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The visibility of secondary caries under bonding agents with two different imaging modalities

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This study investigated the visibility of secondary caries lesions associated with two different adhesive systems of composite restorations (Optibond Solo Plus and Clearfil SE Bond) using a conventional dental x-ray film (Kodak D Speed) and a digital system (Digora) based on storage phosphor-plate technology for detection of secondary caries. For imaging techniques and adhesive systems, false positive scores were high. Intraobserver agreements ranged between 0.432 and 0.778, while interobserver agreements for the readings ranged 0.321–0.731 and 0.411–0.701, respectively. No statistical difference was found between the Az (area under curve) values obtained from PSP (photostimulable storage phosphor) and film images with the exception of the second observer's first reading for total etch adhesive system (Optibond Solo Plus) (p=0.0258). Furthermore, no statistical difference was found between both the bonding systems assessed (p>0.05). Adhesive materials should also have enough radiopacity to facilitate diagnosis of secondary caries.

Keywords: Dental caries, Dental adhesives, Digital, Radiography

INTRODUCTION

There are four reasons usually cited for not removing the old restorative material: the additional expense to the patient involved in rebuilding the foundation, the possibility of pulp exposure, the extensive size of the old restoration, and the possibility of pulp irritation[1)]. Therefore, removing of old restorations should be avoided, unless the existence of secondary caries or incompatible restorations is detected[1)].

Composite materials are now widely used in dentistry, replacing amalgam, because they have the advantages of being free of mercury, resistant to corrosion, and thermally nonconductive[2)].

In spite of significant improvements in physical and chemical characteristics, secondary dental caries and wear resistance are still major concerns in composite restorations. Once detected clinically or radiographically, caries under a composite restoration can reach the pulpal chamber in as little as 6–8 months[3)]. In comparison, the same caries under an amalgam of restoration will take considerably longer to travel the same distance[3)].

Also inadequate opacity of adhesive resins used under composite restorations makes diagnosis more challenging and confusing. Radiographic detection of secondary caries because of the thick layer of adhesive system makes incipient caries invisible.

For proper assessment of the adequacy of composite restorations both at baseline and recall examinations, it is important that not only the composite materials, but also the bonding agents used in the restorations be sufficiently radiopaque to be easily distinguished from the tooth structure on a radiograph. Inadequate radiopacity decreases x-ray diagnostic information and can be a contributing factor for faulty interpretations, making it difficult to assess cavity wall adaptation, marginal gap, voids, and recurrent decay[4)].

Several studies have indicated that the radiopacity of a resin composite equal to or greater than that of enamel is desirable[4-6)]. However, little is known about the radiopacity of bonding agents. There are several dental bonding agents available for commercial use; however, no criteria exist regarding the standardization of the radiopacity of dental bonding agents.

Several studies regarding the imaging performance on caries detection under restorations have been performed. Conventional dental film and digital systems are usually compared[7-9)] Digital image analysis provides a direct record of radiographic density as determined by pixel shade, which is automatically recorded by computer software as a value ranged in 0–255[10)], in contrast to the continuous density curve in the analog film image[11)]. A conventional radiographic image consists of the arrangement of silver grains in photographic emulsion. The density of the silver grains depends on the intensity of the x-ray beam.

The aim of this study is to investigate the visibility of simulated incipient secondary caries lesions under two different adhesive systems of composite restorations, and comparison of conventional dental film and digital system on detection of secondary caries.

MATERIALS AND METHODS

Specimen Preparation

Forty-eight healthy anterior human teeth without caries which were extracted for periodontal reason were stored in 2% benzalkonium chloride. Before the extraction

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protocol, patients were signed an informed consent form in order to use their teeth in this study. In each tooth, mesial and distal cavities (totally 96 cavities) with the aid of a 2-mm-diameter round bur (ISO 806-314-023) were prepared. Simulated carious lesions were prepared in randomly selected 48 cavities using a 0.5-mm-diameter round bur on the gingival side. The lesions were then sealed with red wax. Other 48 cavities were left without simulated caries lesions. In addition, total etch adhesive system (Optibond Solo Plus; Kerr/Sybron, Orange, California, USA) was applied randomly in 48 cavities (24 with and 24 without simulated caries lesions), and a self-etch adhesive system (Clearfil SE Bond; Kuraray Noritake Dental, Tokyo, Japan) was applied randomly in the other 48 cavities (24 with and 24 without simulated caries lesions). Thereafter, all the cavities were restored with the same composite material (Spectrum TPH, Dentsply De Trey, Konstanz, Germany) and all teeth were embedded in wax in groups of four, making a total of 12 groups, with the proximal surfaces in contact.

Radiographic and digital imaging

The teeth were then radiographed by using an X-Ray unit (Evolution X 3000-2C, New Life Radiology Srl, Italy) at 70 kVp, 8 mA, and 0.2 s with a target-to-object distance of 30 cm under reproducible conditions. A D Speed dental film (Size 2, Eastman Kodak Company, Rochester, NY, USA) was used for image acquisition (Fig. 1). All radiographs were processed by automatic processor (Extra-x Velopex, Medivance Instruments Limited, London, England) with fresh solutions (Hacettepe, Ankara, Turkey) according to the manufacturer's instructions. Besides, all teeth were imaged by PSP system (Digora, Soredex, Helsinki, Finland) with a Size 2 plate at 70 kVp, 8 mA, and 0.18 s, with a target-to-object distance of 30 cm. Following exposure, PSP images were scanned immediately, stored and exported in a tagged image file (TIF) format (Fig. 2). The images were then viewed using IrfanView software on a 15" 32-bit color monitor at a 1024×768 pixel resolution (256 gray levels). Digital and film images were interpreted by three dentists (two oral radiologists and one specialist in restorative dentistry) twice a week. No detailed information was given to the observers about the aim of the study. They were independently evaluated the images for decision of the presence or absence of the secondary caries. Secondary caries was diagnosed according to a 5-point confidence rating. The rating scale expressed the presence or absence of caries adjacent to the restoration as: (1) almost definitely present, (2) probably present, (3) unsure, (4) probably not present, and (5) almost definitely not present.

Statistical analysis

Weighted kappa coefficients were calculated to assess intra- and interobserver agreement for each imaging technique, and scores were compared with the gold standard using receiver operating characteristic (ROC) analysis to evaluate diagnostic ability. In addition, the areas under the ROC curves (Az values) for each imaging technique, observer and reading, were calculated using the MedCalc statistical software. The Az values were compared using *t*-tests, with a significance level of 0.05, and Bonferroni correction was applied. Kappa values were calculated to assess intra- and interobserver agreement according to the following criteria: 0.10, no agreement; 0.10–0.40, poor agreement; 0.41–0.60, significant agreement; 0.61–0.80, strong agreement; and 0.81–1.00, excellent agreement. Also, the true positive rates (TPR) and false positive rates (FPR) for both the imaging techniques and adhesive systems were calculated.

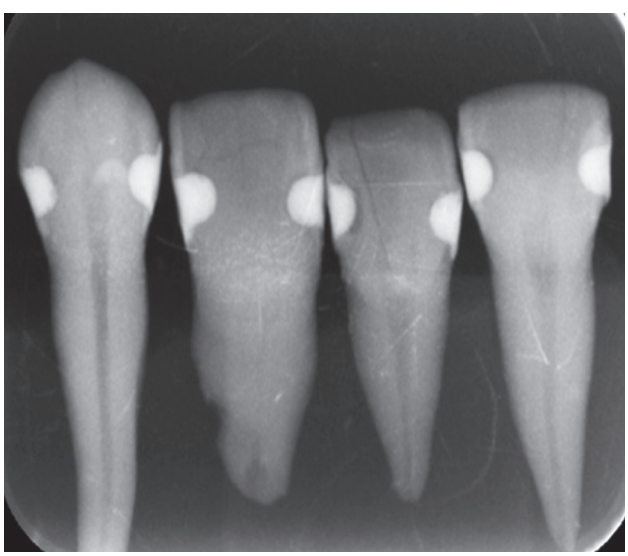


Fig. 1 Conventional radiograph of same teeth samples without caries showing bonding agents' radiolucent areas under composite restoration.

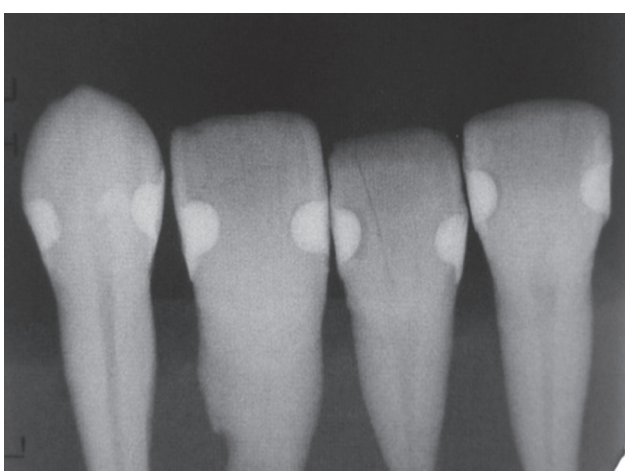


Fig. 2 Digital image of teeth samples without caries showing bonding agents' radiolucent areas under composite restoration.

RESULTS

Intraobserver agreements ranged between 0.432 and 0.778 (Table 1), while interobserver agreements for the first and second readings ranged 0.321–0.731 (Table 2) and 0.411–0.701 (Table 3), respectively. The Az values, their standard errors, and significance levels for the first readings of each observer are given in Table 4. The highest Az value obtained by all the three observers was 0.757. No statistical difference was found between the Az values obtained from PSP and film images, with the exception of the first observer's first reading for self-etch adhesive system (Clearfil SE Bond; Kuraray Noritake Dental, Tokyo, Japan) (p=0.028). Also, no statistical difference was found between both the bonding systems assessed (p>0.05). Furthermore, the FPR (False Positive Rate) for both the imaging techniques and adhesive systems were high (Table 5).

DISCUSSION

Resin composite systems have an inherent problem of contraction stress induced during polymerization. This stress may lead to adhesive failure, thus causing the formation of interfacial gaps between the restoration and dentin surfaces[12]. It was suggested that the thickness of adhesives significantly absorbs and relieves contraction stress. Dentin adhesives, particularly in thick layers, may compromise the radiographic detection of secondary caries and may lead to a false replacement diagnosis[12].

According to the International Standards Organization (ISO), the radiopacity of restorative material should be equal to or greater than the same thickness of aluminum and not be <0.5 mm of any value claimed by the manufacturer[13]. It is generally recommended that a restorative material as radiopaque as the enamel is ideal for caries detection[14,15]. The radiopacity of bonding agents depends on their filler content and the presence of heavier atoms of elements in the filler. Filler percentages and their types are

Table 1 Intraobserver agreement

	Observer 1	Observer 2	Observer 3
	Weighted Kappa-Se	Weighted Kappa-Se	Weighted Kappa-Se
Conventional-Optibond	0.475–0.118	0.533–0.112	0.723–0.053
Conventional-Clearfil	0.492–0.125	0.432–0.110	0.750–0.071
Digital-Optibond	0.752–0.089	0.711–0.091	0.778–0.052
Digital-Clearfil	0.754–0.092	0.680–0.080	0.650–0.097

Table 2 Interobserver agreement for first readings

	Obs1-Obs2	Obs 1-Obs3	Obs2-Obs3
	Weighted Kappa-Se	Weighted Kappa-Se	Weighted Kappa-Se
Conventional-Optibond	0.483–0.086	0.620–0.072	0.321–0.080
Conventional-Clearfil	0.457–0.092	0.672–0.071	0.452–0.082
Digital-Optibond	0.513–0.104	0.665–0.089	0.643–0.087
Digital-Clearfil	0.543–0.121	0.634–0.087	0.731–0.067

Table 3 Interobserver agreement for second readings

	Obs1-Obs2	Obs 1-Obs3	Obs2-Obs3
	Weighted Kappa-Se	Weighted Kappa-Se	Weighted Kappa-Se
Conventional-Optibond	0.421–0.078	0.611–0.062	0.496–0.076
Conventional-Clearfil	0.411–0.079	0.632–0.073	0.443–0.080
Digital-Optibond	0.502–0.114	0.650–0.081	0.620–0.081
Digital-Clearfil	0.513–0.100	0.618–0.086	0.701–0.067

Table 4 Az values, standard errors, and significance levels for each observer's first reading

Adhesive	Imaging System	Observer 1		Observer 2		Observer 3	
		Az (Se)	*p*	Az (Se)	*p*	Az (Se)	*p*
Optibond	Conventional	0.535 (0.40)	0.680	0.513 (0.62)	0.877	0.676 (0.68)	0.037
	Digital	0.591 (0.92)	0.279	0.757 (0.64)	0.02	0.571 (0.40)	0.397
Clearfil	Conventional	0.520 (0.64)	0.812	0.697 (0.60)	0.02	0.660 (0.56)	0.058
	Digital	0.643 (0.52)	0.089	0.480 (0.44)	0.812	0.644 (0.32)	0.087

Table 5 True positive rates (TPR) and false positive rates (FPR) for both the imaging techniques and adhesive systems

Adhesive	Imaging System	Observer 1		Observer 2		Observer 3	
		TPR	FPR	TPR	FPR	TPR	FPR
Optibond	Conventional	0.40	0.58	0.62	0.62	0.68	0.62
	Digital	0.92	0.72	0.64	0.61	0.40	0.57
Clearfil	Conventional	0.64	0.61	0.60	0.62	0.56	0.62
	Digital	0.52	0.63	0.44	0.59	0.32	0.55

the most important factors that influence a material's radiopacity[16]. Clearfil SE Bond used in the present study contains approximately 10% particle filler in its composition and the other adhesive system Optibond Solo Plus contains approximately 15% filler.

Although the manufacturers of composite materials have taken many measures, there is little information in the literature about the radiopacity of adhesive systems. Currently, no criteria exist regarding the bonding agent's radiopacity, although it plays a critical role in the ability to distinguish from both tooth structure and secondary caries on a radiograph.

As bonding agents used under composite restorations mimic the incipient caries, it is mostly difficult to determine the treatment procedure for clinicians. Hotta and Yamamoto[16] compared the radiopacity of 15 bonding agents and found that with the exception of Fluoro Bond II (Shofu; Kyoto, Japan), which had an aluminum-equivalent radiopacity similar to dentin, all other bonding agents tested had radiopacity values below that of dentin. In that study, they examined Optibond Solo Plus and Clearfil SE Bond, similar to the present study. Both the adhesive systems exhibited less opacity than dentin. They suggested that the radiopacity of bonding agents is insufficient to make them useful in clinical diagnosis[16].

The result of the present study show that all the observers who participated in the study expressed high false positive scores because the radiolucent image of the bonding agents led them to presume the presence of caries. As a result of the high number of false positive decisions and the lack of true negative decisions in the current study, it was proved that bonding agents with inadequate opacity can lead to a faulty replacement decision.

Pamir *et al.*[12] evaluated the bonding agents' influence on the decision to replace composite restorations. The result of that study showed that diagnosis of secondary caries seems to be a challenge with the currently used adhesive systems that possess insufficient radiopacity.

The differences in radiopacity between the restoration and the tooth are determined by the differences in the absorption of radiation. The absorption is dependent upon the composition of the material (radiopacity) and the thickness of the restoration in the x-ray beam direction[6].

It has been reported that radiopaque composites are more visible on radiographs in the anterior teeth than in the posterior teeth[17,18]. This is because the restorations are relatively thicker in the x-ray beam direction in the incisors, when compared with premolars and molars[9]. Therefore, we preferred to use anterior teeth in the present study.

Both the imaging techniques used in the present study exhibited same performance for the visibility of secondary caries. In line with our study, Nair *et al.*[7] found that the performance of conventional film, enhanced PSP, and CCD images was not significantly different on the detection of simulated recurrent decay. In a study about the diagnostic accuracy of different imaging modalities in detection of proximal caries performed by Senel *et al.*[19], it was found that PSP plates and film exhibited a detection level similar to that observed in the present study. False replacement diagnosis usually occurs in radiological examination of patients with composite restorations, due

to the radiolucent appearance of bonding agents, which mimic dental caries. Incorrect treatment procedure, such as renewal of restorations, may be carried out because of difficulty for the clinician to come to a decision about the origin of radiolucency that is from the secondary caries or bonding agent. This condition also leads to loss of time and money for the clinician and the patient. Although there are many studies on different properties of bonding materials, such as physical and mechanical, those on radiographical density evaluation is considerably scarce. Bonding materials should have adequate radiopacity to be distinguished from secondary caries lesions, and further studies should be conducted with commercially available adhesive materials to encourage their manufacturers to produce materials with more appropriate opacity levels.

CONCLUSION

The present results indicate that both bonding systems and imaging modalities assessed are not statistically different from each other for the visibility of secondary caries. It was also concluded that as bonding systems used under composite restorations mimic secondary caries, they should have adequate radiopacity.

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