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The Impact of Integrated Education on Dental Students' Diagnostic Accuracy Using ICDAS

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Abstract

Objective(s): This study aimed to evaluate the effectiveness of the International Caries Detection and Assessment System (ICDAS) practical training in dental education, focusing on its impact on the accuracy of caries detection among dental students. **Methods:** In this quasi-experimental study, 18 dental students were enrolled and divided into control (theoretical training) and experimental (theoretical and practical training) groups (N=9 in each group). Theoretical training covered the ICDAS system's principles, coding methods, and caries examination techniques, while practical training involved hands-on experience on diagnosing caries in four patients identified with different ICDAS codes. Participants' diagnostic performance was subsequently assessed at the chairside of a new patient. Statistical analysis included Fisher's exact test and logistic regression at $p<0.05$. **Results:** The experimental group significantly outperformed the control group in diagnostic accuracy, particularly for ICDAS codes 0, 1, and 4 ($p=0.02$, $p=0.02$, and $p=0.004$, respectively). Similarly, the experimental group achieved 100% accuracy for codes 0, 1, 5, and 6, while the control group showed lower accuracy, especially for codes 0 and 1. **Conclusion:** The findings highlight the importance of integrating practical training with theoretical instruction. The ICDAS-based practical education is crucial for enhancing diagnostic accuracy among dental students. Incorporating such training into dental curricula could improve caries assessment, ultimately leading to better patient outcomes. Future studies should explore these findings in larger and more diverse clinical settings.

Keywords: Dental Education; Dental Caries; Early Diagnosis; Early Detection of Disease

Introduction

Dental caries remains one of the most prevalent and costly oral health problems globally, impacting individuals across all age groups [1]. Despite advancements in preventive measures and restorative techniques, the early detection and accurate assessment of caries are crucial for effective management and treatment [2]. In this context, the training of dental students plays a pivotal role in equipping future professionals with the necessary skills to diagnose and treat caries effectively [3].

The International Caries Detection and Assessment System (ICDAS) was developed as a standard method for detecting and assessing caries [4, 5]. It provides a detailed scoring system that aids in the early detection of carious lesions, allowing for timely intervention. The system's comprehensive approach not only facilitates accurate diagnosis but also enhances the consistency of assessments among practitioners [5]. Caries detection has historically depended on visual assessments and tactile evaluations, which have different level of sensitivity for early caries identification [6].

The World Health Organization (WHO) has introduced a widely accepted approach for assessing and quantifying dental caries across different populations [7] by means of decayed, missing, and filled teeth (DMFT) index, valued for its applicability and significant reproducibility [7]. Nevertheless, this method overlooks the pre-cavitation phases of carious lesions, potentially restricting its ability to provide a comprehensive evaluation of the entire range of dental caries [6]. In response to these shortcomings, the ICDAS system has been developed, providing a more nuanced classification of carious lesions that takes into account the extent and severity as well [5].

Previous studies have highlighted the advantages of ICDAS in clinical settings. For instance, research comparing ICDAS with traditional methods has demonstrated its superior sensitivity and specificity in detecting early enamel lesions [8]. Moreover, studies have shown that ICDAS can reduce inter-examiner variability [9, 10], leading to more consistent diagnoses. Furthermore, previous research has focused on the importance of various learning strategies in mastering ICDAS. For instance, Luz et al., [11] investigated the effectiveness of different educational methods on undergraduate dental students' proficiency with ICDAS clinical caries detection. Their findings underscored the critical role that tailored toward teaching to enhance diagnostic skills among dental students. Similarly, Marcov et al., [12] conducted a longitudinal study over six years to evaluate the implementation of ICDAS II in dental education, and provided valuable insights into the long-term impact of ICDAS training on students' caries detection capabilities. Mohamed et al., [13] assessed the performance of dental undergraduates using ICDAS and emphasized the need for continuous assessment and refinement of educational strategies to improve caries detection accuracy. Additionally, El-Damanhoury et al., [14] investigated the effectiveness of an e-learning program designed to teach ICDAS II to freshman dental students, focusing on its impact on detecting occlusal caries. Their work highlighted the potential of digital tools in enhancing traditional educational methods.

Together, the previous studies provide a comprehensive view of the challenges and advancements in teaching ICDAS to dental students. However, despite the recognized advantages of ICDAS and ongoing refinements in teaching methodologies, dental curricula worldwide continue to report significant variability in students' caries detection accuracy and long-term retention of ICDAS skills [11-14]. Furthermore, a critical gap exists in understanding how the integration of specific theoretical and practical educational components within diverse curricula directly influences students' diagnostic competency and the consistency of ICDAS application in clinical settings. The present study; therefore, aimed to build on this body of research by evaluating current theoretical and practical educational aspects and their effectiveness in preparing dental students to accurately detect and assess carious lesions, ultimately contributing to improved clinical outcomes in dental care.

Methods

Study design and participants

The present study was conducted in May-June 2013 using a quasi-experimental design. Participants included 18 dental students selected by convenience sampling method from School of Dentistry, Shahid Beheshti University of Medical Sciences, who were in the 7th semester of their undergraduate program. The students were divided into two groups (N=9 in each group): the control group, who received only theoretical training, and the experimental group, that received both theoretical and practical education on application of the ICDAS system.

Study procedure

The study consisted of three stages: Stage 1. Theoretical training: In this stage, the ICDAS system was introduced and taught theoretically to all participating students (18 individuals) by a dentist who had been trained and calibrated through two educational sessions. Training of students was held in a session in one of the classrooms at School of Dentistry, Shahid Beheshti University of Medical Sciences in June 2013. Subsequently, for further studying, an educational English booklet from the ICDAS website (https://www.iccms-web.com/content/icdas) with the following items was provided to all participants:

1. Introduction to the ICDAS system
2. The two-digit coding method of this system
3. Important points to consider during examination
4. The relationship between ICDAS coding system and the depth of carious lesion histologically
5. Educational images for the coding method of this system
6. Image and specifications of the WHO probe used for caries detection in this system

Stage 2. Practical training: In this stage, which took place one week after the theoretical training stage, nine students (the experimental group) who had been theoretically trained in the previous stage were divided into three subgroups. Over three consecutive days, for two hours per day, they received practical training on the ICDAS coding system at chairside of four patients, conducted by the calibrated dentist. The patients on whom practical training was performed had been selected from the staff of School of Dentistry, Shahid Beheshti University of Medical Sciences and determined to have various ICDAS codes after examination by the calibrated dentist. Additionally, to encourage their cooperation, each of them had been paid an amount of money. Before examination, patients brushed their teeth with toothpaste and used dental floss to clean their teeth. A disposable mouth mirror and a WHO probe were used for demonstration which was conducted under the light of dental unit. In this practice, each tooth was first examined in a wet state and then in a dry state (dried with an air spray for five seconds). All surfaces of all teeth of the four patients were examined and coded based on the ICDAS system.

Stage 3. Assessment of participants' learning: In this stage, after one day, a test was conducted at the chairside of a new patient (other than the four patients recruited in the previous stage) for diagnosing and coding dental caries, involving all 18 students. Each student was requested to complete a form consisted of 10 questions from 10 different teeth of one patient. The form also included the students' name, age, gender, date of examination, ICDAS codes, and schematic representations of the teeth for referencing ICDAS system codes. The students employed the WHO probe for dental examination and entered their codes into the form. For the data analysis, the correct identification of the codes was provided by the calibrated dentist as a gold standard.

Ethics

Participation in this study was voluntary for both students and patients. Both were assured that the results of their examinations would be used solely for research purposes. Patients recieved a gift for enhanced cooperation. Before the examinations, all patients were informed about the procedure, and those requiring dental treatments were notified of their condition and referred to other departments of the dental school for obtaining appropriate care. Moreover, ethical considerations of the study were discussed and approved in the department of community oral health, School of Dentistry, Shahid Beheshti University of Medical Sciences.

Data analysis

Statistical analysis involved presenting the students' responses through frequency tables, serving as descriptive statistics. The analytical statistics utilized Fisher's exact test to compare the responses of students between the intervention and control groups, alongside a logistic regression model to assess the impact of independent variables (age and gender) on the students' diagnoses. The Statistical Package for the Social Science (IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: I.B.M. Corp, 2020) was used to perform statistical tests. The level of significance was set at 0.05.

Results

Diagnostic performance of students in the experimental group (who received both theoretical and practical training) was

compared with that of the control group (who received theoretical training only) using the ICDAS codes. Table 1 demonstrates that the experimental group showed a high level of agreement with the gold standard diagnosis across all ICDAS codes. The total number of correct answers in the experimental group (examination of 10 teeth by nine students) was 84 out of 90 answers, equivalent to 93.4%. The codes that were misdiagnosed in this group included codes 2, 3 and 4, where code 2 was mistaken for code 1 in two cases, code 3 was mistaken for code 2 in three cases and code 4 was misdiagnosed as code 3 in two cases.

Table 1 – Diagnostic performance of students in experimental group (N=9) based on different ICDAS codes in comparison to gold standard.

		Gold Standard						
		0	**1**	**2**	**3**	**4**	**5**	**6**
Students	0	18	0	0	0	0	0	0
	1	0	9	0	0	0	0	0
	2	0	2	7	0	0	0	0
	3	0	0	3	15	0	0	0
	4	0	0	0	2	16	0	0
	5	0	0	0	0	0	9	0
	6	0	0	0	0	0	0	9

Table 2 shows that the control group exhibited lower overall diagnostic accuracy. In this group, the total number of correct answers was 63 out of 90, equivalent to 70%. The correct diagnosis rates for codes 0 and 1 were particularly low, with 72.2% (13 correct diagnosis out of 18 total) for code 0 and 44.4% (4 correct diagnosis out of 9 total) for code 1, while for codes 5 and 6, 100% accuracy was achieved, similar to the experimental group.

Table 2- Diagnostic performance of students in control group (N=9) based on different ICDAS codes in comparison to gold standard.

		Gold Standard						
		0	**1**	**2**	**3**	**4**	**5**	**6**
Students	0	13	2	3	0	0	0	0
	1	1	4	4	0	0	0	0
	2	0	0	8	1	0	0	0
	3	0	0	4	11	3	0	0
	4	0	0	5	4	9	0	0
	5	0	0	0	0	0	9	0
	6	0	0	0	0	0	0	9

Table 3 provides a detailed analysis of the percentages of correct diagnoses for each group. The experimental group consistently outperformed the control group, especially for the early (codes 0 and 1) and severe (code 4) stages of caries, where the control group showed significant deficiencies in diagnostic accuracy.

Moreover, table 3 presents a statistical comparison of the diagnostic accuracy between the two groups. The experimental group's performance was significantly better for codes 0, 1, and 4, ($p=0.02$, $p=0.02$, and $p=0.004$), respectively. No significant differences were found for codes 2, 3, 5, and 6. In relation to code 5 and 6 both groups performed equally well.

Table 3 – Comparison of students' diagnosis on dental caries based on different ICDAS codes between the two groups.

Codes	Correct diagnosis (Control group who got just theoretical education)	Correct diagnosis (Experimental group who got both theoretical and practical education)	p-value*
0	72.2	100	0.023
1	44.4	100	0.015
2	88.9	77.8	0.5
3	61.1	83.3	0.132
4	50	94.4	0.004
5	100	100	1
6	100	100	1

*Statistical evaluation by Fisher exact test at a significance level of 0.05.

With regard to the influence of age and gender as independent variables on the students' diagnoses, the results of the logistic regression analysis revealed that neither of these independent variables exerted a significant impact on the diagnostic outcomes of students.

Discussion

The findings of the present study demonstrated that integrating practical education with theoretical instruction significantly enhanced dental students' diagnostic accuracy in assessing carious lesions using ICDAS. Specifically, students who received both theoretical and practical education exhibited higher diagnostic accuracy across the most of ICDAS codes compared to those who only received theoretical education. The statistically significant differences observed for codes 0, 1, and 4 between the experimental and control groups emphasized the impact of practical training on diagnostic outcomes. The observed increase in accuracy scores underscore the value of incorporating practical ICDAS-based training into dental curricula, in line with available supporting literature on the importance of combined teaching approaches in dental education.

Luz et al., [11] and Schwendicke et al., [15] explored the performance of undergraduate dental students on ICDAS coding after using different learning strategies. They reported that students who engaged in practical exercises following theoretical instruction, performed significantly better in caries detection compared to those who only received theoretical training. The present study corroborates these findings, as the

experimental group in this research also outperformed the control group, particularly in the early (codes 0 and 1) and more advanced (code 4) stages of caries detection.

Similarly, findings of a study by Marcov et al., [12] indicated that hands-on training was crucial for improving diagnostic skills among students. In line with that study, our findings showed significantly higher diagnostic accuracy in the experimental group, further supporting the argument that practical experience is essential for enhancing the diagnostic accuracy of dental students.

The results of the present study align with the findings of Mohamed Zohdi et al., [13], Pishipati et al., [16], and Braga et al., [17], who all reported that students exposed to practical clinical sessions exhibited superior diagnostic capabilities compared to those who were not. This underscores the importance of clinical training in cultivating competent diagnostic skills.

Two studies investigated the effectiveness of teaching ICDAS II by including an e-learning component to freshman dental students [14, 18]. They found that while e-learning was beneficial, the addition of practical hands-on training significantly improved students' ability to detect occlusal caries. In line with their findings, results of the present study underscore the value of practical education in achieving higher diagnostic accuracy, particularly in identifying both early and severe caries lesions.

Overall, the consistency between our findings and those reported in the literature suggests a robust consensus that practical education, in conjunction with theoretical instruction, is essential for effective caries detection using ICDAS. Future research should continue to explore the optimal balance of theoretical and practical instruction to maximize diagnostic accuracy in dental education.

While our findings strongly support integrated training, some studies report persistent challenges in ICDAS proficiency. Al Dhubayb et al., [19] observed low overall caries detection ability among Saudi Arabian dentists and students despite ICDAS familiarity, particularly for early lesions. Similarly, Alves et al., [20] found only moderate improvements in Brazilian students' performance after e-learning training, with sensitivity/specificity gains varying across diagnostic thresholds. These discrepancies may stem from key methodological differences, where Al Dhubayb et al. [19] assessed baseline skills without structured intervention, reflecting pre-training limitations rather than training efficacy, and Alves et al., [20] used in vitro models and digital tools, lacking the tactile/contextual dimensions of live-patient interaction central to our practical training.

The results of this study have significant implications for dental education. Incorporating practical ICDAS training into dental curricula could enhance the diagnostic capabilities of future practitioners, leading to improved patient outcomes. Early and accurate detection of caries is crucial for effective prevention and treatment, and the use of ICDAS in education could help ensure that dental graduates are well-equipped to meet this challenge.

The outcomes of this study are promising; however, several limitations must be considered. The investigation was performed with a relatively small sample drawn from a single dental school, which may limit the extent to which the findings can be generalized. Due to certain administrative constraints, it was not feasible to randomly assign students to either the intervention or control group that may lead to potential bias in the study. Additionally, the study was conducted in a controlled environment that may not represent actual clinical practice. Future studies should strive to conduct these procedures with thorough theoretical and practical training to guarantee adequate coverage of examination techniques, alongside larger sample sizes and diverse clinical settings.

Conclusion

This study demonstrated the effectiveness of the ICDAS practical training on enhancing the diagnostic accuracy of dental students in detecting and assessing carious lesions. The significant improvement in the experimental group's performance suggests that ICDAS-based practical training could play a crucial role in dental education, preparing future practitioners to provide high-quality care.

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Author Contributions: H.G.: Conceptualization, Methodology, Investigation, Writing – Original and Review drafts, Supervision; and F.S.: Methodology, Project implementation, Data Curation.

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Ethical Approval Code: At the time of performing this study, having an ethical approval code was not mandatory. However, participants were informed that participation in the study was entirely voluntary. They were given details about the study's objectives, and questionnaires were distributed only to those who provided their consent. Participants were also assured that their responses would be kept confidential. The study received approval from the Department of Community Oral Health at School of Dentistry, Shahid Beheshti University of Medical Sciences.

Informed Consent Statement: Questionnaires were distributed only to those who provided their written informed consent.

Data Availability Statement: The datasets generated during the current study are available from the corresponding author upon reasonable request.

Using AI: This manuscript has benefited from the use of

Deepseek (version 3) exclusively for language improvement. Deepseek was utilized to enhance the clarity, coherence, and grammatical accuracy of the text while ensuring that the original meaning and scholarly integrity of the content remained unchanged. No part of the research design, data analysis, interpretation of results, or conceptual contributions were generated or influenced by AI. The authors take full responsibility for the intellectual content of this work.

Conflict of Interest: No conflicts of interest to declare.

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