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RESEARCH ARTICLE

Diagnostic accuracy of panoramic radiography and ultrasonography in detecting periapical lesions using periapical radiography as a gold standard

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Objectives: The purpose of this study was to compare the accuracy of imaging techniques in diagnosing periapical lesions.
Methods: Imaging records of 80 patients (51 females, 29 males, aged between 14 and 75 years) including periapical and panoramic radiographs and ultrasonographic images were selected from databases of Selcuk University Dentistry Faculty. Periapical radiographs were accepted as gold-standard and 160 anterior maxillary and mandibular teeth with or without periapical lesion were included to the study. Three specialist observers (dental radiologists) evaluated the presence and appearance of periapical lesions on panoramic radiograph and ultrasonographic images.
Sensitivity, specificity, positive predictive value, negative predictive value and diagnostic value of panoramic radiographs and ultrasonography were determined.
Results: Sensitivity was 0.80 and 0.77 for ultrasonographic images and panoramic radiographs, respectively which shows that periapical lesion was correctly detected in 80% of the cases with ultrasound and in 77% of the cases with panoramic radiography. Specificity values were determined as 0.97 for ultrasound and 0.95 for panoramic radiography. Overall diagnostic accuracy was 0.86 and 0.84 for ultrasound and panoramic radiography, respectively.
Conclusions: Periapical and panoramic radiographs are commonly used to visualize periapical lesions. Besides, ultrasonography is an alternative method to digital radiographic techniques in the diagnosis of anterior teeth with periapical lesions.
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Introduction

Periapical lesions occur as a result of pulpal infection or necrosis, which is caused by trauma or dental caries. The provocative agent induces an acute or chronic bone resorption in the periradicular tissues there by preventing the spread of infection, resulting in a radiolucent image in radiographs. If the tooth with lesion is not treated properly, it can be lost. Some lesions are asymptomatic and only detected in routine radiographic evaluations.[1–3]

Radiological examination is important in the diagnosis, treatment and follow-up stages of periapical lesions. In dental applications, periapical and panoramic radiographs are commonly used in detecting periapical lesions. Periapical imaging provides detailed knowledge about the teeth and surrounding tissues such as interdental alveolar bone and periapical region. It is used

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both before and after endodontic treatment to evaluate root canal morphology, calcifications, root canal fractures, root curvatures apical region morphology as well as periapical lesions.[4]

Panoramic radiography is a radiological method that contains mandibular and maxillary dental arches and their supporting structures in a single image. It allows imaging of temporomandibular joints and sinuses in a single film with low dose of radiation.[5,6]

In recent times, digital radiography is preferred to conventional radiography because of the fact that the dose of radiation is considerably reduced (80%), that it has a shorter processing time, and changes can be made to the image such as density, contrast, image orientation, clarity, pseudocolor changes. It also allows archiving images and eliminating the disadvantages of dark room and bath solutions.[4,7]

The radiographic image is two-dimensional representation of a three-dimensional structure; therefore the buccolingual plane cannot be assessed. Radiographs are not adequate to ensure information about the real size of periapical lesion, the characteristics of soft tissue and the relationship between tooth and surrounding anatomical structures.[1,4] Some periapical lesions may not give radiographic finding. If perforation, destruction in the bone cortex or erosion of the cortical bone is present, it can be detected radiographically. In addition, a periapical lesion requires about 30–50% bone mineral loss in order to be diagnosed in the radiograph. The situation of the lesion affects the radiographic image due to the thickness of the cortical bone in the area where it is located. Factors such as lesion localization, morphology of the apical region, magnification, distortion, bone density, contrast also affect the radiographic image and interpretation.[8,9] It is essential to assess new techniques to overcome these limitations.

Ultrasonography (USG)(which is also known as real-time echography/sonography) is an alternative diagnostic imaging technique that is based on reflection of ultrasound waves from different tissue interfaces. When an alternative electrical current is applied to quartz or synthetic ceramic crystal, tranducer (probe) converts it to mechanical energy and generates sound waves oscillating at the same frequency as a result of the piezoelectric effect. The echoes return back from the interface of different biological tissues which has different acoustic properties to the transducer that converts them to the electrical energy. So, ultrasound image (that includes black, white and gray tones) appears on the computer screen.[4,10]

Ultrasound is a painless, non- invasive, relatively inexpensive and safe imaging technique that it's absolute non-ionizing nature. In recent years, it has been used in imaging of maxillofacial region and widely accepted as a diagnostic aid due to all of these advantages. Ultrasound is used to diagnose swellings in head and neck region, midfacial fractures, ramus and condyle fractures, temporomandibular joint disorders, salivary gland disorders, cervical lymphadenopathy and intraosseos lesions such as periapical lesions. It also provides information about the presence and direction of blood flow with the Doppler feature.[10–13] Along with the doppler function, ultrasonographic features contribute to accurate diagnosis of lesions and appropriate treatment planning.[13]

USG is a repeatable and useful method that can be used in the diagnosis and follow up of periapical lesions, as well as in the intraoperative period. In addition, it contributes to differential diagnosis by showing lesion content and vascularization.[9,12]

Diagnostic accuracy of periapical lesions is important to find out the infection source and to reduce unnecessary root canal treatments. The aim of this study was to compare the accuracy of imaging techniques (digital radiography and USG) in diagnosing periapical lesions.

Methods and materials

Patient selection

The study was approved by Selçuk University Ethical Committee (2017/16). Imaging records of 80 patients (51 females 29 males, aged between 14 and 75 years) including periapical and panoramic radiographs and ultrasonographic images were selected from databases of Selçuk University Dentistry Faculty (Konya, Turkey). Images were taken between September 2017 and February 2018. Periapical radiographs were accepted as gold-standard and 160 anterior maxillary and mandibular teeth with or without periapical lesion were included to the study. Panoramic and periapical radiographs with good image quality were selected. The study excluded periapical lesions originating from bone pathology such as hyperparathyroidism, Paget's disease, fibrous dysplasia, multiple myeloma, and periapical cemental dysplasia and that appeared as radiopaque on the radiographs. Besides, radiographs with poor image quality were not included in the study.

Imaging methods

The panoramic radiographs were taken using a digital orthopantomograph machine (Kodak 8000 Panoramic system, Carestream Health Inc, Rochester NY, 60 kV 4mA 13,9 s). Kodak CCX digital equipment (Trophy Radiologies 6510, Croissy-Beaubourg, France, 70 kV 8 mA 0,18 s) was used in obtaining periapical radiographs and bisecting angle technique was used.

Ultrasound images were taken using a DC-N2 ultrasound device (Mindray Bio-Medical Electronics, Shenzhen, China), with color Doppler function, multi-frequency, linear ultrasonic probe (75L38EA) operating at a frequency of 7–10 MHz. The ultrasound probe was first covered with disposable cling film for control of infection, and then covered with a layer of ultrasound gel. The probe was placed extraorally in the anterior region, both longitudinally (sagittal plane)

Figure 1 Transducer positions in anterior region in ultrasonographic evaluation. (a) Extraoral transverse positions in maxilla (b) Extraoral longitudinal positions in maxilla (c) Extraoral transverse positions in mandibula (d) Extraoral longitudinal positions in mandibula

and transversally (axial plane), from outside the mouth (Figure 1). Because of the large size of transducers which make them unsuitable for intraoral use, most patients could not tolerate intraoral positioning of the probes. Therefore; ultrasonographic evaluation was not performed intraorally. Then, the best images of the periapical region were recorded.

The panoramic and periapical images were saved as JPEG files. At the beginning of the study, dental radiologists were trained to assess the ultrasonographic images by the specialist who had an experience of 8 years for 2 months. Periapical radiographs were accepted as gold-standard for the existence of periapical lesion, then panoramic and ultrasonographic images were classified respectively.

Three specialist observers (3 years experienced dental radiology) evaluated the presence and appearance of periapical lesions on panoramic radiographs and ultrasonographic images. Observers were requested to indicate the presence or absence of a periapical lesion using three scale classification:

1 - Periapical lesion absolutely not present.
2 - Periapical lesion likely present, but not clear.
3 - Periapical lesion absolutely present.

For both imaging techniques (panoramic radiography and USG), the periapical lesion classifications were recorded by each observer and then a consensus was reached by selecting the most common classification. In the event of disagreement, the three observers discussed the event until consensus was reached. The consensus classification was divided into two groups as "periapical lesion absent" (Classification 1 and some Classification 2) and "periapical lesion present" (Classification 3 and some Classification 2).

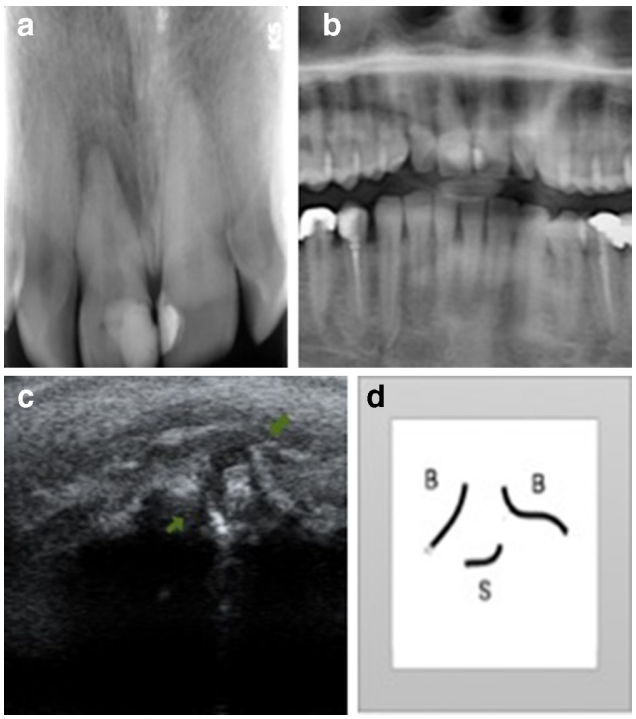

Figure 2 (a) Periapical, (b) panoramic and (c) ultrasonographic view of the lesion in the tooth of upper right central incisor. (d) schematic equivalent of c; B: surface of buccal cortical plate of bones, S: the deep surface of the periapical lesion. Region of between B and S showing lesion area.

Statistical analysis

Data analysis was carried out using IBM Statistical Package for Social Sciences Statistics 22 program (IBM SPSS Statistics, Armonk, NY). Frequency tables were created for the presence of periapical lesion, considering periapical radiography as the reference method. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and diagnostic value of panoramic radiographs and USG were determined. The interobserver agreement for diagnosing periapical lesions was assessed with Fleiss κ statistics. Fleiss κ values were interpreted according to the following criteria: <0.40 poor agreement; 0.40–0.75- moderate-good agreement; >0.75- excellent agreement.

Results

The presence or absence of periapical lesions on the periapical, panoramic and ultrasonographic images of 160 anterior teeth were evaluated by three observers (Figure 2). The κ value for overall interobserver agreement was 0.765 and 0.780 for ultrasound and panoramic radiography, respectively (Table 1).

κ values were found to be excellent and the presence or absence of periapical lesions in two diagnostic tests (Ultrasound and Panoramic) was decided by reaching the consensus between the observers. Table 2 shows the results of consensus for periapical lesion diagnosed

Table 1 κ statistic for interobserver agreement in ultrasound and panoramic images

Method	*κ Values*	*Std.error*	*Z-values*	p-*values*
Ultrasound	0.765	0.042	18.188	.000
Panoramic	0.780	0.042	18.607	.000

in ultrasound and panoramic radiography by using periapical radiograph as gold standard. Sensitivity, specificity, PPV, NPV and diagnostic accuracy (true positive + true negatives) were determined for USG and panoramic radiography using the results obtained from Table 2 (Table 3).

The overall sensitivity was 0.80 and 0.77 for USG and panoramic radiography respectively, which shows that periapical lesion was correctly detected in 80% of the cases with ultrasound and in 77% of the cases with panoramic radiography. Although there is no significant difference, the ultrasound sensitivity was found to be higher than panoramic radiographs. Specificity values were determined as 0.97 for ultrasound and 0.95 for panoramic radiography. PPVs of periapical lesion recognition rate of the test were found to be high in both diagnostic tests (0.98–0.96). NPVs were determined lower in ultrasound (0.26). NPV, which determines the ability to show the absence of the lesion, was higher on the panoramic radiograph (0.29). Overall diagnostic accuracy was 0.86 and 0.84 for ultrasound and panoramic radiography, respectively. The diagnostic accuracy values of the two methods were similar.

These results show that although the ultrasound has a higher value than the panoramic, the two techniques have similar diagnostic accuracy values and there is no significant difference between the two techniques in the detection of periapical lesions.

Discussion

Conventional radiography techniques and cone beam CT (CBCT) have been used successfully in dentistry for many years and dentists are very familiar with the appearance of anatomical structures in these imaging techniques. However, the use of ultrasound in dentistry is more recent compared to these techniques and the appearance of anatomical structures and pathologies in ultrasound images are relatively new for dentists and they are not as familiar with these images as in conventional imaging techniques. In this study, periapical radiography was accepted as gold-standard and it was aimed to compare the accuracy of panoramic radiography and USG in diagnosis of periapical lesions were compared.

Table 2 Results of ultrasound and panoramic for the presence or absence of periapical lesion (consensus observer) diagnosed by periapical radiography as gold standard (n = 160)

	Ultrasound			***Panoramic***		
Periapical	*Positive*	*Negative*	*Total*	*Positive*	*Negative*	*Total*
Positive	80	20	100	77	23	100
Negative	2	58	60	3	57	60
Total	82	78	160	80	80	160

Table 3 Mean of sensitivity, specificity, PPV, NPV and diagnostic accuracy (true positivies + true negatives) for ultrasonography and panoramic radiography, in all examined teeth

Method	*Sensitivity*	*Specificity*	*PPV*	*NPV*	*Accuracy*
Ultrasound	0.80	0.97	0.98	0.26	0.86
Panoramic	0.77	0.95	0.96	0.29	0.84

NPV, negative predictive value; PPV, positive predictive value.

Radiographic examination is absolutely necessary during diagnostic process, treatment and post-treatment follow-up of periapical lesions and this situation causes the patients to be exposed to repeated radiation doses. Therefore, new researches must be conducted with a view of reducing radiation dose and finding non-invasive alternative imaging method.[14] Since periapical radiographs are easy to use, accessible and inexpensive, they are the most widely used and accepted main diagnostic method for the evaluation of periapical lesions over the years.[7]

In this study, the presence or absence of apical lesions in 160 anterior teeth was detected by periapical radiography. Then, panoramic and ultrasonographic images of these teeth were evaluated and the diagnostic accuracy of these imaging methods were determined. Overall, diagnostic accuracy was 0.86 and 0.84 for ultrasound and panoramic radiography, respectively. Periapical lesion was correctly detected in 80% of the cases with ultrasound and in 77% of the cases with panoramic radiography.

USG is an alternative new diagnostic imaging technique that is radiation free and non- invasive.[4,10] Several studies have been done for the diagnosis of periapical lesions by USG. Cotti et al[11] are the first researchers who performed a study evaluating the utility of USG in 12 patients diagnosed with periapical lesion of endodontic origin on periapical and panoramic radiographic views. Their study revealed that ultrasound was an easily reproducible method that can be used in the diagnosis and follow up of periapical lesions. Gundappa et al[14] reported that there was a high correlation between ultrasonographic findings and histopathological results of periapical lesions. And then this study suggested that USG is a useful diagnostic technique for periapical lesions in the anterior region when the cortical bone is thinned or perforated. Ferreira et al[12] in the preliminary work on the pig mandible, emphasized that cortical bone should be thin enough to permit the passage of ultrasonic waves so that ultrasonographic evaluation can be performed. Sandhu et al[15] performed ultrasonographic examination with color Doppler in 30 patients diagnosed with periapical lesion by intraoral radiography in the anterior region. They

reported that USG provides important diagnostic information about periapical lesions in the anterior region that cause perforation or thinning of the buccal bones. It is easy to perform ultrasonographic evaluation in the anterior region but it is more difficult to position the probes in the posterior teeth and obtain a clear image due to the region anatomy.[4] Therefore, the maxillary and mandibular teeth with periapical lesion in the anterior region were included in our study. 80 of 100 periapical lesions detected by periapical radiography were visualized by USG (high sensitivity, 0.80). In the ultrasonographic evaluation, it was observed that there was expansion or perforation of the buccal cortical bone in most of the lesions. Ultrasonographic images could not display 20 periapical lesions due to various anatomical causes or thick buccal cortical bone.

In the ultrasonographic image, when the alveolar bone is healthy, the surface is completely reflected and appears as white, the lines of the roots of the teeth appear whiter and called hyperechoic. In order to visualize the periapical lesion on USG, there must be thinning, expansion or perforation in the buccal bone. When the buccal expansion was present, hyperechoic line of the lesion's buccal bone wall was observed as convex. When buccal perforation occurred, the continuity of the hyperechoic line of the lesion's buccal bone wall was observed to be discontinued. In our study, most of the periapical lesions appeared as hypoechoic areas with sometimes containing hyperechoic foci or mix areas which were generally well-circumscribed. Slight hyperechogenic and completely anechoic internal structure were also observed in some cases.

In a study, Cotti et al[16] evaulated different features of lesions' content and vascularization using ultrasound and color power Doppler. They showed that ultrasound contributes to the differential diagnosis of periapical lesion. Gad et al[17] used results of CBCT and histopathologic results as reference and evaluated cystic jaw lesions in 32 patients by USG. They examined the vascularization and internal structure of different lesions with Doppler. It has been emphasized that USG and Doppler can be used routinely as a diagnostic tool.

It is important to know the nature of the periapical lesions because it affects the way of treatment, outcomes and success of treatment. In addition, incomplete or overtreatment is prevented. Radiographs alone are not enough to distinguish whether periapical lesions are cystic, non-cystic or granuloma. For more detailed information, histopathological findings, CBCT and USG techniques are required. Ultrasound has some advantages over the other imaging methods such as it is inexpensive, it has no known biologic side-effect, it uses non-ionized part of radiation, its application is practical and patient comfort is better.[18]

On the other hand, the lack of a specific image for dental landmarks has been considered as a limitation of USG.[11] The absence of reference points makes it difficult to assess the anatomical localization of periapical lesions in different regions. Unlike ultrasound imaging, periapical and panoramic radiographs provide information about the anatomical location and the size of the periapical lesion associated with the tooth.[19] So, ultrasound with Color Power Doppler can be used as an auxiliary and supportive technique of the other diagnostic imaging methods in accurate diagnosis of suspected periapical lesions and then during treatment and follow up of periapical lesions.[18]

Estrela et al[8] performed a study on 1508 teeth with periapical lesions. They accepted CBCT as a reference imaging technique and assessed the accuracy of periapical and panoramic radiographs for diagnosis of periapical lesions. The results showed that panoramic radiographs has a low sensitivity (0.28) and diagnostic accuracy (0.54). Nardi et al[20] accepted CBCT as a reference imaging method and investigated the accuracy of panoramic radiographs in the determination of untreated apical periodontitis in different sizes and regions. They found low sensitivity (34.2) and diagnostic accuracy (65.0) of panoramic radiography, similar to Estrela et al. Contrary to these results in our study, panoramic radiography showed good sensitivity (0.77) and diagnostic accuracy (0.84), high specificity (0.95) and PPV (0.96), low NPV (0.29) in the detection of periapical lesions. In addition, similar values were found for USG and panoramic radiography. The reason for this difference between the results may be that the panoramic radiographs had high image quality and no superposition in the anterior region provide more accurate results for the diagnosis of the lesion.

Estrela et al[8] showed that the accuracy of periapical radiographs in the diagnosis of periapical lesions was considerably higher than the panoramic radiographs at the end of their study. In some publications which support this finding, it is stated that panoramic radiographs provide diagnostic information but may not be sufficient in diagnosing periapical lesions alone and should be supported by intraoral radiography.[5,6,8]

Nardi et al[20] reported that the visualization of the apical lesion was related to the anatomical region, lesion size and its effects on cortical bone. The formation of thinning or fenestration in the cortical bone allows the visualization of the periapical lesion by USG. Besides, periapical lesions cannot be visualized on a periapical or panoramic radiograph unless there is about 30–50% mineral loss in the bone. There are factors like morphologic variations of the apical region, bone density, X-ray angulations, radiographic contrast that can lead to misinterpretation in radiographs.[8] False-positive lesions detected on panoramic radiography due to artifact or other reasons can be correctly eliminated by ultrasound examination.[17] Moreover, it may be difficult to identify by panoramic radiographs of apical or cystic lesions in maxillary posterior region due to reasons such as anatomical variation of maxillary sinus, pathology, superposition of tooth roots.[10] In these cases, lesions that are missed on panoramic imaging can be diagnosed by USG. In our study, some periapical lesions that could not be detected or clearly visualized in the panoramic radiographs were evaluated

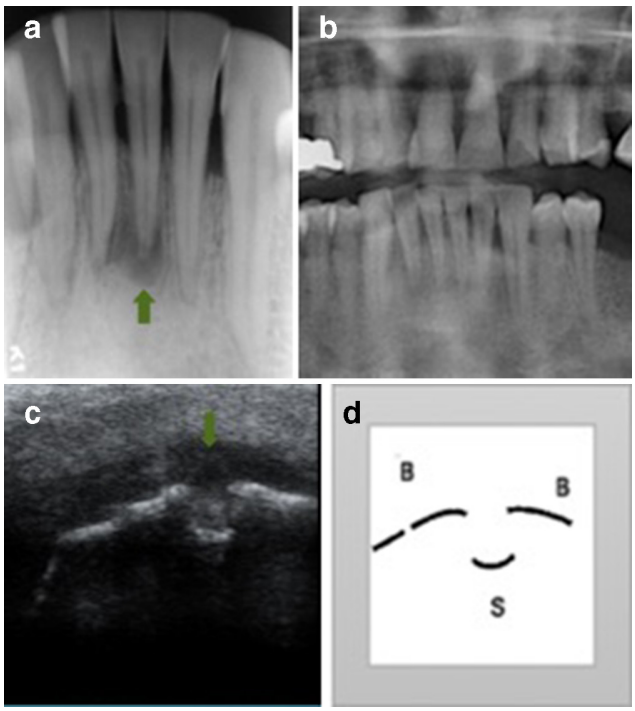

Figure 3 (a) Periapical radiography shows periapical lesion of the mandibular incisor tooth. (b) Panoramic view (lesion is not seen clearly identifiable) (c) Ultrasonography showing a periapical lesion and buccal perforation (yellow arrow: interrupted the hyperechoic image of the buccal cortical bone of the lesion) caused by lesion. (d) Schematic equivalent of c; B: surface of buccal cortical plate of bone, S: the deep surface of the periapical lesion. Region of between B and S showing lesion area.

by USG (Figure 3). In addition, Sandhu et al[15] obtained results which support that apical lesion can be diagnosed by USG without periapical radiography as long as its clinical findings exists. Considering this, USG may be used instead of conventional methods to eliminate hazardous radiation exposure in special cases such as children and pregnant females.

Bansal et al[18] compared the sizes of periapical lesions on USG and radiography. They reported that the ultrasound measurements were almost always smaller than radiographs, similar to the work of Gundappa et al[14] and Raghav et al.[7] Besides, ultrasonographic artifacts such as acoustic shadow (originating from bone) may cause the lesion size to appear smaller on the ultrasound.[7,14,18]

USG, which is a real-time imaging method, enables the evaluation of the internal structure of the lesion (echogenic pattern) and determination of the presence of vascularization by color Doppler feature. Thus, it can be used in the differential diagnosis of lesions such as periapical cyst and granuloma.[14]

USG provides information about the structure of the lesion, but it may not show the correct size of the lesion.[15] We evaluated the validity (accuracy) of radiographic techniques in the diagnosis of periapical lesions without performing size measurement in this study. According to other techniques, dimensional measurements are made in the most accurate way with CBCT.[9] However, CBCT should not be used routinely in the diagnosis of periapical lesions and endodontic applications due to the ALARA (As Low As Reasonably Achievable) principles. It should only be preferred when other techniques do not provide adequate diagnostic information.[21] In our study, CBCT was not taken only for periapical lesion because it would cause unnecessary additional radiation dose for the patient. Periapical radiographs have been used traditionally for years to visualize periapical lesions, so we interpreted accuracy of other techniques by accepting periapical radiographs as the gold standard. The accuracy of USG and panoramic radiography was found to be high in our study of 160 anterior teeth. Our results support that ultrasonographic evaluation by an educated radiologist in this field is sufficient for the detection of periapical lesions that cause thinning or perforation in the anterior region, buccal bones. These results also show that panoramic radiography which is properly exposed and has good image quality is an important diagnostic method for the evaluation of periapical lesion.

USG is a convenient, non-invasive, non-radiation, repeatable and useful method that can be used in the diagnosis and follow up of periapical lesions. One of the other advantages of the technique is that it can be used in the intraoperative period.[12] In addition, Doppler USG contributes to differential diagnosis by showing the lesion content and vascularization.[9] On the other hand, speckling noise which is an inherent property of medical ultrasound imaging generally tends to reduce the image resolution and contrast and this property may be reducing the diagnostic value of this imaging modality. To overcome this property, some preprocessing and filter techniques are recommended.[22] However, if the lesion size is important and should be evaluated for a successful treatment, periapical radiography supported with CBCT should be used in selected cases. CBCT is considered to be the most accurate method for the evaluation of apical lesions.[20] On the other hand, since the radiation dose is higher than other diagnostic techniques, it should be used only in selected cases when it is necessary for a successful treatment.

The limitation of this study is that the lesion structure cannot be assessed by ultrasound because histopathological results are not available.

Conclusion

Periapical and panoramic radiographs are commonly used to visualize periapical lesions. Besides, USG is an alternative or supportive method to digital radiographic techniques in the diagnosis of anterior teeth with periapical lesions. However, thick cortical bone, lack of anatomical landmark and probe size limit the use of USG in the posterior region.

With increasing use in recent years, all dental radiologists should receive training in ultrasonographic evaluation and interpretation of images. USG should be routinely used in dentistry radiology when all its advantages are taken into consideration.

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