ISSN: 2573-8224

Research Article

Journal of Oral & Dental Health

Observers Agreement in Perception of Non-Cavitated Approximal Dental Caries by Intraoral Digital CCD Radiography at Different Exposure Parameters and Corresponding Required Radiation Dose

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Submitted: 22 Dec 2018; **Accepted:** 29 Dec 2018; **Published:** 07 Jan 2019

Abstract

Objectives: *To evaluate the diagnostic accuracy of Charged Coupled device (CCD) in detection of Non- Cavitated Approximal caries at different exposure parameters in relation to radiation dose in vitro.*

Study Design: *Seventy-eight surfaces of extracted teeth were inserted in acid gel to create non-cavitated proximal caries with different depth, and then Radiographs have been taken to all teeth by CCD sensor. Radiographs were interpreted by three observers. The lesions were classified as (N) No lesion, (D1) Less than ½ enamel thickness, (D2) more than halfway of enamel but not involve DEJ. (D3) Dentin caries. Teeth were randomly selected for histological analysis after consensus from three oral and maxillofacial radiologists as Gold standard. The corresponding radiation dose was measured by unfors meter device at different exposure parameters.*

Results: *The histological examination showed that the distribution of lesions was 39.8% Sound, both enamel lesions are equal 17.8%, Dentin lesions 24.6.*

The sensitivity and specificity of CCD to detect normal surfaces were 0.95, D1 was 0.37, D2 was 0.74 and D3 was 0.86. As the lesions depth increased, the sensitivity increased.

The higher image quality was produced by using exposure parameters (70 KvP, 160 ms) and (70 KvP, 200 ms). While, (60 KvP, 200 ms) and (60 KvP, 250 ms) produced the worse image quality.

Conclusion: *Regard the balance between the higher diagnostic accuracy of digital images and minimum radiation dose: using exposure parameters as (70 KvP, 160 ms) is considered the best image quality and relative dose (81 mSv). While, (70 KvP, 125ms) and (66 KvP, 160 ms) are little bit lower quality and corresponding dose are (63), (73) respectively. Although (70 KvP, 200 ET) produce higher image quality but its relative dose is high (101mSv).*

Keywords: CCD: Charged Coupled Device, CR: Computed Radiography, DR: Digital Radiography

Introduction

Radiography after detailed clinical findings is considered as a routine diagnostic approach for caries detection. Unfortunately, there is not a quite sensitive and precise method available for the early detection of non cavitated caries at the present time. Accurate diagnosis of primarily, non-cavitated caries is a high significance condition since disease progression can be easily ceased early, and tooth structure can also be preserved with minimal invasion only by utilizing conservative and not by restorative treatment [1,2].

Although researchers are seeking tools with sufficient sensitivity and specificity for early detection of Approximal caries. Nevertheless, radiography is still considered as the most common approach [3,4]. However, few studies have been implemented on non-cavitated Approximal caries detection. Furthermore, sensitivity of imaging systems is supposed to be more for cavitated caries diagnosis [5-7].

Intra-oral digital Radiography has been adopted by dentists and is widely used for diagnosis of Approximal caries. Recent developments in the digital imaging systems and introduction of new types of digital sensors with advanced software are increasing the clinical advantages; leading to many dentists replacing the conventional film with digital sensors [8-10].

Over the past recent years, diagnostic accuracy of digital radiography systems for caries detection has been compared mutually and with conventional film system. Some studies consider the image quality of conventional image receptor comparable to that of the systems with charge coupled devices (CCD) [11-13]. Other studies reported superiority of the digital CCD systems over conventional radiographs [14-17].

Most modern CR and DR systems now effectively offer substantial patient dose reduction compared to screen-film radiography. Unfortunately, the reverse is also possible. There is the risk of substantially increasing the patient dose, possibly without being aware of it, or of decreasing diagnostic information because of impairment image quality [18]. Therefore, Reduction of is patient dose according to the ALARA principle is not only a question of selecting the right sensor, but also requires selection is appropriate imaging parameters [19-21]. The purpose of present study to detect the diagnostic accuracy of CCD in detection of Approximal caries in different exposure parameters in vitro with corresponding relative dose.

Materials and Methods

1. Teeth Selection

- A total of 52 extracted human posterior teeth (78 proximal surfaces with sound surfaces) excluded non-contact outer proximal surfaces and 5 contact proximal surfaces to be include 73 proximal surfaces in contact.
- The teeth were embedded in rubber base blocks in an anatomical position to establish Approximal surfaces in contacts. Each block consisted of four teeth (included 6 proximal surfaces in contacts. Which numbered from surface1 to 6, surface 1 represented to first contact left one and surface 6 represented to first contact right surface).
- Whole 73 interdental contact surfaces were classified to create lesions with different depths as 29 normal surfaces, 13 surfaces prepared to create D1 carious lesion (less than ½ enamel thickness), 13 surfaces to be D2 carious lesion (more than ½ enamel thickness but not involve DEJ. 18 surfaces to be D3 (involve DEJ and dentin carious lesion).
- All teeth included surfaces needed to be normal were masked by varnish, then immerse for 14 days into acidified gel demineralizing solution (mixing 0.1M lactic acid and 0.1M NaOH in proportions to give a PH of 4.5, then add 6% (w/v) hydroxyethyl cellulose to gel) (Figure 1) for production of D1 artificial lesions. Then surfaces were cleaned and masked the whole teeth surfaces except surfaced needed to create D2 and D3 lesion. Which immersed again into gel for next 14 days, then masked all surfaces except D3 lesions and inserted into gel for next 14 days.

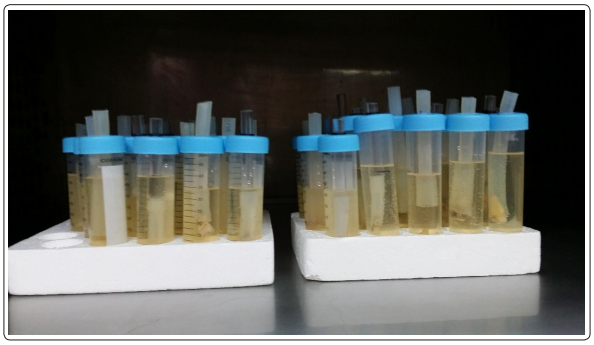


Figure 1: Photo of teeth inside the gel to create lesions

2. CCD System

- Standardized images of all blocks were obtained using Trophy intra-oral X-ray unit and CCD sensor size 2 in prepared rubber base block to fix the distance. Plexy- glass plate was placed between tube and teeth to simulate soft tissue (Figure 2).
- Images were taken using the following exposure parameters (Table 1).
- The effective dose was measured in each exposure by unfors meter device for further correlation between the effective dose and image quality.

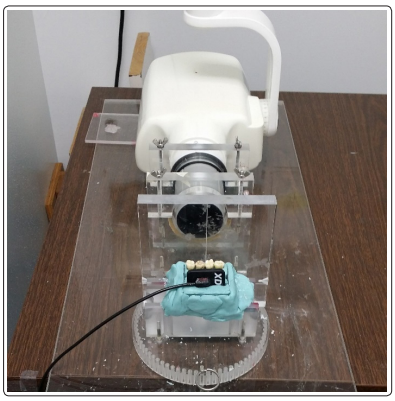


Figure 2: Phantom showing trophy intra-oral X-ray unit and CCD sensor size 2 in prepared block to fix the distance

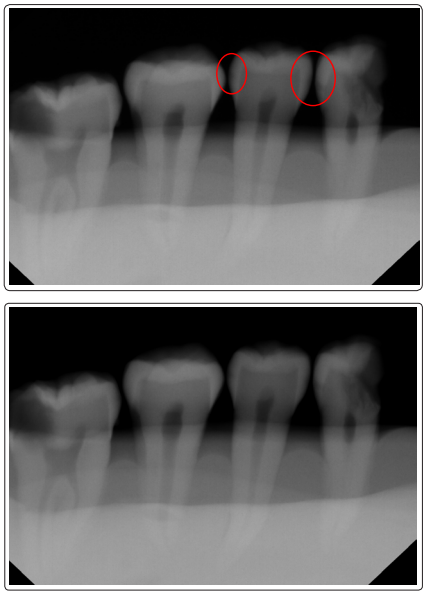


Figure 3: Periapical radiographs by CCD sensor at different setting (top image 70 KvP, 125 ET) (bottom image 70 KvP, 160 ET)

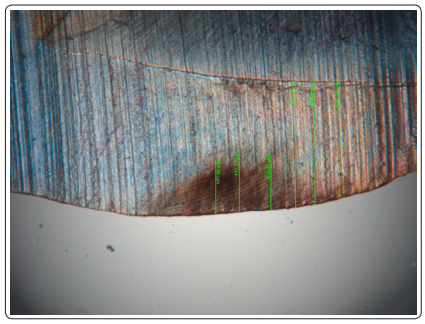


Figure 4: Histological photo of surface 4

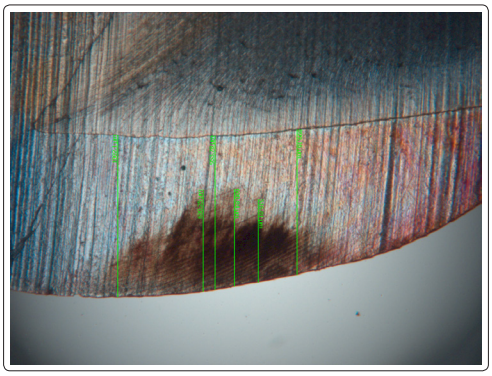


Figure 5: Histological photo of surface 5

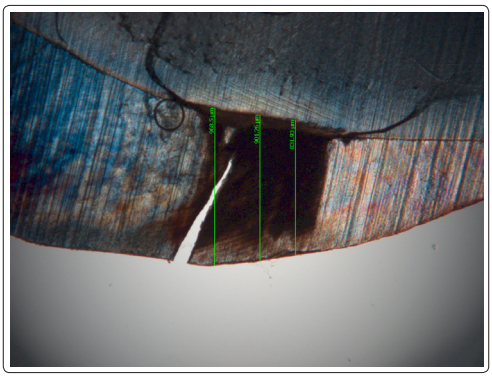


Figure 6: Histological photo of surface 6

3. Evaluation of Radiographic Images

- All radiographs were interpreted by three observers independently to examine included Approximal surfaces of all teeth. All teeth surfaces were interpreted for presence of carious lesions on proximal surfaces using a five-point confidence rate scale: 1= definitely no lesion, 2= probably no, 3= questionable, 4= probably carious lesion, and 5= definitely carious lesion.

4. Gold Standard

- All included surfaces (73 surfaces) were examined by 3 observers counseling to classify the included Approximal surfaces.
- Randomly selected 20 different approximal surfaces for histological analysis for emphasizing the observers counseling reports.
- During histological analysis, tooth crowns were separated longitudinally (mesio-distal direction) at the proximal surfaces. Each tooth surface was examined and any lesions were measured for depth using the following criteria: H0= sound, H1= caries less than outer half of enamel, H2= up to DEJ but not involved it, H3= caries in the outer half of dentin.

5. Statistical Analysis

- Observers counseling reports which were emphasized by histological analysis served as the gold standard for all selected Approximal surfaces.
- The diagnostic accuracy of intra-oral CCD sensor was evaluated independently for three readers from the area under the receiver operating characteristic curve (ROC), inter and intra-observer agreement were assessed, the values obtained for area under the curve were analyzed by pairwise comparison of ROC curve.

Results

- According to the gold standard of total 73 surfaces, showed that 29 surfaces (39.8%) sound, equal 13 surfaces (17.8%) for each enamel carious lesions, and 18 surfaces (24.6%) of dentin carious lesions.
- The mean sensitivity, specificity, AUC scores for all three readers combined for caries detection in relation with corresponding effective dose is presented (Table 1 and ROC curve). The higher image quality by using exposure parameters (70 KvP with ET 160 and 200), while the worse quality with (60 KvP and ET 200 and 250). While, the remaining exposure parameters have equivalent AUC. Regarding the effective dose; the highest dose with exposure parameter (60 KvP and ET 320) and the lowest dose with (70 KvP, ET 125).
- (Table 2) show the fractions of accurate predictions of depth for all readers. Which, indicating to increase the accurate predictions as increase the lesion depth. Moreover, using exposure parameters (70 KvP with ET 160 and 200) are considering the most consistently good performers.
- Intraobserver agreement for each observer, calculated using Kappa coefficients, was very strong, ranging between 0.8 to 0.9. Interobserver Kappa coefficient, ranging from 0.61 to 0.78. (Table 3) shows Kappa score for 1 and 2 is equivalent to scores for 2 and 3; while, Kappa score for 1 and 3 is lower than other two Kappa scores; due to different levels of readers.

Table 1: Sensitivity and Specificity for All Readers in Relation to Dose

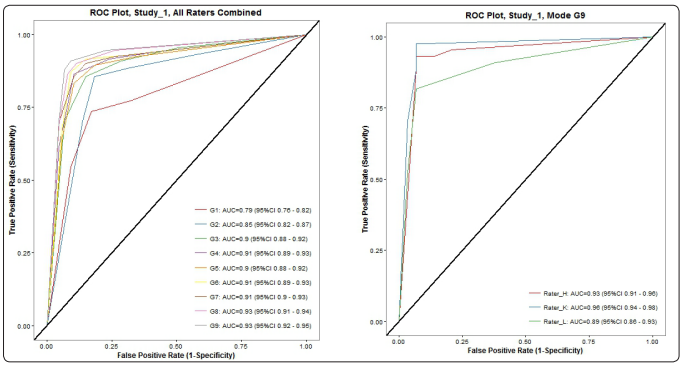
Mode	Sensitivity* (true positive rate)	Specificity* (1 - false positive rate)	AUC (Area under ROC curve)	95% CI for AUC	Corresponding dose
G1(60 Kvp, ET 200)	0.735	0.678	0.790 D	0.761 - 0.819	75.6
G2(60 Kvp ,ET 250)	0.856	0.678	0.845 C	0.821 - 0.870	96.25
G3(60 Kvp, ET 320)	0.856	0.713	0.895 B	0.875 - 0.915	122.9
G4(66 Kvp, ET 160)	0.864	0.759	0.908 B	0.889 - 0.927	73.03
G5(66 Kvp, ET 200)	0.833	0.816	0.899 B	0.879 - 0.918	91.75
G6(66 Kvp, ET 250)	0.871	0.851	0.911 B	0.893 - 0.930	114.4
G7(70 Kvp, ET 125)	0.856	0.851	0.914 B	0.896 - 0.932	63.3
G8 (70 Kvp, ET 160)	0.864	0.885	0.927 A	0.911 - 0.944	81.1
G9 (70 Kvp, ET 200)	0.879	0.908	0.933 A	0.917 - 0.949	101.9

Table 2: Fraction of Accurate Predictions of Depth for All Readers

	True Depth = 3		True Depth = 2		True Depth = 1		No Lesion Present	
Mode	Exact Match	2 or 3	Exact Match	1, 2, or 3	Exact Match	1 or 2	No Lesion (0)	0 or 1
G1	0.76	0.54	0.54	0.82	0.28	0.54	0.75	0.89
G2	0.83	0.65	0.64	0.90	0.41	0.72	0.82	0.91
G3	0.87	0.69	0.74	0.97	0.33	0.77	0.83	0.91
G4	0.89	0.69	0.69	0.97	0.44	0.74	0.84	0.93
G5	0.87	0.67	0.72	0.95	0.33	0.69	0.85	0.95
G6	0.89	0.69	0.87	0.97	0.41	0.74	0.89	0.95
G7	0.89	0.63	0.87	0.95	0.36	0.72	0.87	0.95
G8	0.89	0.69	0.77	0.95	0.44	0.74	0.90	0.97
G9	0.91	0.69	0.87	1.00	0.36	0.72	0.93	0.97
Total	**0.86**	**0.66**	**0.74**	**0.94**	**0.37**	**0.7**	**0.95**	**0.93**

Table 3: Inter-Rater Reliability Scores, using Cohen's Kappa

Readers Compared	Observed Agreement	κ	95% CI for κ
1 & 2	0.900	0.784	0.729 - 0.838
1 & 3	0.809	0.610	0.546 - 0.673
2 & 3	0.870	0.732	0.675 - 0.788



Discussion

This in vitro study used consensus confirmed by histological analysis of approximal caries as ultimate validation criterion. The sensitivity value of CCD Sensor to detect approximal lesions was improved with the depth of the lesion, as lesion shifted from enamel to dentin, the sensitivity value ranged from 0.37 in small enamel lesions to 0.86 in dentin lesions. this finding is in accordance with previous studies done by wenzel and Haiter-Neto, demonstrating failure in small lesions detection by intra-oral digital detectors, which had sensitivity value ranged from 0.13 to 0.21, meaning that all used digital systems failed to detect the smallest enamel approximal lesions [8,10,22].

Among the studies performed on non cavitated carious lesions. Previous study done by Alireza Mirshekar, et al. which demonstrated the higher sensitivity and specificity of intra-oral digital CCD Sensor to detect non cavitated approximal caries, which in line with our study [23]. That detected the higher sensitivity and specificity of CCD Sensor to detect proximal lesions especially by using exposure parameters (70 KvP, ET 160) and (70 KvP, ET 200).

Whereas, in Wenzel study, Diagora optime digital system displayed higher sensitivity but had a lower specificity, not accordance with our study, which used XDR sensor with pixel size is 19 microns. This provides a spatial resolution 26.3-line pairs/mm and radiation dose ranged from 63.3 to 114.4 msv during different selected exposure parameters. While in Wenzel`s study used Diagora optime with spatial resolution 15-line pairs/mm and dose approximately equal to film, meaning there is a significant dose reduction by using XDR`s sensor in our study [8].

Our study finding demonstrated a good agreement between CCD findings and gold standard that regard to higher XDR spatial resolution and XDR designed with the Caries/Endo filter. This filter extends hard tissue contrast by adaptively adjusting contrast to the local regions within the radiograph. This maintains sufficient detail in all regions while locally boosting contrast to the signal-to-noise limit for that region.

However, in Alireza study, there is a poor agreement between CCD findings and gold standard. This due to increase noise level in CCD images despite the use of anti-noise item in software [23]. Some studies have demonstrated that despite advances in spatial resolution in new generations of solid states, the difference between modalities was still non-significant for the overall accuracy [22,24,25].

The strong point of our study, that overcome limitations of previous studies, is correlation between the different exposure parameters and corresponding effective dose [23]. Which demonstrated as the following; the highest sensitivity, specificity and AUC gained by exposure parameters (70 KvP, ET 160) and (70 KvP, ET 200) with corresponding effective doses 81msv and 101 msv respectively. Then, exposure parameters (70 KvP, ET 125) and (66 KvP, ET 160) with corresponding effective doses 63 msv and 73 msv respectively.

In conclusion, our study demonstrated that the detection of non cavitated approximal caries by CCD sensor improved with the depth of lesion (as the depth of lesion increased, the sensitivity increased). Moreover, the preferred image quality with corresponding effective doses are; exposure parameters 70 KvP, 160 ET and 70 KvP, 125 ET with exposure doses 81 msv and 63 respectively.

Acknowledgement

The authors would like to acknowledge Prof. Bennett Amaechi, Professor of Dentistry and Director of Cariology at University of Texas, Health Science Center, San Antonio, for his help in creation of lesions and histological analysis in this work.

The authors would like also to acknowledge Mr. Michael Mader, MS School of Medicine, University of Texas, Health Science Center, San Antonio, for his help in statistical analysis for this study.

References

1. Behere RR, Lele SM (2011) Reliability of Logicon caries detector in the detection and depth assessment of dental caries: an in-vitro study. Indian J Dent Res 22: 362.
2. Bottenberg P, Jacquet W, Stachniss V, Wellnitz J, Schulte AG (2011) Detection of cavitated or non-cavitated approximal enamel caries lesions using CMOS and CCD digital X-ray sensors and conventional D and F-speed films at different exposure conditions. Am J Dent 24: 74-78.
3. Summitt JB, Robbins JW, Schwartz RS, dos Santos J (2006) Fundamentals of operative dentistry: a contemporary approach. Quintessence Pub.
4. Torres MG, Santos Ada S, Neves FS, Arriaga ML, Campos PS, et al. (2011) Assessment of enamel-dentin caries lesions detection using bitewing PSP digital images. J Appl Oral Sci 19: 462-468.
5. Abreu M Jr., Mol A, Ludlow JB (2001) Performance of RVGui sensor and Kodak Ektaspeed Plus film for proximal caries detection. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 91: 381-385.
6. Uprichard KK, Potter BJ, Russell CM, Schafer TE, Adair S, et al. (2000) Comparison of direct digital and conventional radiography for the detection of proximal surface caries in the mixed dentition. Pediatr Dent 22: 9-15.
7. Pontual AA, de Melo DP, de Almeida SM, Boscolo FN, Haiter Neto F (2010) Comparison of digital systems and conventional dental film for the detection of approximal enamel caries. Dentomaxillofac Radiol 39: 431-436.
8. Wenzel A, Haiter-Neto F, Gotfredsen E (2007) Influence of spatial resolution and bit depth on detection of small caries lesions with digital receptors. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 103: 418-422.
9. Peker I, Toraman Alkurt M, Altunkaynak B (2007) Film tomography compared with film and digital bitewing radiography for proximal caries detection. Dentomaxillofac Radiol 36: 495-499.
10. Haiter-Neto F, Wenzel A, Gotfredsen E (2008) Diagnostic accuracy of cone beam computed tomography scans compared with intraoral image modalities for detection of caries lesions. Dentomaxillofac Radiol 37: 18-22.
11. Syriopoulos K, Sanderink GC, Velders XL, van der Stelt PF (2000) Radiographic detection of approximal caries: a comparison of dental films and digital imaging systems. Dentomaxillofac Radiol 29: 312-318.
12. Hintze H, Wenzel A, Frydenberg M (2002) Accuracy of caries detection with four storage phosphor systems and E-speed radiographs. Dentomaxillofac Radiol 31: 170-175.
13. Wenzel A (2006) A review of dentists' use of digital radiography and caries diagnosis with digital systems. Dentomaxillofac Radiol 35: 307-314.
14. Borg E, Grondahl HG (1996) On the dynamic range of different X-ray photon detectors in intra-oral radiography. A comparison of image quality in film, charge-coupled device and storage phosphor systems. Dentomaxillofac Radiol 25: 82-88.
15. Moystad A, Svanaes DB, Risnes S, Larheim TA, Grondahl HG (1996) Detection of approximal caries with a storage phosphor system. A comparison of enhanced digital images with dental X-ray film. Dentomaxillofac Radiol 25: 202-206.
16. Huda W, Rill LN, Benn DK, Pettigrew JC (1997) Comparison of a photostimulable phosphor system with film for dental radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 83: 725-731.
17. Svanaes DB, Moystad A, Larheim TA (2000) Approximal caries depth assessment with storage phosphor versus film radiography. Evaluation of the caries-specific Oslo enhancement procedure. Caries Res 34: 448-453.
18. Uffmann M, Prokop M (2009) Digital radiography: The balance between image quality and required radiation dose. European Journal of Radiology 72: 202-208.
19. Seibert JA (2004) Tradeoffs between image quality and dose. Pediatr Radiol 34: 183-195.
20. Honey ID, Mackenzie A, Evans DS (2005) Investigation of optimum energies for chest imaging using film-screen and computed radiography. Br J Radiol 78: 422-427.
21. Uffmann M, Neitzel U, Prokop M, Kabalan N, Weber M, et al. (2005) Flat-panel-detector chest radiography: effect of tube voltage on image quality. Radiology 235: 642-650.
22. Haiter-Neto F, dos Anjos Pontual A, Frydenberg M, Wenzel A (2008) Detection of non-cavitated approximal caries lesions in digital images from seven solid-state receptors with particular focus on task-specific enhancement filters. An ex vivo study in human teeth. Clin Oral Investig 12: 217-223.
23. Farida Abesi, Alireza Mirshekar, Ehsan Moudi, Maryam Seyedmajidi, Sina Haghanifar, et al. (2012) Diagnostic Accuracy of Digital and Conventional Radiography in the Detection of Non-Cavitated Approximal Dental Caries. Iran J Radiol 9: 17-21.
24. Haiter-Neto F, dos Anjos Pontual A, Frydenberg M, Wenzel A (2007) A comparison of older and newer versions of intraoral digital radiography systems: diagnosing noncavitated proximal carious lesions. J Am Dent Assoc 138: 1353-1359.
25. Anbiaee N, Mohassel AR, Imanimoghaddam M, Moazzami SM (2010) A comparison of the accuracy of digital and conventional radiography in the diagnosis of recurrent caries. J Contemp Dent Pract 11: E025-32.