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The detection and management of root resorption lesions using intraoral radiography and cone beam computed tomography – an *in vivo* investigation

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Abstract

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Aim To compare the accuracy of intraoral periapical radiography with cone beam computed tomography (CBCT) for the detection and management of resorption lesions.

Methodology Digital intraoral radiographs and CBCT scans were taken of patients with internal resorption ($n = 5$), external cervical resorption ($n = 5$) and no resorption (controls) ($n = 5$). A 'reference standard' diagnosis and treatment plan was devised for each tooth. Sensitivity, specificity, positive predictive values, negative predictive values and receiver operator characteristic (ROC) curves, as well as the reproducibility of each technique were determined for diagnostic accuracy and treatment option chosen.

Results The intraoral radiography ROC Az values were 0.780 and 0.830 for diagnostic accuracy of internal and external cervical resorption respectively. The CBCT ROC Az values were 1.000 for both internal and external cervical resorption. There was a significantly higher prevalence ($P = 0.028$) for the correct treatment option being chosen with CBCT (%) compared with intraoral radiographs (%).

Conclusion CBCT was effective and reliable in detecting the presence of resorption lesions. Although digital intraoral radiography resulted in an acceptable level of accuracy, the superior accuracy of CBCT may result in a review of the radiographic techniques used for assessing the type of resorption lesion present. CBCT's superior diagnostic accuracy also resulted in an increased likelihood of correct management of resorption lesions.

Keywords: cone beam computed tomography, external cervical resorption, internal resorption.

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Introduction

Root resorption is the loss of hard dental tissue (i.e. cementum and dentine) as a result of odontoclastic cell action. Root resorption is inhibited by the protective unmineralized innermost pre-dentine and outermost pre-cementum surfaces of the root (Lindskog *et al.* 1983, Wedenberg & Lindskog 1985, Heithersay 2004). The resorptive process may be inconsequential, lasting for 2–3 weeks only (Fuss *et al.* 2003). However, with continual stimulation by infection (Gunraj 1999, Tronstad 2002), or pressure (Fuss *et al.* 2003) the odontoclasts will continue to resorb the damaged surface of the root which may result in extensive damage to the tooth.

Resorption defects can be challenging to diagnose correctly which may result in inappropriate treatment being carried out (Chapnick 1989, Patel & Pitt Ford 2007, Patel & Dawood 2007). An accurate diagnosis is essential for an appropriate treatment plan to be devised. Radiographically, internal root resorption appears as a 'ballooning-out' of the root canal. The

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resorption lesion is radiolucent and has smooth, well defined margins and is oval or round in shape (Çalişkan & Türkün 1997, Whitworth 2004). The radiographic appearance of external cervical root resorption depends on the severity of the lesion. Early lesions appear as cloudy radiolucencies in the cervical region of the tooth and the border of the defect is usually poorly defined. The root canal walls should be visible and running vertically through the radiolucent defect, indicating that the lesion lies on the external surface of the root (Heithersay 1999, Tronstad 2002, Heithersay 2004). Root resorption may be confirmed using the parallax radiograph technique (Haapasalo & Endal 2006, Patel & Dawood 2007). The parallax technique may be helpful to detect and determine the location (palatal or labial) of the external cervical root resoprtion lesions. However, intraoral radiographs do not provide an indication of the true dimensions of such lesions (Kim *et al.* 2003). The resorption defect may spread within the root in all directions, this may not be reflected in the size and position of the radiolucency detected on the radiograph (Patel & Dawood 2007).

One of the major problems with diagnosing and predictably managing internal and external cervical root resorption is that intraoral radiographs only reveal limited diagnostic information (Cohenca *et al.* 2007). The amount of information gained from these analogue and digital periapical radiographs is incomplete due to the fact that the three-dimensional anatomy of the area being radiographed is compressed into a two-dimensional image or shadowgraph (Patel *et al.* 2009). In addition, anatomical noise may result in an underestimation of the actual size of the resorption lesion.

Cone beam computed tomography (CBCT) technology has been specifically designed to produce three-dimensional scans of the maxillo-facial skeleton (Mozzo *et al.* 1999, Arai *et al.* 1999). One of CBCT's major advantages over computed tomography (CT) scanners is the reduction in radiation exposure (Cotton *et al.* 2007, Patel *et al.* 2007, Scarfe & Farman 2008). CBCT has been successfully used to evaluate the true nature and severity of resorption lesions in isolated case reports (Cohenca *et al.* 2007, Patel & Dawood 2007) indicating that the clinician could confidently diagnose and manage the defect.

There are no studies which have tested the ability of CBCT to improve the diagnosis of internal and external cervical root resorption. The aim of the present study was firstly to compare the diagnostic accuracy of intraoral periapical radiography with CBCT for the detection of internal and external cervical resorption, and secondly to compare the treatment strategies chosen for the management of resorption lesions using intraoral periapical radiography and CBCT.

Materials and methods

Data collection

The radiographs and CBCT data records of 15 teeth (from 15 patients) were included. The teeth had either been successfully managed by one operator in specialist practice ($n = 12$) or by endodontic postgraduate students ($n = 3$) under the supervision of the same individual. Ethical approval was granted to use the clinical data for research purposes. The study population consisted of 10 males and five females:

- Five teeth were diagnosed with internal resorption.
- Five teeth were diagnosed with external cervical resorption.
- Five teeth were controls (i.e. no resorption present).

The radiographs and CBCT data were assessed by a consensus committee consisting of three experienced specialist endodontists who confirmed the diagnosis and ideal treatment plan for each case. The three members of this consensus committee between them had 60 years experience in Endodontology. All three members of the consensus committee independently assessed the resorption cases. There was unanimous agreement between the consensus committee. Their diagnoses were confirmed in all cases when the resorption lesions were treated, in all cases the diagnoses of the consensus committee were correct.

Radiographic technique

Patients were radiographed with a dental X-ray machine (Planmeca Prostyle Intra, Helsinki, Finland) using a digital CCD sensor (Schick Technologies, New York, NY, USA) with exposure parameters of 66 kV, 7.5 mA and a 0.10 s and a paralleling technique. CBCT scans were either taken using a small volume CBCT scanner (3D Accuitomo 80; J Morita Manufacturing, Kyoto, Japan) with exposure parameters 80 kV, 3.0 mA and 17.5 s) or a large volume scanner (i-CAT, Imaging Sciences International, Hatfield, PA, USA) with, exposure parameters of 120 Kv, 5 mA and 20 s) for the large volume CBCT scan.

CBCT data were reformatted to align the root axis with the vertical plane in the sagittal and coronal views. The brightness and contrast of all the acquired images

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was enhanced to improve visualization of the resorption lesions. All CBCT data were reformatted (0.125 mm slice intervals and 1.5 mm slice thicknesses).

Radiological assessment

Six examiners (two specialist endodontists and four endodontic post-graduates) individually assessed the radiographs and CBCT scans in the following sequence: session 1 – radiographs, session 2 – CBCT scans, session 3 – radiographs and CBCT scans repeated (to assess intra-observer agreement).

All the examiners were reminded of the salient features of resorption lesions using sample radiographs and CBCT images. The examiners were then trained using radiographs and CBCT images of teeth with and without internal and external cervical root resorption. Only examiners who were able to correctly diagnose images in at least 80% of the cases were allowed to go on to assess the test cases. After the completion of this training session the examiners were shown the 'training' cases again with a member of the consensus committee who discussed the salient diagnostic features in each case. This served to consolidate the knowledge of the radiographic features of resorption lesions. These discussion sessions with the consensus committee member were carried out over three sessions, with two examiners in each session.

The test images were randomly ordered in each session and viewed as a powerpoint presentation (Microsoft Corp, Washington, WA, USA) on a laptop computer (Toshiba Portege R500-11Z; Tokyo, Japan) which had a Liquid Crystal Display (LCD) screen with a pixel resolution of 1280×1024. A CBCT image that best confirmed the presence or absence of the resorption defect in the sagittal and coronal planes was used as the starting point for each tooth observation. Examiners also had access to the raw CBCT data allowing them to scroll through any of the orthogonal scans. All images were assessed in a dark room.

Examiners were asked to note down the presence or absence of internal resorption and external cervical root resorption and their treatment plan (Table 1 & Fig. 1). In each case there was only one correct diagnosis and treatment option that had been previously established by the consensus committee and in resorption cases confirmed after the completion of the treatment of the lesion.

There was at least a 1 week interval between each session. Eight radiographs and eight CBCT scans were randomly chosen and assessed in session 3 to assess intra-examiner agreement.

Data analysis

Stata™ software (Stata 9, College Station, TX, USA) were used to analyse the raw data. Sensitivity, specificity and predictive values were determined; receiver operating characteristic (ROC) curve analysis was used to assess the diagnostic accuracy of each examiner and each imaging system in detecting the presence of each type of resorption defect against the alternate type of defect and controls. Summary data were described using mean (standard deviation) and median (interquartile range) to accommodate the small sample size, and differences between radiographs and CBCT were analysed using Wilcoxon matched-pairs, signed-ranks test. Inter-examiner and intra-examiner agreement was assessed by Kappa statistics for scores from both the intraoral radiographs and CBCT scans.

Table 1 Questionnaire which examiners completed for each case

	Definitely present	Probably present	Unsure	Probably not present	Definitely not present
Internal resorption					
External cervical resorption					

	Very sure	Reasonably sure	Unsure	Reasonably unsure	Very unsure
• Leave alone					
• Review					
• Nonsurgical endodontic treatment					
• Surgical endodontic treatment					
• Combination of nonsurgical and surgical endodontic treatment					
• Extraction					

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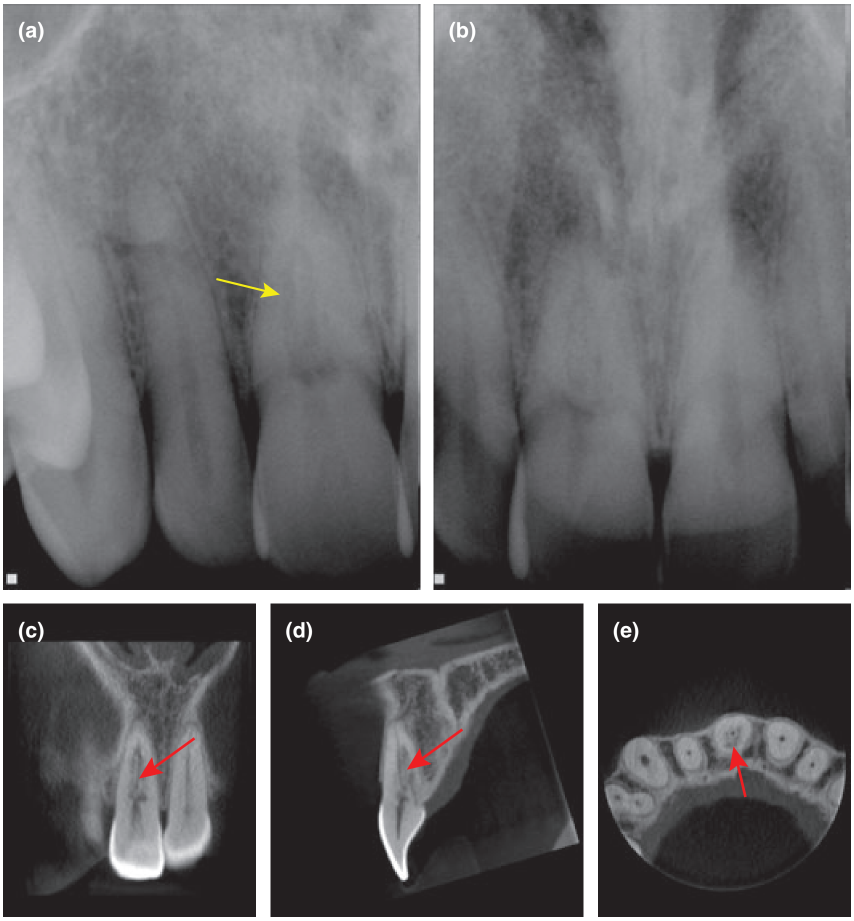

Figure 1 (a–b) Typical radiographs shown in session 1 and 3 to assess diagnostic accuracy of intraoral radiographs. A cloudy radiolucency (yellow arrow) is present in the mid-third of the root. (c–e) A typical series of CBCT reconstructed (coronal, sagittal and axial) views of the same tooth shown in session 2 and 3 to assess diagnostic accuracy of cone beam computed tomography. An external cervical root resorption lesion (red arrow) can clearly be seen, note the severity of the lesion.

Results

Diagnosis

The overall sensitivity of intraoral radiography was lower than CBCT (Table 2). The ROC analysis revealed that intraoral radiography had a lower median Az value (0.780) than CBCT (1.000) for diagnosing internal resorption ($P = 0.027$). Similarly, the mean Az value (0.830) of intraoral radiography was lower than CBCT (1.000) for diagnosing external cervical resorption ($P = 0.027$) (Tables 3–4).

The kappa value for inter-examiner agreement was 0.365 and 0.925 for intraoral radiography and CBCT respectively for the diagnosis of internal resorption. The kappa value for inter-examiner agreement was 0.444 and 0.951 for intraoral radiography and CBCT respectively for the diagnosis of external cervical resorption.

Intra-examiner agreement was assessed in 53% (eight of the 15) of the cases for each imaging system in session 3. The median intra-examiner agreement was 0.810 and 0.885 for intraoral radiography and CBCT respectively for the diagnosis of internal resorption. The mean intra-examiner agreement was 0.657 and 1.000 for intraoral radiographs and CBCT respectively for the diagnosis of external cervical resorption (Table 5).

Treatment options

The median percentage correct treatment option selected by the six examiners was 53% and 73% for

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Table 2 Mean (standard deviation), median [inter-quartile range] of sensitivity, specificity, PPV and NPV for radiographs and CBCT for detecting (a) internal and (b) external resorption at confidence level 5

	Sensitivity	Specificity	PPV	NPV
a				
Radiographs	0.590 (0.216)	0.974 (0.064)	0.945 (0.136)	0.713 (0.120)
	0.51 [0.46–0.86]	1.00 [1.00–1.00]	1.00 [1.00–1.00]	0.70 [0.61–0.83]
CBCT	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)
	1.00 [1.00–1.00]	1.00 [1.00–1.00]	1.00 [1.00–1.00]	1.00 [1.00–1.00]
b				
Radiographs	0.724 (0.302)	0.790 (0.076)	0.645 (0.114)	0.865 (0.157)
	0.82 [0.36–1.00]	0.79 [0.78–0.81]	0.64 [0.57–0.67]	0.93 [0.67–1.00]
CBCT	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)
	1.00 [1.00–1.00]	1.00 [1.00–1.00]	1.00 [1.00–1.00]	1.00 [1.00–1.00]

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

Table 3 Mean (standard deviation), median [inter-quartile range] of area under the curve from ROC analysis of radiographs and CBCT for individual examiners: correct diagnosis of internal resorption at confidence level 5

Examiner	Radiograph	Cone beam	*P*-value
1	0.800	1.000	0.103
2	0.840	1.000	0.249
3	0.800	1.000	0.103
4	0.720	1.000	0.053
5	0.760	1.000	0.073
6	0.760	1.000	0.073
Mean (SD)	0.780 (0.078)	1.000 (0.000)	
Median [IQR]	0.780 [0.760–0.800]	1.000 [1.000–1.000]	0.027[a]

[a]Wilcoxon matched-pairs, signed-ranks test for differences in sensitivity.

Table 4 Mean (standard deviation), median [inter-quartile range] of area under the curve from ROC analysis of radiographs and CBCT for individual examiners: correct diagnosis of external resorption at confidence level 5

Examiner	Radiograph	Cone beam	*P*-value
1	0.900	1.000	0.134
2	0.880	1.000	0.179
3	0.900	1.000	0.134
4	0.740	1.000	0.051
5	0.760	1.000	0.023
6	0.820	1.000	0.062
Mean (SD)	0.830 (0.070)	1.000 (0.000)	
Median [IQR]	0.850 [0.760–0.900]	1.000 [1.000–1.000]	0.027[a]

[a]Wilcoxon matched-pairs, signed-ranks test for differences in sensitivity.

Table 5 Kappa values for inter-examiner agreement and mean (standard deviation), median [inter-quartile range] of Kappa values for intra-examiner agreement in reading radiograph and CBCT for internal and external resorption

	Internal resorption		External resorption	
	Radiograph	Cone beam	Radiograph	Cone beam
Inter-examiner	0.365	0.925	0.444	0.951
Intra-examiner	0.711 (0.378)	0.788 (0.257)	0.625 (0.288)	0.966 (0.084)
	0.810 [0.600–1.000]	0.885 [0.529–1.000]	0.657 [0.556–0.750]	1.000 [1.000–1.000]

Table 6 Mean (standard deviation), median [inter-quartile range] of percentage correct treatment decisions chosen by the examiners with radiographs and CBCT at confidence levels (5) and (4 + 5)

	Confidence level (5)		Confidence level (4 + 5)	
	Radiographs	CBCT	Radiographs	CBCT
Mean (SD)	52 (15)	74 (9)	60 (10)	79 (8)
Median [IQR]	53 [47–67]	73 [73–80]	60 [53–67]	80 [73–87]

Table 7 Mean (standard deviation), median [inter-quartile range] of Kappa values for agreement in treatment decisions between sessions for radiographs and CBCT

	Radiograph	CBCT
Mean (SD)	0.606 (0.274)	0.632 (0.360)
Median [IQR]	0.629 [0.400–0.750]	0.686 [0.250–1.000]

intraoral radiography and CBCT respectively when assessed using the confidence level of 5 alone (Table 6). These results increased to a median of 60% and 80% for intraoral radiographs and CBCT respectively when assessed accepting a combination of confidence levels 4 and 5. This difference was statistically significant ($P = 0.028$).

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There was poor agreement between radiography and cone beam decisions (median kappa = 0.127). The median kappa for intra-examiner agreement was 0.629 and 0.686 for intraoral radiographs and CBCT respectively (Table 7).

Discussion

Ideally a diagnostic test for root resorption should be able to correctly detect the presence or absence of different types of root resorption (validity), and should be repeatable, i.e. to generate the same result (reliability). In this study intraoral radiographs and CBCT were assessed for their diagnostic accuracy, and their ability to allow the examiner to arrive at the correct treatment option. This is the first clinical study that has attempted to validate CBCT for the clinical management of internal and external cervical root resorption.

The test sample size included 10 teeth with either internal or external cervical root resorption defects. This small sample size reflects the rare occurrence of these type of defects (Haapasalo & Endal 2006), and was in fact reached after collecting cases in a specialist practice and in a teaching hospital for almost 2 years. Five additional healthy teeth were included as controls. The results of this study suggest that CBCT imaging of teeth with internal and external cervical root resorption is of value. Although intraoral radiography was reasonably accurate in correctly diagnosing internal and external cervical root resorption, CBCT scans resulted in perfect diagnosis of the presence and type of root resorption. This is also reflected in the sensitivity and specificity results. Intraoral radiography was slightly more accurate in diagnosing external cervical root resorption than internal root resorption. The slightly more accurate diagnosis of external cervical root resorption with intra oral radiographs may be due to the fact that their irregular margins may be pathognomic of this type of resorption lesion. The examiner's ability to choose the correct treatment option was also improved when CBCT was used. Despite perfect diagnostic accuracy, the treatment decisions with CBCT were only 80% correct when compared with the consensus committee.

Metz (1989) has suggested that a ROC Az value between 0.75–0.80 is acceptable for clinical imaging techniques. The overall diagnostic accuracy of intraoral radiographs for detecting internal (ROC Az value 0.780) and external cervical resorption (ROC Az value 0.830) confirmed that intraoral radiography is a fairly accurate diagnostic tool. The results from the present study were in the same order of magnitude as previous studies assessing artificially prepared root resorption lesions assessed using ROC analysis (Borg *et al.* 1998, Holmes *et al.* 2001). The perfect diagnostic accuracy of CBCT in diagnosing resorption lesions is a result of the three-dimensional assessment of these resorption lesions. The sophisticated CBCT software allows the clinician to select the most favourable orthogonal views for each specific problem being assessed. In addition the thickness of each slice (i.e. how much information) and the interval between each slice may be adjusted. These factors ultimately result in root resorption lesions being significantly more perceptible to the clinician compared with intraoral radiographs. Unlike other studies (Borg *et al.* 1998, Kamburoğlu *et al.* 2008a,b) assessing root resorption, a third session was included in our study to assess intra-examiner agreement. There was at least a 1 week interval between each viewing session to reduce the lilkelihood of the examiner recalling any of the previous cases they had assessed. Images were viewed as a powerpoint presentation in order to facilitate the examiners' work.

The examiner's results were compared to the 'reference standard' results of the consensus committee. The question arises as to how valid were the diagnosis and treatment plan for each resorption lesion assessed by the consensus committee. Ideally the 'reference standard' test would be to extract all these teeth to confirm whether the results from assessing the radiographs and CBCT scans correlate to macroscopic and histological findings of the extracted teeth. Obviously, this is not possible in healthy teeth and/or teeth which can be treated successfully. However, in the treatment phase the accuracy of the diagnosis agreed by the consensus panel was confirmed in all cases. Of the 10 resorption cases, six were deemed to be successful at 1 year follow up which would suggest that the consensus panel were correct with their treatment options. Two of the remaining four teeth that were unsalvageable were extracted. The last two patients did not attend the recall visit.

The results of this study validate the use of CBCT to determine the presence and type of root resorption. CBCT also appears to be extremely useful for assessing the severity of resorption lesions, which in turn influences the treatment decision made (Cohenca *et al.* 2007). It would be desirable, in a future study to compare intraoral radiographs with CBCT for assessing the location of the resorption lesions as this factor may influence its management.

Each case in this study was unique, therefore the severity and location of the resorption lesions varied from case to case. In addition anatomical noise and

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geometrical positioning of the film holder may also have contributed to the poorer diagnostic accuracy of intraoral radiography. However, it was important to carry out a clinical study as mechanically 'machined' resorption lesions used in *ex-vivo* studies, although standardized, do not truly reflect the true nature of resorption lesions, as *in vivo* resorption lesions are not perfect semi-spherical shaped cavities.

It was interesting to note that the favourable results achieved with CBCT in this study were despite the fact that none of the examiners had previous experience in the interpretation of CBCT data. In addition there was no difference in the results between the examiners with different levels of experience (i.e. endodontists versus post-graduate students). The poorer results achieved with intraoral radiographs confirmed the difficulty using these two-dimensional images for correctly diagnosing root resorption.

With a digital intraoral radiographic system the resulting image is dynamic allowing it to be easily enhanced (contrast/brightness) to improve the diagnostic yield of the radiographic image (Kullendorf & Nilsson 1996). Several studies have concluded that intraoral radiographic films and CCD digital sensors perform equally well in diagnosing resorptive lesions (Borg *et al.* 1998, Kamburoğlu *et al.* 2008a,b). The examiners were allowed to adjust the contrast and brightness of the radiographic images. However, they did not have access to any other image enhancement software (for example, colourizing, revealing and inverting) as this type of image manipulation had been shown not be useful in other aspects of endodontic diagnosis (Kullendorf *et al.* 1996, Barbat & Messer 1998, Kamburoğlu *et al.* 2008b). In our study a LCD screen with a high pixel resolution was chosen to provide an high image quality of the radiographs and CBCT scans. There is evidence to suggest that LCD and high resolution cathode ray tubes are equally effective for assessing CBCT and digital radiographs (Baksi *et al.* 2009). A consensus agreement between all the examiners may also have improved the results from the radiographs used in the study (Molven *et al.* 2002). This was not done in the present study as it does not represent the normal clinical situation for most practitioners.

Only potential examiners who were shown to be competent in a pilot study were accepted as examiners. Intra-examiner agreement was assessed by having a third examiner session, with a selection of randomly selected intraoral radiographs and CBCT scans, rather than two individual sessions to assess intraoral radiographs and CBCT scans respectively. The rationale for this was that the majority of examiners were happier to commit to three rather than four sessions. The number of cases selected for the third session was kept to 16 to prevent examiner fatigue.

The inter-examiner and intra-examiner agreement between the examiners was higher with CBCT. This is a result of the examiner being able to select with CBCT reconstructed images with no overlying anatomical noise and having the ability to assess the resorption lesion in any dimension (for example, reconstructed axial slices). Similar results have been found in studies comparing the diagnostic accuracy of intraoral radiographs with CBCT for assessing periapical lesions (Patel *et al.* 2009, Özen *et al.* 2009). Zachariasen *et al.* (1984) also found a poor inter-examiner agreement with intraoral radiographs.

Conclusion

The results of this study indicate CBCT's validity and reliability for detecting the presence of resorption lesions. Although intraoral radiography resulted in an above average level of accuracy, the superior accuracy of CBCT may result in a review of the radiographic techniques used for assessing the presence or type of resorption lesions. CBCT's superior diagnostic accuracy also resulted in an increased likelihood of correct management of resorption lesions compared with intraoral radiographs.

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