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Evaluate the Influence of Combined Composite Restorations Radiopacity in Deep Class II Cavities with Three Imaging Systems: Conventional Film, Digital System and Cone Beam Computed Tomography

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ABSTRACT

Statement of the Problem: The radiopacity of esthetic restorative materials is important requirement in radiographic diagnosis especially in secondary caries.

Purpose: The aim of this study was to evaluate the influence of combined composite restorations radiopacity in deep class II cavities with three radiographic systems.

Materials and Methods: Class II preparations were made in 40 extracted molar teeth. The teeth were divided into four groups: fully current resin composite, flow composite associated with current resin composite, glass ionomer associated with current resin composite, amalgam associated with current resin composite. Groups 2, 3, and 4 were filled as combined restorations (sandwich technique). The images on film, charge-coupled device (CCD) digital systems, and cone beam computed tomography (CBCT) were evaluated by two examiners and the data were achieved. The systems for obtaining images presented were similar for each material. The data were analyzed according to ANOVA and Kendall's tau-b, Kruskal-Wallis, Exact, and Fisher's exact tests were applied.

Results: Amalgam had the highest radiopacity among the materials being tested (equivalent to 9 mm Aluminium). The groups 2 and 3 ranked next (equivalent to 8 mm Al). Group 1 had the lowest radiopacity among the materials being tested (equivalent to 7 mm Al). All groups were more radiopaque than enamel (enamel=6 mm Al).

Conclusion: Radiopacity rates were as follows: Amalgam>flow glass ionomer>current composite>enamel>dentin.

According to this study amalgam, between the said combined composite restorations, has the maximum radiopacity in deep class II cavities with these three imaging systems.

Key words: Cone-beam computed tomography, Composite resins, Radiography

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INTRODUCTION

The early diagnosis of recurrent caries is one of the present problems in dentistry. Recurrent caries refers to the decay present in the edge or beneath the previous restorations. The diagnosis of recurrent caries is difficult around old restorations and is more difficult in the deep class II restorations. Also due to incompatibility and inappropriate bond of the composite with the floor of the cavity materials with better marginal integrity such as flow composite, glass inomer and amalgam are suggested [1]. The dentist's carefulness and scrutiny in diagnosing the caries beneath the present restorations is mandatory as some radiolucent dental materials possess an apparent radiographic appearance similar to caries [1,2]. On the other hand, due to the radiopacity resemblance of many composite resin restorations to dentine, enamel, or cementum, the diagnosis of recurrent caries seem to be difficult. It is said that composite restorations with opacity similar to that of enamel make the caries diagnosis easier [1]. Radiopacity is a significant physical property of restorative materials specifically in the posterior teeth [3]. The obligation for radiopacity is one component of the standards of dental resins used in class I and class II restorations [4,5]. This feature is more important in proximal surface and cervical margin; this is also important for differentiation of secondary carries from restorations [6-9]. Manufacturers add some radiopaque materials to the resins. A filling material used in the posterior teeth needs a radiopacity higher than enamel [3]. According to American National Standard/American Dental Association (ANSI/ADA)-SPECIFICATION 27 [5], for resin-based composite materials, the material should have an opacity equivalent to the same thickness of Al not less than 0.5 mm which is consistent with the International Standards Organization (ISO 4049) [3]. Regarding the shortcomings of conventional radiography, experts have always been trying to provide more comprehensive methods of imaging. Among the common disadvantages of conventional radiography are the relatively high dose of X-ray exposure and time-consuming processes of film development and fixation and unfavourable changes in film quality in the course of time [2]. The conventional radiographs merely display the mesiodistal aspects. Regarding the mentioned demerits, digital radiography competes nowadays with conventional radiography. Also, 3D imaging procedures as CBCT may be used to enhance accuracy in lesion diagnosis [10-12]. Various techniques have been developed for reducing the contraction of polymerization in fissure and there is micro leakage in cavities extended to cementum. One such technique is the sandwich technique in which various materials are placed under the composite resin [13]. Regarding the problems mentioned above and also the challenges confronting dentists in presenting the best possible treatment plan, this study focused on comparing the rate of radiopacity of four different techniques of combined composite resin restorations using methods of conventional film, the digital system of CCD, and CBCT (Cone Beam Computerized Tomography). Few studies have been conducted on investigating radiopacity of composites and different techniques of class II cavities restoration on the gingival floor. For example, Oztas et al. decided to investigate the rate of radiopacity of 9 composite resins and 8 types of bonding, their radiopacity on film was assessed using a transmission densitometer, and the radiopacity with phosphor plates detector (PSP) was assessed digitally using the system's own software (Digora). All 9 types of composite resins studied had a radiopacity greater than dentine. Further, all 8 types of bonding materials showed a radiopacity less than enamel or dentine [14].

The aim of this study was to evaluate the influence of combined composite restorations radiopacity in deep class II cavities with three radiographic systems.

MATERIAL AND METHODS

This descriptive-analytic study was conducted using the Lab Trial method and a parallel design. The samples were obtained from human molar teeth with healthy crowns fixed in acrylic blocks. There were 40 samples (10 cases for each imaging group). A total of 40 extracted healthy molar human teeth were selected and washed with water. Then, they were sterilized in 0.5% sodium hypochlorite solution for one week and kept in physiologic saline solution (PSS) till the time of the study. Next, a standard deep class II cavity was prepared on the mesial and distal aspect of each sample (Buccolingual cavity width of 3 mm. gingival floor of cavity 1 mm below CEJ. The depth of the cavity is 2 mm from the external surface of the tooth in the gingival floor. Using turbine and diamond fissure tip 008 along with air-water spray. Changing the turbine tip, a cavity with the following characteristics was obtained after four cavities perpetrate.

Restoration techniques

The secured samples were randomly divided into four groups of 10 and Toffle mayor holder and metallic matrix were placed round the teeth and fastened as tightly as possible. All the cavities were prepared and restored by one individual.

Group one (control group)

Conventional restoration with light composite resin: The whole cavity was etched with 37% phosphoric acid for 20 s and then irrigated with water for 20 s. Next, the cavity was dried with mild pressure of water-air syringe and the extra water of the dentinal region was removed using cotton micro brush (Microbrush International, China). Two layers of bonding (Optibond solo plus , Kerr, Germany) were applied to all walls and cured for 20 s with LED (Dent America, USA) light cure device using a stable intensity of 500 mw/s. Optic composite P60 (3M, USA) with 2 mm thickness was placed as oblique layers and light cured for 40 s.

Group two

Restoration with flowable composite and light composite resin: The procedures for this group were the same as those for Group One except that a 1 mm layer of flow able composite (3M, USA) was placed at the floor of the cavity. The light composite layer was placed without curing and then cured.

Group three

Restoration with glass ionomer and light composite resin: The procedures were the same as those of Group One except that a 1 mm layer of light glass ionomer (GC Fuji, Japan) was placed and then light cured.

Group four

Restoration with capsular amalgam (SDI, Australia) and light composite resin: The procedures were the same as those for Group Three except that amalgam was used instead of light glass ionomer. To do so, a metallic matrix band was used in the following way: as the width of the matrix band is 8 mm, 6 mm of the middle portion (the point where it is adjacent to the cavity after being tied round the tooth) was separated with scissors and positioned in such a way that it was placed more apically than the gingival margin up to 1 mm. In this way, amalgam was placed up to the margin of cutout matrix band. Cellulose transparent matrix band were used for the first three groups (Figures 1 and 2).

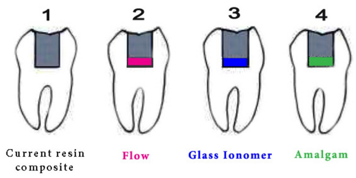

Figure 1: Different types of combined composite restorations used in the study

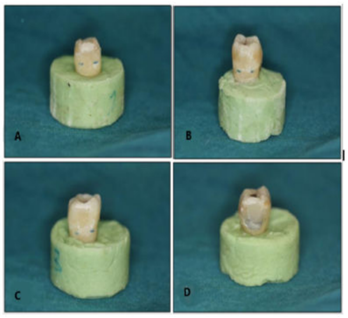

Figure 2: A sample of 4 groups used in the study: (A) Conventional restoration with light composite, (B) Flowable composite, (C) Glass ionomer composite and (D) Amalgam

Evaluation of the rate of opacity

To determine the radiopacity of materials, three types of radiographs were obtained for each tooth.

The first method: A radiograph was obtained with conventional film using Planmeca (Planmeca, Helsinki, Finland) with exposure conditions of: KVP=60, mA=8, s=0.100, and PID=8 cm (Figure 3).

The second method: The image was obtained using CCD digital system (Soredex, Helsinki, Finland) with exposure conditions of KVP=60, mA=7, s=0.40, and PID=18 cm (Figure 4).

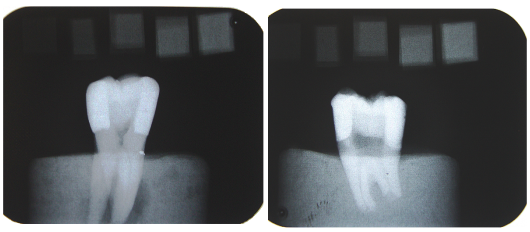

Figure 3: A sample of the obtained periapical radiographs

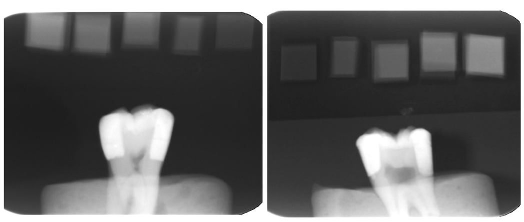

Figure 4: A sample of the acquired digital images (CCD)

The third method: Images were acquired with CBCT device (Planmeca Promax 3D, Helsinki, Finland) with exposure conditions of kvp=80, mA=10, s=12.083, Voxel size=160 μm, and image size=501/501/315, Field of view 8 × 8 cm the wide of section is 0/2 mm (Figure 5).

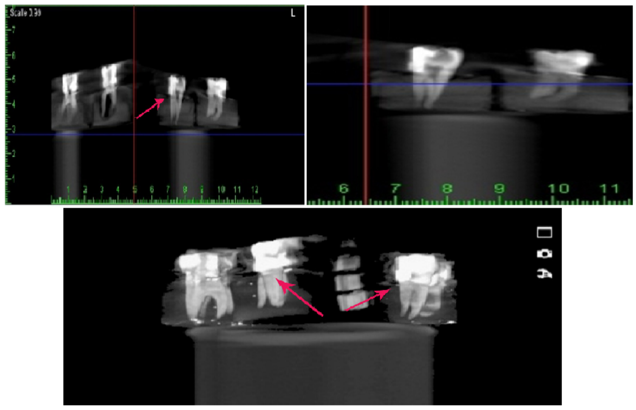

Figure 5: A sample of the CBCT images acquired with amalgam gingival floor

For all images, a fixed aluminium step wedge with five different thicknesses of 1, 2, 3, 4, and 5 mm was used adjacent to the tooth to measure radiopacity using the Gold Standards. All films were of the type Sky dent (Slovak Republic) with the speed of E and processed with the automatic film development and fixation device Velopex (UK) using film development and fixation solution Champion (UK). The development and fixation time was 4.5 min. The rate of their radiopacity was evaluated blindly by two radiologist observers and interpreters without being aware of each other's opinions or comments. The radiopacity of the intended materials was compared to that of enamel, dentine, and aluminium. The observers commented on the rate of radiopacity of the materials used in the study only for the conventional radiographs and digital images.

However, the story was different with CBCT images. Since each material in a CT image has its own unique number, based on the density of the substance (Hounsfield Unit), there was no need for the observers' interpretations. In other words, it could be said that CBCT images played the role of Gold Standards as CT scans show a specific number for each material (Hounsfield Unit) which is related to the density of that material. In fact, there is no study that evaluated the rate of radiopacity of materials by using CBCT and also due the fact that all categorizations for determining the rate of radiopacity were expressed in mm of aluminium, so we had to use aluminium wedges in images. The categorizations in aluminium thickness were converted to Hounsfield numbers in CBCT yielding the following categorization:

Code 1: Weak: from 517 HU to 1599 HU=6 mm of Al

Code 2: Moderate: from 1600 HU to 2999 HU=7 mm of Al

Code 3: Good: from 3000 HU to 3039 HU=8 mm of Al

Code 4: Excellent: from 3040 HU to 3100 HU=9 mm of Al

The data was analysed *via* ANOVA and Kendall's tau-b, Kruskal-Wallis, Exact, and Fisher's exact tests. We analysed the correlation between the results of observed radiographs and Gold Standards *via* ANOVA. To compare the correlation among different indices, Kendall's tau-b, Kruskal-Wallis, Exact, and Fisher's exact tests were applied.

RESULTS

Based on the findings given by the statistical tests used, with p-value<0.001. Determination of materials opacity on the basis of conventional radiography was 87.5% reliable between two observers. Determination of materials opacity on the basis of digital radiography (CCD) was 92.5% reliable. The opacity means score of flow able composite resin restoration in CBCT was 2412 HU. The opacity means score of glass ionomer restoration in CBCT was 2327 HU. The opacity means score of amalgam restoration in CBCT was 3095 HU. The CBCT technique approved the results obtained by conventional film and digital images.

The rate of radiopacity of materials used in the study

***Based on CBCT:** Amalgam>flow able composite ≥ glassionomer>conventional composite.

***Based on conventional film images:** Amalgam>flow able composite>glass ionomer ≥ conventional composite.

***Based on digital images:** Amalgam>flow able composite ≥ glass ionomer>conventional composite.

The CBCT technique, expresses the degree of correspondence between the conventional film and digital images in determining the rate of radiopacity to be less than 50%.

It was observed that 35 out of 40 (87.5%) cases were the same between the two observers and only 5 cases (12.5%) were different. This correlation was tested by Kendall's tau-b test which was statistically significant with p-value<0.001. The responses of the two observers were consistent (87.5%) for the conventional radiographs and their comments on radiopacity of materials were reliable (Table 1).

Table 1: Results of radiopacity of combined composite resin restorations in conventional radiography from the viewpoint of two observers (interpreters)

	Weak		Moderate		Good		Excellent		Total	
Observer 1/ Observer 2	No.	%	No.	%	No.	%	No.	%	No.	%
Weak	4	10	0	0	0	0	0	0	4	10
Moderate	0	0	11	27.5	3	7.5	0	0	14	35
Good	0	0	2	5	10	25	0	0	12	30
Excellent	0	0	0	0	0	0	10	25	10	25
Total	4	10	13	32.5	13	32.5	10	25	40	100
p-value<0.001										

It was observed that 37 (92.5%) out of 40 cases were the same between the two observers and their responses regarding the rate of materials opacity in CCD were different only in 3 cases (7.5%). This correlation was tested with Kendall's tau-b test which was statistically significant at p-value<0.001. The responses of the two observers were consistent with each other for digital images (92.5%) and their comments on materials opacity rate in these images are reliable (Table 2).

Table 2: Results of radiopacity of combined composite resin restorations in CCD from the viewpoint of the two observers

	Weak		Moderate		Good		Excellent		Total	
Observer 1/ Observer 2	No.	%	No.	%	No.	%	No.	%	No.	%
Weak	2	5	0	0	0	0	0	0	2	5
Moderate	0	0	13	32.5	0	0	0	0	13	32.5
Good	0	0	2	5	11	27.5	0	0	13	32.5
Excellent	0	0	0	0	1	2.5	11	27.5	12	30
Total	2	5	15	37.5	12	30	11	27.5	40	100
Kendall's tau-b Test: p-value<0.001										

Based on the information given in Table 1 (Table of Variances), the obtained opacity mean score in CBCT was as the following:

Conventional composite=2060 HU

Flow able composite=2411 HU

Glass ionomer=2326 HU

Amalgam=3095 HU

Based on the results given in the Table 2, the rate of opacity of materials used in the study was as follows:

Amalgam>flow able composite ≥ glassionomer>conventional composite

Based on the statistical results obtained, there was no significant difference between "glass ionomer and conventional composite" and "glass ionomer and flow able composite" regarding the rate of opacity with p-value<0.001. Furthermore, the comparison of the results of conventional radiography and CBCT using Kendall's tau-b test with p-value<0.001 demonstrated that there was a significant association between the two. The CBCT technique approved the results obtained with film. Additionally, the comparison of the results of digital imaging and CBCT using Kendall's tau-b test with p-value<0.001 demonstrated that there was a significant association between the two (Table 3).

Table 3: The opacity means score of combined composite restorations in CBCT in terms of materials used in the study

Type of Material	No. of Samples	CBCT mean score	SD
Conventional Composite	10	2060	0
Flowable Composite	10	2411.8	633.3
Glass ionomer	10	2326.9	265.4
Amalgam	10	3095	0
Total	40	2473.4	508.1
Kruskal-Wallis Test: p-value<0.001			

The CBCT technique approved the results obtained with CCD. The comparison of conventional radiography with the results of CCD revealed a significant correlation with p-value<0.001, but there was a trend. There was correspondence in more than 19 cases (less than 50%). 13 cases were shown more vividly by digital images than conventional films and 8 cases were less visible with digital images compared to conventional films. Conventional radiographs and digital images approve each other by 50%.

The results of CBCT were examined using Exact Test, Fisher Exact Test, and Chi-square Test showing a statistically significant relationship at p-value<0.001. Based on CBCT results:

For conventional composite, 100% of cases possessed moderate radiopacity. For flow able composite, 70% of cases showed moderate radiopacity, 20% showed excellent radiopacity, and 10% had weak radiopacity. For glass ionomer, 100% of cases had moderate radiopacity. For amalgam, 100% of cases showed excellent radiopacity, and none of the cases used in the study had good radiopacity. Based on the results in the table, it could be said that the materials used in the study can be ranked in the following way regarding the rate of radiopacity:

Amalgam>flow able composite ≥ glass ionomer>conventional composite.

Based on the results obtained from conventional radiographs, it was observed that for conventional composite, 40% of cases had good radiopacity, 40% moderate radiopacity, and 20% weak radiopacity. Also, for flow able composite, 40% of cases showed good radiopacity, 40% moderate radiopacity, and 20% weak radiopacity. Further, for glass ionomer, 50% of cases had good radiopacity, and 50% moderate radiopacity. Finally, for amalgam, 100% of cases possessed excellent radiopacity.

On the basis of the results given in the table, the radiopacity of materials used in the study was as follows:

Amalgam>flow able composite>glass ionomer ≥ conventional composite.

According to the results obtained from digital images, for conventional composite, 40% of cases had good radiopacity, 40% moderate radiopacity and 20% weak radiopacity. For flowable composite, 30% of cases possessed good radiopacity, 50% moderate radiopacity, and 20% excellent radiopacity. Also, for glass ionomer, 50% of cases had good radiopacity, and 50% moderate radiopacity. Finally, for amalgam, 100% of cases had excellent radiopacity. It could be asserted that regarding the rate of radiopacity, the materials under examination were as follows:

Amalgam>flow composite ≥ glass ionomer>conventional composite.

DISCUSSION

According to ADA guidelines, the filling materials should possess the following five mandatory characteristics [3]:

1. High wear resistance
2. Good marginal correspondence
3. Resistance against hydrolytic degeneration
4. Radiopacity
5. Easy application

Radiopacity of materials that used in dentistry has been evaluated by several techniques. Schoenfeld et al. created a theoretical model for explaining opacity of materials by giving a set of radiographic variables [15]. Other researchers proposed a similar technique of comparing specific thicknesses of composite to Aluminium step wedges or Aluminium standards under typical radiographic conditions [16-21]. In this study, the value of radiopacity was measured with Aluminium as the reference.

The radiopacity of composite resins plays an important role in composite restorations from tooth structure and recurrent caries. According to ISO-4049 the radiopacity of composite resins should be greater than dentine (equal to the opacity of the same or greater thickness of Aluminium). Nonetheless, excessive opacity is reported to be a negative trait as it diminishes the discrimination of recurrent caries from other defects [3,22,23].

Radiographs are valuable not only for assessing fillings but also for following their long-lasting stability. Radiopaque materials are more convenient for distinguishing recurrent caries in interdental radiographs in the interdental space and fillings compared to radiolucent materials. Very few studies have been carried out in the recent decade on radiopacity of dental composite resins. On the other hand, some new dental composites have been developed during this period [22]. CBCT is not widely used in diagnosing dental caries due to its high dose compared to many types of intra-oral radiographs; yet, this is still related to the conditions. For instance, if we are to obtain a full mouth series using D film without the use of square collimator, then CBCT is preferable [17]. On the other hand, the patient may be referred to radiologist to have CBCT for other reasonable causes. It is a good idea to diagnose caries in the CBCT images.

In our study, for all three methods of conventional film, CCD, and CBCT, all cases used in the study had radiopacity greater than enamel. The Aluminium wedge and CBCT were used as gold standard. On the basis of CBCT results (Hounsfield Numbers), the amalgam had the highest rate of opacity with excellent rank. Flowable composite came next with a great distance and glass ionomer followed it with a small distance. Conventional optic composite had the least amount of radiopacity with a weak rank though all these materials had opacity greater than enamel and dentine:

Amalgam>flowable composite ≥ glass ionomer>conventional composite

It was interesting to note that despite our expectation that we may not be able to read the gingival floor of the cavity and the region around the restoration due to the "metal artifact" of amalgam and the possibility of creation of metal artifact, this phenomenon was not severe enough to prevent us from examining the surrounding tissue. It should be noted that to reduce metal artifact due to amalgam, we used the smallest field of view (8 × 8).

The results of digital radiography were very similar to the results of CBCT:

Amalgam>flowable composite ≥ glass ionomer>conventional composite

We reached the same conclusion for conventional radiographs with a little more differences:

Amalgam>flowable composite>glass ionomer ≥ conventional composite

The conclusion is that all three materials studied had the required radiopacity for application in gingival floor of deep class II cavities. The present study found a linear correlation between conventional film and CCD. These findings were similar to those of Pedrosa et al. [3], Senel et al. [24], Park et al. [25], and Oztas et al. [14], yet they were different from the findings by Sabbagh et al. [26] and Salzedas et al. [27] who state that the results of digital system are less reliable than conventional film. This difference could be attributed to the type and methodology of their study. It has also been said that even if conventional films are processed and developed carefully, still there will be a significant difference between the ultimate image of a conventional film and a digital film, and of course, the results of the digital film are more stable [22]. Another study investigated the rate of radiopacity of composite resins using CCD, PSP, and the speedy conventional film E and found that it is unlikely that the type of imaging affects the rate of radiopacity [14]. Of the three imaging modalities, CBCT was more exact and accurate. As Charuakkra et al. [28] showed that CBCT diagnoses recurrent caries better than bitewing radiography. Also, CBCT images display noncavitated proximal caries more accurately than PSP and conventional radiographs. CBCT imaging should not be used as the first option in diagnosing caries in dental procedures [29]. Additionally, a study investigating the role of conventional film, CCD, PSP, and CBCT in caries diagnosis, found that all these modalities are similar in diagnosing proximal caries [25]. The amount of radiation to the patient should also be considered in selecting a method for caries detection; so as CBCT poses the patients to a higher degree of radiation.

Regarding the rate of radiopacity, of the four materials studied, amalgam is the best and most suitable material for restoration of gingival floor in deep class II cavities specifically in patients with high amounts of caries.

CONCLUSION

All of the tested material had enough radiopacity for evaluation of deep class II restoratives. Radiopacity rates were as follows: Amalgam>Flow ≥ Glass ionomer>Packable composite>Enamel>Dentin. Among the three imaging modalities (conventional film, CCD, PSP, and CBCT), CBCT was more exact and accurate. Also amalgam was the best and most suitable material for restoration of gingival floor in deep class II cavities specifically in patients with high amounts of caries.

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