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Comparison of Lateral Cephalometry and Cone-beam Computed Tomography Techniques for Measuring Alveolar Bone Thickness around Maxillary Incisors

Abstract

Purpose: It is valuable to detect whether bone thickness measurements performed on lateral cephalograms reflect the values obtained from three-dimensional images. The present study compared lateral cephalometry and cone-beam computed tomography (CBCT) for evaluating alveolar bone thickness surrounding maxillary central incisors.

Methods: The study included the records of 55 patients who had both lateral cephalograms and CBCT scans of the maxilla. In cephalograms, the alveolar bone thickness was measured at the crestal, middle, and apical levels of maxillary incisors at the buccal and lingual sides. Bone thickness was also measured at the corresponding points on CBCT images, and the data were compared by paired t-test and Wilcoxon signed rank test. The correlation between the two techniques was determined.

Results: The buccal bone thickness was significantly greater in cephalometry than CBCT at the middle and apical root areas ($P < 0.05$). There was no significant difference in the thickness of buccal alveolar bone at the crest, and lingual alveolar bone at all root levels between the two techniques ($P < 0.05$). A strong to very strong correlation was observed between the two techniques for measuring bone thickness on the palatal side ($P < 0.001$), but no significant correlation was found at the buccal side of the middle and apical root areas ($P < 0.05$).

Conclusions: Maxillary bone thickness values are overestimated in 2-dimensional as compared to 3-dimensional im-ages. Lateral cephalometry provides bone thickness measurements that are highly correlated with the actual values obtained from the CBCT examination at the palatal side, but it is not reliable for buccal bone assessments.

Keywords

Alveolar bone; Bone thickness; Cone-beam computed tomography; Incisor; Lateral cephalometry.

ORIGINAL ARTICLE

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ABSTRACT

Purpose: **It is valuable to detect whether bone thickness measurements performed on lateral cephalograms reflect the values obtained from three-dimensional images. The present study compared lateral cephalometry and cone-beam computed tomography (CBCT) for evaluating alveolar bone thickness surrounding maxillary central incisors.**

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Conclusions: **Maxillary bone thickness values are overestimated in 2-dimensional as compared to 3-dimensional images. Lateral cephalometry provides bone thickness measurements that are highly correlated with the actual values obtained from the CBCT examination at the palatal side, but it is not reliable for buccal bone assessments.** *Taiwanese Journal of Orthodontics 2023;35(3):120−127*

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INTRODUCTION

Due to the high incidence of malocclusion in most populations, the demand for orthodontic treatment is ever-increasing. Although orthodontic treatment can lead to an excellent improvement in the esthetics, function, and quality of life of the patients, it is occasionally associated with complications such as enamel decalcification, periodontal problems, and root resorption.[1−4] Periodontal problems including gingival recession and alveolar bone resorption (vertical bone loss, dehiscence, and fenestration) are among the common complications that may be observed during or after orthodontic therapy and their treatment is challenging in most cases. It has been demonstrated that alveolar bone surrounding the anterior teeth is deficient at certain root areas even in untreated patients.[1,5,6] During orthodontic treatment, bone resorption occurs in the direction of tooth movement and may create pronounced alveolar defects in subjects with already poor periodontal

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support or those who experience extensive incisor movements for camouflaging Class II or Class III malocclusions.[1,5,7] Therefore, the use of an appropriate imaging technique for the assessment of bone morphology and anatomy is of great importance in orthodontic treatment planning to avoid further bone loss around the teeth.

Traditionally, lateral cephalometry has been employed for orthodontic diagnosis and treatment planning. This radiography can also be applied for the measurement of labiolingual alveolar bone width at the anterior parts of the maxilla and mandible.[6,8] However, lateral cephalometry is a two-dimensional imaging technique and contains limitations such as magnification, geometric distortion, and structural superimposition, which inevitably cause errors in identifying and measuring anatomic structures.[1,7] With the introduction of cone-beam computed tomography (CBCT) into the dental practice, it was possible to capture three-dimensional (3D) images of hard tissues with high resolution and lower radiation dose than that of the traditional medical CT. CBCT enables accurate and reliable evaluation of dental and maxillofacial bone structures, without overlapping and distortion that is inherent to two-dimensional (2D) radiographs.[7,9–12]

Although CBCT appears to be a more reliable and preferred technique for evaluating the alveolar process, it is expensive and associated with additional radiation exposure than the cephalogram. Indeed, lateral cephalometry is still the main and irreplaceable diagnostic tool for orthodontic patients.[11] In this way, a comparison of lateral cephalometry and CBCT is valuable to detect whether the measurements performed on lateral cephalograms reflect the actual values obtained from three-dimensional images. There is limited research concerning the accuracy of cephalometry in comparison with CBCT for determining the anatomical limits of alveolar bone and detecting areas with deficient periodontal support. Therefore, the present study was conducted to quantitatively compare lateral cephalometry and CBCT techniques for evaluating alveolar bone thickness at the buccal and palatal sides of maxillary central incisors.

METHODS AND MATERIALS

Subjects

The ethics committee of Mashhad University of Medical Sciences reviewed and approved the study protocol (approval number IR.MUMS.DENTISTRY.REC.1400.010). The research was conducted under the guidelines presented in the Declaration of Helsinki.

The data for this cross-sectional study was obtained from the available records of patients in a private Oral and Maxillofacial Radiology Center. The selected patients had sets of lateral cephalometry and CBCT images with high resolution, taken for various treatment purposes other than that of the present study. The patients were in the age range of 15 and 50 years and presented different classes of malocclusion. The exclusion criteria were the presence of cleft lip/palate or other craniofacial anomalies, the history of orthodontic treatment, and observation of internal or external root resorption, root canal treatment, or post and core in the upper central incisors. Furthermore, patients with deciduous, missing, impacted, or supernumerary teeth in the anterior part of the maxilla were excluded from the study. The sample size was calculated as n = 55, according to a pilot study performed on the records of 30 patients using a significance level of 5% and a power of 80%.

Image acquisition

The lateral cephalometry images were taken at the natural head position (NHP) using a Planmeca Promax 2D radiography equipment (Planmeca Oy, Helsinki, Finland) with the following parameters: a power of 80 kV, a current of 10 mA, and a scan time of 1.2 s. The lateral cephalometry images were analyzed by a software program (Planmeca Romexis 5.3.4.39, Helsinki, Finland). The numerical values obtained from lateral cephalograms were converted to 100% magnification using the magnification coefficient of the apparatus.

CBCT scans were taken by Planmeca Promax 3D Max system (Planmeca Oy) at the NHP, using the following specifications: 88 kV power, 8 mA current, 12 s exposure time, 0.200 mm voxel size, and 90 × 90 mm field of view (FOV). The CBCT images were stored in Digital Imaging and Communications in Medicine (DICOM) format and processed using a multiplanar reformation program (Planmeca Romexis 5.3.4.39).

Alveolar bone thickness measurements

In the lateral cephalograms, four reference lines (A, B, C, D) were traced perpendicular to the longitudinal axis of the most forward upper incisor. The "A" line was drawn at the cementoenamel junction (CEJ), and the "B", "C", and "D" lines were drawn at 2.4 mm, 4.8 mm, and 7.2 mm apical to the CEJ, respectively. Then, the distance between the root

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surface and the buccal and lingual cortical bone was measured perpendicular to the longitudinal axis of the root at levels B, C, and D. These values represented alveolar bone thickness at the crestal, middle, and apical levels of incisors, respectively (Figure 1 A, B).

In CBCT images (Figure 2), the reference lines were drawn perpendicular to the longitudinal axis of the tooth, as explained previously. To keep a similar horizontal orientation between the two techniques, the upper incisor to palatal plane (ANS-PNS) angle was considered as the reference. The measurement of bone thickness around central incisors was performed in the axial view at the selected root level. Bone thickness was measured around the right and left central incisors (Figure 3A), and also at the midline between the two incisors (Figure 3B). To obtain midline values, a line was drawn from the most prominent part of the two central incisors at the buccal or lingual side perpendicular to the midsagittal plane. Then, the distance between the cortical bone surface and the line passing through the incisor outline was measured at the midsagittal plane (between the two incisors) and considered as the corresponding value to the cephalogram (Figure 3B). The midline measurements were selected for statistical comparisons because they better correspond with the lateral cephalometry, where the cortical bone thickness is measured between the most forward central incisor and the most forward bone projection at the midline.

The cephalometry and CBCT measurements were made by an experienced and calibrated investigator who was not involved in the study process. The assessments were performed on a 27-inch liquid crystal display (LCD) monitor with a resolution of 1920 × 1080 pixels under dark lighting conditions. To determine intra-examiner reliability, 20% of the specimens were randomly selected and the measurements were repeated one week later.

Statistical analysis

The intra-observer reliability of the assessments was detected by the intraclass correlation coefficient (ICC) analysis. The normal distribution of the data was assessed by the Kolmogorov–Smirnov test, which showed that some variables were not normally distributed. The statistical comparison between the two techniques was made using the midline measurements in CBCT images. The differences in alveolar bone thickness between lateral cephalometry and CBCT images were determined through the paired-sample t-test (for data with normal distribution) and the Wilcoxon signed rank test (for data that did not present normal distribution). The association between the two radiographic techniques was assessed by Pearson's and Spearman's correlation tests. The data analysis was performed through SPSS software (version 16.0; SPSS Inc, Chicago, Il, USA) and the significance level was set at $\alpha = 0.05$.

RESULTS

There were 27 males and 28 females with a mean age of 23.1 ± 5.8 years in the sample. The mean intraclass correlation coefficient between the

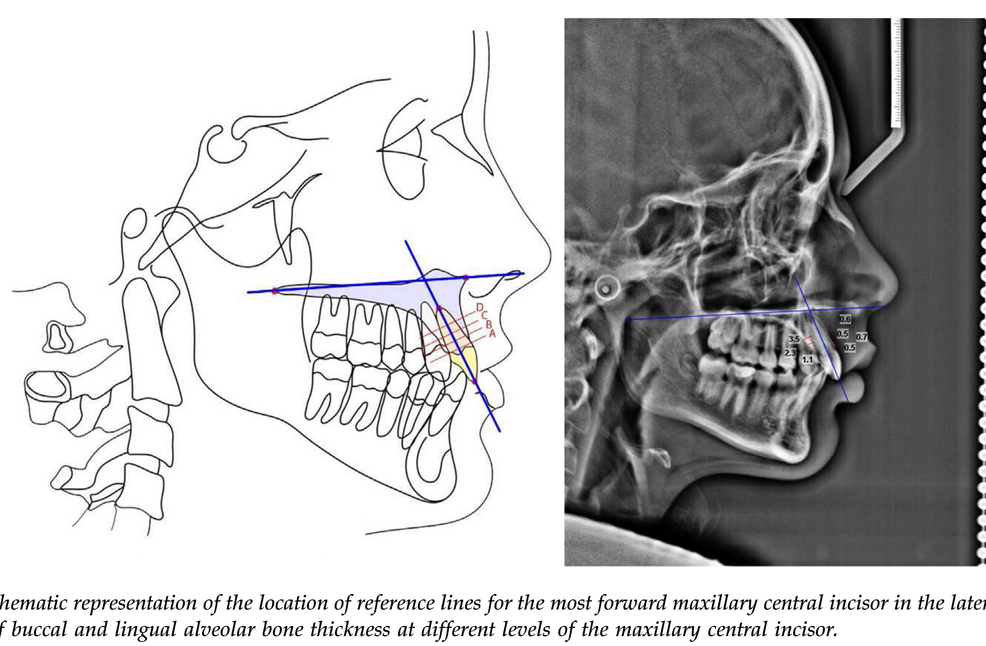

Figure 1. A. A schematic representation of the location of reference lines for the most forward maxillary central incisor in the lateral cephalogram, B. Measurements of buccal and lingual alveolar bone thickness at different levels of the maxillary central incisor.

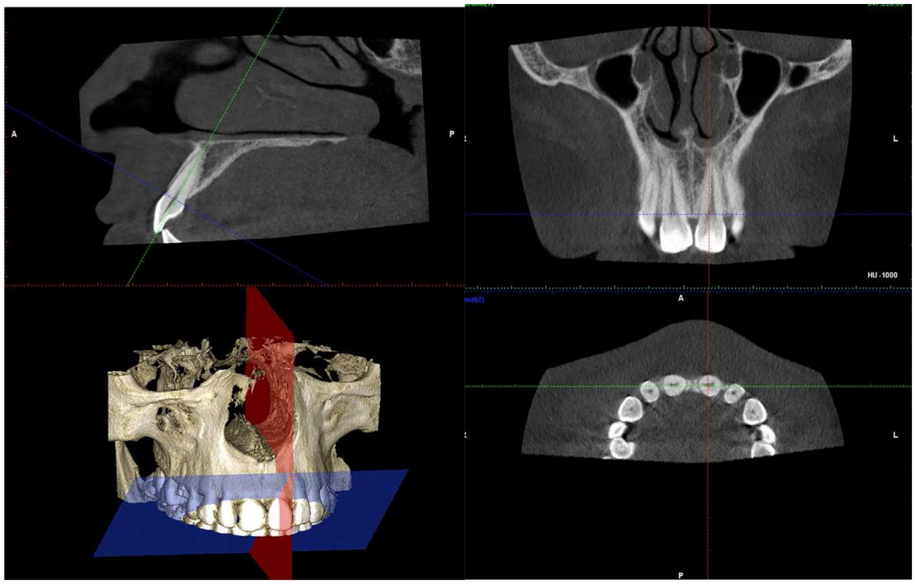

Figure 2. Orientation of the CBCT image for bone thickness measurements.

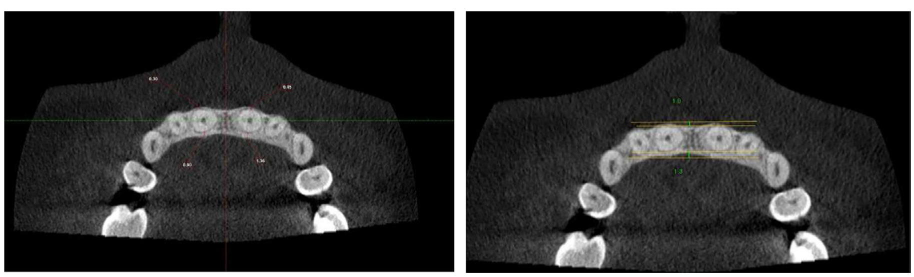

Figure 3. The axial view of the maxilla at the determined root level represents the measurement of buccal and lingual alveolar bone thickness around central incisors (A) and at the midline area between the two incisors (B).

repeated measurements was 0.95 and varied from 0.83 to 1.00, representing excellent intra-rater reliability.

Table 1 indicates the mean and standard deviation (SD) of bone thickness around the maxillary central incisor in lateral cephalograms, as well as bone thickness around the right and left central incisors and at the midline area between the two incisors in CBCT images, measured at different root levels on the buccal and lingual sides. All values were greater in cephalometry than CBCT, either around the individual incisors or at the midline area. The statistical analysis between the two radiographic techniques in midline revealed that bone thickness was significantly greater in cephalometry than in

Table 1. Descriptive statistics relating to bone thickness (mm) around the central incisor in lateral cephalometry, and bone thickness around the right and left central incisors and at the midline area between the incisors in CBCT images, measured at different root levels on the buccal and lingual sides.

		Cephalometry		CBCT						P-value
				Right central		Left central		Midline		
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Buccal	Crest	0.78	0.25	0.54	0.30	0.65	0.37	0.70	0.26	0.385
	Middle	1.1	0.37	0.67	0.28	0.64	0.33	0.77	0.34	0.044*
	Apex	1.49	0.58	0.68	0.33	0.73	0.36	0.79	0.33	0.003*
Palatal	Crest	1.07	0.45	0.61	0.54	0.68	0.47	1.01	0.60	0.673
	Middle	2.02	0.77	1.76	1.51	1.85	1.23	1.77	0.93	0.300
	Apex	3.33	1.42	2.95	2.28	3.06	2.0	2.96	2.05	0.248

*indicates a statistically significant difference at $P < 0.05$ between lateral cephalometric measurements and midline values in CBCT images, SD: standard deviation.

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CBCT at the middle and apical root areas on the buccal side ($P < 0.05$; Table 1). No significant difference was found between the two techniques at the crestal level on the buccal side, and at all root levels on the palatal side ($P > 0.05$; Table 1).

Table 2 presents the results of the correlation analysis between the two radiographic methods. A strong to very strong correlation was observed between lateral cephalometry and CBCT for determining bone thickness on the palatal side ($P < 0.001$; Table 2). There was a mild correlation for measuring bone thickness at the bucco-crestal region ($R_p = 0.371$, $P = 0.007$), but no significant association was found between lateral cephalometry and CBCT techniques for measuring buccal alveolar bone thickness at the middle and apical root areas ($P > 0.05$; Table 2).

DISCUSSION

The present study compared lateral cephalometry and CBCT for measuring bone thickness surrounding maxillary and mandibular central incisors. The sample was selected from patients with different malocclusions to compare the two methods in teeth with various inclinations. The buccal and lingual alveolar bone thickness was measured at three different distances from CEJ, representing the crestal, middle, and apical root levels. It is believed that the loss or insufficiency in cervical bone support may contribute to gingival recession, bony dehiscence, or fenestration, especially in the presence of plaque and inflammation.[7] The bone support at the middle and apical root areas is also important,[13] as the apices of incisors occasionally experience a wide range of movement.

In this study, bone thickness at the crestal part of the upper right and left central incisors was <0.7 mm on the buccal and lingual sides, as measured in CBCT scans. Buccal bone thickness at the middle and apical root areas was approximately 0.7 mm around the central incisors in CBCT images. Generally, bone thickness around each central incisor was a bit smaller than that obtained at the midline area between the incisors because the alveolar bone is usually more prominent at the midline. We believe that the midline measurements in CBCT better correspond with the values obtained from cephalograms because, in lateral cephalometry, bone thickness is measured between the most forward central incisor and the most forward bone projection at the midline. Therefore, in the statistical analysis, midline values were included. The palatal bone was substantially thicker than the labial bone at the middle and apical root levels of maxillary incisors in both radiographs. Oh et al.[1] assessed alveolar bone thickness over maxillary and mandibular incisors in untreated Class III patients and found that all incisors showed <1.0 mm bone thickness at the crestal and middle root levels. It is assumed that alveolar thickness <0.5 mm represents a “quasi defect”.[5] Several studies indicated that orthodontic treatment results in a significant reduction in the height and thickness of alveolar bone.[7,14–16] Therefore, tooth movement should be planned with caution to prevent aggravation of the thin periodontal support, especially at the cervical tooth area.

In the present study, the thickness of alveolar bone was greater in lateral cephalometry than in CBCT images at all root levels of maxillary incisors. However, the difference was only significant in the middle and apical parts of the labial alveolar bone, whereas in other regions, the values obtained from the two imaging techniques were comparable. The mean numerical differences in bone thickness between the two radiographic techniques ranged from 0.06 mm to 0.7 mm, which may have clinical implications in areas with thin periodontal support. The outcomes of this study indicate that bone thickness is overestimated in cephalograms as compared to CBCT-based examinations. The reason for an overestimation in 2D versus 3D images is the possible superimposition of the surrounding structures, which makes accurate localization of anatomical points difficult.[16] There were strong or very strong correlations between CBCT and lateral cephalometry in determining alveolar bone thickness in the palatal root areas of the anterior maxilla. The measurements at the

Table 2. The correlation analysis between lateral cephalometry and CBCT techniques for measuring alveolar bone thickness surrounding the maxillary incisor.

	Buccal	P-value	Palatal	P-value
	Correlation coefficient		Correlation coefficient	
Crest	Rp = 0.371	0.007*	Rp = 0.724	<0.001*
Middle	Rsp = 0.115	0.418	Rsp = 0.605	<0.001*
Apex	Rsp = 0.108	0.545	Rp = 0.838	<0.001*

*Statistically significant differences were noted at $P < 0.05$.
Rsp = Spearman's correlation coefficient; Rp = Pearson's correlation coefficient.

buccal side, however, showed a weak correlation at the cervical area, and no association at the middle and apical areas.

The morphology of the alveolar bone plays a great role in orthodontic treatment planning, as tooth movement should occur within the thickness of the cortical plate. The overall outcomes of this study revealed that lateral cephalometry provides bone thickness measurements that are highly correlated with the actual values obtained from CBCT examination in the palatal side, but it is not reliable for buccal bone assessment at the middle and apical areas. Indeed, cephalograms are not interchangeable with CBCT images for measuring alveolar bone thickness, because of the natural limitations and lower accuracy of 2D versus 3D techniques for the assessment of anatomical structures. Furthermore, cephalograms cannot provide bone thickness values for individual incisors.[13] According to the outcomes of this study, lateral cephalometry can be used with caution and only as a screening tool in pre-orthodontic assessments to detect areas that are susceptible to bone resorption and the occurrence of dehiscence and fenestration. Although bone thickness values obtained from the palatal side of the central incisor are reliable, the data on the buccal alveolar bone in lateral cephalograms should not be relied on in the treatment planning process of orthodontic patients. It is suggested that the clinician take CBCT images for accurate assessment of bone thickness, in cases with thin gingival biotypes[14,15] and those who require extensive labiopalatal movement for camouflaging a more severe malocclusion.[5,11]

Previous studies demonstrated a relatively high occurrence of gingival recession[17] or alveolar defects including dehiscence and fenestration[18] around maxillary and mandibular anterior teeth during orthodontic treatment. Others indicated significant differences in the thickness of alveolar bone between various classes of malocclusion[19–23] or vertical facial patterns.[21,24–26] There are a few studies that quantitatively compared cephalograms and CBCT scans for assessment of alveolar bone thickness, therefore comparison of the results of this study with previous studies is limited. The outcomes of this study are in agreement with those of Kula et al.[16] who found that alveolar bone buccal to the maxillary incisor apices was overestimated in 2D compared with 3D evaluations, possibly due to the superimposition of the anterior nasal spine over the incisors in the 2D assessment. It should be noted that in the study of Kula et al.,[16] cephalograms were derived from CBCT images by the software, and only bone thickness buccal to the most forward maxillary incisor was compared between images. Wei et al.[11] evaluated 30 sets of lateral cephalograms and CBCT scans and measured bone thickness on the most forward maxillary incisor in lateral cephalograms and four maxillary incisors in CBCT images. They found a mild to moderate correlation in determining alveolar bone thickness between the two imaging techniques. Furthermore, the thickness of maxillary alveolar bone was always greater in lateral cephalometry than in CBCT images with the overestimations ranging from 0.3 to 1.3 mm.[11] Nayak Krishna et al.[13] reported that in a few patients, bone dehiscence as detected in CBCT images was not visible in cephalograms. They assumed that the limits of palate and symphysis in the traced cephalograms may be wider than the actual values, as cephalograms are associated with mid-sagittal projections of other teeth on cortical plate borders.[13]

The limitation of this study was the small sample size. Furthermore, CBCT imaging is not a gold standard for defining alveolar bone thickness,[11] as the linear measurements in CBCT scans are influenced by technical parameters such as the spatial resolution, voxel size, dimensions of FOV, the magnitude of the focal spot, the number of basis images, and the reconstruction algorithm of the system software.[1,25,27,28] It is assumed that delicate structures such as the buccal or lingual alveolar bone or sphenoid sinus walls may be less visible in images with poor spatial resolution.[1] It is recommended that future studies evaluate the diagnostic accuracy of lateral cephalometry in detecting bone limits in a larger sample size. Further studies are also warranted to elucidate the influence of age, gender, facial height, skeletal discrepancy, and radiographic parameters on the measurement of bone support around anterior teeth in 2D vs 3D images.

CONCLUSIONS

Under the conditions of this study, the following conclusions can be drawn:

1. The thickness of the alveolar bone was greater in lateral cephalometry than in CBCT images at all root levels of maxillary incisors. However, the difference was only significant in the middle and apical parts of the labial alveolar bone, whereas in other regions, the values obtained from the two imaging techniques were comparable.
2. There were strong or very strong correlations between CBCT and lateral cephalometry in determining alveolar bone thickness in the palatal root areas of the maxillary central incisor. The measurements at the buccal side, however,

showed a weak correlation in the cervical area, and no correlation in the middle and apical areas between the two techniques.

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ETHICAL APPROVAL

This study was approved by the Institutional Review Board of Mashhad University of Medical Sciences (No. IR.MUMS.DENTISTRY.REC.1400.010).

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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