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Prevalence and Characteristics of Radiographic Radiolucencies Associated with Class II Composite Restorations

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Abstract: Bitewing radiographic examination of the Class II composite restorations is commonly performed for diagnosis and preoperative planning of posterior teeth. The purpose of this study was to describe the prevalence; location; and characteristics of radiolucency findings associated with proximal class II composite restorations. Bitewing radiographs of proximal composite restorations of healthy adult patients (18 to 88 years old) who underwent restorative care at predoctoral clinics at the University of Maryland School of Dentistry from August 2016 to July 2019 were identified. Atypical radiographic features were categorized by location and associated material (adhesive or composite). In addition, demographic and clinical details (tooth position; restored surface) were recorded. Out of the 669 radiographically examined bitewings of restorations; 16.5% of radiographs showed no atypical findings; and 83.5% had unusual radiographic signs. The atypical radiographic findings were distributed as 16.5% internal voids; 3% overhang; 7.8% interlayer lines; 12.6% secondary caries; 20.7% interfacial gaps; and 23.1% multiple atypical findings. Class II composite restorations have a high prevalence of atypical radiolucency; particularly in the body of the composite; premolars; and disto-occlusal restorations. The information reported here emphasizes the clinical challenge of ascertaining an appropriate diagnosis of the radiolucencies underneath composite restorations.

Keywords: radiography; bitewing; dental composite; dental caries; bonding

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1. Introduction

Bitewing radiographic examination of the Class II composite restorations is commonly performed for diagnosis and preoperative planning of posterior teeth. The American Dental Association (ADA) recommends a posterior bitewing exam for adults with high caries risk every six to eighteen months. In contrast, exams can be recommended for adults with low caries risk every two to three years [1–3]. From a radiographic point of view, successful restorative treatment can be measured by the absence of radiographic signs suggestive of underlining carious lesions, open margins, voids, or overhang [4,5]. However, determining the health status of the restoration is challenging when radiolucent areas (radiolucencies) are associated. Particularly for Class II restorations because of the proximal gingival interface. Misdiagnosing radiolucencies may lead to unnecessary restoration replacement or a delayed diagnosis with failure in timely access to dental care.

About half of all restorations placed in adults in general dental practice are replacements [6]. Replacement restorations take up a substantial part of the tooth structure than the initial restorative treatment for the primary carious lesion. Therefore, they are very

cost-intensive for patients and the health system [7,8]. In addition to the financial burden imposed on the patient, there are other reasons to avoid replacement, such as the risk of pulp exposure and pulp irritation [9].

In daily practice, the complexity of the diagnosis of radiolucencies is even more challenging. For example, radiolucencies observed at the interface restoration\cavity walls can be predictive of a lack of the adequate seal, which can directly contribute to secondary caries formation [10,11]. Moreover, an increased adhesive thickness layer or low adhesive opacity may impose some difficulties in diagnosis [2,11]. Another factor affecting radiographic evaluation is the concentration of radiopacifiers in the composite. Low radiopacity in the resin-based material makes it hard to discriminate between composite and tooth structures [12]. The radiographic limitation of bitewings should also be considered. In a 2D view of a 3D object, a radiolucent lesion could be superimposed on the restoration and be missed. Therefore, the potential influence of radiolucency findings during recall bitewing of class II composites on replacement outcomes remains controversial.

From a functional perspective, voids within restorations may negatively affect the material's mechanical properties over time [13]. Reduced resistance to fatigue and wear, due to their contribution to the initiation and propagation of cracks, may lead to premature failure of the restoration when subjected to mechanical and external loads [14,15]. The presence of voids in the body of composite restorations has also been reported to be a detrimental factor for the clinical longevity of posterior composites [16].

Secondary caries is reported to be the most common reason to replace or repair a defective dental restoration in general practice [6]. If gaps or voids are at the margin, there is a risk of leakage and secondary caries. Detecting carious lesions, or gaps at margins caught by explorer associated or not with reported pain and sensitivity symptoms often assist in precise diagnosis and decision to replace the restoration [17]. However, secondary caries diagnosis without clinical findings can pose a challenge [18,19], leading to uncertainty regarding the need to replace or repair existing restorations. Besides assessing a patient's caries risk status, radiographic interpretations are critical for new patients who have received comprehensive treatment from another provider and are now under periodic evaluation.

This scenario suggests that although significant technological advances and educational efforts are underway, mainstream awareness of these findings is still lacking. Therefore, The purpose of this study was to describe the prevalence, location, and characteristics of radiolucency findings associated with proximal class II composite restorations completed in a university setting.

2. Methods and Materials

2.1. Study Design

This retrospective cohort study uses 669 bitewing radiographs with Class II restorations selected to quantify the prevalence of atypical radiographic findings in Class II composite restorations. The study was approved by the respective Institutional Review Board (IRB) (HP-00084713).

A digital search using Electronic Health Records (EHR) on Axium (Exan Group, Las Vegas, NV, USA). The search filtered patients aged 18–84 years old who would qualify for the following categories: (1) patients with two or more surface resin-based restorations placed by third and fourth-year dental students on posterior teeth from August 2014 to July 2016. (2) Patients with single, two-, four-, or vertical bitewings were taken from August 2016 to July 2017. Data were extracted into a Microsoft Excel file (Microsoft, Redmond, WA, USA).

2.2. Eligibility Criteria

Inclusion criteria included men and women between 18–84 years old who underwent Class II restorative treatment from August 2016 to July 2019. Only bitewing radiographs captured with direct digital sensors were included. In this study, we included XDR (XDR Radiology, Los Angeles, CA, USA), the available digital sensor system at the university

with a flexible intraoral X-ray unit, wall mounted (milliamperage (8 mA), kilovoltage (63 kVp), and time (0.08 s)).

The exclusion criteria included posterior bitewing radiographs showing superimpositions on the restoration, poor image quality, or using different restorative material other than composite resin. In addition, excluded radiographs displaying objects or restoration interfere with the vision of the Class II composite restoration, such as orthodontic brackets, Class V restoration, or crown. Also, radiographs that do not show the assigned tooth due to extraction or bitewings that guide the teeth on the contralateral side were excluded (Table 1).

Table 1. Description of the categories for classification of findings.

Location	Category	Description
	No atypical radiographic finding	No radiolucent or radiopaque results suggesting atypical radiographic findings in composite restoration
Body of the restoration Mass of composite constituting the restoration	Internal void/porous	Void = pore Circular volumetric (2D) empty radiolucent spaces located at the body
	Interlayer line	Lack of continuity between the composite layers characterized by a thin radiolucent line
	Overhang	Excess radiopaque composite in the interproximal area
Bonding interface Surface (Line) between tooth and composite	Internal gap–not gingival margin	Lack of continuity, radiolucency between the composite and tooth not involving gingival margins
	External gap–at the gingival margin	Radiolucency, lack of continuity between the composite and tooth involving gingival margins: usually "notch" shape.
	Secondary caries	Presence of radiolucency in dentine indicating recurrent caries
	Other	More than one radiographic finding indicating multicategory

2.3. Radiographic Assessment

Digital radiographs were assessed by two examiners (general dentists with 2 and 20 years of experience, respectively). In cases of disagreement, a consensus was obtained. Reliability tests were performed for the radiographic assessment (kappa = 0.72). After three months, approximately 50% of the radiographs were re-evaluated under the same settings to calculate the intra-examiner reproducibility.

Six hundred sixty-nine images in the jpg format from 351 patients were assessed using MiPacs software (Medicare Imaging, Charlotte, NC, USA) displayed on ViewSonic VX3276-MHD 32" high definition light-emitting diode backlit display monitor (native resolution 1535 × 2048) in a view distance of 70 cm in dim lighting. Radiographic filters were applied to adjust sharpness and brightness. Three hundred thirty-five radiographs were excluded following the exclusion criteria (Figure 1).

2.4. Categorization of the Radiographic Findings

Three hundred thirty-four included images were transferred to PowerPoint (Microsoft) on black slides. Slides were labeled with the sample number, tooth number, and restoration surface. PowerPoint Slides and Excel sheets were linked with a numeric coding system for each sample. A classification was designed to codify the radiographic findings and used for screening. The classification consists of a description of each category intended to reduce ambiguity. Figure 2 illustrates the definition used for findings classification in a bitewing radiographic image.

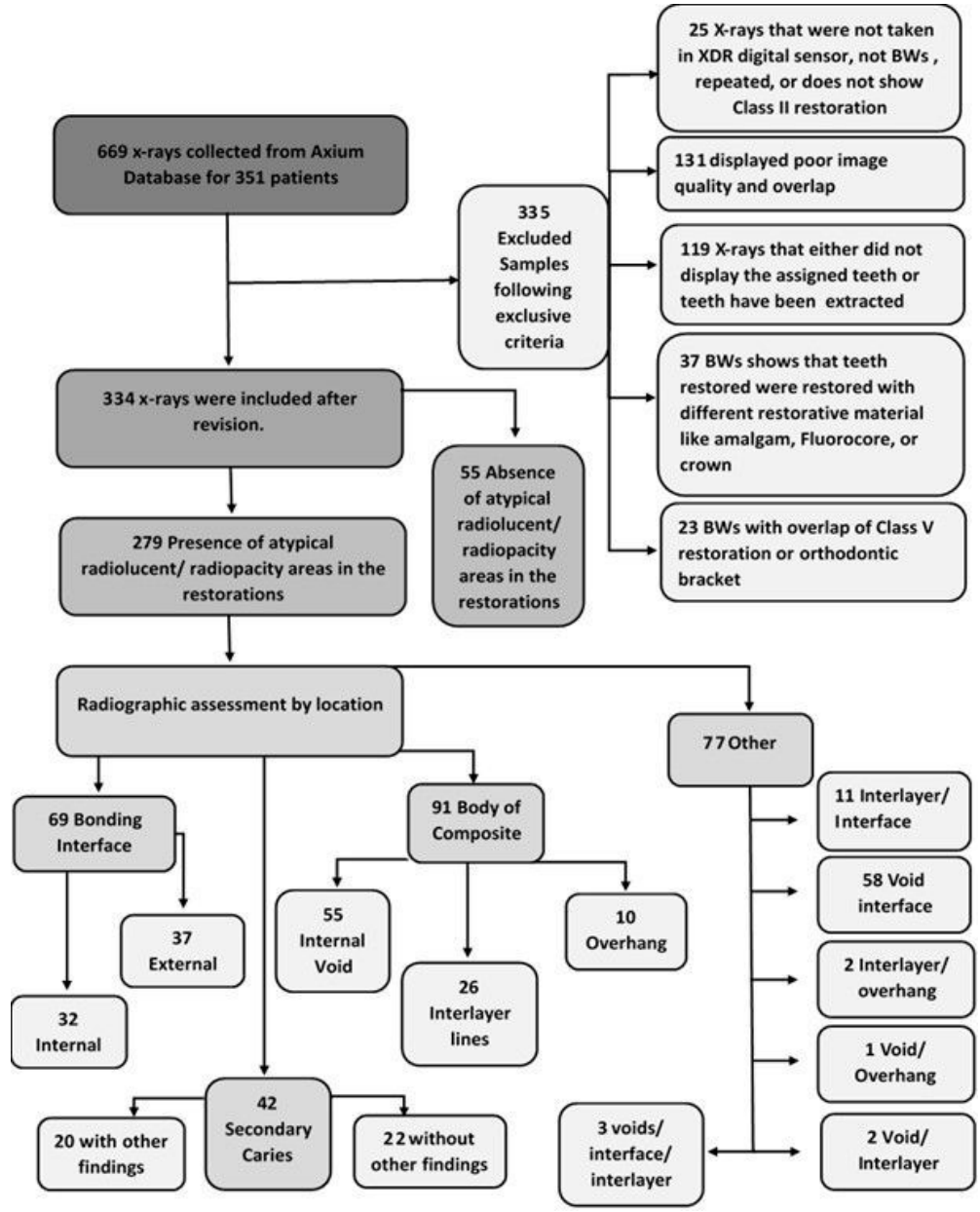

Figure 1. Flow chart showing the selection criteria and categorization of the findings used in this study.

From the pool of 334 included x-rays, 55 bitewings showed no atypical radiographic findings, and 279 showed atypical radiolucency/radiopacity findings. This category of radiographs sets the appearances classifiable as standard, normal appearance. This atypical radiolucency category refers to radiographs where areas of radiolucency are present. Those divisions are defined by the standard radiographs, together with the written description. The presence or absence of a radiolucent halo adjacent to the gingival, mesial, distal, and pulpal walls was considered to assess the bonding interface.

The 279 bitewings were categorized according to the type of material (composite or adhesive) and location (internal or external) (Table 1). The information recorded for each patient included age, sex, tooth, and restored surface. Guidelines were placed to avoid misinterpretation of bond interface radiolucency and secondary caries. Radiolucent areas detected at the cavity preparation walls were considered interfacial gaps. Large radiolucent regions not bound to the preparation structure and extending into the dentine were interpreted as secondary caries. The radiographic prevalence of atypical findings was presented as frequencies and percentages, whereas demographic variables were presented as frequen-

cies and percentages when appropriate. Figure 3 displays a panel of radiographic images illustrating some of the radiolucences associated with Class II composite restorations. A. Secondary caries, B. Voids in the body of the composite, C. Interlayer lines within the body of composite, D. External gap, E. Internal gap, and F. Combination of void in the composite and internal gap at the bonding interface.

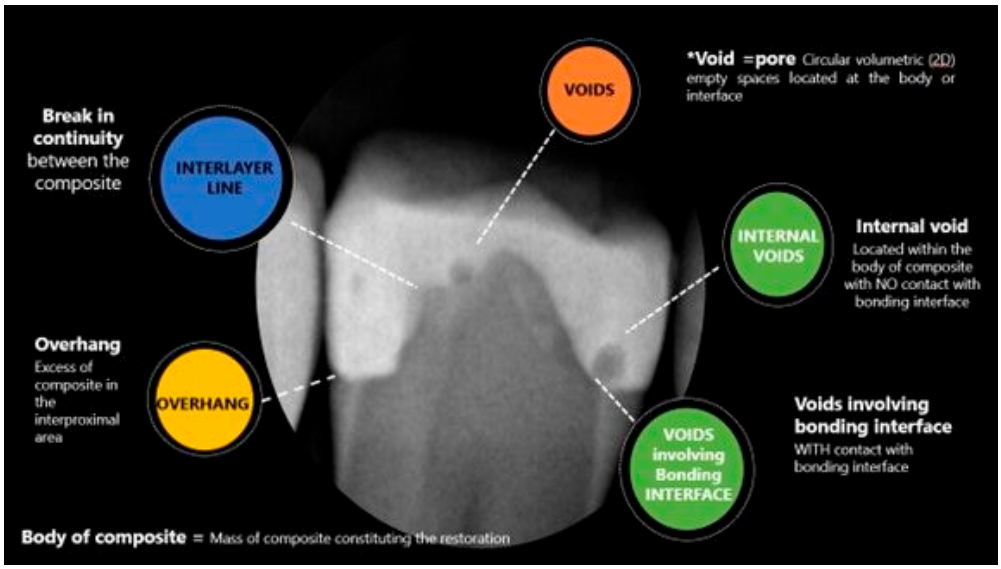

Figure 2. Illustrative scheme of the classification criteria for radiographic findings in class II composite restorations.

Figure 3. A panel of radiographic images illustrating some of the radiolucences found associated with Class II composite restorations (yellow arrows are highlighting the area of interests). (**A**) Secondary caries, (**B**) Voids in the body of the composite, (**C**) Interlayer lines within the body of composite, (**D**) External gap, (**E**) Internal gap, and (**F**) Combination of void in the composite and internal gap at the bonding interface.

3. Results

Table 2 summarizes the results of the radiographic findings. Of 669 bitewing radiographs, 335 were excluded for meeting the exclusion criteria; therefore, 334 bitewings were used in the current study. 55 (16.5%) BW did not show any atypical radiographic findings. However, 279 (83.5%) radiographs showed radiolucent or radiopaque areas in the restoration, suggesting atypical radiographic findings.

Table 2. The prevalence of radiographic abnormalities found in class II composite restorations.

Radiographic Finding	Frequency/Total	Percentage %
No atypical findings	55/334	16.5%
Atypical findings	279/334	83.5%
Bonding interface	69/334	20.7%
External bonding interface	37/334	11.1%
Internal bonding interface	32/334	9.6%
Body of composite	91/334	27.2%
Internal Void	55/334	16.5%
Interlayer lines	26/334	7.8%
Overhang	10/334	3.0%
Secondary caries	42/334	12.6%
With other radiographic findings	20/334	6.0%
Without other findings	22/334	6.6%
Other findings	77/334	23.1%
Interlayer/interface	11/334	3.3%
Void interface	58/334	17.4%
Void/overhang	1/334	0.3%
Void/interlayer	2/334	0.6%
Void/interlayer/interface	3/334	0.9%
Interlayer/overhang	2/334	0.6%

There were 91 of 279 (27.2%) restorations that had at least one atypical finding in the body of the composite recorded and were classified as follows: 55(16.5%) presented with internal body voids, 26 (7.8%) interlayer lines, 10 (3%) demonstrated radiopacity suggesting overhang. Sixty-nine (20.7%) restorations showed a discontinuity in the adhesive bond area, leaving a gap between the tooth structure and the composite. Thirty-seven (53.6%) of these restorations had notch-like appearance suggesting a noticeable gap at or around the gingival margin, and 32 (46.4%) out of the 69 had an internal inconsistency between tooth structure and resin-base material not involved with the exogenous seal of the restoration. Secondary carious lesions were in 42 (12.6%) restorations. Of the 42 restorations suggesting secondary caries, 20 (47.6%) had other radiographic findings, and 22 (52.4%) did not present with additional radiographic findings other than secondary caries.

Furthermore, 77 (23.1%) restorations presented multiple radiolucencies or mixed radiolucency and radiopacity abnormal radiographic findings. In addition, 11(3.3%) BWs indicate the tooth bond interface gap and interlayer gaps between the body of composite layers. Next, the remaining bitewing radiographs with multiple radiolucent findings were classified as follows: 58 (17.4%) restorations presented with voids within the composite and bonding interface, 2 (0.6%) restorations had void interlayer radiolucencies, and 3 (0.9%) BWs revealed radiolucencies of interlayer lines and voids within composite with the interface.

Three bitewings presented heterogenous radiographic findings composing radiopaque and radiolucent areas. Of the three, 1 (0.3%) restoration had radiolucent composite body pore and radiopaque excess composite, indicating an overhang on the gingival margin. The other 2 (0.6%) BWs showed radiolucent lines within the composite body and radiopaque overhang. Table 3 describes the information recorded for each patient, including age, sex, tooth, and restored surface.

Table 3. The prevalence of radiographic abnormalities found in class II composites restorations among genders, age groups, tooth, and restoration surfaces.

Radiographic Finding		Gender		Age				Tooth		Restoration Surface		
		F	M	<21	21–45	46–65	>65	PM	M	MO	DO	MOD
No Voids	freq.	36/55	19/55	0/55	29/55	20/55	6/55	24/55	31/55	20/55	28/55	7/55
	perc.	65.5%	34.5%	0.0%	52.7%	36.4%	10.9%	43.6%	56.4%	36.4%	50.9%	12.7%
Internal Void	freq.	37/55	18/55	2/55	29/55	22/55	2/55	38/55	17/55	11/55	36/55	8/55
	perc.	67.3%	32.7%	3.6%	52.7%	40.0%	3.6%	69.1%	30.9%	20.0%	65.5%	14.5%
Interlayer	freq.	15/26	11/26	2/26	16/26	6/26	2/26	18/26	8/26	4/26	15/26	7/26
	perc.	57.7%	42.3%	7.7%	61.5%	23.1%	7.7%	69.2%	30.8%	15.4%	57.7%	26.9%
Overhang	freq.	5/10	5/10	1/10	4/10	5/10	0/10	6/10	4/10	6/10	3/10	1/10
	perc.	50%	50%	10%	40%	50%	0%	60%	40%	60%	30%	10%
Interface	freq.	35/69	34/69	3/69	36/69	21/69	9/69	44/69	25/69	24/69	38/69	7/69
	perc.	51%	49%	4%	52%	30%	13%	64%	36%	35%	55%	10%
Caries	freq.	23/42	19/42	3/42	16/42	19/42	4/42	30/42	12/42	13/42	19/42	10/42
	perc.	55%	45%	7%	38%	45%	10%	71%	29%	31%	45%	24%
Other	freq.	58/77	19/77	2/77	43/77	26/77	6/77	65/77	12/77	11/77	53/77	13/77
	perc.	75%	25%	3%	56%	34%	8%	84%	16%	14%	69%	17%

4. Discussion

This study aimed to establish the prevalence of radiographic abnormalities in class II composite restorations. The prevalence rates and data obtained in this radiographic analysis resonate with the previously comprehended notion that radiographic assessment, class II composite, continues to be underrecognized.

Voids within the body of the restoration are also referred to as porosities or bubbles. Here, referred to as internal voids, represented a large subset of these atypical findings. This study found a prevalence of 16.5% of voids, while Opdam [20] found a majority of 70% of voids in vitro study using a light microscope to assess the presence of voids in the composites. Voids are caused by air entrapment and incorporated inadvertently into composites during their manipulation or even while being manufactured [20]. Olmez et al. found that internal voids correlated with marginal microleakage in class II composite restorations. Voids can affect the mechanical properties and indirectly reduce the lifespan of dental composites [21]. They mainly degrade matrix-dominated properties such as interlaminar shear strength, longitudinal compressive strength, and transverse tensile strength [22]. The presence of voids within composites can trigger the crack formation and stress development. The stress development varies according to the location of the void in the restoration. Suppose the void is located at the restoration/tooth interface. In that case, the volumetric shrinkage will harm the immediate area of the void due to the stress development around it, resulting in increased vulnerability to the adhesive failure of the composite [18]. In addition, the force distribution within the material causes stress development due to the volumetric shrinkage of the material on the void [22]. Voids between the layers of class II composite were another subset of our study. In the previously

mentioned in vitro study, nearly 63% of the examined samples had voids between the layers [23]. These results were substantially higher than the 7.8% examined radiographically in the present study. Pre-molars and disto-occlusal restorations had a high rate in this radiographic condition. The appearance of interlayer gaps is frequent in incremental techniques if the layers are not appropriately adapted [24]. These interlayer gaps affect the physical properties of the restoration [23]. All the restorations were assumed to be performed by an incremental technique using Optibond solo unidose (Kerr, Brea, CA, USA) and low-viscosity or high-viscosity universal hybrid composites TPH Spectra ST (Dentsply, Milford, DE, USA) available in the predoctoral clinics.

The operator's ability may also have influenced this outcome. Providers performed all the restorations under training (juniors and senior dental students). Sixty-five percent of voids were found in restored premolars, and 69% accounted for two surfaces (disto-occlusal) restorations. Cavity preparations in premolars are often conservative. They are represented by slot preparations compromising the proximal lesions and occlusal access. The placement and adaptation of the first increment of composite on the bottom of the slot preparation may offer challenges due to the restricted access. Furthermore, in specific clinical scenarios, the distal box of the preparation can be more difficult for visualization and adaptation of the material.

Three percent of the examined restorations had overhangs. Reeves et al. [25] found similar rates of 4% of prevalence overhang [26]. The positive ledge at the margins is an iatrogenic factor for gingivitis through mechanical irritation. Jasson et al. [27] showed higher radiographic attachment loss with marginal overhangs in periodontally involved patients [27]. Corroborating with this find, Reeves et al. [28] also suggest the degradation of local periodontal health and the promotion of secondary caries formation [28]. The irregular rough surface of the overhang acts as the perfect area for bacterial plaque accumulation. The presence of overhang is mainly caused by incorrect proximal matrix placement. Prior studies have pointed out that applying low-viscosity composites may increase the presence of overhang [29].

Twenty-one percent of the radiographs examined had an abnormal adhesive interface, implying the presence of radiolucent areas between the restoration and tooth structure (Table 3). Furthermore, 11.1% of this radiographic condition is present as an external bonding interface and 9.6% as an internal interface gap. This result is consistent with previously published findings for a 14% (111/770) bond layer interface and 11.8% (91/770) lack of adaptation, which includes both external interface gap and overhang [30].

Gaps at the gingival margins are a dilemma for class II composites is the most common zone for secondary caries development. Our data indicated a higher prevalence of external gaps at the gingival margin. This result is less than other studies of 33 % underfilled restorations [23]. The gingival interfacial gap at the enamel level suggests weaker bonds and higher microleakage potential at the dentine level [28]. Several studies showed a correlation between the depth of the ditched margins and the demineralization process [29,30].

Other technique-related factors can also create radiolucent halos [31]. For example, a thick adhesive layer can lead to misdiagnosis and retreatment [7]. On the other hand, a more apparent radiolucent zone promoted by adhesive pooling in the bottom of the cavity may be easily interpreted as secondary caries, marginal gaps, or voids beneath the restoration [31–33]. According to Frohlich et al. [34], the relative risk of identifying a radiolucent zone under restoration in sound and demineralized dentin were 2 and 1.85 times higher when two adhesive layers were applied. Very experienced dentists may consider the morphology of the radiolucency, trying to distinguish between secondary caries and the adhesive layers, but it remains an educated speculation. To obtain assurance that the radiolucencies are not recurrent caries underneath the composite, many dentists prefer to replace the restoration entirely, which may be completely unnecessary. Radiopacity has thus become a critical property for dental restorations. For this reason, radiopaque glass particles—such as barium, strontium, and zirconia atoms, or microfillers containing yttrium and ytterbium are incorporated into adhesive formulations. The radiopacity of

adhesive depends on their filler content and type of filler. Optibond Solo, use in the present study, contains approximately 15% of glass filler.

Here, suggestive radiolucencies indicative of secondary caries were observed in 12.6% of the bitewings. A study evaluating radiographs had consistent findings of 15% (119/770) [27]. In another study, suggestive radiolucencies indicative of secondary caries were diagnosed radiographically in 14% of restorations [35]. Examination of bitewings for radiolucent secondary caries is a diagnostic challenge. Because the image only mirrors the extent of demineralization, radiographs alone cannot diagnose secondary caries. However, the radiographic appearance of the demineralization (radiolucency) can assist the dentist in clinically diagnosing secondary caries. Many factors can influence the ability to detect these alterations accurately, such as exposure parameters, type of image receptor, image processing, display system, and viewing conditions. Furthermore, the illusory optical effect of each band appears when there is a vast difference between the radiopacity of the tooth structure and restorative material [36]. Therefore, optical illusions such as the Mach-band effect and phenomena such as the cervical radiolucency (burn-out effect) may be falsely interpreted as caries lesions [34,37,38]. In the present study, we have managed to cover the restoration (less radiopacity) with a black square filter during radiographic evaluation to inhibit the false effect on optical receptors.

We acknowledge several limitations of our study. First, it is a database review and was limited by the number of patients with adequate radiographs. The radiographs that were excluded were not indicative of clinically unacceptable radiographs. The BW radiographs exclusion was based on parameters that would affect the accurate detection and calculation of the prevalence of atypical radiographic abnormalities. The 83.5% prevalence of atypical findings is an aggressive estimate of the restorative practice because this percentage was based on patients who received restorative treatment from dental students. Dental students are providers under training, and their performance may differ from general dentists with years of experience. Published results in the previous study showed a difference in the resulting restorations between operators [20]. Finally, many studies discussed the presence of atypical radiographic findings in bitewings. However, these variables were discussed separately, and there was limited research on the prevalence of radiographic interlayer gaps [20,23,27,36].

Second is the subject-defined parameters for assessing the adhesive interface. We have not measured the thickness of adhesive space and did not include a quantitative reference for it. Thus, we may have underestimated the number of atypical adhesive interfaces. Likewise, not much information was provided in the records to know if any liners were applied underneath the restoration. Liners would contribute to the radiolucency. Third, our study does not include clinical data such as pain or sensitivity on oral examination, analysis of the interpretation of radiographs by oral care providers, or assessment of patients' restoration complaints.

In summary, our findings reinforce the importance of accurate radiographic analysis to allow optimal treatment planning and avoid the unnecessary replacement of the restorations. In addition, the dentist should be aware of the confounding variable and how we can minimize it by following high-quality bonding and composite placement and knowing the characteristics of the materials used for the restorations. Finally, further studies should be conducted with adhesive materials to encourage manufacturers to produce materials with more appropriate opacity levels.

5. Conclusions

This study showed a high prevalence of radiolucencies associated with class II composite restorations. The radiolucencies prevailed in the composite body (voids), followed by the bonding interface. The findings were also most observed in premolars, and disto-occlusal restorations. Clinicians need to be more aware of confounding factors pertinent to the diagnosis of radiolucencies associated with composite restorations.

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