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ORIGINAL ARTICLE

Comparison of Ultrasonography and Cone Beam Computed Tomography in the Differential Diagnosis of Periapical Lesions: A Prospective Radiopathological Study

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ABSTRACT

Objective: The aim of this study is to evaluate the correlation between ultrasonography (USG) and cone beam computed tomography (CBCT) and the accuracy between histopathological diagnosis and preliminary diagnosis in the diagnosis of periapical lesion. **Methods:** 20 patients with periapical lesion in the jaw, were included in the study. The presence of expansion or perforation and dimensions of the lesion were performed with CBCT. In the examination of the lesion with USG, shape, echogenicity, vascularization of the lesion and the presence of buccal expansion and perforation, were determined. Subsequently, a biopsy was taken from the lesion for histopathological examination and the final result was compared with the accuracy of the preliminary diagnoses. **Results:** Kolmogorov-Smirnov test, Wilcoxon test (w) and Cohen's kappa coefficient (κ) was used to analyze the data. Three of the 4 lesions diagnosed as periapical granuloma as a preliminary diagnosis were confirmed as periapical granuloma in histopathological examination. Periapical cyst was confirmed in histopathological examination of 14 of 16 lesions diagnosed as periapical cyst as a preliminary diagnosis. Mesiodistal (MD) measurements in CBCT measurements were significantly higher than the USG group ($p < 0.05$). There was 100% agreement ($p = 0.000$) between the evaluation of buccal expansion, buccal perforation, and palatal-lingual perforation between CBCT and USG. **Conclusion:** It was concluded that the combined use of USG and CBCT can provide the clinician with important information in the diagnosis of periapical lesion.

Key words: cone-beam computed tomography, periapical cyst, periapical granuloma, ultrasonography

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INTRODUCTION

Imaging techniques are constantly being updated with developments in technology. Techniques that provide detailed images are necessary for the examination of periapical lesions, as in many areas of dentistry. With advances in technology, various imaging methods have been introduced for professional use in this field.[1] One such method, panoramic radiography, fails to distinguish between cystic and noncystic lesions. Differentiating between a true cyst and a granuloma can help to predict the prognosis of the treatment.[2] The limitations of two-dimensional imaging, such as magnification, distortion, and superposition, may lead to misdiagnoses by clinicians. To obtain more accurate information, the use of three-dimensional imaging techniques in the examination of pathological lesions in the jaw bones may be necessary.[3,4]

Cone beam computed tomography (CBCT) with reduced radiation doseshas been developed specifically for use in the dentomaxillofacial region. CBCT produces three-dimensional images with a shorter imaging time, better image resolution, and less radiation than medical CT. The shapes, sizes, anatomical locations, and relationships of intraossesous jaw pathologies with surrounding anatomical structures can be evaluated using CBCT. However, CBCT is not suitable for detecting soft tissue lesions due to its low contrast resolution. Thus, by itself, it is not sufficient to assess the content of soft tissue lesions.[5–7]

Real-time ultrasonography (USG) relies on the detection of sound waves generated *how*and the conversion of waves reflected from tissues into electrical signals. Ultrasound imaging systems are widely used in medicine and dentistry because of their advantages, such as pain-free delivery, ease of use, safety, noninvasiveness, and accurate display of tissues, without the need for ionizing radiation.[8] USG is useful in imaging inflammatory soft tissue disorders affecting the head and neck region.[9] Many obstructive, inflammatory, and tumoral lesions can be detected by USG. It is also useful in distinguishing cystic formations, abscesses, benign and malignant lesions and in detecting intraosseous jaw lesions.

There are some studies in the literature on the importance of using USG in the evaluation of endodontic jawbone lesions.[10–14] However, only a limited number of studies have investigated the role of ultrasound in the evaluation of bone lesions.[11] In 1996, Lauria et al.[15] prospectively evaluated the role of USG as a complementary imaging method in the diagnosis of intraosseous jaw lesions and concluded that it is a useful technique in the evaluation of lesion content. Cotti et al.[12,13] and Gundappa et al.[14] reported that the combined use of USG and color Doppler can differentiate periapical lesions according to lesion contents. They concluded that USG was a useful technique to distinguish between cysts and granulomas by providing information about the content of a bone lesion. In 2009, Sumer et al.[16] reported that USG provides accurate information about the content of intraosseous jaw lesions and that Doppler ultrasound can show the vascularization of such lesions.

The aim of this study was to compare preliminary diagnoses made using CBCT and USG with definitive diagnoses based on a histopathological examination to determine the ability of CBCT and USG to differentiate periapical lesions, granulomas, and cystic lesions.

METHODS

The study protocol was carried out according to the principles of the Helsinki Declaration of 1975, as revised in 2013. Patients or their legal guardians gave verbal informed consent before radiography, and the study was reviewed and approved by the local ethics committee of Hatay Mustafa Kemal University University (date: 04.04.2019, decision no: 01).

Twenty patients (males, n = 11; females, n =9) aged between 19 and 62 years (mean: 36.9±13.3) who visited

Figure 1. The mesio-distal, bucco-lingual, and antero-posterior size and 3D image of the lesion on CBCT.

the Department of Dentomaxillofacial Radiology with the complaint of pain and/or swelling and had radiolucency in the apical region on a conventional radiograph were included in the study. Only images of diagnostic quality were included in the study. Images with artifacts that would hinder measurement accuracy were excluded.

CBCT Imaging Procedure and Image Evaluation

All CBCT images of the maxillofacial region were taken using a KaVo OP 3D Pro (KaVo Dental GmbH, Germany) with a field of view varying from 5 × 5 cm to 13 × 15 cm diameter (scanning parameters: 90 kV, 5 mA, 8.14 seconds of exposure time, 0.38 mm voxel size). All evaluations were performed by a 15.6-inch full HD notebook with resolution of 1,920 × 1,080 pixels. Two observers with 6 years of experience since the end of specialization in dentomaxillofacial radiology evaluated the CBCT images. Based on the study of Bayrakdar et al.,[10]the following factors were taken into account when interpreting the CBCT images:

a) **The lesion sizes**
The size of the lesion was measured in the mesiodistal (MD), buccolingual (BL), and anteroposterior (AP) directions in all three sections (axial, sagittal, and coronal) where the lesion was the widest (Figure 1).
b) **The presence of expansion/perforation of the bone**
Lesion perforation or expansion of the bone was examined.

USG Imaging Procedure and Image Evaluation

An SIUI APOGEE 3300 (Shantou Institute of Ultrasonic Instruments Co., Ltd, China) USG system was used to obtain information about the soft tissue content of the lesion. Extra-oral scanning was performed in the transverse and longitudinal planes using a high-definition, regular-size, multifrequency USG linear probe at a frequency of 5–12MHz. Air was prevented from entering between the tissue and the probe by means of ultrasonic gel. The probe was placed externally in the relevant area, color Doppler was applied to evaluate the blood flow in each case, and the images were interpreted.

The following points were taken into account when interpreting the USG images[10,13]:

a) **The characteristics of the lesion**
   - **Cystic lesion:** Anechoic or hypoechoic, well-circumscribed, surrounded by bony walls, filled with fluid, and lacking internal vascularization on Doppler
   - **Granuloma:** Weakly circumscribed, both hyperechoic and hypoechoic, and shows a rich vascular supply on Doppler

b) **The shape of the lesion**
   The shape of the lesion was divided into three groups: oval, circular, and irregular.

c) **The internal echogenicity of the lesion**
   - Anechoic: If the lesion appeared completely black
   - Hypoechoic: If the echogenicity of the lesion was lower than that of the surrounding soft tissue
   - Isoechoic: If the echogenicity of the lesion was the same as that of the surrounding soft tissue
   - Hyperechoic: If the echogenicity the lesion was greater than that of the surrounding soft tissue

d) **The presence of posterior echogenicity**
   Poster echogenicity was defined as a strip-like echo extending down from the base of the lesion.

e) **The presence of expansion/perforation of the bone**

Expansion/perforation on the USG image was defined as follows:

- **Buccal expansion:** The hyperechoic line of the buccal bone wall of the lesion was convex;
- **Buccal perforation:** The continuity of the hyperechoic line of the buccal bone wall of the lesion was interrupted.
- **Palatal/lingual perforation:** A posterior echo was present.

f) **The lesion sizes**
   The lesion size was measured from the widest part of the lesion in MD, AP, and superior-inferior (SI) directions (Figure 2).

g) **The form of vascularization**
   Lesion vascularization was divided into three groups: internal, external, or both.

Biopsy and Histopathological Evaluation

Patients with an indication for apical surgery with a preliminary diagnosis made after both USG and CBCT examinations were referred to the Dentomaxillofacial Surgery clinic for a biopsy and pathological diagnosis. The pathological mass excised after completion of enucleation by the dentomaxillofacial surgeon was placed in a sterile container and fixed with formol at a ratio of 10 to one. The biopsy specimen was then sent to the Department of Medical Pathology for evaluation, along with the prepared pathology form. After routine tissue follow-up in the Department of Medical Pathology, hematoxylin-eosin-stained preparations were evaluated under a light microscope (Figure 3). The accuracy of the preliminary diagnosis was then compared with the histopathological diagnosis.

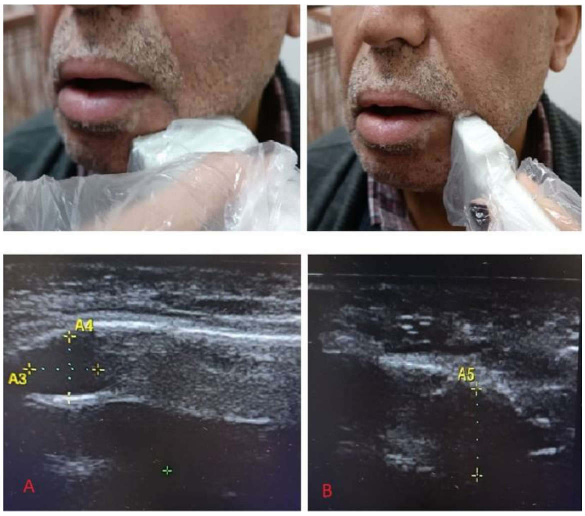

Figure 2. Probe placement. Mesio-distal and anterior-posterior size (A) and superior-inferior size (B) of the lesion on USG.

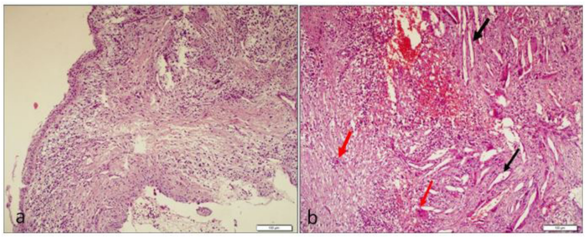

Figure 3. (a) Nonspecific squamous epithelial lined cyst with chronic inflammation (H+E, x100) (b) Cholesterol clefts (black arrow) and multinucleated giant cells (red arrow) in cyst wall (H+E, x100).

Statistical analysis

The distribution of the variables was determined using the Kolmogorov–Smirnov test. Wilcoxon's test (*w*) was used in the analysis of dependent quantitative data. Cohen's kappa coefficient (κ) was used to measure compliance analysis of qualitative dependent data. In measuring the dimensions of the lesion, the average of the measurements obtained by both observers was statistically evaluated.The Statistical Package for the Social Sciences(SPSS) v.28.0 program (IBM Corp., Armonk, NY, USA) was used in the analysis. The significance level was $p < 0.05$.

RESULTS

Of the 20 patients included in the study, there were 9 (45%) females and 11 (55%) males. The age range of the patients was between 19 and 62 years, and the mean age was 36.2±13.3 years. The most common lesion shape

Table 1. Descriptive statistical information of lesion findings.

		Mean	N-%	p	
Histopathological Diagnosis	Granuloma	5	25.0%	0.000	K
	Cyst	15	75.0%		
Preliminary Diagnosis	Granuloma	4	20.0%	0.000	K
	Cyst	16	80.0%		
Lesion Shape	Oval	15	75.0%	0.000	K
	Circular	5	25.0%		
Internal Echogenicity	Anechoic	11	55.0%	0.000	K
	Hypoechoic	4	20.0%		
	Isoechoic	2	10.0%		
	Hyperechoic	3	15.0%		
Buccal Expansion (CBCT)	Absence	5	25.0%	0.000	K
	Presence	15	75.0%		
Buccal Perforation (CBCT)	Absence	20	100.0%	0.000	K
	Presence	0	0.0%		
Palatal-Lingual Perforation (CBCT)	Absence	20	100.0%	0.000	K
	Presence	0	0.0%		
Buccal Expansion (USG)	Absence	5	25.0%	0.000	K
	Presence	15	75.0%		
Buccal Perforation (USG)	Absence	20	100.0%	0.000	K
	Presence	0	0.0%		
Palatal-Lingual Perforation (USG)	Absence	20	100.0%	0.000	K
	Presence	0	0.0%		
Posterior Echogenicity	Absence	14	70.0%	0.000	K
	Presence	6	30.0%		
Vascularization	Internal	2	10.0%	0.000	K
	External	15	75.0%		
	Internal & External	3	15.0%		

Table 2. The lesion dimension measured on CBCT and USG in MD, AP and SI.

	CBCT		USG		p	
	Mean±SD	Median	Mean±SD	Median		
Mesiodistal (MD)	8.23±2.05	7.95	7.98±1.25	7.90	0.002	w
Anterioposterior (AP)	7.22±1.00	6.80	7.26±0.94	6.80	0.177	w
Superioinferior (SI)/ Buccolingual (BL)	7.21±1.05	7.00	7.29±0.97	7.15	0.092	w

was oval (75%). The most common type of internal echogenicity was anechoic (55%), and the second most common type was hypoechoic (20%) (Table 1). Descriptive statistical analysis of cortical bone changes, posterior echogenicity, lesion type, histopathological diagnosis, preliminary diagnoses, and vascularization types of the lesion on CBCT and USG are given in Table 1. The dimensions of the lesions measured on CBCT, and USG in the MD, AP, and SI directions are given in Table 2.

There was 100% compliance between the observers in the evaluation of lesion shape, histopathological diagnosis, preliminary diagnosis, and internal echogenicity ($p = 0.000$). There was also 100% agreement between the observers in the evaluation of buccal expansion, buccal perforation, and palatal-lingual perforation of the lesions on both CBCT and USG ($p = 0.000$). In addition, there was 100% compliance between the observers in the evaluation of posterior echogenicity of the lesions and vascularization ($p = 0.000$) (Table 1).

The MD measurements of the lesions on CBCT were significantly higher than the MD measurements on USG ($p < 0.05$). On the other hand, there were no significant differences in the AP and SI measurements of the lesions using the two devices ($p > 0.05$) (Table 2).

Histopathological examination

In seventeen of the 20 periapical lesions, the preliminary diagnosis was compatible with the histopathological diagnosis. Three of four lesions diagnosed as periapical granulomas on the CBCT, and USG examinations were confirmed as periapical granulomas on the histopathological examination. However, 14 of 16 lesions diagnosed as periapical cysts on the CBCT and USG examinations were confirmed as periapical cysts on the histopathological examination.

DISCUSSION

Periapical or radicular cysts are inflammatory cysts associated with teeth with infected and necrotic pulp.[17] They are usually detected during a routine radiographic examination or consultation for acute toothache.[18] More than 90% of periapical lesions can be classified as dental granulomas, radicular cysts, or abscesses.[19] A definitive diagnosis of periapical lesions can be made only by histological examination. However, a clinical diagnosis of a periapical cyst is possible based on the following factors: (i) one or more devital teeth with a periapical lesion, (ii) lesion size greater than 200 mm^2, (iii) radiologically, a lesion margin consisting of a thin radiopaque line,and (iv) a radiolucent area surrounded by straw-colored fluid draining from the root canal system on aspiration.[20]

Periapical lesions are usually first diagnosed and treated based on radiological findings. Sometimes, periapical surgery is required for diagnosis and treatment, depending on the cystic or noncystic nature of the lesion. It is important to evaluate new and perhaps more promising imaging modalities to better predict the outcome of nonsurgical endodontic treatment and, in some cases, avoid surgical trauma.[14] In our study, we compared the accuracy of the clinical prediagnosis of periapical lesions examined by USG and CBCT with that of a histopathological examination, which is the gold standard.

There are advantages and disadvantages of using USG and CBCT in the examination of periapical lesions. USG is a simple, noninvasive, real-time imaging method, with lower cost equipment compared to that of other imaging devices. There is also no need to use ionizing radiation. USG gives a clinician an idea about the shape, vascularity, and content of a periapical lesion.[9] On the other hand, the visibility of a cyst changes when using USG, depending on the position of the cyst in the jaws. Due to difficulty visualizing the cyst, it may be difficult to determine the presence of buccal/lingual perforations.[21] In addition, the use of USG is limited to soft tissue.[16] CBCT, on the other hand, provides valuable information on lesions in all three dimensions, including whether they have caused cortical bone destruction. However, CBCT does not provide sufficient information about the contents of periapical lesions because it does not have Hounsfield unit values.[10] Considering the advantages and disadvantages of both CBCT and USG for evaluating periapical lesions, we used both imaging techniques in our study.

In studies that evaluated the use of USG in the diagnosis of periapical lesions, Cotti et al.[13] found that USG echography findings were confirmed by histopathological findings in the differential diagnosis of cysts and granulomas in all cases they examined. Therefore, they concluded that USG is helpful in the differential diagnosis of cysts and granulomas. Bayrakdar et al.[10] also reported concordance between USG and histopathological findings. Arslan et al.[22] compared periapical radiography, panoramic radiography, and USG in the diagnosis of periapical lesions and reported that USG is an alternative to periapical and panoramic radiography for diagnosing periapical lesions in anterior teeth. Gundappa et al.[14] reported that an ultrasound diagnosis was compatible with a histopathological diagnosis in all 15 cases they examined, and that USG can provide accurate information about the pathological nature of a lesion, although underestimating the extent of the lesion. Shahidi et al.[11] evaluated 15 intraosseous lesions, including three radicular cysts and one infected radicular cyst, with panoramic radiography, computed tomography or CBCT, and USG. Their work confirmed that USG is a useful imaging technique for determining the size of intraosseous jaw lesions with little underestimation, providing important diagnostic information about the content of jawbone lesions where the buccal bone thickness is sufficiently thin. Bansal et al.[23] concluded that USG with color Doppler was an effective tool in the diagnosis of periapical lesions, with these imaging modalities having better diagnostic accuracy than that of conventional and digital radiography. Goel et al.[24] reported that 19 of 20 lesions prediagnosed as periapical cysts by USG and 10 lesions prediagnosed as periapical granulomas were confirmed as periapical cysts by histopathological findings. They calculated that conventional radiography diagnosed periapical cysts with sensitivity of 78.95% and specificity of 45.55% and periapical granulomas with sensitivity of 45.45% and specificity of 78.95%. On the other hand, Doppler USG diagnosed periapical cysts with sensitivity of 100% and specificity of 90.91% and periapical granulomas with sensitivity of 90.91% and specificity of 100%. It was stated that there was a strong statistical significance between both methods. As a result, they concluded that Doppler and USG are superior to conventional radiographs in detecting periapical lesions. Etöz et al.[21] reported that USG could be an alternative technique for use in the follow-up of visualized periapical lesions. In the present study, the preliminary diagnosis was confirmed by the histopathological diagnosis in 17 of 20 periapical lesions. In the CBCT and USG examinations, three of four prediagnoses of lesions as periapical granulomas were confirmed by the histopathological examination. The histopathological findings confirmed the prediagnoses of 14 of 16 periapical cysts as periapical cysts.

In this study, the most common lesion shape was oval (75%). This finding is similar to that of Bayraktar et al.,[10] who examined 123 lesions using both USG and CBCT. In their study, 66.1% of the cysts they examined were oval, 17.9% were circular, and 16.1% were irregular.

Internal echogenicity on USG images provides information about the content of the lesion. Many studies have found correlations between lesion content and internal echogenicity features.[10,11,24] Consistent with the study of Bayrakdar et al.,[10] in our study, the most common type of echogenicity was anechoic (55%), and there was a correlation between the histopathological determined lesion content and the features of the USG images classified in terms of internal echogenicity. The second most common type of echogenicity was a hypoechoic pattern (20%). Shahidi et al. stated that five cysts with anechoic echogenicity were radicular (n=3), residual (n=1), and dentigerous (n=1) and that three cysts with hypoechoic echogenicity were infected radicular (n=1), residual (n=1) cysts and odontogenic keratocytes (n=1).[11] In their study, the cystic lesions showed hypoechoic or anechoic echogenicity, whereas the lesions with more solid contents showed hyperechoic echogenicity. On the other hand, Goel et al. detected hypoechoic patterns in five of 30 periapical lesions they examined.[24]

Traditionally, the size of a periapical radiolucent lesion has been used to differentiate between a cyst and a granuloma.[24] In this study, the mean MD, AP, and SI dimensions of the lesions were 8.24±2.10 mm, 7.22±1.01 mm, and 7.21±1.08 mm on CBCT, respectively. The same values on USG were 7.98±1.27 mm, 7.26±0.95 mm, and 7.29±0.99 mm, respectively. Bayrakdar et al. reported MD, AP, SI lesion dimensions on CBCT images of 24.9 mm, 16.5 mm and 21.8 mm, respectively.[10] On USG, these dimensions were 25.5 mm, 17.2 mm, and 16.8 mm, respectively. They stated that there was no statistically significant difference between the MD and AP dimension measurements using both techniques but that the difference in the SI dimension measurement between CBCT and USG was statistically significant. In another study that used periapical radiography, panoramic radiography, and USG, the authors reported that the maximum MD size of the lesions was compatible among all three techniques.[21] Gundappa et al. measured the mean SI, MD, and AP dimensions of periapical lesions in 15 patients by USG and calculated them as 6.8±2.4 mm, 6.6±2.6mm, and 6.2±2.8 mm, respectively.[14] Goel et al. compared the MD, AP and SI dimensions of 30 periapical lesions on USG and conventional radiographs.[24] They observed no significant difference in the MD dimension measurements of the lesions but a significant difference in the SI dimensions on USG versus conventional radiographs. In their study, the mean MD, AP, and SI dimensions of the lesions on USG were 12.08 mm, 9.14 mm, and 9.49 mm, respectively. Bansal et al. calculated the mean MD (9.2 mm) and SI dimensions (8.7 mm) of periapical lesions using USG, conventional and digital radiography.[23] They reported a decreasing trend in mean lesion sizes on conventional radiography versus USG. In a study on 21 patients with periapical lesions, Raghav et al. measured the MD and SI dimensions of the lesions on conventional and digital radiographs and reported that the lesion dimensions were smaller on USG than conventional and digital radiographs.[25] It has been reported that the reason for this is that the lateral bone walls of the lesions cause acoustic shadows and that the measurement points cannot be determined exactly using USG.[14,25] In this study, the mean MD, AP, and SI dimensions of the lesions on CBCT were 8.23 mm, 7.22 mm, and 7.21 mm, respectively. The same values on USG were 7.98 mm, 7.26, mm and 7.29 mm, respectively, on USG. In our study, the MD measurements on CBCT were significantly higher than those on USG. The AP and SI measurements on CBCT did not differ significantly from those on USG. When we evaluated the periapical lesions in terms of expansion and perforation, only buccal expansion was found in the lesions prediagnosed as cysts on both the CBCT images and USG. Bayrakdar et al. reported that CBCT and USG findings were not compatible in detecting buccal expansion.[10] In contrast, in our study, there was 100% agreement between the CBCT and USG evaluations of buccal expansion, buccal perforation, and palatal-lingual perforation.

In our study, posterior echogenicity was absent in 70% of the lesions. External vascularization (75%) was the most common type of vascularization. Bayrakdar et al.[10] determined that 60.7% of cysts did not have posterior echogenicity and that 39.3% had posterior echogenicity. In their study, 28.6% of the cysts had internal vascularization, 61.9% had external vascularization, and 9.5% had both internal and external vascularization. Cotti al. examined 11 periapical lesions by USG and stated that five periapical lesions were well circumscribed and did not show internal vascularization.[13] They found that periapical lesions had sharp borders and showed external vascularization. In their study, four periapical lesions had rounded borders and showed rich vascularization.

In our study, we compared the accuracy of the preliminary diagnoses of periapical lesions examined on both USG and CBCT images with that of a histopathological examination, which is the gold standard. We believe that the use of both CBCT and USG is a strength of our study. Although the number of samples was determined by power analysis, a study with a larger number of samples would yield more accurate results.

CONCLUSION

In this study, the preliminary diagnoses of periapical lesions determined using CBCT and USG were compatible with the definitive histopathological diagnoses. The absence of a significant difference between CBCT and USG in the AP and SI measurements and the finding of 100% agreement between the two imaging techniques in terms of changes in cortical bone show that USG can provide useful information in the diagnosis of periapical lesions. We conclude that CBCT can provide useful information to aid the diagnosis of periapical lesions (cysts and granulomas) and that USG can support CBCT by providing information about the content of the lesion.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

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