure 3). Measures were performed by one examiner specialist in periodontics and transcribed into a Microsoft Office Excel 2010 spreadsheet.

When the distance from the cementoenamel junction to the bone crest was shorter than or equal to 2 mm, no alveolar bone defects were recorded because this distance had to be greater than 2 mm to be classified as alveolar bone dehiscence.[5]

The same procedures were repeated to measure the CBCT scans obtained after orthodontic treatment, using axial, sagittal, and coronal sections and the criteria described above.

To evaluate method reproducibility, we randomly selected 432 teeth of the total sample for measurements at two different time points at an interval of 1 month (T1 and T2). Means and standard deviations of measurements before and after orthodontic treatment were calculated and transcribed into a Microsoft Office Excel 2010 spreadsheet. The statistical differences between measurements at the two time points were analyzed using the Wilcoxon signed rank test, and the level of significance was set at $P < .05$.

Data normality was assessed using the Kolmogorov-Smirnov test. The Wilcoxon test was used for the statistical analysis of measurements before and after

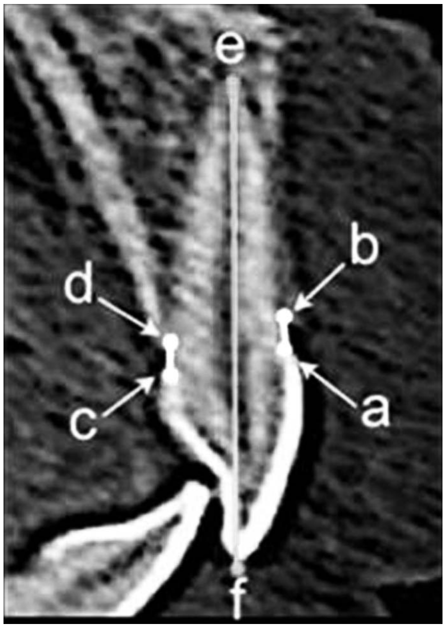

Figure 3. CBCT sagittal view of maxillary central incisor: distance from (a) buccal cementoenamel junction, (b) buccal alveolar crest, distance from (c) lingual cementoenamel junction to (d) lingual bone crest. Line = VDA of (e) root apex to (f) incisal edge.

orthodontic treatment, which determined the increase in distance from the cementoenamel junction to the bone crest. The level of significance was set at $P < .05$. All statistical analyses were performed using SPSS 19.0 (SPSS Inc, Chicago, Ill), and the level of significance was 5%.

RESULTS

The analysis of method reproducibility did not reveal any statistically significant difference ($P = .990$) between T1 (1.63 ± 1.13) and T2 (1.67 ± 1.20) for measurements.

Of the 30 CBCT scans, a total of 1440 root surfaces were defined: 60 buccal and 60 lingual surfaces for each, maxillary and mandibular teeth. The scans included were obtained from 11 male and 19 female patients, whose mean age was 13.3 years.

The distance from the cementoenamel junction to the bone crest was greater than 2 mm in 162 (11%) of the 1440 root surfaces before orthodontic treatment and in 270 (19%) after orthodontic treatment. Before orthodontic treatment, the highest alveolar bone dehiscence frequency was found in the buccal surfaces of maxillary and mandibular canines and the lingual surfaces of mandibular central incisors and after orthodontic treatment, in the buccal surfaces of maxillary canines (60%) and the lingual surfaces of mandibular central incisors (55%; Table 1).

Mean increases and standard deviations of distance between the cementoenamel junction to the alveolar bone crest before and after orthodontic treatment were statistically significant ($P < .05$) for the surfaces of the teeth, as described in Table 2.

DISCUSSION

The high definition and sensitivity of CBCT images ensures that the buccal and lingual cortical bone and teeth are visualized without any overlapping, making it possible to measure increases in the distance between the cementoenamel junction and the alveolar bone crest as a result of orthodontic movement.[11,17,18]

This study found that the distance from the cementoenamel junction to the bone crest increased in 57% of the cases, most often in the buccal (75%) and lingual (72%) surfaces of the mandibular central incisors. Similar results were found in the study conducted by Lund et al.,[20] who found increased frequencies of 85% and 68%.

The buccal surface of the mandibular canines had the largest increase in mean distance from the cementoenamel junction to the alveolar bone crest ($P < .05$) before (mean = 2.07 mm) and after (mean = 2.76 mm) treatment. Results of the study conducted by Garib et al.[12] revealed a mean 2.40 mm on the buccal and lingual surfaces of mandibular teeth after orthodontic treatment, and the authors concluded that the morphology of the alveolar bone is a limiting factor for orthodontic movement. These results are substantiated by the results of studies that found dehiscence in the buccal surfaces of mandibular anterior teeth, particularly because these surfaces have a thinner cortical bone and less bone marrow.[17,21,22]

The association between orthodontic treatment and changes in the distance between the cementoenamel junction and the bone crest has been widely studied,[2–4,6,8,12,16] but the differences in orthodontic techniques, the various criteria for radiographic evaluation, and the several methods of diagnostic imaging used in the different studies have limited the comparison of results.

Cadaver studies showed that alveolar bone defects on the buccal or lingual surfaces might not be visualized using periapical radiographs.[4,15,22] Fuhrmann[11] found that CT was the only diagnostic imaging method that provided three-dimensional quantitative assessment of buccal and lingual bone to evaluate artificial bone dehiscence in jaws of corpses. The high accuracy of CBCT for the diagnosis and quantitative analysis of the level of the buccal and lingual bone crest was confirmed.[4]

In this study, 11% of the values of the distance between the cementoenamel junction and bone crest

Table 1. Absolute Frequency and Percentage of Distances Greater Than 2 mm From the Cementoenamel Junction to the Alveolar Bone Crest Before and After Orthodontic Treatment

			Distance >2 mm			
			Before Treatment		After Treatment	
Teeth	Surface	n	*f*(*a*)	*f*(%)	*f*(*a*)	*f*(%)
Central incisor (maxilla)	Buccal	60	6	10	7	12
	Lingual	60	1	2	0	0
Lateral incisor (maxilla)	Buccal	60	3	5	25	42
	Lingual	60	2	3	1	2
Canine (maxilla)	Buccal	60	23	38	36	60
	Lingual	60	2	3	3	5
First premolar (maxilla)	Buccal	60	5	8	14	23
	Lingual	60	7	12	6	10
Second premolar (maxilla)	Buccal	60	1	2	1	2
	Lingual	60	3	5	0	0
First molar (maxilla)	Buccal	60	5	8	11	18
	Lingual	60	3	5	8	13
Central incisor (mandible)	Buccal	60	8	13	22	37
	Lingual	60	19	32	33	55
Lateral incisor (mandible)	Buccal	60	12	20	19	32
	Lingual	60	3	5	14	23
Canine (mandible)	Buccal	60	21	35	29	48
	Lingual	60	4	7	9	15
First premolar (mandible)	Buccal	60	8	13	17	28
	Lingual	60	12	20	9	15
Second premolar (mandible)	Buccal	60	4	7	4	7
	Lingual	60	1	2	0	0
First molar (mandible)	Buccal	60	3	5	3	5
	Lingual	60	6	10	8	13
Total		1440	162	11	279	19

measured using CBCT scans obtained before orthodontic treatment was greater than 2 mm, which may be classified as alveolar bone dehiscence. These results were lower than those reported by Evangelista et al.,[2] who evaluated CBCT scans of 79 patients older than 18 years with class I malocclusion and no orthodontic treatment and found alveolar bone dehiscence (>2 mm) in 51.09% of their sample. The discrepancy between values may be assigned to the difference in sample size, sample type, and patient age.

Many CBCT factors influence the visibility of thin bony structures such as the cortical bone.[17] Lower voxels result in the detection of thinner cortical bone and greater image resolution. These features make results more reliable, but patients are exposed to a greater amount of radiation.[17,21] In this study, the voxel used was 0.25 mm, and cortical bone thinner than 0.25 mm, although present, might not have been detected.[2,4,20,22] This was a limitation of this study and might have increased the percentage of alveolar bone dehiscence that did not actually exist (false-positive).

In this study, 19% of the measurements made using CBCT images obtained after orthodontic treatment revealed that distance from the cementoenamel junction to the alveolar bone crest was greater than 2 mm, and the highest frequency of alveolar bone dehiscence was found in the buccal surface of maxillary canines and the lingual surface of mandibular central incisors. This result is in agreement with that reported by Yagci et al.,[8] who found a high frequency of alveolar bone dehiscence in the region of the mandibular central incisors (27.92%), regardless of type of malocclusion. Those authors assigned the increase in alveolar bone dehiscence in this region to the thinning of the alveolar bone cortex and the compensation of dental inclinations in patients with class II malocclusion.

Moreover, Evangelista et al.[2] found that the frequency of alveolar bone dehiscence was lower in mandibular second molars (5.38%), whereas Lund et al.[20] found that maxillary canines (4.2%) had the lowest frequency. Their findings differ from the results of this study, which found the highest percentage of alveolar bone dehiscence in the buccal surfaces of maxillary central incisors (2%) and second premolars (2%) before treatment. After treatment, the lowest percentage was found in the lingual surfaces of maxillary central incisors (0%), buccal surfaces of maxillary second premolars (0%), and lingual surfaces of mandibular second premolars (0%). Discordant results may have resulted from sampling differences, as our study did not assess mandibular second molars, and

Table 2. Mean Distances and Standard Deviations Before and After Orthodontic Treatment

Teeth	Surfaces	n	Before Mean ± SD	After Mean ± SD	*P*
Central incisor (maxilla)	Buccal	60	1.56 ± 0.51	1.71 ± 0.54	.019
	Lingual	60	1.08 ± 0.37	1.15 ± 0.47	.172
Lateral incisor (maxilla)	Buccal	60	1.58 ± 0.55	1.95 ± 0.87	.000*
	Lingual	60	1.12 ± 0.51	1.12 ± 0.46	.661
Canine (maxilla)	Buccal	60	2.14 ± 1.19	2.65 ± 1.35	.000*
	Lingual	60	1.04 ± 0.46	1.28 ± 0.51	.001*
First premolar (maxilla)	Buccal	60	1.52 ± 1.21	1.70 ± 0.73	.001*
	Lingual	60	1.33 ± 0.59	1.39 ± 0.54	.379
Second premolar (maxilla)	Buccal	60	0.89 ± 0.47	1.08 ± 0.48	.068
	Lingual	60	1.08 ± 0.44	1.12 ± 0.43	.561
First molar (maxilla)	Buccal	60	1.43 ± 1.16	1.60 ± 1.17	.068
	Lingual	60	1.27 ± 0.76	1.54 ± 0.62	.000*
Central incisor (mandible)	Buccal	60	1.72 ± 0.98	2.28 ± 1.56	.000*
	Lingual	60	1.81 ± 0.60	2.46 ± 1.70	.000*
Lateral incisor (mandible)	Buccal	60	1.77 ± 1.38	2.16 ± 1.37	.000*
	Lingual	60	1.45 ± 0.50	1.83 ± 0.89	.000*
Canine (mandible)	Buccal	60	2.07 ± 1.36	2.76 ± 1.97	.001*
	Lingual	60	1.23 ± 0.56	1.49 ± 0.81	.031
First premolar (mandible)	Buccal	60	1.63 ± 1.30	2.05 ± 1.48	.004*
	Lingual	60	1.44 ± 0.51	1.49 ± 0.51	.434
Second premolar (mandible)	Buccal	60	1.13 ± 1.07	1.40 ± 1.02	.004*
	Lingual	60	1.20 ± 0.44	1.28 ± 0.45	.222
First molar (mandible)	Buccal	60	0.88 ± 0.53	1.20 ± 0.79	.003*
	Lingual	60	1.38 ± 0.53	1.55 ± 0.58	.067

* $P < .05$.

from the type of orthodontic treatment that the patients underwent.

Clinically relevant findings about alveolar bone dehiscence due to tooth movement affect orthodontic treatment plans directly, as gingival recessions should be prevented or made more predictable. Studies including patients with class III malocclusion found that the buccal and lingual mandibular alveolar bone is thinner than the bone in patients with class I and II malocclusions, and therefore, orthodontic movements of mandibular incisors should be planned carefully.[8,16]

In this study, orthodontic treatment did not include tooth extractions, which is different from the study conducted by Lund et al.[20] Those authors found that during the course of extractive orthodontic treatment for a relatively common type of malocclusion, there were large decreases of marginal bone height in the buccal and lingual surfaces of anterior teeth, but these decreases were smaller in most proximal surfaces. Although some differences may be explained by reasons other than the orthodontic treatment per se, it seems likely that loss of marginal bone height, at least in the short term, is a side effect of extractive orthodontic treatment for a specific type of malocclusion, during which the retraction of teeth in anterior regions results in remodeling of the alveolar bone.[20]

Although CBCT scans provide an accurate evaluation of alveolar bone dehiscence and show structures without any overlapping, indications should be based on the clinical needs of each patient and should consider risks and benefits.

Recently, orthodontics expanded its diagnostic potential and ability to outline a more realistic prognosis because of the introduction of CBCT. CBCT may confirm alveolar bone dehiscence and the consequent gingival recessions, two important effects of tooth movement on alveolar bone that may limit orthodontic treatments.

CONCLUSIONS

- The distance from the cementoenamel junction to alveolar bone crest changed during orthodontic treatment in adolescents, although it cannot attribute change to orthodontic treatment.
- Bone dehiscence was prevalent in 11% of the teeth before treatment and increased to 19% after non-extraction orthodontic treatment.

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