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# Diagnosis of Secondary Caries in Esthetic Restorations: Influence of the Incidence Vertical Angle of the X-Ray Beam

Patrícia Lima MOREIRA[1]
Michel Reis MESSORA[2]
Stela Márcia PEREIRA[3]
Solange Maria de ALMEIDA[4]
Adriana Dibo da CRUZ[5]

*[1]Dental School, University Center of Lavras, Lavras, MG, Brazil*
*[2]Department of Surgery, Dental School, University Center of Lavras, Lavras, MG, Brazil*
*[3]Department of Veterinary Medicine, Area of Epidemiology and Public Health, Federal University of Lavras, Lavras, MG, Brazil*
*[4]Department of Oral Diagnosis, Dental School of Piracicaba, UNICAMP - University of Campinas, Campinas, SP, Brazil*
*[5]Department of Specific Formation, Area of Dental Radiology, Dental School, UFF - Fluminense Federal University, Polo of Nova Friburgo, Nova Fribrgo, RJ, Brazil*

The aim of this study was to evaluate the accuracy on the diagnosis of secondary caries-like lesions simulated on esthetic restorations of different materials, changing the incidence vertical angle (IVA) of the x-ray beam. Twenty human teeth received MOD inlay preparations. In the experimental group (n=10), a round cavity was made in the floor of the proximal box to simulate the caries-like lesion. All teeth were restored with 3 composite resins (Charisma, Filtek-Z250 and TPH-Spectrum) at 3 moments. Two radiographic images were acquired with $0^o$ and $10^o$ IVA. Ten observers evaluated the images using a 5-point confidence scale. Intra- and interobserver reliability was analyzed with the Interclass Correlation Coefficient and the diagnostic accuracy was evaluated using the area under the ROC curve ($A_z$), Friedman test and Wilcoxon test ($\alpha$=0.05). Higher accuracy values were obtained with $10^o$ IVA ($A_z$=0.66, Filtek-Z250>$A_z$=0.56, TPH-Spectrum) compared to $0^o$ ($A_z$=0.55, Charisma>$A_z$=0.37, TPH-Spectrum), though without statistically significant difference ($p>0.05$). The detection of secondary caries-like lesions simulated on esthetic restorations of different materials suffered no negative influence by changing the IVA of the x-ray beam.

Key Words: radiography, dental caries, dental restoration, ROC curve.

## INTRODUCTION

Composite resins have been widely used to fulfill the growing concern with esthetics. However, despite the improvement of these materials, there are still some disadvantages to be overcome such as wear and secondary caries (1,2). Secondary caries is the most frequent cause of restoration loss. The correct diagnosis of this condition is of key importance to determine the useful time of the restorations (3). The radiographic examination is the main method for detection of caries in posterior teeth (4). However, several factors may influence this exam, namely the proximity between lesion and restoration, lesion size, lesion orientation, incidence geometry from x-ray beam (5-9), and optical factors derived from differences in the radiopacity of the restorative material, lesion and dental structure (10-12).

For better visualization of secondary caries, fractures and imperfections of adaptation and contour, the restoration needs to have radiopacity similar to dental structures (11). The restorative material should be more radiopaque than the dentin and, preferably, with the same radiopacity of the enamel. However, the increase of the radiopacity of restorative materials reduces caries detection, increasing the incidence of false positive results (2). Materials that have greater radiopacity than dental structures, such as amalgam, can hide secondary caries and sometimes several different

Correspondence: Profa. Dra. Adriana Dibo da Cruz, Faculdade de Odontologia, UFF, Pólo de Nova Friburgo, Rua Doutor Silvio Henrique Braune, 22, Centro, 28625-650 Nova Friburgo, RJ, Brasil. Tel: +55-22-2528-7166. Fax: +55-22-2528-7168. e-mail: adrianadibo@gmail.com

x-ray beam incidences are necessary for the detection of these lesions (6). According to Magalhães et al. (12), only the clinical presence of ditches and bluish-gray coloring on the margins of occlusal amalgam restorations cannot predict the existence of secondary carious lesions.

As the secondary caries determine the clinical lifetime of a restoration, the radiographic system must be efficient in its diagnosis, independently of the influence of radiopacity from restorative material or the incidence geometry from x-ray beam. The aim of this study was to evaluate the accuracy on the diagnosis of secondary caries-like lesions simulated on esthetic restorations of different materials, changing the incidence vertical angle (IVA) of the x-ray beam.

## MATERIAL AND METHODS

After approval of the research project by the Research Ethics Committee (protocol #CAAE-0047.0.189.000-09), 20 human non-carious permanent teeth, 10 premolars and 10 molars, were selected. The teeth were cleaned by removing debris and stored in distilled water at 4ºC for no more than 6 months post-extraction. In all test teeth, a mesio-occluso-distal (MOD) inlay cavity was prepared with a #1094 diamond bur in a water-cooled high-speed air turbine handpiece. The MOD inlay preparations had depth of 1.5 mm in the occlusal box and 3 mm in the proximal boxes for premolars, and 2 mm in the occlusal box and 4 mm in the proximal boxes for molars. The MOD width was the same of the bur width. The teeth were randomly divided into 2 groups: Experimental group (n=10, with 5 molars and 5 premolars), which received a round cavity in the floor of the proximal box (medial or distal) to simulate the caries lesion; and Control group (n=10, with 5 molars and 5 premolars), which did not receive a simulated lesion. The cavities that simulated secondary caries lesions were made with a #1 round bur, having the depth approximately equal to half bur. The cavities were filled with #7 wax to provide no radiographic image.

The teeth were restored with 3 composite resins with the same indication for use, at 3 different moments: Charisma (Heraeus-Kulzer, Gonsennheumer, Mainz, Germany); Filtek-Z250 (3M ESPE, St. Paul, MN, USA); TPH-Spectrum (Dentsply International Inc., Milford, DE, USA). The same shade (A2) was used for all materials. The same protocol was followed for all teeth: restoration with one of the three composite resins, radiographic examination, removal of the restoration with a #1094 diamond bur at high-speed, and restoration with another resin, until the three materials were used in each tooth.

Five non-test teeth were included in sample to use as contact point for the test tooth, seeking to simulate the anatomical condition. A restored tooth-test was mounted in contact with 2 non-test teeth in a phantom simulating the upper dental arch, the other 3 non-test teeth were mounted to simulate the lower dental arch. All radiographic images were obtained of this phantom changing only the restored tooth-test.

Standardized bitewing radiographs from phantom were acquired with 0º and 10º IVA of the x-ray beam. All radiographs were made under standardized conditions (70 kVp, 10 mA, 0.32 s, 40 cm target-to-receptor distance) using the same x-ray machine (Spectro 70; Dabi Atlante Ltda, Ribeirão Preto, SP, Brazil). A 12-mm-thick soft tissue-equivalent material was placed between the tube extension and the phantom to simulate the radiation scatter. As image receptor, F-speed radiography films (Insight; Carestream Health Inc., Kodak Dental System, Rochester, NY, USA), processed automatically (GXP; Dentsply International/Gendex; Dental Xray), was used. Conventional radiographs were digitized by means of a laser scanner (ScanMaker i900; Microtek International Development Systems Division, Inc. Carson, CA, USA) and processed using the Adobe Photoshop CS3 software (Adobe Systems Incorporated, San Jose, CA, USA) in gray scale mode with a resolution of 300 dpi and stored as 8-bit TIFF images.

Digital images from digitized radiographs were randomly ordered in 4 Power-Point presentation, with 30 image each. Ten observers (all dentistry students, a semester before to receive an academic degree) independently recorded the images using a 5-point confidence rating scale: 1- secondary caries-like lesion definitely absent; 2- secondary caries-like lesion probably absent; 3- unsure if secondary caries-like lesion is present or absent; 4- secondary caries-like lesion probably present; 5- secondary caries-like lesion definitely present. Before the study, a rehearsal session was held, in which the observers became familiar with the scoring program, and how to evaluate images for the secondary caries-like lesion diagnosis. The reading order of each presentation varied for each observer, and a period of at least 1 day separated the sessions. When viewing the images, the room light was turned off. After conclusion of the 4 presentations, 50% of the sample was re-evaluated to obtaining the intra-observer reliability.

Interclass correlation coefficient (ICC) was used to evaluate the intra- and interobserver reliability response pattern. Receiver operating characteristic (ROC) analysis was used to assess the observers' performance in detecting secondary caries-like lesion with different composite resins and IVA from x-ray beam. Using the SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA), ROC curves were generated for each combination of composite resins (3) and IVA of the x-ray beam (2) with the median value of the observer's responses. The areas under the ROC curves, designated as $A_z$, represent the efficiency of the diagnostic method and were used as indices of accuracy. Differences between response patterns of observers for each composite resin and IVA of the x-ray beam were tested using the Friedman test and Wilcoxon test. The level of significance was set at $\alpha$=0.05.

## RESULTS

ICC values for intra-observer reliability were calculated as 0.677, varying from 0.572 to 0.762 with 95% confidence interval, and for inter-observer as 0.593, varying from 0.476 to 0.684 with 95% confidence interval. The value for intra- and inter-observer agreement above 0.4 indicates a satisfactory agreement level.

The performance of observers in the evaluation of images for detecting secondary caries-like lesion in composite resin restorations using different IVAs of the x-ray beam is shown in Table 1. Higher accuracy values were obtained with 10º IVA ($A_z$=0.66>$A_z$=0.65>$A_z$=0.56 for Filtek-Z250, Charisma, TPH-Spectrum respectively) compared to 0º ($A_z$=0.55>$A_z$=0.52>$A_z$=0.37 for Charisma, Filtek-Z250, TPH-Spectrum respectively).

Response patterns of observers showed no differences in the same restorative material comparing the two IVAs of the x-ray beam (p>0.05; Wilcoxon test), and with same IVA of the x-ray beam comparing the three composite resins (p>0.05; Friedman test) (Table 2).

Table 1. $A_z$ values for detecting secondary caries-like lesion in restorations of composite resins using two IVAs of the x-ray beam.

| Group (IVA from x-ray beam) | $A_z$ | Standard error | Confidence interval (95%) |
|---|---|---|---|
| Charisma (0º) | 0.555 | 0.135 | 0.291 - 0.819 |
| Charisma (10º) | 0.650 | 0.127 | 0.401 - 0.899 |
| Filtek-Z250 (0º) | 0.520 | 0.137 | 0.252 - 0.788 |
| Filtek-Z250 (10º) | 0.655 | 0.132 | 0.396 - 0.914 |
| TPH-Spectrum (0º) | 0.370 | 0.127 | 0.122 - 0.618 |
| TPH-Spectrum (10º) | 0.560 | 0.135 | 0.296 - 0.824 |

## DISCUSSION

Considering that radiography is the most feasible method for detecting secondary caries lesions and in clinical practice, there are several factors that could change its detection, as exposure geometry and optic illusion, it would be justifiable to compare the diagnostic accuracy of radiographs acquired with different IVAs of the x-ray beam and with composite resins from three distinct manufacturers. In this *in vitro* study, secondary caries-like lesions simulated on esthetic restorations of different materials was used as an alternative to evaluated the influence of these factors on radiographic capability to caries detection (5-8).

In terms of the diagnostic accuracy for caries-like lesions simulated on esthetic restorations of different materials using different IVAs of the x-ray beam, no significant differences between two angulations (0º and 10º) were demonstrated. The present findings are in accordance with the results of a previous study (8), which used 4 different IVAs of the x-ray beam (0º to 15º), and did not find significant differences either, although higher accuracy values were observed at 10º. Van der Stel et al. (7), on the other hand, found that the maximum IVA able to provide a satisfactory secondary caries diagnosis was 7.5º because an increase of the angle would confuse the caries image due to its superimposition with the restorative material. However, in that study (7), the restorative material was amalgam, which has a high atomic number causing large absorption from x-ray beam. In the present only composite resins of low atomic number were used. Akarslan et al. (8)

Table 2. Median (minimum-maximum) of the scores used in evaluation of secondary caries-like lesions.

| IVA of the x-ray beam | Median (min-max) | | |
|---|---|---|---|
| | Charisma | Filtek-Z250 | TPH-Spectrum |
| 0º | 3 (1-5) Aa | 2.75 (1-5) Aa | 4 (1-5) Aa |
| 10º | 3 (1-5) Aa | 2.25 (1-5) Aa | 3 (1-4.5) Aa |

Statistical analysis indicated no significant differences (p>0.05) among groups (Wilcoxon test comparing columns and Friedman test comparing rows).

indicated that the bitewing projection was more accurate than periapical projection for detection of proximal carious lesions in posterior teeth because any change in x-ray projection angle can influence the detection of lesions in this region.

In relation to radiopacity of restorative materials, no significant differences were observed among the composite resins used in present study. The materials showed radiographic images with radiopacity that was similar clinically, being equivalent to the radiopacity of dental structures (11). These results corroborate those of the Haak (2), who also showed no difference in the accuracy of secondary caries detection due to very similar radiopacities of the tested materials. However Ergücü et al. (13) observed that the radiopacity of composite resins varied considerably, and care must be taken when selecting an appropriate material to enable secondary caries detection under posterior composite restorations. Others studies (2,10) showed that restorative materials with radiopacity equivalent to that of enamel enabled a better accuracy in secondary caries diagnosis. In present study, however, it was observed that the material with highest radiopacity - TPH-Spectrum - showed the worst performance for secondary caries-like diagnosis.

In present study, higher $A_z$ values were obtained using 10º IVA of the x-ray beam. However, the $A_z$ values found in this study were around 0.5, independently of the IVA, referring to a response pattern by guessing (14). This $A_z$ values might be attribute to 3 different factors. The first factor is that caries lesions under esthetic restorations are more difficult to diagnose because of optical influence from the radiopacity of the restoration added to the lesion, especially in small sized lesions (5-8). The second factor is the inexperience of the observers, who were dental students attending the last period before receiving an academic degree, and who had little experience in caries diagnosis (15). This justifies the low ICC for intra- and inter-observer reliability. The third factor is the use of phantom features, which simulated the conditions of tooth inclination of the buccal cavity, as used by Haak et al. (2); this justifies the higher $A_z$ values obtained using 10º IVA of the x-ray beam, as the test teeth were placed in the upper dental arch.

The $A_z$ values found in the present study - around 0.5 - are similar to those obtained in previous studies (2,6,15,16) that had more experienced observers in secondary caries diagnosis. In fact, even with the benefit of radiographs, it is recognized that the diagnosis of caries lesions is an inherently difficult task because over 40% demineralization must occur for radiographic detection to be possible (17). In addition, superimposition of the restorative material image contributes to make caries diagnosis even more difficult (16). Besides, the process of digitization has been shown to add physical noise to the radiographic image. Noise is an important factor when determining image quality, and it may have an impact on the detection of small caries lesions (18). On the other hand, the results obtained reflect everyday clinical practice, as reported in a previous study (15), which observed lack of calibration of dentists for the accurate diagnosis of secondary caries lesions. Only the accurate diagnosis can provide a good basis for dental treatment planning. According to Kirkevang (3), composite resins still have a low performance as restorative material of posterior teeth and should be periodically checked for prevention of caries recurrence. In this case, in spite of the low precision, bitewing radiographs are recommended together with clinical examination (4). Training of dentists for diagnosis lesions in interproximal areas is also indispensable.

Considering the methodology used, the conclusion reached is that the detection of secondary caries-like lesions simulated on esthetic restorations of different composite resins suffered no negative influence (decrease in diagnostic accuracy) by changing the IVA of the x-ray beam. Thus, the bitewing radiographic exam is a safe method for detection of secondary caries lesions on esthetic restorations, even when the parallelism technique is badly performed.

## RESUMO

O objetivo deste estudo foi avaliar a precisão no diagnóstico de lesões iguais-à-cárie secundárias simuladas em restaurações estéticas de materiais diferentes, mudando o ângulo vertical de incidência (AVI) do feixe de raios-x. Vinte dentes humanos foram submetidos a preparo cavitário inlay MOD. No grupo experimental (n=10), no soalho da caixa de proximal, foi confeccionada uma cavidade esférica para simular lesões iguais-a-cárie. Todos os dentes foram restaurados com 3 resinas compostas (Charisma, Filtek-Z250, TPH-Spectrum), em três tempos diferentes. Duas imagens radiográficas foram adquiridas com 0 e 10 graus de AVI o feixe de raios-x. Dez observadores avaliaram as imagens usando uma escala de confiança de 5-pontos. A reprodutibilidade intra- e inter- observador foi analisada com o coeficiente de correlação interclasse e a precisão do diagnóstico foi avaliada usando a área sob a curva ROC ($A_z$), o teste de Friedman e de Wilcoxon ($\alpha$=0,05). Os mais altos valores de precisão (p>0,05) foram observados com o AVI em 10º (Filtek-Z250 $A_z$=0,66>TPH-Spectrum $A_z$=0,56) comparado com 0º (Charisma $A_z$=0,55>TPH-Spectrum $A_z$=0,37), porém, sem diferenças estatisticamente significantes (p>0,05). A detecção de lesões iguais-à-cárie secundárias simulada em

restaurações estéticas de diferentes materiais não foi influenciada pela mudança de AVI do feixe de raios-x.

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