

# In vivo effectiveness of visual inspection and laser fluorescence in the diagnosis of early pit-and-fissure carious lesions

## A cross-sectional study in a group of Romanian children

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### Abstract

General practitioners are still facing great challenges in the management of occlusal caries. Therefore, the development of better diagnostic protocols and assessment of caries activity might improve the results of nonoperative treatment. This study aimed to evaluate the effectiveness of visual inspection based on ICDAS-II (International Caries Detection and Assessment System) and DiagnoDent pen in the detection of pit-and-fissure early lesions in young permanent molars. The evaluation of 237 occlusal surfaces and caries risk assessment were performed in 96 children aged 7 to 15 years. The presence of pit-and-fissure noncavitated lesions was recorded using ICDAS-II scoring system and laser fluorescence. Statistical analysis was performed using McNemar test, with a level of significance of  $P < .05$ . The caries risk was measured for all participants. In 109 occlusal surfaces both methods identified enamel changes (46%) and in 62 cases both methods excluded the carious lesion (26.2%). The statistical analysis showed a significant moderate agreement between ICDAS-II code and DiagnoDent pen measurements (McNemar chi-squared statistic 9.5,  $P = .002$  and Cohen kappa coefficient = 0.427). The majority of children (69.8%) had moderate caries risk and the most frequent risk factors recorded were sugar intake between meals, lack of regular dental control and poor oral hygiene. We concluded that ICDAS-II is a valuable and reliable diagnostic tool for early pit-and-fissure lesions and could be used alone during dental examination in children. The evaluation of caries risk should become clinical routine, as parameters belonging to high risk were frequently recorded in our study group.

**Abbreviation:** ICDAS = International Caries Detection and Assessment System.

**Keywords:** early lesion, in vivo diagnosis, laser fluorescence, pit-and-fissure caries, visual inspection

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The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of the George Emil Palade University of Medicine, Pharmacy, Science, and Technology of Târgu Mureș, Romania (274/21.11.2018).

Informed consent was obtained from all subjects involved in the study.

All data generated or analyzed during this study are included in this published article.

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## 1. Introduction

Dental caries is a multifactorial disease that has a negative impact on the development, social life and school performance of children. Despite prophylactic measures, in 2015, 7.8% of the world child population of 573 million had untreated dental caries, with highest prevalence at 15 to 19 years of age.<sup>[1]</sup> Current knowledge upon the etiology and progression of the disease favored a better understanding of dental caries process and determined a paradigm shift regarding its clinical management. As a consequence, nowadays guidelines indicate that operative treatment should be used only when a cavity is present, as plaque control in these cases is impossible, while noncavitated lesions are better addressed by conservative treatment.<sup>[2,3]</sup>

In young patients, the occlusal surfaces are susceptible to be affected by caries from the beginning of tooth eruption and molars are the most affected teeth, as the developmental pits and fissures of the enamel are the most susceptible sites for caries initiation.<sup>[4]</sup> Recently published data showed that even though occlusal surfaces represent only 15% of total dental surfaces, caries located in these areas are responsible for 50% of lesions in 18-year-old patients.<sup>[5]</sup> Occlusal surfaces are more severely attacked compared to proximal sites and therefore the management of these lesions is still a major challenge for dental specialists. The therapy is most effective when the lesions are identified in early stages, but these are more difficult to diagnose, due to uncertainty regarding their activity status, as they can be either active with successive phases of demineralization/remineralization, or arrested (inactive).<sup>[6]</sup>

Due to the complex morphology of the occlusal surfaces, detection of early lesions and monitoring of caries progression are difficult even for experienced researchers and it is important to find a highly reliable and easy to use method, applicable in clinical situations.<sup>[7]</sup> Sharp explorers are no longer indicated in the diagnosis of pit-and-fissure caries, as the instrument might determine the collapse of the demineralized, noncavitated enamel and transform the early lesion into a cavity and furthermore, it does not have an increased diagnostic value compared to visual inspection alone. Moreover, the use of probing for the detection of pit-and-fissure caries did not improve the sensitivity of visual examination.<sup>[8–10]</sup> Visual inspection is a common diagnostic method, simple and with no additional costs, but it is subjective and proved to be more useful for advanced stages, when heavy demineralization of the underlying dentin or cavitation are already present. As dentists may give inconsistent interpretations of the clinical characteristics of the lesion and the use of bite-wing radiographs did not prove to be a valuable diagnostic tool in pit-and-fissure early caries, there was a need to find better caries diagnostic protocols.<sup>[11,12]</sup> One step in this direction was the introduction of the International Caries Detection and Assessment System (ICDAS), which allows a better quantification of carious lesion, by recording it from the early stages.<sup>[13,14]</sup> Dental caries is a continuous process characterized by minute loss of minerals from the tooth structure which is not possible to quantify with current examination techniques used *in vivo*. Early lesions can be effectively treated by noninvasive interventions, therefore the diagnosis of dental caries in this stage becomes of utmost importance. A new diagnostic method came from the development of fluorescence-based caries detection systems like DiagnoDent (LF, KaVo, Biberach, Germany) which are based on the absorption of the light by both tooth structures and porphyrins produced by microorganisms, when the tooth surface is illuminated by a diode laser with a wavelength of 655 nm.<sup>[11,15,16]</sup> It is the most widely used device and it was proposed as a diagnostic system alongside with radiographic examination<sup>[17]</sup>; however, it was reported to be more effective than radiographs in the detection of occlusal lesions.<sup>[18]</sup> Recently published data reported that visual and laser fluorescence examinations were similar regarding the accuracy of detecting early pit-and-fissure caries *in vitro*, but more studies are needed to measure their efficiency in clinical situations.<sup>[19]</sup> As there are few data regarding the effectiveness of different diagnostic protocols used for the assessment of pit-and-fissure early lesions in young permanent molars and considering the importance of a correct diagnosis on the treatment decision-making, the aim of our study was to evaluate the effectiveness of visual inspection based on ICDAS-II criteria and DiagnoDent pen in the detection of pit-and-fissure early lesions in young permanent molars. The null hypothesis to be tested was that there is no statistically significant difference between the clinical performances of the 2 diagnostic methods.

## 2. Materials and methods

### 2.1. Study design and participants

This cross-sectional study was conducted between September and December 2019 in the Clinic of Odontology of the Faculty of Dental Medicine of our university. A total of 96 children aged 7 to 15 years old were examined in order to detect and diagnose any alteration of the occlusal morphology of the young permanent molars, as the first part of a preventive program which included also the evaluation of caries risk and therapeutic indications. The

inclusion criteria were: fully erupted permanent molars, macroscopically intact surfaces, enamel aspect from sound to different degrees of noncavitated carious lesions. As exclusion criteria we used: presence of caries on lateral surfaces (proximal, buccal, lingual), presence of restoration or fissure sealant, hypoplastic defects, teeth in eruption, treatment with orthodontic fixed appliances. Patients' selection for the study is illustrated in Figure 1.

### 2.2. Diagnostic tests and caries risk assessment

**2.2.1. Visual examination.** The teeth were cleaned with a rotary brush and prophylactic paste in order to eliminate the biofilm and deposits, washed with water for 10 seconds and dried. The occlusal surfaces of permanent molars were visually assessed by the same investigator (C.I.B.), who has been previously trained based on the educational software proposed by the ICDAS Committee. The examinations were performed without magnification, under controlled light from the dental unit (Fig. 2A). The signs of demineralization were recorded according to ICDAS-II criteria which in the early lesion are represented by scores between 0 and 3: Code 0 – the tooth is sound; Code 1 – after drying, a lesion becomes visible; Code 2 – discoloration or opacity is visible without drying, but no cavity is present.<sup>[20]</sup> Code 3 defined as localized enamel breakdown with no visible dentin or underlying shadow was considered the cutoff threshold for dentin lesions.

**2.2.2. Laser fluorescence measurements.** The DiagnoDent pen device (LF, KaVo, Biberach, Germany) was used according to the manufacturer's instructions. The calibration of the device was made by using a ceramic standard and the procedure was repeated after 20 examinations. Careful cleaning, rinsing, and gently drying for 5 seconds but without dehydration were performed, in order to eliminate any trace of materials (biofilm, staining debris) that could lead to altered results. The tip of the instrument was placed in a vertical position into the pits and fissures and for each examined item the highest fluorescence value was recorded (Fig. 2B, C). All examinations were performed by the same investigator (M.M.) and the readings on the display were interpreted based on the cutoff criteria used for *in vivo* studies<sup>[21]</sup> (Table 1).

### 2.3. Caries risk assessment

The evaluation of caries risk was made based on an interview conducted by 1 examiner (D.E.) which included 10 questions regarding the use of fluorides, daily oral hygiene protocol, dietary habits, frequency of sugar intake and caries experience over the last 3 to 36 months, in order to include the patient in a caries risk category (Table 2). We used the following scoring criteria: low (score 0–10), moderate (score 11–30), high (score > 30).

The researchers involved in this study were calibrated for intra-observer reproducibility and the kappa coefficient was  $0.79 \pm 0.06$  (C.I.B) and  $0.82 \pm 0.03$  (M.M). All investigators are specialists with over 15 years of practical activity and the recordings were made in a blind manner. The results of each examination were recorded by another member of the study team (R.E.V.) who collected all data for each case and informed the children and their legal representatives about the diagnosis, caries risk and therapeutic indications.

### 2.4. Statistical analysis

Statistical analysis was carried out using GraphPad Prism7 (GraphPad Software, San Diego, CA). The continuous variables

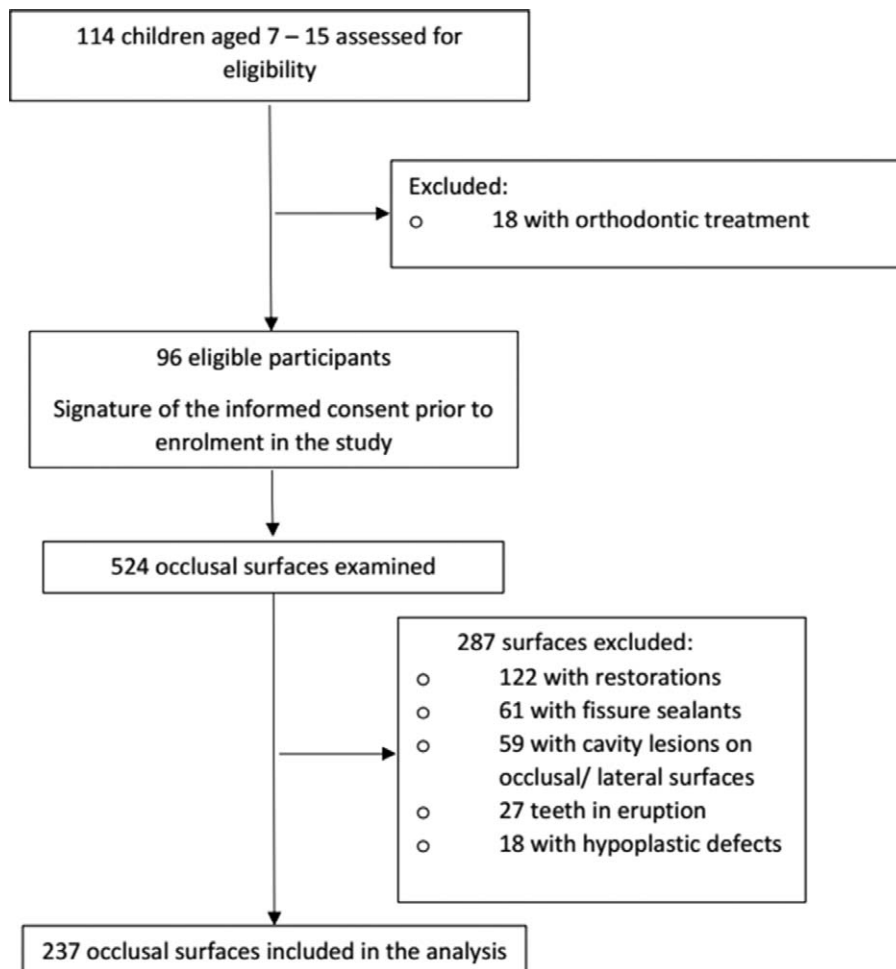


Figure 1. Flow diagram illustrating participants' selection for the study.

were expressed as mean ± standard deviation and categorical variables as percentages and frequency distribution. The level of agreement between the 2 diagnostic methods was calculated based on McNemar test. The level of statistical significance was set at a *P* value < .05 (two-tailed).

**2.5. Ethics statement**

The study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee of the George Emil Palade University of Medicine, Pharmacy, Science,

and Technology of Târgu Mure (No. 274/21.11.2018). A written consent was signed by the parents or legal representatives and children were also asked if they agreed to participate to this study.

**3. Results**

The mean age of the study group was 11.7 ± 3.2 years. A total of 237 occlusal surfaces were evaluated. Based on ICDAS-II scoring system, 82 (34.6%) were considered code 0, 50 (21.1%) code 1, 71 (30%) code 2 and 34 (14.3%) code 3. The diagnosis according to the measurements displayed by DiagnoDent pen showed the



Figure 2. (A) Visual inspection of a clean, dry tooth surface; (B) DiagnoDent pen device, the readings on the device were interpreted according to manufacturer's specifications; (C) Examination of the occlusal surfaces, by placing the instrument in vertical position along the fissures in order to get the best reading.

**Table 1**  
DiagnoDent pen measurements proposed for detection of non-cavitated lesions.

Cut-off limits	Score	Depth of carious lesion
0 to 13	0	Sound dental tissues
14 to 20	1	Lesion present in the outer ½ of the enamel
21 to 29	2	Lesion present in the inner ½ of the enamel, caries in the dentin – enamel junction
>29	3	Lesion present into the dentin

Adapted from Diniz et al (2009).<sup>[21]</sup>

following distribution: 108 surfaces (45.6%) with values between 0 and 13, 79 surfaces (33.3%) with values between 14 and 20 and 50 surfaces (21.1%) with values between 20 and 29. The correspondence between the results obtained with the 2 diagnostic methods is presented in Table 3.

The dependence of the paired categorical data obtained using the 2 diagnostic methods was evaluated by McNemar test (Table 4). The McNemar chi-squared statistic was 9.5 (which is greater than the McNemar critical value of 3.84 for 1 degree of freedom) and  $P = .002$ , which proves that there is a statistically significant difference between the discordant pairs. The inter-rater reliability, analyzed using Cohen kappa coefficient, showed a value of 0.427 (95% confidence interval: 0.314–0.541), which suggests a moderate agreement between the 2 diagnostic methods.

Caries risk assessment revealed that 67 children (69.8%) had a moderate risk for caries, 11 (11.4%) had low risk and 18 (18.8%) presented with high risk. Sugar intake between meals was the most frequent habit among children with moderate (50.7%) and high risk (100%) for caries. The lack of regular dental visits was noted in 46 (68.7%) children with moderate risk for caries development, followed by poor oral hygiene. 58.2% reported lack of twice daily tooth brushing and 41.8% presented with visible dental plaque (Fig. 3).

#### 4. Discussion

The most important aspect in caries management is to control its progression using nonoperative treatment and to reduce the

**Table 2**  
Assessment of the caries risk.

Risk factors	Risk			Patient risk
	Low score 0	Moderate score 1	High score 10	
Fluoride exposure (supplements, tooth paste, professional application)	Yes	No		
Receiving regular dental care	Yes	No		
Twice daily tooth brushing	Yes	No		
Visible plaque/tooth morphology that favors plaque accumulation	No	Yes		
Sugar intake (food, drinks)	At meal times		Between meals	
Eating disorders	No	Yes		
Caries experience	No caries in the last 24 mo	Caries in the last 6 to 24 mo	Caries in the last 6 mo	
Cavitated or noncavitated lesions	No new caries or restorations in the last 36 mo	1 to 2 new caries or restorations in the last 36 mo	3 or more caries or restorations in the last 36 mo	
Special health care needs	No	Yes (over age 14)	Yes (ages 6–14)	
Interproximal restorations – 1 or more	No	Yes		
Total				

Adapted from Ritter et al (2012).<sup>[22]</sup>

**Table 3**  
Distribution of the results according to visual inspection and laser fluorescence.

ICDAS code (n)*	DiagnoDent pen measurements (n)*		
	0 to 13	14 to 20	21 to 29
0 (82)	62	14	6
1 (50)	25	18	7
2 (71)	17	39	15
3 (34)	4	8	22

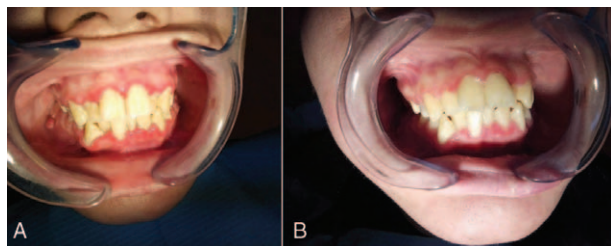
\* n = number of results.

**Table 4**  
Contingency table used for the evaluation of discordant pairs.

ICDAS code	DiagnoDent pen measurements	
	≥14 (carious lesion)	0 to 13 (sound tooth)
≥1 (enamel change)	109	46
0 (sound tooth surface)	20	62

number of patients who need cavity preparation procedures.<sup>[15]</sup> Over the last decades, different populations and age groups have shown a change in the patterns of dental caries, with an important reduction in caries prevalence and progression rate, which favored early diagnosis and better management. The latter is represented by application of topical fluorides included in dentifrices, gels, mouth rinses or varnishes, which offer appropriate protection of tooth surfaces exposed to demineralization. The use of fluoride favors the remineralization process, allowing the prevention and effective management of early lesions.<sup>[23]</sup>

Despite these promising results offered by these methods, in Romania caries levels are still high compared to well-developed countries and recently published data showed that 95.5% of adolescents are affected by caries; alarming conditions affecting caries risk were also recorded, such as poor oral hygiene, high intake of sweet beverages and lack of annual dental control.<sup>[24]</sup> Therefore, our study focused on the diagnostic outcomes of early caries on occlusal surfaces on first and second molars in children and adolescents, by using both visual examination and laser



**Figure 3.** (A) 13-year-old child with a high risk for dental caries (score 35) based on the presence of several risk factors; (B) Aspect after professional cleaning and instructions on oral hygiene procedures.

fluorescence and comparing the results of these tests, in order to enhance the prompt detection of early pit-and-fissure lesions. In our study, visual inspection based on ICDAS-II scoring system was used to quantify the early changes of enamel associated to pit-and-fissure lesions. Although ICDAS was considered difficult to use and the recordings difficult to analyze, it offers the most detailed data on caries classification and is the only method able to detect the first clinical signs of caries.<sup>[2,5]</sup> It can be associated with other diagnostic methods and therefore we considered it useful for our clinical study, where only the noncavitated occlusal surfaces of young permanent molars were evaluated. The ICDAS-II system is considered to be a complex and time-consuming method due to the use of a 2-digit system, first digit to indicate fillings and sealants and the second for the detection of carious lesions; furthermore, enamel lesions are classified in 3 different levels, before and after drying the tooth surface and the average time needed for examination was reported double compared to decay, missing, filled index, with a mean of 9 and 5 minutes, respectively.<sup>[14,26,27]</sup> Our study focused on the detection of early caries from more reasons: first, these lesions are difficult to diagnose in the daily clinical practice and second, we wanted to avoid over-treatment and cavity preparation. The ICDAS-II scoring system was our choice as its criteria were favorably associated with the histological stages of caries.<sup>[20]</sup> In clinical studies, the presence of acquired pellicle, saliva or bacterial plaque might reduce the detection of carious lesions, lowering the sensitivity of the diagnostic tests. In a meta-analysis published by Gimenez et al<sup>[12]</sup>, visual inspection had an overall accuracy similar to that reported for radiography and fluorescence-based methods. For the last 2 methods, the results of clinical studies reported higher sensitivities and lower specificities, therefore, the use of visual inspection alone was considered to be effective enough for caries diagnosis.<sup>[28]</sup> Moreover, by using a validated scoring system such as ICDAS-II, it was possible to improve the sensitivity and reliability of the visual examination.<sup>[11,12]</sup> Data from literature suggested that the breakdown of the enamel with a high concentration of fluorapatite around pits and fissures may not appear before important dentine demineralization had already occurred. Therefore, in such cases occlusal caries can be underdiagnosed and the cavitation appears when the caries has advanced a long way inside the dentine.<sup>[10]</sup> Even though visual inspection of the occlusal surfaces is considered the major tool in the process of treatment choice, as radiographs or fluorescence-based methods are not enough sensitive to identify the lesions in the early stages, researchers were trying to improve the diagnostic options of early lesions.<sup>[12]</sup> Thus, recently published data reported that DIAGNO cam, a new device using near-infrared light with a wave length of 7780nm, was found to be the most

effective method for the diagnosis of occlusal caries without cavitation in permanent molar teeth.<sup>[4]</sup>

The DiagnoDent pen demonstrated good reproducibility and accuracy in the detection of occlusal dental caries,<sup>[13]</sup> which was a strong argument for including it as a diagnostic method in our study. In previous clinical studies, the caries extension was evaluated based on cutoff values of the DiagnoDent pen which were associated with the best therapeutic approach. As several thresholds have been proposed,<sup>[21,29]</sup> in our study we used those provided by the device manual according to which a threshold of 13 indicates the presence of the lesion. The intra-examiner reproducibility in our study was high and similar results were reported by other studies<sup>[16,30]</sup> confirming that a good training supports the specialist in giving an accurate diagnosis.

The results of our study showed a moderate agreement between visual inspection and laser fluorescence, which encourages us to promote better training for our undergraduate students in using only ICDAS-II. Moreover, by replacing decay, missing, filled index with ICDAS-II we can obtain detailed information upon early lesion and can develop better preventive programs. Our results are similar to previously reported data<sup>[23,31]</sup> which confirm that laser fluorescence does not significantly improve the diagnostic accuracy of early pit-and-fissure caries and therefore, visual inspection based on ICDAS-II criteria is a useful diagnostic tool, given that specialists are well trained in using this index.

Oral health is negatively influenced by economic, cultural and political factors, which determine social inequalities between groups of population and geographic areas of a country. Among oral diseases, dental caries still has the highest prevalence and incidence affecting up to 90% of children worldwide.<sup>[23]</sup> It was shown that general and oral health are influenced by the parents' level of education and income, which were considered important indicators in studies focusing on the oral health status of children. García Pérez et al<sup>[32]</sup> found that the prevalence of carious lesions in children were related to the mother's level of education and oral hygiene habits. Furthermore, the socioeconomic status of the parents was not associated with the presence of noncavitated lesions.

The data from caries risk assessment of our study group confirms that there is great variability among children from different geographic areas.<sup>[33]</sup> In our study a large proportion of children demonstrated moderate and high caries risk, based on the presence of cariogenic factors related to bad dietary habits, inadequate oral hygiene and lack of dental visits. Caries risk assessment should begin during early childhood in order to promote a good oral health throughout the life. As its parameters tend to change over time, it is important to repeat the evaluation periodically, in order to identify the risk factors that promote tooth demineralization.<sup>[34]</sup> This information is valuable in determining the need for treatment to be provided in each case and the schedule of oral health maintenance visits. Furthermore, it is important to adapt our dental curriculum in both under and postgraduate training for a better approach of diagnosis, treatment and prevention of carious lesions in children.

#### 4.1. Limitations

The major limitation of any clinical study is the absence of a gold standard such as the histological validation of the results. Another limitation of our study was the lack of evaluation of the dental occlusal plaque. Therefore, in a future study we intend the

use The Visible Occlusal Plaque Index in order to complete the results of the visual examination. In this study we relied on the high accuracy of ICDAS-II, as scientific data confirmed a strong correspondence between ICDAS-II scores and histologic examination. Conversely, radiographs are not sensitive enough for early occlusal lesions and micro-computed tomography is associated with a high dose of radiation. The examination was more difficult in patients with a high risk for caries, where we faced the risk of false positive recordings and over-treatment.

## 5. Conclusion

The results of our *in vivo* study suggest that there is a moderate agreement between visual inspection based on ICDAS-II scoring system and laser fluorescence measurements. Therefore, in the lack of substantial agreement, we consider that the use of laser fluorescence does not significantly improve the quality of diagnosis in early pit-and-fissure lesions of young permanent teeth. ICDAS-II offers a more detailed description of the carious process and in epidemiological studies it will be important that researchers use the same criteria proposed worldwide, which will allow the results to be included in future meta-analyses. We emphasize the importance of caries risk assessment for patients starting from early ages, as in Romania most dentists consider it is enough just to treat the existing lesions, without taking into consideration the future development of the disease.

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## Author contributions

Conceptualization, Monica Monea and Cristina Ioana Bica; methodology, Daniela Eşian; software, Ramona Elena Vlad; validation, Monica Monea, Daniela Eşian, and Cristina Ioana Bica; formal analysis, Monica Monea; investigation, Monica Monea, Daniela Eşian, and Cristina Ioana Bica; resources, Cristina Ioana Bica; data curation, Ramona Elena Vlad; writing – original draft preparation, Monica Monea and Ramona Elena Vlad; writing – review and editing, Daniela Eşian and Cristina Ioana Bica; visualization, Monica Monea; supervision, Cristina Ioana Bica. All authors have read and agreed to the published version of the manuscript. Monica Monea, Daniela Eşian and Cristina Ioana Bica contributed equally to this manuscript.

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