

EVALUATION OF THE OCCLUSAL COMPOSITE RESIN RESTORATIONS BASED ON CARS CRITERIA AND OPTICAL METHODS: A CROSS-SECTIONAL STUDY

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Abstract

Aims of the study were as follows: to assess the status of posterior coronal composite resin restorations using the CARS criteria and the optical methods DIAGNOdent Pen and VistaCam; to analyze the correlation between clinical CARS scores and the scores recorded by the DIAGNOdent Pen (KaVo) and VistaCam (Dürr Dental) devices in the evaluation of composite resin restorations. **Materials and methods:** The retrospective study included 32 patients (mean age: 24.25 ± 2.918 years; gender: 13 males, 19 females; $p = 0.526$). A total of 161 direct composite resin restorations aged between 3 and 5 years were evaluated clinically and using DIAGNOdent Pen (KaVo) and the VistaCam device (Dürr Dental). Statistical analysis was conducted using SPSS 29.0, applying both parametric and non-parametric tests to evaluate associations between clinical findings and optical methods outcomes. **Results:** Based on CARS scores, 54% of restorations showed enamel-limited demineralization, with no cases of extensive cavitation. DIAGNOdent Pen results indicated that 49.7% of restorations had signs of enamel or dentin demineralization, with a mean value of 18.40 ± 15.50 . VistaCam evaluation revealed that 30.4% of restorations had varying degrees of demineralization, while 69.6% presented healthy enamel margins, with a mean value of 0.73 ± 0.88 . **Conclusions:** More than half of the restorations exhibited various degree of enamel demineralization. The overall consistency among CARS scores, DIAGNOdent Pen readings, and VISTACam values supports the integration of fluorescence-based technologies into routine clinical practice for improved diagnostic accuracy and conservative treatment planning.

Keywords: composite resins, restorations, CARS, DiagnodentPen, VistaCam

INTRODUCTION

The visual-tactile detection of caries adjacent to coronal composite resin restorations increases the risk of over- or under-diagnosis, depending on the experience and competence of the dentist. The strategy used to evaluate caries adjacent to coronal restorations can lead to different treatment decisions—more or less invasive—depending on the type of clinical scoring systems used for visual-tactile assessment. For example, the use of FDI criteria (caries recurrence, marginal staining, and adaptation) leads to a higher number of invasive interventions compared to the CARS criteria [1].

The weak correlation between the CARS criteria and the presence of marginal

staining often results in misinterpretations regarding the presence of caries adjacent to composite resin restorations, as staining is a poor predictor of caries [2].

As for the CARS scores, scores 1, 2, and 3 are clinically relevant (indicating the need for topical fluoride) only if the carious lesion surrounding the restoration is progressing (active lesion). In such cases, topical fluoride application is recommended, while scores 4, 5, and 6 are clinically significant because they indicate the need to repair or replace the restorations [1]. Meanwhile, the FDI criteria for caries adjacent to coronal restorations do not take into account the activity of the carious lesion, which more often leads to unnecessary intervention decisions.

The diagnostic process for caries adjacent to composite resins restorations should be based solely on clinical (and in some cases radiographic) signs of the lesion, and not on the marginal characteristics of restorations [3, 4]. The management of caries adjacent to coronal restorations should be based on revision/repair/partial restoration/replacement of defective restorations, as recently defined in a Delphi expert consensus statement [5].

In clinical practice, occlusal caries adjacent to composite resin restorations often go undetected until they progress to microcavitation or even until significant tooth structure loss occurs [6]. In this context, some research groups investigating dentists' preferences, perspectives, trends, and attitudes regarding the use of modern diagnostic methods have reported low usage rates worldwide. This is largely due to a lack or deficiency of knowledge about the performance of these methods, as well as concerns related to cost, skepticism, and/or fear of change [7-9]. Therefore, dentists must be familiar with both the operating principles and the specific threshold values of each diagnostic method that indicate the presence and severity of dental caries. In this context, dentists have come to recognize the importance of modern (optical) techniques in detecting incipient primary caries and caries adjacent to coronal restorations. Devices such as the DIAGNOdent (latest version: DIAGNOdent Pen, KaVo), DIAGNOcam (KaVo), and VistaCam (Dürr Dental) are among the preferred choices for dentists in Europe and the USA [12]. When deciding to purchase and use these devices, dentists should consider balancing sensitivity—which allows for early intervention to

prevent lesion progression—with the device's specificity, which helps minimize the risk of false positives and unnecessary invasive treatments.

Given that visual-tactile assessment shows low diagnostic accuracy [11], combination of clinical evaluation methods with optical methods for assessing occlusal composite resin restorations may improve both clinical efficiency and communication with patient regarding therapeutic decisions of non-intervention, repair, or replacement [12-16].

The aims of the study were as follows:

- To assess the status of coronal composite resin restorations using the CARS criteria and the optical methods DIAGNOdent Pen and VistaCam.
- To analyze the correlation between clinical CARS scores and the values recorded by the DIAGNOdent Pen (KaVo) and VistaCam (Dürr Dental) devices in the evaluation of posterior composite resin restorations.

MATERIALS AND METHOD

The retrospective study included 32 patients (mean age: 24.25 ± 2.918 years; gender: 13 males, 19 females) who presented for evaluation at the Clinical Base of the Faculty of Dental Medicine, “Grigore T. Popa” University of Medicine and Pharmacy, Iași (Romania). A total of 161 direct composite resin restorations aged between 3 and 5 years were evaluated. The research was conducted in accordance with the ethical principles of the Declaration of Helsinki and received approval from the Ethics Committee of “Grigore T. Popa” U.M.Ph. Iași. All

patients were informed about the study objectives and provided written informed consent. Inclusion criteria: occlusal and occluso-proximal posterior composite restorations; cavities classified as ICDAS 05–06; vital molars or premolars; age ≥ 18 years. Exclusion criteria: non-carious lesions; bruxism; high consumption of cola beverages, coffee, or black tea.

Prior to the clinical examination, dental surfaces were cleaned using a ProphyJet device to effectively remove all organic deposits that could lead to false-positive results. The clinical evaluation of composite resin restorations was performed using the CARS criteria (Table 1), on a scale from 0 to 6.

Table 1. CARS criteria and therapeutic protocol [14]			
Code	Lesion Appearance	Description	Recommended Therapeutic Management
0	Sound tooth surface with restoration or sealant	No evidence of changes in enamel translucency due to caries after plaque removal and air-drying. Non-carious surfaces with enamel defects (including fluorosis), erosive tooth wear, and extrinsic/intrinsic stains are considered caries-free.	No treatment
1	First visual change in enamel	Changes in enamel seen as carious opacity or visible discoloration (white/brown spots) inconsistent with healthy enamel, without surface breakdown, underlying dentin shadow, or cavitation.	No treatment – inactive adjacent lesions OR Topical fluoride – active adjacent lesions
2	Distinct visual change in enamel/dentin adjacent to the restoration margin	White/brown lesion with microcavity/discontinuity, no visible dentin exposure. Visible after drying.	No treatment – inactive adjacent lesions OR Topical fluoride – active adjacent lesions
3	Caries defects <0.5 mm with Code 2 signs	Marginal caries in enamel/dentin/cementum adjacent to the restoration with a dark shadow suggesting dentin involvement.	Repair OR Replacement * Replacement should be considered if caries affects more than half the restoration
4	Marginal caries in enamel/dentin/cementum adjacent to restoration with underlying dark dentin shadow	Visibly discolored dentin under an apparently intact surface or microcavity. Easily observed with moist tooth surface.	Repair OR Replacement * Replacement should be considered if caries affects more than half the restoration
5	Distinct cavity adjacent to the restoration	Visible dentin cavity in opaque/discolored enamel.	Replacement

		A WHO/CPI/PSR probe can easily confirm that the cavity extends into dentin.	
6	Extensive cavity with visible dentin	A clearly visible extensive cavity affecting both enamel and dentin.	Replacement

For each patient, a single examiner (the doctoral student) conducted the clinical assessment (visual-tactile method), followed by the evaluation of restored teeth

DIAGNOdent Pen (KaVo) – Laser Fluorescence Technique (655 nm)

The evaluation of coronal restorations using the DIAGNOdent Pen device was based on the value ranges proposed by the manufacturer and by various research groups [10, 15, 17]. In the first stage, the device was calibrated using the reference disc and a smooth surface of the upper right central

using the DIAGNOdent Pen (KaVo) and the VistaCam device (Dürr Dental), in accordance with the value ranges and codes recommended by the manufacturers.

incisor (tooth 1.1). In the second stage, the margins of the restorations were scanned, and the maximum values were recorded in areas susceptible to caries. The cut-off values established by the manufacturer for detecting incipient caries were also used to detect adjacent to coronal restorations using the DIAGNOdent Pen fall within the range of 20–30 on the device's numerical scale [18] (Table 2).

Table 2. DiagnodentPen values

Value	Description
< 13	healthy enamel
13-20	early enamel demineralisation
20-25	enamel caries
>25	dentine caries

VistaCam (Dürr Dental) – Visible Light-Induced Fluorescence Technique (405 nm)

Images of the restored tooth were captured using the VistaCam, with the intraoral camera tip, by focusing the camera with the focus adjustment button. Subsequently, the interchangeable Proof head was used, with the focus level preset by applying the spacer, and then further adjusted using the focus button. The interchangeable Proof head was employed

both for identifying margins of enamel that were superficially or deeply demineralized, as well as for visualizing bacterial plaque. The optical system includes two blue-violet light LEDs (wavelength 405 nm), which act on the hard dental tissues and the microbial metabolic by-products of cariogenic bacteria (porphyrins). The values indicating the status of dental tissues adjacent to coronal restorations are presented below, according to the manufacturer (Table 3).

Table 3. Valori VistaCam

Color	VistaCam value	Description
Green	0-1	healthy enamel
Blue	1-1,5	early enamel caries
Red	1,5-2,0	caries limited to enamel-dentine jonction

Orange	2,0-2,5	external third dentine caries
Yellow	>2,5	deep dentine caries

Statistical Analysis

The distribution of caries adjacent to coronal restorations in relation to the investigated parameters was illustrated using graphs created in Microsoft Excel. Statistical analysis was performed using SPSS version 29.0. The analyzed parameters were described using frequency distributions and descriptive statistics. For univariate analysis of numerical parameters, the Mann-Whitney and Kruskal-Wallis tests were used to compare samples, after verifying whether their value distributions followed a normal distribution using the Kolmogorov-Smirnov goodness-

of-fit test. For qualitative parameters, contingency tables were constructed, and the Pearson Chi-square test was used to identify statistically significant differences. Associated risks were evaluated where statistically significant differences were observed.

RESULTS

Figures 1.a-c show clinical and paraclinical (DiagnodentPen, VistaCam) aspects of caries adjacent to occlusal composite restoration.



Fig. 1.a. Clinical aspect- CARS score 3.4



Fig. 1.b. DIAGNOdent Pen evaluation
(43- carie extinsă la nivel dentinar)

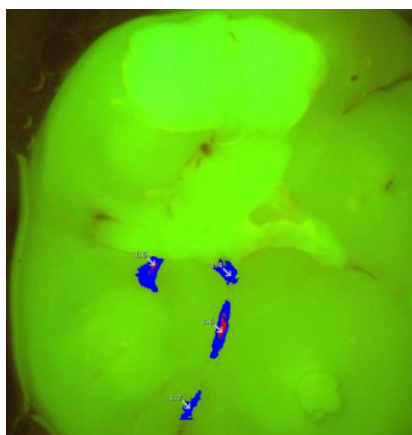


Fig. 1.c. VistaCam evaluation
(1,5- demineralisation extended to enamel-dentine junction)

The distribution of CARS scores, DIAGNOdent Pen and VISTACam values in the study group is shown in Table 4 and Figures 2.a–d.

According to the clinical evaluation (CARS scores), 46% of restorations were assigned code 30 (absence of demineralization at the enamel margins), 29.8% were given code 31 (demineralization without microcavitation), 11.2% were scored as code 32 (demineralization with discontinuity/microcavitation), 6.8% as code 33 (microcavitation with possible dentinal involvement but without visible dentin), and 6.2% as code 34 (discolored dentin visible through a microcavity or an apparently intact surface). Codes 35 and 36 were not present in the investigated sample. According to the CARS index, 54% of restored teeth presented at least one area of demineralization limited to the enamel margins adjacent to composite resin coronal restorations.

According to the DIAGNOdent Pen examination, 50.3% of restorations fell within the 0–12 value range (no demineralization), 21.7% were classified in the 13–25 range (enamel-limited demineralizations), and 28% were in the >25 range (caries extending into dentin).

According to the VISTACam assessment, 69.6% of restorations were evaluated with values between 0–1 (healthy enamel margins), 7.5% received values of 1.5 (enamel-limited demineralizations), 24.9% received values of 2.0 (demineralizations extending beyond the enamel-dentin junction), and 8.1% received values of 2.5 (deep, extensive demineralizations).

According to Table 4, the mean value was 18.40 ± 15.497 for the DIAGNOdent Pen examination (value range 13–25), and 0.734 ± 0.8823 for the VistaCam examination.

Table 4. Descriptive statistical analysis
for DIAGNOdent Pen and VISTACam Values

	N	Mean	std.error	Std.dev	Min	Max	Mediane
VISTACam	161	0.734	0.0695	0.8823	0.0	2.5	0.000
DGNPEN	161	18.40	1.221	15.497	2	72	12.00

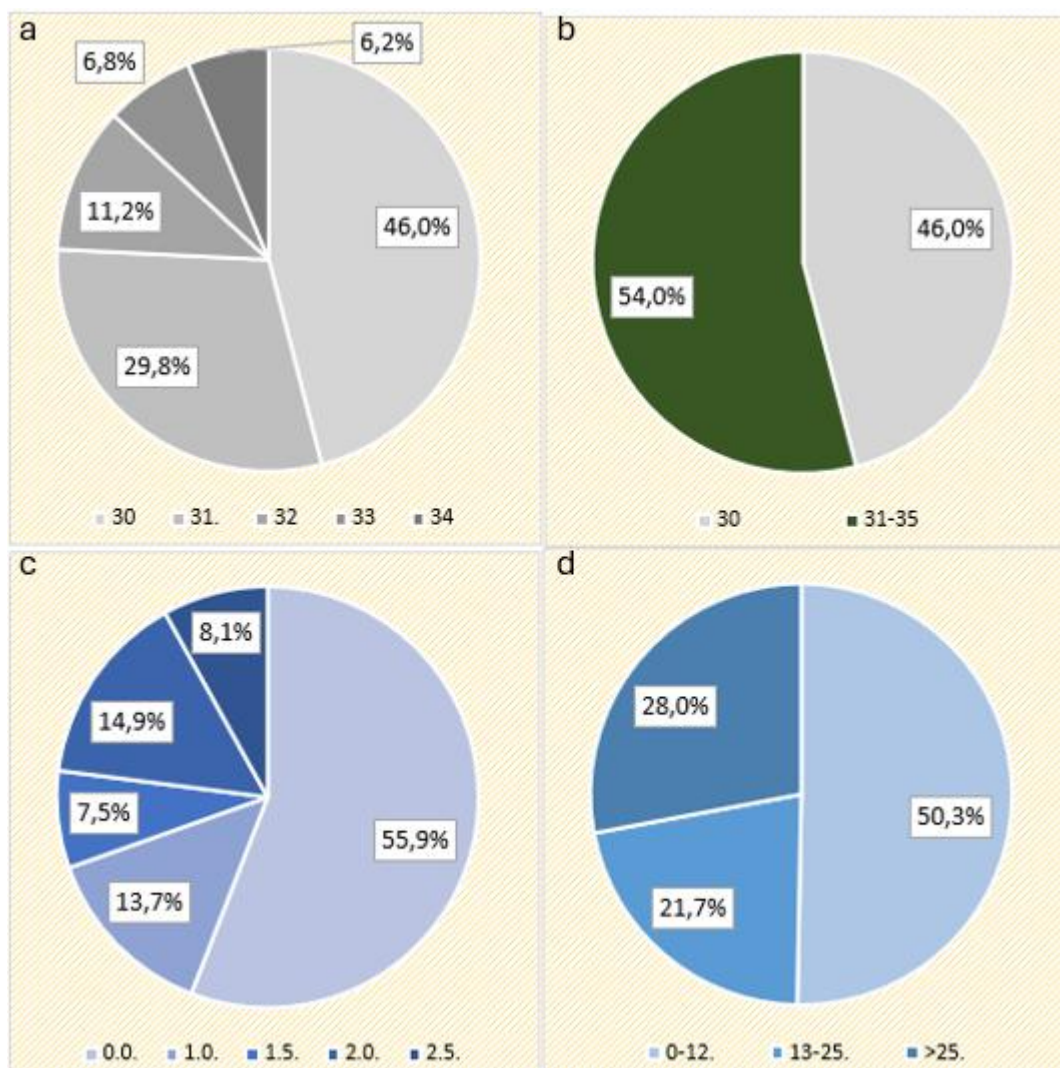


Fig.2.a-d. Distribution of clinical scores CARS(Figures 6.5.a-b),
VISTA Cam values (Fig. 6.5.c), DIAGNOdentPen values (Fig. 6.5.d)

Table 5 shows the analysis of Spearman's non-parametric correlation coefficients between the CARS scores, VISTACam, and DIAGNOdent Pen values. A strong, statistically significant, direct proportional correlation was established between the following variables:

- CARS scores and VISTACam codes ($\rho = 0.665$);
- CARS scores and VISTACam values ($\rho = 0.639$);
- CARS scores and DIAGNOdent Pen values ($\rho = 0.785$);

- VISTACam codes and DIAGNOdent Pen values ($\rho = 0.755$);
- VISTACam codes and DIAGNOdent Pen scores ($\rho = 0.744$).

Table 5. Spearman Test: Statistical Analysis of the Correlation Between CARS Scores and DIAGNOdent Pen and VISTACam Values

Confidence Intervals of Spearman's rho	Spearman's rho	p-value	95% CI	Interpretation
CARS - VISTA code	0.665	<0.001**	0.565 – 0.745	Direct, strong, statistically significant correlation
CARS - VISTA value	0.639	<0.001**	0.534 – 0.724	Direct, strong, statistically significant correlation
CARS - DIAGNOdent Pen	0.785	<0.001**	0.715 – 0.839	Direct, strong, statistically significant correlation
VISTA code - DIAGNOdent Pen	0.755	<0.001**	0.678 – 0.816	Direct, strong, statistically significant correlation
VISTA value - DIAGNOdent Pen	0.744	<0.001**	0.663 – 0.807	Direct, strong, statistically significant correlation

DISCUSSIONS

In the diagnosis of caries adjacent to coronal restorations, research groups focus on the diagnostic accuracy of each technique in relation to the type of restorative material used, in order to achieve precise and predictable results [8].

Schwendicke et al. (2016) reported that modern methods for detecting carious lesions adjacent to coronal restorations are effective when used in combination and when specific threshold values are considered [17]. This approach helps reduce the likelihood of false-positive diagnoses, which could otherwise lead to

unnecessary, invasive, and cost-ineffective overtreatment. However, in routine practice, dentists predominantly rely on visual-tactile examination in combination with radiographic evaluation. As such, there is no clear representation of clinical criteria that would help dentists make appropriate decisions regarding non-intervention, minimally invasive intervention (repair), or invasive treatment (replacement) [17]. Thus, in fissures and retentive margins where the probe becomes stuck, or areas with discoloration at the margins of restorations are present, these may be misdiagnosed as caries adjacent to restorations [18].

In this context, the working hypothesis of our study was that the values displayed by the DIAGNOdent Pen device (laser fluorescence method) and VistaCam (visible light-induced fluorescence method) correlate with clinical scores (CARS system) in the diagnosis of caries adjacent to composite resin coronal restorations. Through the statistical tests conducted, we aimed to either confirm or reject this hypothesis. This study was not designed to compare the diagnostic accuracy of the clinical method (CARS criteria) with that of the two optical methods, but rather to assess the status of coronal restorations by determining the degree of correlation between the CARS scores and the value ranges measured with the DIAGNOdent Pen device, as well as the VistaCam codes. The interpretation of the results is therefore limited to this objective.

The correlation between the values measured with the DIAGNOdent Pen and the clinical CARS scores supports the use of the laser fluorescence method in detecting caries adjacent to composite resin restorations, a finding confirmed by data in the literature [4, 19]. CARS scores showed a strong and statistically significant correlation with both the VISTACam codes and values, as well as with the DIAGNOdent Pen values. The VistaCam iX fluorescence camera demonstrated a high level of correlation with clinical scores (CARS) in detecting carious lesions limited to the enamel (3.1–3.2) or with possible extension into dentin (3.3–3.4). We noted that CARS scores of 3.2–3.4 correlated with DIAGNOdent Pen values > 25 and VistaCam codes ≥ 2 , values which, according to manufacturers, indicate caries progression into dentin. VISTACam codes and values also showed a strong and

statistically significant correlation with DIAGNOdent Pen values, demonstrating the validity of these two optical methods in detecting caries adjacent to composite resin coronal restorations. The distribution of CARS scores revealed that more than half of the evaluated restorations exhibited some degree of enamel demineralization, emphasizing the importance of early detection of marginal lesions in composite resin restorations. The absence of scores 35 and 36 in the clinical evaluation suggests a low prevalence of advanced dentinal caries in the study group, possibly due to the inclusion of patients with recent or well-maintained restorations. The DIAGNOdent Pen results were largely consistent with the clinical findings, with approximately half of the restorations falling within the “no demineralization” range, supporting its use as a non-invasive tool for monitoring lesion progression. VISTACam values confirmed the clinical and DIAGNOdent findings, with nearly 70% of restorations showing healthy enamel margins, while around one-third presented signs of enamel or dentin-level demineralization, aligning with the CARS score distribution. The comparative distribution of values across the three methods supports the integration of optical technologies into routine clinical practice to enhance the detection and monitoring of early carious changes adjacent to restorations.

Interpretation of results from studies investigating the sensitivity and specificity of optical diagnostic methods varies due to differences in methodology, such as inclusion and exclusion criteria for teeth and differences in threshold values across studies [20]. The laser fluorescence method has shown similar sensitivity values (ranging from 0.50 to 0.59) and

specificity values (ranging from 0.78 to 0.83). Both visual and laser fluorescence detection proved satisfactory in diagnosing caries adjacent to composite resin restorations, while tactile evaluation demonstrated lower diagnostic accuracy. For the laser fluorescence method in detecting non-cavitated caries located at enamel margins adjacent to composite restorations, Ghoncheh et al. (2017) reported values as follows: at a cut-off value of 8.5: sensitivity was 0.73, with significantly lower specificity (0.57); at a cut-off of 9.5: sensitivity was 0.68, with specificity of 0.67; at a cut-off of 10.5: sensitivity was 0.62, with significantly higher specificity (0.82); a specificity value of 1.00 was reported for the laser fluorescence method at a threshold of 29 [4]. According to these results, Ghoncheh et al. (2017) recommended the threshold value of 8.5 as a baseline for screening caries adjacent to composite restorations in epidemiological or large-scale *in vitro* studies [4]. However, threshold values between 8.5 and 10.5 carry a higher risk of false-positive diagnoses. Both Ghoncheh et al. (2017), at a threshold of 29 (specificity 1), and Rodrigues et al. (2010), referring to a threshold of 30, highlight that these higher values carry an increased risk of false-negative diagnoses [4, 21]. Neuhaus et al. (2012), in a study evaluating the detection capacity of caries adjacent to composite restorations, reported sensitivity values ranging from 41% to 81%, and specificity values ranging from 60% to 80% for the laser fluorescence method [22]. Bamzahir et al. (2005) reported a sensitivity of 60% for the laser fluorescence method in detecting caries adjacent to composite coronal restorations, compared to just 44% for visual inspection. However, specificity

was 82% for the laser fluorescence method and higher—96%—for visual examination [15].

While visual examination and radiography may have limitations in detecting occlusal caries adjacent to coronal restorations—since these lesions are often hidden beneath the restoration margins—DIAGNOdent Pen can complement these methods by providing an objective measurement of enamel and dentin demineralization adjacent to restorations [14].

Although dentists with long-term clinical experience are generally more familiar with the clinical and paraclinical diagnostic techniques for detecting caries adjacent to coronal restorations compared to younger dentists and dental students, Hamikashi et al. (2014) concluded that the laser fluorescence method produced promising results in detecting caries adjacent to composite resin coronal restorations, regardless of the operator's level of clinical experience [12]. However, in the interpretation of our study results we must consider some limitations of the DIAGNOdent Pen in detecting occlusal caries adjacent to coronal restorations: interference from restorative materials—natural fluorescence of certain restorative materials, such as composites or amalgam, can influence measurement results, potentially leading to false-positive or false-negative readings; individual variability in teeth and restorations—differences in the composition and structure of teeth, as well as in the materials used for restorations, can affect the accuracy of the DIAGNOdent Pen (a tooth discolored due to prior tetracycline therapy may exhibit increased fluorescence, potentially resulting in inaccurate readings) [16].

Regarding the VISTACam device (Dürr Dental), its operating principle is based on blue light-induced fluorescence, which varies depending on the condition of the hard dental tissues. Carious enamel margins emit a different fluorescence (weaker or of a different color) compared to healthy enamel. The resulting fluorescent image is analyzed to detect the presence of caries or other dental issues. The digital scores provided by the VistaCam device typically range between 0.9–1.1. A key advantage is that these scores are not affected by dryness or moisture caused by saliva, though the presence of blood residues should be avoided [23]. The major benefit of this system include real-time imaging. However, specific limitations in detecting caries adjacent to occlusal coronal restorations include [16]: interference from materials, particularly those with intrinsic fluorescence (e.g., composites may produce false-positive or false-negative results); limited access to areas beneath restorations: since the system relies on the reflection and fluorescence of light from the tooth surface, caries located under restoration margins may go undetected until they are more advanced and visible on radiographs; interpretation errors due to tooth structure variability: areas with hypomineralization or inactive demineralizations may lead to inaccurate readings; need for calibration and operator experience: incorrect use or misinterpretation of the images can result in false-positive or false-negative diagnoses.

One limitation of this study was the use of a single examiner (the doctoral candidate) to assess coronal restorations both clinically and with the two optical methods. While involving multiple examiners could introduce additional

sources of variability, adherence to objective criteria by a single examiner helps eliminate inter-examiner variability, thereby enhancing internal consistency [1]. Another limitation was the absence of a method to evaluate the examiner's ability to consistently record clinical and paraclinical scores under identical conditions over time. However, this can be mitigated by employing well-defined criteria based on detailed scoring systems, which strengthens intra-examiner reproducibility, provided that standardized measures are used to minimize measurement variations [1]. Under these conditions, intra-examiner reliability in caries detection is high and is expected to remain stable over time [24]. Similar to studies on the diagnosis of non-cavitated occlusal caries, where validation through fissurotomy may raise ethical concerns [16], we did not validate the presence of carious lesions adjacent to restorations through operative intervention for the same ethical reasons. CARS scores of 30 and 31 were assessed clinically without further validation through removal of the restoration or carious enamel margins. A limitation of *in vivo* studies is the lack of validation using the gold standard—histopathological examination. Ideally, histopathology is used as the reference standard to assess the demineralisation extension in occlusal early caries [25]; however, it is restricted to *ex vivo* studies or can only be performed in clinical studies involving a small number of teeth scheduled for extraction and subsequent laboratory analysis [26].

CONCLUSIONS

- More than half of the restorations exhibited some degree of enamel demineralization, reinforcing the need

- for early identification of caries adjacent to coronal restorations to prevent lesion progression.
- The overall consistency among CARS scores, DIAGNOdent Pen readings, and VISTACam values supports the integration of fluorescence-based technologies into routine clinical practice for improved diagnostic accuracy and conservative treatment planning.
- A strong, statistically significant, direct proportional correlation was established between CARS scores and VISTACam values, CARS scores and DIAGNOdent Pen values, and between VISTACam codes and DIAGNOdent Pen values.
- The threshold values established by the manufacturers for the laser fluorescence method are correlated with the CARS scores and VISTACam codes in detecting caries adjacent to composite resin coronal restorations.
- The codes defined by the manufacturer for assessing the severity stages of dental caries using VistaCam (visible light fluorescence method) are correlated with the CARS scores and DiagnodentPen in the detection of caries adjacent to composite resin coronal restorations.

REFERENCES

1. Signori C; CaCIA collaborative group; Uehara JLS, Romero VHD, Moro BLP, Braga MM, Mendes FM, Cenci MS. Comparison of two clinical approaches based on visual criteria for secondary caries assessments and treatment decisions in permanent posterior teeth. *BMC Oral Health*. 2022 Mar 18;22(1):77. doi: 10.1186/s12903-022-02112-6.
2. Demarco FF, Collares K, Correa MB, Cenci MS, Moraes RR, Opdam NJ. Should my composite restorations last forever? Why are they failing? *Braz Oral Res* 2017, 31(suppl 1):e56.
3. Schwendicke F, Splieth CH, Bottenberg P, Breschi L, Campus G, Doméjean S, Ekstrand K, Giacaman RA, Haak R, Hannig M, Hickel R, Juric H, Lussi A, Machiulskiene V, Manton D, Jablonski-Momeni A, Opdam N, Paris S, Santamaria R, Tassery H, Zandona A, Zero D, Zimmer S, Banerjee A. How to intervene in the caries process in adults: proximal and secondary caries? An EFCD-ORCA-DGZ expert Delphi consensus statement. *Clin Oral Investig*. 2020 Sep;24(9):3315-3321.
4. Ghoncheh Z, Zonouzy Z, Kiomarsi N, Kharazifar MJ, Chiniforush N. In Vitro Comparison of Diagnostic Accuracy of DIAGNOdent and Digital Radiography for Detection of Secondary Proximal Caries Adjacent to Composite Restorations. *J Lasers Med Sci*. 2017;8(4):172-176.
5. Nassar HM, Yeslam HE. Current Novel Caries Diagnostic Technologies: Restorative Dentists' Attitude and Use Preferences. *Healthcare (Basel)*. 2021 Oct 17;9(10):1387. doi: 10.3390/healthcare9101387.
6. Radwan W, AlNasser AA, Aloqab H, Al-Saggaf K, Almuhtab NA, Alnasyan B. Knowledge and Use of Caries Detection Methods among Dental Students and Dental Practitioners in Riyadh, Saudi Arabia. *Int J Dent*. 2020 Dec 2;2020:8825890. doi: 10.1155/2020/8825890
7. Tagliaferro E., Junior A.V., Rosell F.L., Silva S., Riley J.L., Gilbert G.H., Gordan V.V. Caries diagnosis in dental practices: Results from dentists in a Brazilian community. *Oper. Dent*. 2019;44:E23–E31. doi: 10.2341/18-034-C.

8. Spagopoulos D, Michou S, Gizani S, Pappa E, Rahiotis C. Fluorescence and Near-Infrared Light for Detection of Secondary Caries: A Systematic Review. *Dent J (Basel)*. 2023 Nov 28;11(12):271. doi: 10.3390/dj11120271.
9. Brouwer F, Askar H, Paris S, Schwendicke F. Detecting Secondary Caries Lesions: A Systematic Review and Meta-analysis. *J Dent Res*. 2016 Feb;95(2):143-51.
10. Abrams T., Abrams S., Sivagurunathan K., Moravan V., Hellen W., Elman G., Amaechi B., Mandelis A. Detection of Caries Around Resin-Modified Glass Ionomer and Compomer Restorations Using Four Different Modalities In Vitro. *Dent. J*. 2018, 6, 47.
11. Diniz MB., Eckert GJ., González-Cabezas C., Cordeiro RC., Ferreira-Zandona AG. Caries Detection around Restorations Using ICDAS and Optical Devices. *J. Esthet. Restor. Dent*. 2016, 28:110–121.
12. Hamishaki KS, Chiniforush N, Monzavi A, Khazarazifard MJ. An in vivo comparison of two diagnostic methods in secondary caries detection. *J Dent (Tehran)*. 2014;11(1):17-21.
13. Rodrigues JA, Neuhaus KW, Hug I, Stich H, Seemann R, Lussi A. In vitro detection of secondary caries associated with composite restorations on approximal surfaces using laser fluorescence. *Oper Dent*. 2010 Sep-Oct;35(5):564-71.
14. Pitts NB, Ekstrand K. International caries detection and assessment system (ICDAS) and its international caries classification and management system (ICCMS) - Methods for staging of the caries process and enabling dentists to manage caries. *Community Dent Oral Epidemiol*. 2013;41:41–52..
15. Bamzahim M, Aljehani A, Shi XQ. Clinical performance of DIAGnodont in the detection of secondary carious lesions. *Acta Odontol Scand*. 2005 Feb;63(1):26-30.
16. Walsh L.J. Caries Diagnosis Aided by Fluorescence. In *Dental Caries*; InTech Open: Rijek, Croatia, 2018.
17. Schwendicke F, Brouwer F, Paris S, Stolpe M. Detecting Proximal Secondary Caries Lesions: A Cost-effectiveness Analysis. *J Dent Res*. 2016 Feb;95(2):152-9.
18. Kopperud SE, Staxrud F, Espelid I, Tveit AB. The Post-Amalgam Era: Norwegian Dentists' Experiences with Composite Resins and Repair of Defective Amalgam Restorations. *Int J Environ Res Public Health*. 2016 Apr 22;13(4):441. doi: 10.3390/ijerph13040441.
19. Abrams TE, Abrams SH, Sivagurunathan KS, Silvertown JD, Hellen WMP, Elman GI, Amaechi BT. *In Vitro* Detection of Caries Around Amalgam Restorations Using Four Different Modalities. *Open Dent J*. 2017 Dec 12;11:609-620.
20. Salama M, Hassanein O, Shaalan O, Yassen A. Clinical effectiveness of high definition fluorescence camera in detection of initial occlusal caries. *J Clin Exp Dent*. 2022 Feb 1;14(2):e177-e184.
21. Rodrigues JA, Neuhaus KW, Hug I, Stich H, Seemann R, Lussi A. In vitro detection of secondary caries associated with composite restorations on approximal surfaces using laser fluorescence. *Oper Dent*. 2010 Sep-Oct;35(5):564-71.
22. Neuhaus K.W., Rodrigues J.A., Seemann R., Lussi A. Detection of proximal secondary caries at cervical class II-amalgam restoration margins in vitro. *J. Dent*. 2012, 40: 493–499.
23. Shakibaie F, Walsh LJ. Effect of oral fluids on dental caries detection by the VistaCam. *Clin Exp Dent Res*. 2015 Dec;1(2):74-79.
24. Qudeimat MA, Alomari QD, Altarakemah Y, Alshawaf N, Honkala EJ. Variables affecting the inter- and intra-examiner reliability of ICDAS for occlusal caries diagnosis in permanent molars. *J Public Health Dent*. 2016 Winter;76(1):9-16.
25. Topoliceanu C, S. Stoleriu, A. Gheorghe, M. Salceanu, A.V. Sandu, S. Andrian. Chemical changes of enamel occlusal surfaces affected by incipient dental caries : an EDX study. *Rev. Chimie*, 2013; 64, 11:1324-1328.
26. Foros P, Oikonomou E, Koletsi D, Rahiotis C. Detection Methods for Early Caries Diagnosis: A Systematic Review and Meta-Analysis. *Caries Res*. 2021;55(4):247-259.