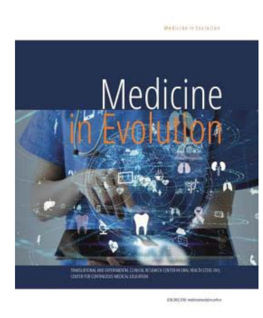
Modern Stragies for Diagnosing Occlusal Caries in Permanent Teeth



https://doi.org/10.70921/medev.v31i1.1266

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Received: 6 March 2025; Accepted: 16 March 2025; Published: 31 March 2025

Abstract

1.Background/Objectives: This study evaluates the diagnostic reliability of three methods for detecting occlusal caries: International Caries Detection and Assessment System (ICDAS-II) visual criteria, light-induced fluorescence (VistaCam iX, Dürr Dental), and laser-induced fluorescence (DIAGNOdent Pen, KaVo). Early caries detection is crucial for preventive strategies and minimizing invasive treatments. 2.Methods: A total of 97 permanent molars meeting the inclusion criteria were examined by two calibrated evaluators (κ = 0.95 for both fluorescence devices). Carious lesions were classified as non-cavitated, enamel lesions, or lesions extending to dentin. 3.Results: The analysis revealed significant differences among the three diagnostic methods. Laser-Induced Fluorescence was more effective in identifying sound teeth and advanced lesions but showed lower sensitivity to early-stage caries. In contrast, Visual Examination (ICDAS) and Light-Induced Fluorescence demonstrated greater effectiveness in detecting early lesions. These findings highlight the need for a combined diagnostic approach to enhance accuracy in caries detection. 4.Conclusion: Visual and Light-Induced Fluorescence methods were more responsive to early caries, while Laser-Induced Fluorescence better detected advanced lesions. These findings support a multimodal approach for improved diagnostic accuracy and early intervention.

Keywords: dental caries; oral health; ICDAS-II; VistaCam iX; DIAGNOdent Pen; digital dentistry

INTRODUCTION

Dental caries, a non-communicable disease (NCD) that is largely preventable, continues to pose a significant public health challenge, with reports indicating little to no improvement in oral health over the past 25 years. In response to this persistent issue, the World Health Organization (WHO) emphasized the urgent need to enhance global oral health through its most recent resolution in 2021. Achieving optimal oral health necessitates, among other measures, the early detection and treatment of dental caries. As oral health is a critical component of overall well-being, maintaining a healthy oral cavity and dentition free from pathological conditions such as caries or periodontal diseases remains a key objective, requiring continuous advancements in both primary and permanent dentition care [1].

According to the Global Burden of Disease Study (2019), untreated dental caries in permanent teeth remains the most prevalent condition worldwide, affecting an estimated 2.3 billion people. Furthermore, disparities in oral health persist between high-income and low-income countries, with limited access to dental care exacerbating the burden of the disease. The World Health Organization (WHO) has recognized the need for a global strategy to improve oral health, highlighting the importance of early diagnosis and prevention in reducing caries incidence. This underscores the necessity of improving diagnostic methodologies to facilitate timely intervention and prevent disease progression [1;2].

Efforts to improve the detection of carious lesions have intensified in recent years. Traditionally, dental healthcare providers have focused primarily on clinically visible lesions during diagnostic assessments. The most commonly employed diagnostic methods include visual and tactile examinations, involving direct observation of the tooth surface or the use of a dental probe. However, one of the significant challenges in caries diagnosis is the quantification of clinical observations into objective numerical data. To address this, the DMFT index—measuring the number of decayed (D), missing (M), and filled (F) teeth—was introduced as a tool to quantify an individual's oral health status [2]. Despite its widespread use, the DMFT index has proven to be insufficient, often failing to provide insights into the severity of the disease or the need for extensive dental treatment. Furthermore, without the inclusion of radiographic analysis, the DMFT index has been shown to underestimate carious lesions in approximately 44% of cases [3].

To enhance diagnostic accuracy, the International Caries Detection and Assessment System (ICDAS II) was developed as a universal scoring system. This system relies exclusively on the visual inspection of carious lesions and, according to Coelho (2020), provides up to 43% more diagnostic information than the DMFT/dmft index. ICDAS II classifies lesions as either active or inactive, thereby assisting dental professionals in determining prognosis and appropriate treatment plans [4].

The ability to evaluate lesion activity allows for more informed decisions regarding preventive versus therapeutic interventions. For instance, an in vivo study conducted by Ferreira et al. (2012) in Puerto Rico demonstrated that early interventions, such as sealing pits and fissures, are recommended for lesions with ICDAS scores of 3 and 4, while lesions with scores of 1 and 2 should be monitored for progression [5].

In addition to visual assessments, other diagnostic technologies have been introduced to improve caries detection. Laser fluorescence-based devices measure emitted infrared fluorescence and present results as numerical values. This technique leverages the principle that chromophores in dental enamel and dentin generate autofluorescence, which diminishes in the presence of demineralization. Furthermore, chromophores such as porphyrins, present in carious lesions and bacterial biofilms, produce fluorescence that can be quantified by comparing the fluorescence of healthy tooth surfaces to that of carious lesions [6]. Factors such as the presence of blood or other fluids in the oral cavity can affect fluorescence readings, making it essential to ensure that tooth surfaces are thoroughly dried before measurement. To enhance patient compliance and facilitate long-term monitoring, intraoral cameras have been developed to capture and store clinical images of patients' teeth, allowing for continuous evaluation of incipient lesions over time [7].

Given the evolving approaches in cariology, where early-stage caries is considered reversible through infiltration techniques, the ability to detect lesions at their earliest stages is critical. This study aims to investigate the extent to which laser fluorescence and light-induced fluorescence devices can improve diagnostic outcomes derived from visual examinations. Additionally, the research seeks to evaluate the diagnostic reliability of laser-induced fluorescence and light-induced fluorescence in detecting occlusal caries in permanent teeth [6;7].

Aim and objectives

This study aims to evaluate the diagnostic performance of Visual Examination (ICDAS), Laser-Induced Fluorescence, and Light-Induced Fluorescence in detecting occlusal caries in permanent teeth. The objective is to assess their sensitivity and specificity in identifying early and advanced carious lesions and to explore the potential benefits of an integrated, multimodal diagnostic approach to enhance accuracy and early intervention.

MATERIAL AND METHODS

The research focused on patients aged between 7 and 17 years, who were referred to the Department of Dental Prevention, Community Dentistry, and Oral Health at the Victor Babeș University of Medicine and Pharmacy in Timișoara, Romania. The research adhered to the principles of the Declaration of Helsinki (1975) and its subsequent amendments, with written informed consent obtained from all participants before data collection.

Clinical examinations were conducted by two dentists who had undergone calibration to ensure consistency in diagnostic procedures. To assess the level of agreement between the two examiners, the kappa statistic was utilized, yielding a value of 0.95. This rigorous calibration protocol minimized subjective bias and ensured the reliability of visual assessments throughout the study. According to the criteria established by Landis and Koch (1977), this score reflects an almost perfect level of agreement [8].

Participants included in the study exhibited signs of pit and fissure caries in at least one permanent posterior tooth. Each tooth was subjected to a thorough clinical evaluation under appropriate lighting conditions, following careful cleaning of the tooth surfaces. It is important to note that any samples previously involved in the pilot phase were excluded from the main study to maintain data integrity. In total, 97 permanent posterior teeth were analyzed. The selected teeth were either intact or displayed early-stage, subtle carious lesions, with or without visible color alterations.

Teeth presenting occlusal restorations, enamel hypoplasia, hypomineralization, structural anomalies, or pulp necrosis were excluded from the study (Figure 1). For comparative analysis, the two calibrated dentists employed both a laser fluorescence device (DIAGNOdent, Kavo, Biberach, Germany) and an intraoral fluorescence camera equipped with a light-induced fluorescence head (Dürr Dental, Germany) to evaluate the teeth.

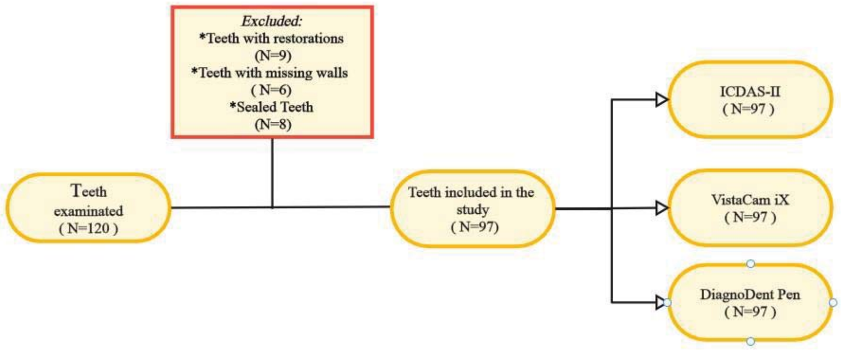

Figure 1. Flowchart of Inclusion and Exclusion Criteria for Teeth Examination

The visual examination of occlusal caries was conducted in accordance with the ICDAS II criteria. Prior to the assessment, the occlusal surfaces of the teeth were thoroughly cleaned to eliminate plaque and debris, using water spray and cotton pellets when necessary.

The ICDAS II system classifies carious lesions on a scale from 0 to 6. A score of 0 indicates a sound tooth surface, showing no evidence of caries even after five seconds of air drying. A score of 1 reflects the first visual changes in enamel, where slight opacity or discoloration (white or brown) becomes visible at the entrance to pits and fissures following prolonged air drying. When distinct visual changes in enamel are noticeable while the tooth is wet and become more pronounced upon drying, the lesion is assigned a score of 2.

A score of 3 corresponds to localized enamel breakdown without any visible clinical signs of dentinal involvement, observable both when the tooth is wet and after extended drying. If an underlying dark shadow from the dentine is detected beneath the enamel, the lesion receives a score of 4. A distinct cavity with visible dentine exposure is classified as a score of 5. Finally, a score of 6 is given to extensive cavities affecting more than half of the tooth surface, where dentine is clearly visible.

This systematic approach ensured consistent and reliable detection and classification of occlusal caries throughout the study.

The assessment utilizing light-induced fluorescence (VistaCam iX, Dürr Dental, Bietigheim-Bissingen, Germany) involved a camera hand piece equipped with two interchangeable lenses (Figure 2). This design enabled the device to function both with the fluorescence attachment for caries detection and as a standard intraoral camera. Patients were positioned in a supine position on the dental chair, with cotton rolls placed in the oral cavity, and the area was thoroughly dried using an air syringe. The fluorescence device was linked to a computer system, and ambient lighting was turned off to enhance imaging accuracy. Initially, images were captured using the fluorescence lens, followed by photographs taken with the white light lens.

The fluorescence scoring system categorized the findings as follows: 0–1.2 indicated healthy tissue, 1.3–1.5 corresponded to enamel caries, and values above 1.5 suggested dentinal caries. To assess the diagnostic accuracy of the applied methods, measurements were coded numerically as 0, 1, or 2 [9;10].

The Wilcoxon signed-rank test was selected for statistical analysis due to the non-parametric nature of the data. Given that the diagnostic scores were ordinal and not normally distributed, a non-parametric approach was required to compare the effectiveness of the three diagnostic methods. The Wilcoxon test allowed for pairwise comparisons of the methods while accounting for the ranked nature of the data. Additionally, Spearman's rank correlation coefficient was applied to assess the degree of association between the diagnostic scores obtained from different methods, providing further insight into their comparative performance. All statistical evaluations were conducted using R software.

Figure 2. VistaCam iX

Figure 3. DiagnoDent Pen

Assement through laser-induced fluorescence were performed using a laser fluorescence device (DIAGNOdent Pen, KaVo, Biberach, Germany) (Figure 3). Calibration was carried out by selecting a healthy dental surface from a central or lateral incisor to establish a baseline reference. Following calibration, laser fluorescence readings were obtained for each occlusal surface, with three measurements taken per site. The highest recorded value from these readings was used for analysis [9; 10].

RESULTS

The outcomes of the three diagnostic methods applied in this study reveal notable differences in caries detection. Through visual examination using the ICDAS system, 42.26% (N = 41) of the assessed teeth received a score of 0, while 52.57% (N = 51) were categorized with a score of 1, and 5.15% (N = 5) were assigned a score of 2. The analysis conducted with the laser-induced fluorescence device demonstrated that 75.26% (N = 73) of the teeth were given a score of 0, whereas 7.22% (N = 7) obtained a score of 1, and 17.52% (N = 17) received a score of 2. In contrast, the light-induced fluorescence device indicated that 35.05% (N = 34) of the teeth were classified with a score of 0, 52.57% (N = 51) were assigned a score of 1, and 12.37% (N = 12) obtained a score of 2 (Table 1).

Table 1. Outcomes of Diagnostic Methods

Score	Visual Examination (ICDAS)	Laser-Induced Fluorescence (DiagnoDent Pen)	Light-Induced Fluorescence (VistaCam iX)
0	42.26% (N = 41)	75.26% (N = 73)	35.05% (N = 34)
1	52.57% (N = 51)	7.22% (N = 7)	52.57% (N = 51)
2	5.15% (N = 5)	17.52% (N = 17)	12.37% (N = 12)

The observed differences among these diagnostic methods underscore their respective strengths and limitations. Visual Examination (ICDAS) and Light-Induced Fluorescence demonstrate greater effectiveness in detecting early-stage caries, making them valuable tools for preventive care. In contrast, Laser-Induced Fluorescence appears to be more proficient in identifying advanced lesions, though it may underestimate early-stage cases.

These findings indicate that no single diagnostic method provides a fully comprehensive assessment of carious lesions. Integrating multiple diagnostic approaches could enhance accuracy and reliability, facilitating the early detection and appropriate management of both initial and advanced lesions.

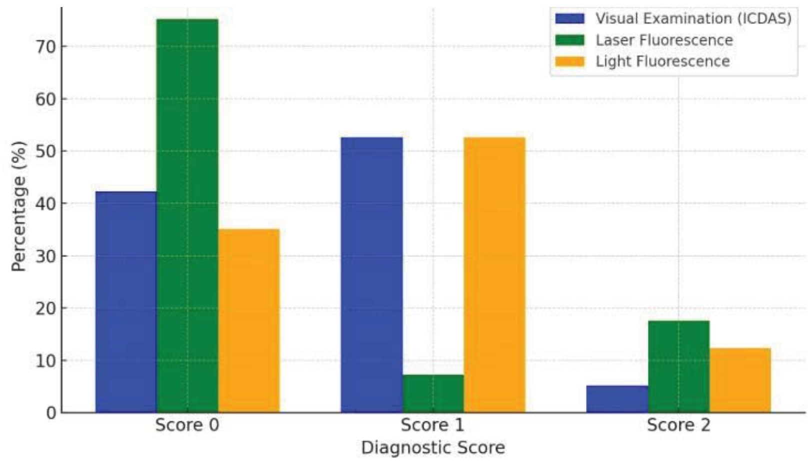

Figure 4. Comparison of Diagnostic Methods

The analysis of diagnostic trends across three methods—Visual Examination (ICDAS), Laser-Induced Fluorescence, and Light-Induced Fluorescence—reveals distinct patterns in their effectiveness at detecting carious lesions. Laser-Induced Fluorescence exhibits a sharp decline from score 0 (75.26%) to score 1 (7.22%), indicating a reduced ability to identify early-stage lesions compared to the other methods.

In contrast, Visual Examination (ICDAS) and Light-Induced Fluorescence follow a similar trend, capturing a high percentage of score 1 cases (52.57%), highlighting their greater sensitivity to early-stage caries. Moreover, Laser-Induced Fluorescence demonstrates a more pronounced increase in score 2 cases (17.52%), suggesting superior efficiency in detecting advanced lesions compared to Visual Examination (5.15%) and Light-Induced Fluorescence (12.37%) (Figure 5).

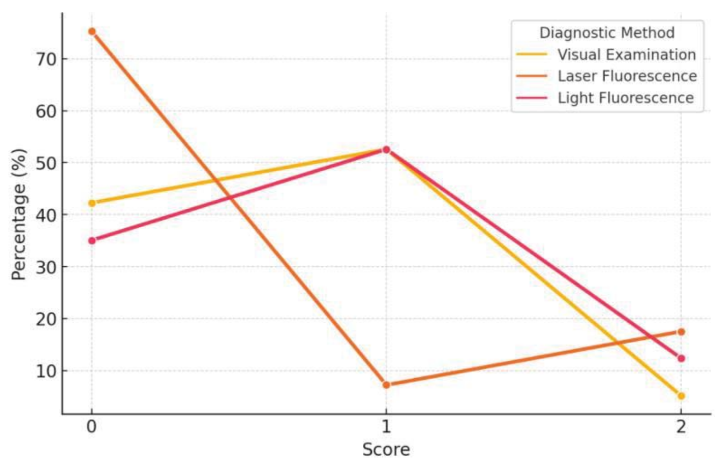

Figure 5. Trend of Diagnostic Scores Across Methods

DISCUSSIONS

The findings of this study provide valuable insights into the comparative diagnostic performance of Visual Examination (ICDAS), Laser-Induced Fluorescence, and Light-Induced Fluorescence in detecting occlusal caries in permanent teeth. The results highlight the strengths and limitations of each method, reinforcing the necessity of an integrated diagnostic approach to enhance caries detection accuracy [11].

Visual Examination (ICDAS) and Light-Induced Fluorescence demonstrated greater sensitivity to early-stage caries, as evidenced by their classification of a high percentage of cases with a score of 1 (52.57%). This aligns with previous studies suggesting that ICDAS is highly effective in identifying enamel demineralization and early carious lesions (Coelho, 2020). Similarly, Light-Induced Fluorescence, which captures autofluorescence variations in enamel, yielded comparable results, reinforcing its role as a reliable tool in detecting incipient lesions (Ferreira et al., 2012). These findings suggest that both methods are well-suited for preventive dental care, facilitating early intervention strategies such as fissure sealants and remineralization therapies [12;13].

Conversely, Laser-Induced Fluorescence demonstrated a significantly lower detection rate for early-stage caries (7.22% classified as score 1) but exhibited superior performance in identifying advanced lesions (score 2: 17.52%) compared to Visual Examination (5.15%) and Light-Induced Fluorescence (12.37%) [14]. This suggests that Laser-Induced Fluorescence may underestimate early enamel changes due to its reliance on fluorescence intensity, which is influenced by bacterial byproducts and the extent of demineralization. Prior research supports this observation, indicating that laser fluorescence devices tend to produce higher specificity but lower sensitivity for initial caries detection (Neuhaus et al., 2010). The ability of Laser-Induced Fluorescence to detect deeper enamel and dentinal involvement highlights its potential utility in confirming advanced caries diagnoses and guiding treatment planning [15].

A key implication of this study is the recognition that no single diagnostic method provides a fully comprehensive assessment of carious lesions. The observed discrepancies between the three methods underscore the need for a multimodal approach that leverages the advantages of each technique. Given the shift towards minimally invasive dentistry, where early detection and intervention are paramount, integrating fluorescence-based techniques with visual examination could improve diagnostic reliability and support individualized patient care.

Despite the strengths of this study, several limitations should be acknowledged. First, the sample size was relatively small (97 permanent posterior teeth), which may limit the generalizability of the findings. Additionally, the study focused exclusively on occlusal caries, and further research is needed to assess the efficacy of these diagnostic methods in detecting proximal and root caries. Another limitation is the potential influence of external factors such as saliva, plaque, and staining on fluorescence readings, which may have affected measurement accuracy. Future studies should explore standardized protocols to mitigate these variables and improve diagnostic consistency.

Future research directions should focus on the integration of fluorescence-based technologies with adjunctive diagnostic methods, such as optical coherence tomography and artificial intelligence-driven image analysis. AI-based image recognition systems have shown promise in enhancing caries detection by providing automated, quantitative assessments of lesion severity. Additionally, longitudinal studies assessing the clinical outcomes of different diagnostic approaches could provide further insights into their long-term effectiveness in caries management.

In conclusion, the results of this study reaffirm the necessity of refining caries detection methodologies to align with the evolving paradigm of preventive and minimally invasive dentistry. By combining Visual Examination (ICDAS), Laser-Induced Fluorescence, and Light-Induced Fluorescence, dental practitioners can improve diagnostic precision, optimize treatment planning, and contribute to more effective caries management strategies in clinical practice [16;17].

CONCLUSIONS

This study highlights the comparative diagnostic performance of Visual Examination (ICDAS), Laser-Induced Fluorescence, and Light-Induced Fluorescence in detecting occlusal caries in permanent teeth. The findings emphasize the superior sensitivity of Visual Examination and Light-Induced Fluorescence in identifying early-stage caries, while Laser-Induced Fluorescence demonstrated greater specificity in detecting advanced lesions. These results underscore the limitations of relying on a single diagnostic method and reinforce the need for an integrated, multimodal approach to improve diagnostic accuracy and early intervention. Given the growing emphasis on minimally invasive dentistry, combining fluorescence-based technologies with visual assessment could enhance caries detection and optimize treatment planning. Future research should focus on refining fluorescence-based diagnostics, integrating artificial intelligence-driven image analysis, and evaluating long-term clinical outcomes to further advance caries management strategies.

From a clinical perspective, these findings highlight the necessity of integrating multiple diagnostic modalities to enhance caries detection. Given that early intervention is fundamental in minimally invasive dentistry, the combined use of visual examination and fluorescence-based methods can aid in identifying lesions at reversible stages, reducing the need for invasive restorative procedures. In clinical practice, practitioners should consider utilizing light-induced fluorescence for routine screening, supplemented by laser fluorescence for confirmation of advanced lesions. Moving forward, the development of standardized diagnostic protocols incorporating these modalities could lead to more accurate, evidence-based decision-making in caries management.

Conflicts of Interest

The authors declare no conflict of interest.

REFERENCES

[1] Baiju RM, Peter E, Varghese NO, Sivaram R. Oral Health and Quality of Life: Current Concepts. J Clin Diagn Res. 2017 Jun;11(6):ZE21-ZE26. doi: 10.7860/JCDR/2017/25866.10110. Epub 2017 Jun 1. PMID: 28764312; PMCID: PMC5535498.

[2] Anaise, J.Z. Measurement of dental caries experience-modification of the DMFT index. Community Dent. Oral. Epidemiol. 1984, 12, 43–46.

[3] Becker, T.; Levin, L.; Shochat, T.; Einy, S. How Much Does the DMFT Index Underestimate the Need for Restorative Care? J. Dent. Educ. 2007, 71, 677–681

[4] Jablonski-Momeni, A.; Stachniss, V.; Ricketts, D.N.; Heinzel-Gutenbrunner, M.; Pieper, K. Reproducibility and accuracy of the icdas-ii for detection of occlusal caries in vitro. Caries Res. 2008, 42, 79–87.

[5] International Caries Detection and Assessment System (ICDAS) Coordinating Committee. Criteria Manual–International Caries Detection and Assessment System (ICDAS II); Dental Health Services Research Unit: Dundee, UK, 2005; Available online: http: //www.icdas.org (accessed on 11 January 2025)

[6] Jablonski-Momeni, A.; Liebegall, F.; Stoll, R.; Heinzel-Gutenbrunner, M.; Pieper, K. Performance of a new fluorescence camera for detection of occlusal caries in vitro. Lasers Med. Sci. 2012, 28, 101–109.

[7] Shakibaie, F.; Walsh, L.J. Dental calculus detection using the VistaCam. Clin. Exp. Dent. Res. 2016, 2, 226–229.

[8] Landis, J.R.; Koch, G.G. The measurements of observer agreement for categorical data. Biometrics 1977, 33, 159–174

[9] Tassery, H.; Levallois, B.; Terrer, E.; Manton, D.; Otsuki, M.; Koubi, S.; Gugnani, N.; Panayotov, I.; Jacquot, B.; Cuisinier, F.; et al. Use of new minimum intervention dentistry technologies in caries management. Aust. Dent. J. 2013, 58, 40–59.
[10] Perdiou, A.; Fratila, A.D.; Sava-Rosianu, R.; Alexa, V.T.; Lalescu, D.; Jumanca, D.; Galuscan, A. In Vivo Performance of Visual Criteria, Laser-Induced Fluorescence, and Light-Induced Fluorescence for Early Caries Detection. Diagnostics 2023, 13, 3170.
[11] Galuscan, A.; Jumanca, D.; Fratila, A.D. Caries Management Aided by Fluorescence-Based Devices. In Dental Cariesi—The Selection of Restoration Methods and Restorative Materials; Rusu, L., Ardelean, L.C., Eds.; IntechOpen: London, UK, 2022
[12] Coelho, M. ICDAS and dmft/DMFT. Sensitivity and specificity, the importance of the index used: A systematic review. J. Public Health Dent. 2020, 11, 176–187
[13] Sheehy, E.C.; Brailsford, S.R.; Kidd, E.A.; Beighton, D.; Zoitopoulos, L. Comparison between visual examination and a laser fluorescence system for in vivo diagnosis of occlusal caries. Caries Res. 2001, 35, 421–426
[14] Bahrololoomi, Z.; Ezoddini, F.; Halvani, N. Comparison of Radiography, Laser Fluorescence, and Visual Examination in Diagnosing Incipient OcclusalCaries of Permanent First Molars. J. Dent. 2016, 12, 324–332.
[15] Tassery, H.; Levallois, B.; Terrer, E.; Manton, D.; Otsuki, M.; Koubi, S.; Gugnani, N.; Panayotov, I.; Jacquot, B.; Cuisinier, F.; et al. Use of new minimum intervention dentistry technologies in caries management. Aust. Dent. J. 2013,
[16] Qudeimat, M.A.; Altarakemah, Y.; Alomari, Q.; Alshawaf, N.; Honkala, E. The impact of ICDAS on occlusal caries treatment recommendations for high caries risk patients: An in vitro study. BMC Oral. Health 2019, 19, 41.
[17] Mazur, M.; Jedli ´nski, M.; Ndokaj, A.; Corridore, D.; Maruotti, A.; Ottolenghi, L.; Guerra, F. Diagnostic Drama. Use of ICDAS II and Fluorescence- Based Intraoral Camera in Early Occlusal Caries Detection: A Clinical Study. Int. J. Environ. Res. Public Health 2020, 17, 2937.