The Assessment and Management of External Cervical Resorption with Periapical Radiographs and Cone-beam Computed Tomography: A Clinical Study

Kreena Patel, BDS(Hons), MJDF, RCS(Eng), Francesco Mannocci, MD, DDS, PhD, FHEA, and Shanon Patel, BDS, MSc, MClinDent, MFDS, MRD, PhD

Abstract

Introduction: This *in vivo* study assessed whether there was a difference between periapical radiographs (PRs) and cone-beam computed tomographic (CBCT) imaging in the detection, assessment, and management of external cervical resorption (ECR). The secondary aim was to determine if parallax radiographs were of any further benefit compared with a single PR. **Methods:** PR and CBCT data were gathered for 115 teeth (98 patients) consecutively diagnosed with ECR. The diagnosis and treatment plan of each tooth were determined with PRs and CBCT imaging. Sensitivity, specificity, positive predictive values, negative predictive values, and receiver operator characteristic values were determined. **Results:** The overall sensitivity (0.86) and specificity (0.89) of PRs was significantly lower than CBCT imaging ($P < .001$). PRs had a limited ability to accurately detect the size (0.75), circumferential spread (0.60), and location of ECR compared with CBCT imaging ($P < .001$). PRs also underestimated the size of the ECR lesion. Significant differences ($P < .001$) were apparent in the treatment plans formed when PRs were assessed versus CBCT imaging. Parallax radiographs were shown to be of no additional benefit compared with a single radiograph. **Conclusions:** PRs have significant limitations in the detection, assessment, and treatment planning of ECR when compared with CBCT imaging. A CBCT scan should be considered before the management of a potentially restorable ECR lesion. *(J Endod 2016;42:1435–1440)*

Key Words

Cone-beam computed tomographic imaging, external cervical resorption, invasive cervical resorption, periapical radiographs

Significance

PRs have significant limitations in the detection, assessment, and treatment planning of ECR when compared with CBCT imaging. A CBCT scan should be considered before the management of a potentially restorable ECR lesion.

External cervical resorption (ECR) is an aggressive and insidious type of external resorption, which can result in significant loss of tooth structure. Early diagnosis is essential for effective management and can lead to a better prognosis (1).

Clinically, ECR may present as a cervical cavitation, irregularity in the gingival contour, and/or pinkish discoloration of the overlying enamel (2). The outer surface of enamel remains relatively intact because of preferential odontoclastic dissolution of interprismatic enamel (3). The base of the lesion has a hard surface, and periodontal probing often results in profuse bleeding (4). The affected teeth are often asymptomatic until a late stage because of the protective predentin and odontoblast layer that surround the root canal and are resistant to resorption (5). In some cases, no obvious clinical signs of ECR are evident, and detection occurs through an incidental radiographic finding.

The histopathological and radiographic appearance of ECR varies according to the extent and nature of the lesion. Odontoclasts initially penetrate the tooth through a small entry point and colonize this region. Clastic cells in association with fibrovascular tissue then spread in a circumferential and apicocoronal direction around the root canal system. Numerous irregular resorptive channels are created that can interconnect apically with the periodontal ligament (6).

Radiographically, ECR may present as an irregular, asymmetric radiolucency. The outline of the root canal is visible through the lesion, indicating that the resorption is on the external aspect of the tooth (4, 7). Deposition of calcific tissue may result in a more mottled or cloudy radiopaque appearance (1, 3). The Heithersay classification categorizes ECR on the basis of penetration of the lesion into coronal and root dentin; class I describes a shallow cervical lesion, and class II describes a more penetrating lesion with closer proximity to the root canal. Classes III and IV are used to describe the degree of vertical extension into the root.

The objectives of treatment are to remove the resorptive soft tissue and restore the cavity. It is important to separate the lesion from its associated periodontal attachment to prevent odontoclasts from repopulating the area. The management of ECR is dependent on the size, location, and proximity of the lesion to the root canal. If the tooth can be restored, treatment involves mechanical excavation of the entire lesion and

From the Department of Endodontology, Kings College Dental Institute, London, United Kingdom.

Address requests for reprints to Dr Shanon Patel, Department of Endodontology, Kings College Dental Institute, Floor 25 – Tower Wing, Guys Hospital, London, SE1 9RT, UK. E-mail address: shanonpatel@gmail.com

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placement of an adhesive restoration. Endodontic treatment might be necessary if the lesion has perforated into the root canal system. However, if the ECR is not completely accessible or is too advanced, then the tooth will require extraction either immediately or when symptoms occur (6).

It is well established that dental radiographs reveal limited information of the dentoalveolar anatomy because of their 2-dimensional nature, geometric distortion, and anatomic noise (8, 9). As a result, the assessment of ECR can often be difficult, and the size of lesions is often underestimated (6, 10). These factors can result in misdiagnosis, which can lead to ineffective or unsuitable management. *Ex vivo* investigations have shown that 3 intraoral radiographs taken with a 20° variation in horizontal angle can be helpful in detecting and determining the approximate location of external resorption defects (11).

Cone-beam computed tomographic (CBCT) imaging has been recommended for the diagnosis and treatment planning of complex endodontic problems such as root resorption (12, 13). *Ex vivo* studies have concluded that CBCT imaging can be reliably used to assess simulated external resorptive lesions (13–15). An *in vivo* study also showed that CBCT scanning was significantly more accurate than intraoral radiographs in differentiating between ECR and internal resorptive lesions. This resulted in a more appropriate treatment plan being chosen to manage the lesions (16).

The aim of this *in vivo* study was to assess the effectiveness of periapical radiographs (PRs) versus CBCT imaging for the detection, assessment, and management of ECR. Our secondary aim was to determine if parallax PRs were of any further benefit compared with a single parallel PR.

Materials and Methods

The study was approved by Guy's and St Thomas' NHS Foundation Trust research and development committee (RJ115/N020).

Sample Selection

Participants were referred to the endodontic postgraduate unit at Guy's Dental Hospital, London, UK, or an experienced specialist endodontist in practice. All the patients were 18 years or older and were assessed by a specialist endodontist or a postgraduate endodontic student under the supervision of a specialist endodontist. Teeth were diagnosed with ECR after a detailed medical history, clinical examination, and appropriate radiographic assessment.

Matching PR and CBCT data for 115 consecutive teeth (98 patients) diagnosed with ECR between November 2011 and April 2015 were obtained. The PR and CBCT data of 40 control teeth without ECR lesions were also collected. Parallax PRs were included for 93 teeth with ECR lesions and 33 control teeth. A single parallel PR was included for the remaining 22 teeth. Stratified randomization was used to select the control teeth to ensure both maxillary and mandibular incisors, premolars, and molars were represented in the sample.

Radiographic Technique

PRs were taken using a digital system with a paralleling technique and beam aiming device (Rinn Sensor Holder XCP-DS; Dentsply Corporate, Ballaigues, Switzerland). The X-ray unit Heliodent (Sirona, Bensheim, Germany; operating at 65 kV and 7 mA) and phosphor plates (PSP) (Digora Optime; Soredex, Tuusula, Finland, or Planmeca Prostyle; Intra, Helsinki, Finland; operating at 66 kV, 7.5 mA) with digital charge-coupled device sensors (Schick Technologies, New York, NY) was used. Parallax PRs were taken with a 20° mesial horizontal beam shift. All radiographs used were scored as grade 1 according to the National Radiological Protection Board (17) 3-grade quality rating system.

CBCT scans were taken using a small volume CBCT scanner (3D Accuitomo 80; J Morita Manufacturing, Kyoto, Japan). A tube voltage of 90 kV, tube current of 3–5 mA, exposure time of 17.5 seconds, field of view of 4 × 4 cm, voxel size of 0.08 mm, and slice thickness of 0.640 mm were used.

Radiologic Assessment

The ECR and control PRs were randomized using a computer-generated sequence, and the tooth under investigation was marked with an arrow. The brightness and contrast of all the images were optimized to improve visualization. Radiographs were viewed using Microsoft Powerpoint (Microsoft, Seattle, WA) on a 15.4-inch MacBook laptop computer (Apple, Cupertino, CA) with a screen pixel resolution of 1680 × 1050 pixels in a quiet, dimly lit room.

All examiners were trained and able to assess calibration images proficiently before being presented with the experimental images. The PRs were individually assessed by 6 examiners (3 specialist endodontists and 3 postgraduate endodontic students). Intraexaminer reliability was tested by reassessing 30 randomized PR images 2 weeks later.

The examiners were asked to answer the following questions:

1. *Detection of ECR:* Yes or no
2. *Heithersay classification:* 1 to 4
3. *Circumferential spread:* <180° or >180°
4. *Location of the lesion:* Mesial, distal, buccal, and/or palatal
5. *Treatment plan:* Restorable, restore (± root canal treatment) or unrestorable, and extraction/review

Two experienced endodontists assessed the ECR and control CBCT data. They confirmed the diagnosis, nature of the ECR lesion, and treatment plan. In all cases, the diagnosis matched the clinical and radiographic diagnosis made at the patient's initial consultation appointment. The CBCT results were used as the reference standard to which PRs were compared. Intraexaminer reliability was tested by reassessing 50 randomized CBCT images 2 weeks later.

Statistical Analysis

SAS/STAT software (SAS Institute Inc, Cary, NC) and custom-designed programming were used for statistical analysis. PR sensitivity, specificity, positive predictive value (PPV), negative predicative value (NPV), and accuracy were determined using CBCT imaging as the reference standard.

Receiver operating characteristic (ROC) curve analysis was used to determine the diagnostic accuracy of PR to detect ECR. This analysis was also used to assess the true positive results for location of ECR, Heithersay classification (grouping into classification 1/2 and 3/4), circumference (grouped into small lesions [<180°] and large lesions [>180°]), and treatment option chosen. A frequency analysis was used to determine if there was any association between the results. ROC curve analysis was used to assess the diagnostic accuracy of each examiner, specialist examiners compared with postgraduate students, and single parallel PRs compared with parallax views. Chi-square values and Wald confidence limits were produced for all ROC curve analyses.

Kappa analysis was used to assess intraexaminer agreement for CBCT scans and intraexaminer and interexaminer agreement for PRs.

Results

Tooth Type Prevalence of ECR

The most commonly affected teeth were maxillary central incisors (30.4%, 35 teeth), mandibular first molars (15.7%, 18 teeth),

TABLE 1. Teeth Diagnosed with External Cervical Resorption (ECR) by Tooth Notation

Tooth notation	Number of teeth with ECR	Percentage of teeth with ECR (%)
Maxillary		
1	35	30.4
2	4	3.5
3	3	2.6
4	4	3.5
5	3	2.6
6	12	10.4
7	0	0
Mandibular		
1	13	11.3
2	5	4.3
3	4	3.5
4	5	4.3
5	7	6.1
6	18	15.7
7	2	1.74

mandibular central incisors (11.3%, 13 teeth), and maxillary first molars (10.4%, 12 teeth) (Table 1).

Assessment of ECR with PRs

PRs had a lower sensitivity (0.86) and specificity (0.89) than CBCT imaging, which was used as the reference standard. The PPV (0.95), NPV (0.70), and accuracy (0.87) for PRs were lower than for CBCT scanning.

The ROC analysis revealed a significantly lower mean A_z (accuracy) value for the detection of ECR lesions with PRs (0.872) compared with the CBCT reference standard ($P < .001$, Fig. 1). Similar results were reported when the 6 examiners individually analyzed the radiographs.

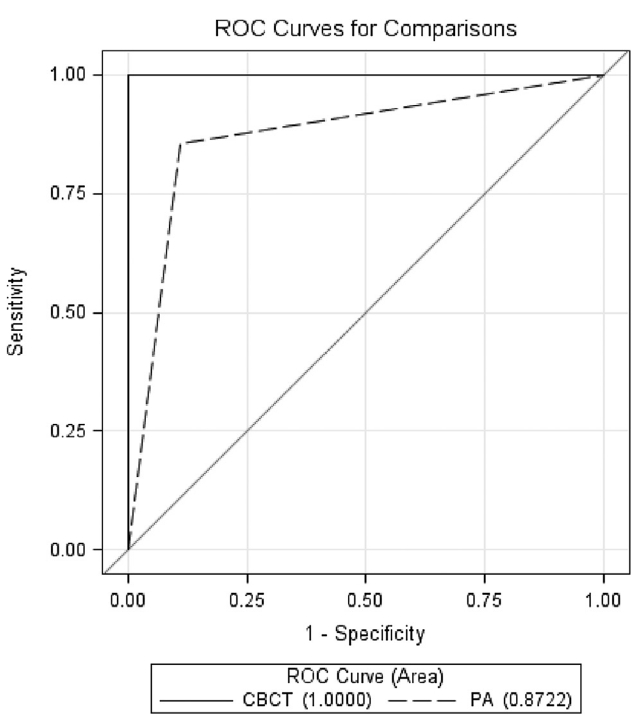

Figure 1. ROC curve for overall examiner results in the detection of ECR when analyzing PRs compared with CBCT imaging.

TABLE 2. Diagnostic Accuracy of Location, Heithersay Classification, Treatment Option, and Circumference (mean area under the curve from the receiver operating characteristic analysis)

Examining factor	CBCT area	PR area	*P* value	Wald confidence limits
Mesial	1.000	0.634	<.0001	0.6–0.667
Distal	1.000	0.641	<.0001	0.605–0.676
Buccal	1.000	0.561	<.0001	0.52–0.601
Lingual	1.000	0.554	<.0001	0.517–0.591
Heithersay classification class 3-4 vs class 1-2	1.000	0.757	<.0001	0.7–0.815
Treatment option Restore or extract	1.000	0.726	<.0001	0.687–0.765
Circumference Large vs small	1.000	0.603	<.0001	0.563–0.643

CBCT, cone-beam computed tomographic; PR, periapical radiograph.

ROC analysis showed radiographs were not able to accurately differentiate between small (<180°) and larger (>180°) circumference lesions (0.603) compared with CBCT imaging ($P < .0001$, Table 2). The Heithersay classification (0.757) and treatment option (0.726) chosen by examiners analyzing PRs were also less effective compared with the CBCT reference standard ($P < .0001$, Table 2).

Frequency analyses of the results showed PRs underestimated the size of ECR lesions compared with CBCT. The examiners chose Heithersay classification 3 or 4 in 64.3% of cases using PRs compared with 91.90% when CBCT imaging was assessed by the consensus panel. A significantly different treatment plan was also chosen; examiners chose to restore teeth in 50.7% of cases when PRs were viewed compared with 21.2% with CBCT scanning.

Comparison Between Single Parallel and Parallax PRs

Parallax PRs had similar sensitivity specificity, PPV, NPV, and accuracy compared with single parallel PRs. ROC analysis showed there was no difference in the diagnostic accuracy when examiners had access to 1 or both radiographs of the lesion (Table 3).

Examiner Agreement

ROC analysis showed no difference between the accuracy of specialist endodontists and postgraduate student examiners' assessment of radiographs (Table 3).

The kappa value for the consensus panel (CBCT) intraexaminer agreement was 1.0 (100%) for lesion detection. There was consistently good agreement for the lesion location, circumference, classification, and chosen treatment option. The corresponding kappa score for PRs was 0.779 (77.9%), and there was low reproducibility for the other tested variables (Table 4).

TABLE 3. Detection of External Cervical Resorption Lesion with Single Versus Parallax Radiographs and Specialists Versus Postgraduate Students Compared with Cone-beam Computed Tomograhic Imaging (mean area under the curve from receiver operating characteristic analysis)

Paired comparison	Area under curve	Wald confidence limits	Chi-square probability
Single	0.850	0.796–0.903	0.3750
Parallax	0.877	0.850–0.903	
Postgraduate	0.858	0.825–0.892	0.2525
Specialist	0.886	0.853–0.919	

TABLE 4. Kappa Values for Radiograph Intraexaminer Reliability, Radiograph Interexaminer Reliability, and Cone-beam Computed Tomographic (CBCT) Intraexaminer Reliability

Examiner	Lesion detection	Mesial	Distal	Buccal	Lingual	Heithersay classification 1/2 vs 3/4	Treatment XLA/restore	Circumference Large/small
Intraexaminer kappa (PR)	0.779	0.682	0.519	0.449	0.183	0.419	0.403	0.571
Interexaminer kappa (PR)	0.740	0.434	0.448	0.222	0.153	0.534	0.534	0.364
Intraexaminer kappa (CBCT)	1.000	1.000	0.941	0.941	0.939	1.000	0.824	0.936

PR, periapical radiograph; XLA, extraction.

The kappa values for interexaminer reliability for PRs was 0.740 for lesion detection and were low for the other variables that were assessed (Table 4).

Discussion

This *in vivo* study assessed whether there was a difference between PRs (single and parallax views) and CBCT imaging in the detection, assessment, and management of ECR. The subject material comprised PRs and CBCT scans of 115 teeth diagnosed with ECR during clinical and radiographic examination. Data were gathered over a 3.5-year period and consisted of various different teeth. Maxillary central incisors were most commonly affected followed by mandibular first molars, mandibular central incisors, and maxillary first molars. Maxillary second molars were the only teeth in which ECR was not detected. To our knowledge, a distribution analysis has not been previously performed on a large number of ECR cases. However, anterior teeth tend to be easier to diagnose and are often referred for treatment because patients are keen to save these teeth. ECR lesions on posterior teeth can be missed, misdiagnosed as a radiographic artifact or caries, or detected at a later stage and are more readily extracted. These factors may have influenced the distribution analysis performed in this study.

Previous studies have been based on *ex vivo* models using dry human mandibles. In these studies, round simulated cavities were machined into extracted teeth using rose head burs. The teeth were then repositioned into the alveolar socket before being radiographically examined with PRs and CBCT scanning (15, 18). Histologically, ECR spreads in an irregular fashion around the root canal, and multiple resorptive channels can be present around the main body of the lesion. As the lesion progresses, disorganized bonelike calcifications can be deposited, resulting in a more radiopaque and mottled radiographic appearance (3, 6). Simulated cavities produced for *ex vivo* studies cannot replicate these features and therefore struggle to represent a true ECR lesion. Typically, a silicone, acrylic, or wax material is used to reproduce the absorption and scatter of the X-ray beam caused by the soft tissues. However, structures in the maxillofacial region have different radiodensities that cannot be accurately represented by a uniform thickness material. CBCT scan times are relatively short in duration (15–20 seconds); nevertheless, the slight patient movement that occurs during this period also cannot be replicated in an *ex vivo* model. Although current *ex vivo* investigations suggest that CBCT imaging can be beneficial when assessing resorptive lesions, it was important to investigate these findings clinically (15, 18, 19).

This study showed that PRs had a lower sensitivity and specificity for detecting ECR than CBCT imaging. This finding is important because early diagnosis and subsequent management of ECR has been shown to improve prognosis; a clinical study of 101 teeth affected by various degrees of ECR showed a successful outcome in all class 1 and 2 resorptions at 3- to 12-year follow-ups. Class 3 resorptions had a reasonably successful outcome (77.8% success), but class 4 lesions had a mostly poor outcome (12.5% success) (1). The PR examiner results for the Heithersay classification, location, circumference, and choice of treatment option were investigated using ROC curve analysis. Radiographs showed a poor ability to evaluate the size, location, and circumferential spread of ECR compared with CBCT imaging. There was also a tendency for PRs to underestimate the size of the lesion. The results of this clinical study reflect findings of previous *ex vivo* studies that assessed external resorptions (18, 19) and clinical observations made during treatment (6, 20). It was also possible to visualize the fine details of the ECR lesion using CBCT imaging, such as resorptive projections extending from the main lesion and the presence of more radiopaque ectopic calcified material (Fig. 2) (6). This is important because these channels can communicate apically with the peridontal ligament and contain resorptive tissue and vasculature to propagate ECR. Failure to remove the ectopic calcified tissue can also result in continued resorption beneath the fibro-osseous base, thus having a negative impact on the outcome of treatment (21).

Overall, more teeth were deemed unrestorable when assessed by CBCT imaging (78.7%) compared with PRs (49.3%). This finding is because of the ability of CBCT imaging to accurately assess the size and location (ie, the nature) of ECR lesions. These factors are essential to formulating appropriate treatment plans; lesions that are extensive or difficult to access might not be possible to treat and could require extraction or monitoring until symptoms and/or failure occurs. Our results are in agreement with a previous *in vivo* study that showed that CBCT imaging improved the examiners' ability to choose the most appropriate treatment option for ECR and internal resorption compared with PRs (16). Several case reports also outline the usefulness of CBCT scanning for the management of ECR (22–24). Accurate assessment of the nature of ECR allows a suitable treatment plan to be made, in some cases eliminating the need for further surgical investigation.

In this study, CBCT imaging was used as the reference standard to which the accuracy of PRs was compared. Under ideal circumstances, the reference standard and true nature of ECR would have been determined by histopathological examination after extraction of the tooth. It is clearly unethical and not possible to perform such examination of restorable teeth. Even when lesions are deemed unrestorable, this type of examination may not be possible because patients often prefer to avoid extraction until the tooth becomes symptomatic or failure occurs. Intraorally, the lesion cannot be fully examined even after it is exposed during treatment because multiple narrow resorptive channels extend within dentin and can be hidden beneath the root surface. These features can be seen on the CBCT scan, and, therefore, it was considered as an acceptable alternative to histopathological examination (Fig. 2). Previous *in vitro* studies have also shown that CBCT images can accurately represent and determine the size of resorptive lesions and are precise enough to be used as a clinical reference standard (18, 25). Multiple studies have used CBCT imaging as the reference standard to compare and evaluate the diagnostic yield of PRs when assessing periapical radiolucencies and root resorption *in vivo* (26–29). CBCT imaging has been shown to produce precise linear measurements and accurate volumetric quantifications (to within 0.5 mm^2) when assessing the size of simulated external

Figure 2. PRs and CBCT scans of teeth 18, 19, and 20. CBCT images display narrow resorptive channels extending from the main body of the lesion into the dentin. The scan also reveals the ECR lesion is more extensive than is represented on the PR. It would be impossible to visualize the true nature of this lesion clinically or from the PR radiographs.

resorptive defects (25). Another *ex vivo* study found CBCT imaging detected lesions in 100% of cases and correctly identified the location in >96% (18). Patel et al (16) reported that CBCT imaging was 100% accurate in detecting ECR lesions for which the diagnosis was confirmed *in vivo*.

As with previous studies, 2 experienced endodontists, who had been using CBCT imaging for 10 years, assessed the CBCT data (27–29). The diagnoses reached using CBCT images matched the clinical diagnosis formed at the patients' consultation appointment in all the cases. The intraexaminer agreement was excellent, confirming that CBCT produces consistent, reliable results. In contrast, the inter- and intraexaminer agreement for PR examiners was moderate for ECR detection and relatively low for Heithersay classification, circumference, and treatment option chosen. These kappa scores indicate that PR has a poor overall accuracy in assessing these variables, which may result in inappropriate treatment planning. There was no significant difference found between the specialist and postgraduate student examiner results.

PRs were taken using charge-coupled devices and PSP digital radiographic systems, and the image contrast and brightness could be enhanced to improve the diagnostic yield of the image. There have been no reported differences found between the different digital systems in detecting simulated external resorptive lesions (30). A paralleling technique and beam aiming device were used to ensure radiographs were as accurate as possible. The sample size for single-view radiographs was relatively small (22 teeth). However, our findings are comparable with other studies that showed that an additional mesioangular parallax radiograph provided no additional benefit in detecting or assessing external resorptive cavities (31).

It is essential that the principles of dose limitation (ALARA [as low as reasonably achievable]) are adhered to and CBCT scans are fully justified before being performed (32, 33). The effective dose for a periapical radiograph is between 1 and 5 μSv, and a small field of view CBCT scan ranges between 11 and 29 μSv (34). The European Society of Endodontology Position Statement (2014) and the American Association of Endodontists and American Academy of Oral and Maxillofacial Radiology Joint Position Statement (2015) advise that CBCT imaging may be considered for the assessment and/or management of root resorption if it appears clinically amenable to treatment. Our study shows that the use of CBCT imaging can yield significant benefits for detecting and managing ECR. A CBCT scan should not be taken if

ECR already appears unrestorable on a PR because these radiographs underestimate lesion size.

A small field of view significantly lowers the effective dose and produces higher resolution images (35). This detail is important when analyzing ECR lesions, which often have resorptive channels extending from the main defect. The dose could potentially be reduced by limiting the arc of rotation. Reducing the arc of rotation from 360° to 180° has been shown to have no effect on the diagnostic yield when assessing simulated external inflammatory resorptive lesions (18). Reduction of the arc of rotation should be investigated further for the assessment and treatment of ECR lesions.

This clinical study highlights the limitations of PRs in detecting and assessing external cervical resorption compared with CBCT imaging. Radiographs were shown to underestimate the size of defect and provided limited information regarding the circumferential spread and location of the lesion on the root surface. This resulted in significant differences in the treatment plan chosen by the clinician. Additional parallax radiographs were shown to be of no additional benefit compared with a single radiograph.

Acknowledgments

The authors deny any conflicts of interest related to this study.

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