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Comparison Between Visual and Radiographic Methods Using ICDAS Criteria in Permanent Molars for Detection of Occlusal and Proximal Caries – A Comparative Study

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ABSTRACT

Early detection of dental caries is critical for timely intervention and prevention of disease progression. The International Caries Detection and Assessment System (ICDAS) offers a standardized approach to evaluate caries through both visual and radiographic methods. **Objectives:** To compare between visual and radiographic methods using ICDAS criteria in permanent molars for detection of occlusal and proximal caries. **Methods:** This comparative cross-sectional study was conducted at Liaquat University of Medical and Health Sciences (LUMHS) after ethical approval, using non-probability consecutive sampling to recruit 378 patients. Individuals aged 16–35 years with fully erupted, clinically intact permanent molars and no signs of periodontal disease were included. Participants were assigned to Group A (occlusal caries) or Group B (proximal caries), with 189 in each group. Caries were assessed visually and radiographically using ICDAS criteria, with scores 1–2 indicating initial and 3–6 indicating advanced lesions. Two calibrated examiners performed the evaluations. **Results:** There were no statistically significant differences in baseline demographics between the occlusal and proximal caries groups. The mean age was comparable (25.9 ± 6.5 vs. 26.1 ± 6.2 years, $p=0.753$), as was gender distribution ($p=0.752$). When comparing diagnostic methods, no statistically significant differences were observed between visual and radiographic ICDAS assessments for detecting initial or advanced caries in either group (all $p>0.050$), indicating comparable diagnostic performance. **Conclusions:** Visual and radiographic methods based on the ICDAS system were equally effective in identifying occlusal and proximal carious lesions in permanent molars.

INTRODUCTION

Better quality information is ensured by using a standardized caries revelation method established on the finest available data. This helps practitioners make well-informed decisions on the optimal clinical treatment of dental caries at the individual and public health levels [1]. The International Caries Detection and Assessment System, or ICDAS, is a straightforward, rational, research backed method for detecting and evaluating dental caries

that groups the phases of the disease according to histological activity and extent [2]. Since its launch in 2001, it has been widely accepted and used in the four fields of health services, clinical practice, education, and research, giving all parties involved a single vocabulary for staging dental cavities [3]. In order to enhance patient treatment and more accurately track caries development in research, it shifts the discipline distant from the oversimplified



diagnosis of either visible decay or no apparent decay and toward a more thorough degree of assessment [4]. By using visually observed surface features, the ICDAS calculates the visual surface changes that correlate to the possible histological depth of carious lesions. Furthermore, it suggests the ICDAS radiographic grading system for a more thorough diagnosis, which groups lesions based on the degree of caries demineralization into enamel and dentin, shown by a radiolucency on the radiograph [5]. While radiography continues to be the most popular caries detection tool, clinical visual identification and evaluation of lesions on clean, dry teeth serves as the foundation for clinical appraisal of the carious lesion [6]. The bitewing method is intended to recognize proximal caries lesions that are invisible to the naked eye. According to recent research, radiographs are more sensitive than clinical examination when it comes to identifying proximal and occlusal lesions in dentin, determining the lesion's depth, and tracking its activity [6, 7]. The ICDAS uses radiography to categorize posterior tooth surfaces in different degrees based on progression. This classification system's high repeatability and accuracy provide more thorough information for managing, diagnosing, and planning dental decay [8, 9]. The null hypothesis was there is no significant difference between the visual and radiographic methods using ICDAS criteria in detecting occlusal and proximal caries in permanent molars.

Although both visual and radiographic approaches based on the ICDAS system are widely used for caries detection, uncertainty remains regarding their comparative diagnostic performance in routine clinical settings, particularly for occlusal and proximal surfaces of permanent molars. Most previous studies have been conducted in vitro or have relied on advanced imaging modalities such as micro-CT, limiting their direct applicability to everyday clinical practice. Furthermore, local data comparing these two modalities within a standardized ICDAS framework are scarce. This highlights the need for clinically relevant comparative research to guide evidence-based diagnostic decision-making. The objective of this study was to compare between visual and radiographic methods using ICDAS criteria in permanent molars for detection of occlusal and proximal caries.

METHODS

This comparative cross-sectional study was conducted from January 2023 to December 2023 in the Department of Operative Dentistry, Liaquat University of Medical and Health Sciences Jamshoro, Pakistan. After obtaining ethical approval from the ethical review board (Ref. No. LUMHS/REC/-05). The study employed a non-probability consecutive sampling technique. The sample size was calculated using an online sample size calculator

(<https://wnarifin.github.io/ssc/sskappa.html>) based on an expected kappa value of 0.74 [10] between radiographic and visual ICDAS methods, assuming a caries prevalence of 29% [11], with 90% power and a 5% significance level. Although the calculated minimum required sample size was 39, all available cases ($n = 378$) were included to satisfy the assumption of normality. These patients were divided into two groups: Group A (occlusal caries) and Group B (proximal caries), with 189 participants in each group. The study included patients between 16 and 35 years of age, of either sex, who had fully erupted permanent molars with clinically intact occlusal and proximal surfaces, and no clinical signs of periodontal disease such as bleeding on probing, periodontal pocket depths greater than 3 mm, clinical attachment loss, or pathological tooth mobility. Only individuals who provided informed written consent were eligible. Patients were excluded if the target molars exhibited structural damage (e.g., fractures or excessive wear), had been restored with crowns or orthodontic appliances, or showed evidence of periodontal compromise. Additionally, individuals with systemic health conditions known to affect oral status, or those who declined participation or radiographic assessment, were not considered for inclusion. After taking the informed consent from patient, history, clinical examination investigations were performed and recorded on proforma. The radiographs were used to diagnose and examine the molars' proximal and occlusal surfaces. Caries detection in molars was performed visually using the International Caries Detection and Assessment System (ICDAS) criteria. Teeth were examined under artificial light after being cleaned (if necessary) to remove plaque or calculus, and then dried with compressed air to enhance visualization of enamel changes. A standard dental mirror and a ball-ended probe were used passively without exerting pressure to avoid causing cavitation. A quadrant-wise sequence was followed to ensure all molars were examined systematically. The ICDAS criteria were applied as follows: Score 0: Sound tooth surface; Score 1: First visual change in enamel; Score 2: Distinct visual change in enamel; Score 3: Localized enamel breakdown due to caries with no visible dentin; Score 4: Underlying dark shadow from dentin (with or without enamel breakdown); Score 5: Distinct cavity with visible dentin; Score 6: Extensive distinct cavity with visible dentin. For analytical purposes, initial caries lesions were defined as scores 1–2, while advanced lesions were categorized as scores 3–6 [12]. Both the occlusal and proximal surfaces were examined for bitewing caries using radiography. Radiographic imaging was performed using an X-linear system DC, with exposures ranging from 20 to 1000 milliseconds at 70 kVp and 7 mA. A digital sensor (Ateco, AT-301) captured the

images within 3 seconds at 5.0V and 500 mA, with 12-bit per pixel digitization, and was connected via a USB 2.0 port to a PC or laptop. The images were printed on paper. Two examiners, previously calibrated for evaluating the radiographs using the ICDAS-recommended radiographic criteria. According to the radiographic ICDAS Caries ranking method, the identified lesions on radiographs were assigned a score, with 0–2 denoting early lesions and 3–6 indicating progressive lesions. Inter- and intra-observer reliability were assessed using kappa statistics, yielding values of 0.83 and 0.87, respectively. SPSS version 22.0 was used for statistical analysis. For qualitative variables like gender, tooth count, and tooth surface, frequency and percentage were computed. The age was either shown as a histogram or as a mean and standard deviation. The ICDAS criteria for optical and radiographic caries diagnosis in permanent molars were evaluated using the Chi-Square test. $p < 0.050$ was the significance threshold.

RESULTS

There were no statistically significant differences in baseline demographic characteristics between the two groups. The mean age of participants in the occlusal caries group was 25.9 years (SD 6.5), and in the proximal caries group, it was 26.1 years (SD 6.2) ($p = 0.753$, independent samples t-test). Gender distribution was also comparable between the groups, with males comprising 38.6% in the occlusal group and 40.2% in the proximal group, and females comprising 61.4% and 59.8%, respectively ($p = 0.752$, χ^2 test)(Table 1).

Table 1: Comparison of Demographic Characteristics Between Group A (Occlusal Caries) and Group B (Proximal Caries)

Variables	Characteristics	Occlusal Caries	Proximal Caries	p-Value
Age (years)	–	25.9 ± 6.5 (range: 16–35)	26.1 ± 6.2 (range: 16–35)	0.753
Gender	Male	73 (38.6%)	76 (40.2%)	0.752
	Female	116 (61.4%)	113 (59.8%)	

*Independent samples t-test was used for age comparison; Chi-square test was used for gender distribution

The distribution of tooth location did not differ significantly between the occlusal and proximal caries groups (χ^2 test, $p = 0.106$). In the occlusal caries group, mandibular molars were more frequently affected, with 61 teeth (32.1%) in the mandibular right quadrant and 60 teeth (31.6%) in the mandibular left. In contrast, the proximal caries group showed greater involvement of maxillary molars, particularly the maxillary left quadrant with 53 teeth (28.6%). In terms of tooth type, a statistically significant difference was observed (χ^2 test, $p = 0.037$). First molars were more frequently involved in both groups, but were significantly more common in the occlusal caries group (154 teeth, 81.1%) compared to the proximal caries group

(137 teeth, 72.3%). Second molars were more often affected in the proximal caries group (52 teeth, 27.7%) than in the occlusal caries group (35 teeth, 18.9%)(Table 2).

Table 2: Distribution of Tooth Location and Type in Occlusal Caries and Proximal Caries Group (N=378)

Category	Subcategory	Occlusal Caries	Proximal Caries	p-Value
Tooth Location	Maxillary Right	33 (17.3%)	35 (18.4%)	0.106
	Maxillary Left	35 (18.9%)	53 (28.6%)	
	Mandibular Right	61 (32.1%)	51 (26.7%)	
	Mandibular Left	60 (31.6%)	50 (26.2%)	
Tooth Type	First Molar	154 (81.1%)	137 (72.3%)	0.037
	Second Molar	35 (18.9%)	52 (27.7%)	

The diagnostic comparison between visual and radiographic methods revealed no statistically significant differences in detecting initial or advanced caries in either group. In the occlusal caries group, initial lesions were identified in 6.3% of cases by visual examination compared to 4.8% via radiographic assessment ($p = 0.622$), while advanced lesions were detected in 93.7% and 95.2% of cases, respectively. Similarly, in the proximal caries group, the visual method identified 5.3% of cases as initial caries versus 4.2% with radiographs ($p = 0.624$), with advanced caries comprising the majority of cases in both modalities (94.7% visual vs 95.8% radiographic)(Table 3).

Table 3: Caries Diagnosis by Visual and Radiographic Methods in Both Groups (N=378)

Groups	Diagnosis Type	Visual, n (%)	Radiographic, n (%)	p-Value
Occlusal Caries Group (n=189)	Initial Caries	12 (6.3%)	9 (4.8%)	0.622
	Advanced Caries	177 (93.7%)	180 (95.2%)	
Proximal Caries Group (n=189)	Initial Caries	10 (5.3%)	8 (4.2%)	0.624
	Advanced Caries	179 (94.7%)	181 (95.8%)	

DISCUSSION

In vitro comparison of ICDAS visual vs. image-based ICDAS using micro-CT as the gold standard showed very similar diagnostic accuracy in molars (accuracy ≈ 0.83 vs 0.85), though both had limited specificity for caries needing operative treatment [13]. However, unlike that study, which used high-resolution micro-CT in a controlled laboratory setting, our study was conducted using conventional radiographs in a clinical environment. This shows the practical relevance of our findings, as they reflect real-world diagnostic conditions where micro-CT is not feasible. A previous in vitro study evaluated the reliability and accuracy of ICDAS and radiographs for detecting and estimating the depth of proximal lesions on directly visible surfaces of extracted primary and permanent teeth [14]. The findings indicated that ICDAS had higher intra- and inter-reproducibility ($\kappa > 0.9$ and > 0.85 , respectively) compared to radiographs ($\kappa = 0.6$ –0.8), and also demonstrated superior accuracy in estimating lesion

depth, particularly for lesions confined to enamel or the outer third of dentine. The correlation for ICDAS with visual depth was ≥ 0.85 , whereas for radiographs it was ≥ 0.45 . In this study, most of the patients were female [116 (61.4%) and 113 (59.8%)] as compared to male patients [73 (38.6%) and 76 (40.2%)], with mean age of 25.9 ± 6.5 and 26.1 ± 6.2 years in Group A (Occlusal caries) and Group B (Proximal caries), respectively. Similar high female prevalence and mean age were observed, with 63% female patients having a mean age of 31 ± 17 years [15]. We observed a non-significant difference in how tooth quadrants were distributed between the two groups. However, occlusal caries was more frequently found in mandibular molars, affecting over 32% of cases, while proximal caries tended to involve the maxillary left quadrant more often. This pattern may reflect differences in anatomical accessibility, salivary flow, and plaque accumulation occlusal surfaces of mandibular molars are more exposed to masticatory forces and pit-and-fissure retention, making them more vulnerable to direct caries development [16, 17]. In contrast, the interproximal surfaces of maxillary molars, especially in the left quadrant, may be more difficult to clean effectively, leading to plaque retention and increased risk of proximal lesions [18]. When examining the types of teeth affected, a noticeable trend was found: occlusal caries was most commonly seen in the first permanent molars (81%), while proximal caries were more frequently detected in the second permanent molars (27.7%). This pattern may be explained by the fact that first molars erupt earlier and are exposed to the oral environment and thus cariogenic factors for a longer period, increasing their risk for occlusal surface breakdown [19]. On the other hand, the shape and contact points of the second molars can make them more prone to plaque accumulation between the teeth, especially if oral hygiene is not well maintained, leading to a higher risk of proximal caries [20]. The strength of this study lies in the meticulous matching of demographic variables, which was undertaken to minimize potential confounding factors. The application of the ICDAS classification system for both visual and radiographic assessments enhances diagnostic reliability and facilitates comparability with existing literature. Nevertheless, certain limitations must be acknowledged. The study relied solely on the ICDAS system without incorporating adjunctive caries detection technologies such as laser fluorescence or trans illumination, which may offer greater sensitivity, particularly in the detection of early proximal lesions. Furthermore, the absence of histological validation precludes definitive confirmation of diagnostic accuracy against established gold standards. Despite its strengths, this study has certain limitations. Being a single-center cross-sectional study using non-

probability sampling, the findings may not be generalizable to broader populations. Additionally, the absence of a histological or micro-CT gold standard limits the ability to determine true diagnostic accuracy, and advanced adjunctive technologies were not incorporated. Future multicenter studies incorporating gold standard validation methods and newer diagnostic tools are recommended to further evaluate sensitivity, specificity, and cost-effectiveness of ICDAS-based visual and radiographic assessments in diverse clinical settings.

CONCLUSIONS

In conclusion, this study found that visual and radiographic methods based on the ICDAS system were equally effective in identifying occlusal and proximal carious lesions in permanent molars. This suggests that both approaches can be reliably used in clinical practice for the detection of dental caries, offering flexibility in diagnostic decision-making depending on clinical circumstances and available resources.

Authors' Contribution

Conceptualization: VN, MM

Methodology: VN

Formal analysis: AAJ

Writing and Drafting: MM, MA, SM, SA

Review and Editing: MM, MA, SM, SA, VN, AAJ

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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