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QUALITATIVE AND QUANTITATIVE EVIDENCE USING ICDAS AND ICCMS: AN INTEGRATIVE REPORT

[Evidencia qualitativa e quantitativa utilizando o ICDAS e ICCMS: Revisão integrativa]

Dissertação de Mestrado

[Mestrado Integrado em Medicina Dentária]

Margarida Isabel Pombo Regatão

Orientador:

Prof. Doutora Patrícia Manarte Monteiro

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A todos os que sempre me apoiaram nunca se esqueçam que o amanhã está a frente e nunca atrás, não tenham medo de passar o risco ou de partir loiça porque as histórias de vida quem as tem é quem as vive e não quem as deixa passar.

“Há um tempo em que é preciso abandonar as roupas usadas, que já têm a forma do nosso corpo, e esquecer os nossos caminhos, que nos levam sempre aos mesmos lugares. É o tempo da travessia. E, se não ousarmos fazê-la, teremos ficado, para sempre, à margem de nós mesmos.”

- Fernando Pessoa

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Aos meus Pais Sãozinha e Adrianinho, que sempre me apoiaram em todas as minhas escolhas. Obrigada pela paciência nos dias mais stressantes e por me encorajarem a seguir em frente com as minhas loucuras pontuais, graças a vocês tive a oportunidades única e enriquecedora de Erasmus, que como bem sabemos foi algo com muito peso em mim e que me fez crescer.

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Aos meus avós que sempre tiveram de lutar para uma vida melhor, e que com a conclusão desta etapa um brilhinho de orgulho se acrescenta ao olhar.

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À Xana, à Maria Bea, Matilde e Maria Helena, quadrinómias mais um, pelos momentos vividos nestes últimos anos, cada um foi único e uma loucura que nunca será esquecida, desde as festas todas a que fomos aos momentos de estudo na sala da casa da Matilde, mas sempre tudo muito descontraído e com pausas de fofoca.

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Resumo

Objetivos: Esta revisão integrativa teve como objetivo categorizar e avaliar qualitativa e quantitativamente, as metodologias científicas atuais usadas na avaliação da cárie dentária, aplicando ambos, Sistema Internacional de Detecção e Avaliação de Cárie (ICDAS) e do Sistema Internacional de Classificação e Abordagem da Cárie (ICCMS).

Métodos: Pesquisa bibliográfica estruturada nas bases de dados PubMed, B-on e ScienceDirect, entre novembro de 2024 e março de 2025, considerando artigos revistos por pares nos últimos sete anos, em inglês, contendo os termos “ICDAS” e “ICCMS” no título ou resumo. Foram incluídos ensaios clínicos randomizados (RCTs) e estudos observacionais transversais ou longitudinais não-randomizados (NRE), conforme PRISMA 2020. A metodológica foi avaliada com STROBE- nos estudos observacionais não randomizados- e CONSORT 2020- nos RCTs, enquanto a qualidade e risco de viés com as ferramentas ROBINS-E e RoB-2, respectivamente. A questão de investigação, estruturada pelo modelo PICOS, abordou objetivos atuais, metodologias e desfechos qualitativos e quantitativos derivados de estudos selecionados.

Resultados: Dos 52 estudos identificados, apenas cinco atenderam aos critérios de inclusão: quatro NRE e um estudo RCT. Observou-se um desencontro relevante entre as diretrizes do ICDAS/ICCMS e sua aplicação clínica. Em países como Tailândia e Jordânia, há uma tendência ao tratamento cirúrgico precoce, em divergência com as recomendações minimamente invasivas do ICCMS. Também foram identificadas lacunas na formação acadêmica, com limitada familiaridade dos estudantes com o ICCMS.

Conclusão: A integração efetiva dos sistemas ICDAS e ICCMS na formação clínica é essencial para promover estratégias preventivas, evitar tratamentos excessivos e aperfeiçoar a abordagem da cárie dentária com base na evidência.

PALAVRAS-CHAVE: Carie Dentária, Diagnostico, ICDAS, ICCMS.

Abstract

Aims: This integrative review aims to systematically categorize and evaluate, both qualitatively and quantitatively, the current scientific methodologies employed in dental caries assessment, using the combined application of the International Caries Detection and Assessment System (ICDAS) and the International Caries Classification and Management System (ICCMS).

Methods: A structured and comprehensive literature search was conducted across PubMed, B-on, and ScienceDirect databases -November 2024 March 2025. Inclusion criteria were restricted to peer-reviewed articles published in English within the past seven years, incorporating both ICDAS and ICCMS in the title or abstract. Eligible studies comprised randomized controlled trials (RCTs) and non-randomised exposure cross-sectional or longitudinal (NRE) designs, selected in accordance with the PRISMA 2020 guidelines. Methodological quality was appraised using STROBE (for observational studies) and CONSORT 2020 (for RCTs), while risk of bias was assessed through ROBINS-E and RoB-2 tools, as appropriate. The research question, structured using the PICOS framework, addressed current objectives, methodologies, and quantitative outcomes derived from studies employing both systems.

Results: From 52 screened studies, five met the inclusion criteria: four NREs and one RCT study. Findings revealed a significant disconnect between ICDAS/ICCMS guidelines and clinical implementation. Geographically, differences were observed in treatment decisions, particularly in Thailand and Jordan, where a preference for surgical management of early caries persists despite ICCMS recommendations for non-invasive care. Additionally, educational gaps were noted, with dental students revealing limited familiarity with ICCMS. Identified methodological inconsistencies and sample limitations underscore the need for more robust, longitudinal studies.

Conclusions: Enhanced integration of ICDAS and ICCMS into clinical training and practice is essential to promote preventive strategies, reduce overtreatment, and advance evidence-based caries management.

KEYWORDS: Dental Caries, Diagnosis, ICDAS, ICCMS.

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Annex 1 *Main description of the in vivo, NREs and RCTs (n=5) included in this integrative review, namely the authors/year, aims, methodology, population, statistics, main results, limitations and conclusions* _____ 35

LIST OF ABBREVIATIONS

PICO – Population, Intervention, control, outcome

MESH – Medical Subject Headings

ICDAS – International Caries Detection and Assessment System

ICCMS – International Caries Classification and Management System

DMFT – Decayed, Missing, Filled Teeth

DMFs – Decayed, Missing, Filled surface

RCT – Randomised Clinical Trial

AB – Abstract

NREs – Non-randomised, exposure, cross-sectional or longitudinal studies.

NS – Not significant

SI – Significant increase

RR – Relative Risk

RD – Risk Reduction

TPOC – Tooth-Preserving Operative Care

1. Introduction

Dental caries is a well-known burden, multifactorial disease of extreme complexity being currently classified as a non-communicable disease (NCD) with high-importance both at global and at countries contexts and policies. It shares similar risk-factors with other chronic/systemic diseases (Pitts et al., 2021). The prevention and the better management of dental caries, from initial stages up to cavity lesions, can help to promote the prevention and control other human pathologies. Nowadays high knowledge of humans and the oral microbiomes leads to the recognition of balancing protective and pathological risk factors (Huang et al., 2023; Jablonski-Momeni et al., 2019; Lin et al., 2021).

The Global Burden of Disease Study 2019 identified dental caries as a significant public health problem, providing both global and regional data that facilitate the analysis of demographic and epidemiological factors contributing to this highly prevalent disease. The results indicated that, in 2019, untreated caries in permanent teeth represented the most common health condition worldwide. Although there was a modest decrease in age-standardized prevalence of caries in permanent teeth (−3.6%) between 1990 and 2019, the authors emphasized that there were no substantial reductions in global prevalence. The persistence of this high disease burden underscores the urgent need for reform in oral health care, with a particular focus on strategies for the promotion and prevention of dental caries (Wen et al., 2022).

Despite advances in global public health, oral health remains largely neglected in the spot of social progress. The study by Listl and Bärnighausen (2025) highlighted the absence of specific oral health metrics, such as dental caries, from widely used indicators like the Human Development Index or the Sustainable Development Goals. This omission undermines comprehensive assessments of population well-being, as dental caries have direct implications for quality of life, productivity and health equity. The authors advocate for the inclusion of simple and practical oral health metrics- such as, the number of natural teeth, self- assessment of oral health, and unmet oral health needs- as essential markers of social progress (Listl & Barnighausen, 2025).

In alignment with these concerns, the World Health Organization (WHO) launched the Global Health Action Plan 2023-2030, which recognizes dental caries as one of the most prevalent and preventable chronic diseases, currently affecting approximately 3.5 billion people worldwide. This action plan sets forth ambitious targets to be achieved by 2030,

including ensuring that 80% of the global population has access to essential oral health care and that at least 50% of the countries adopt preventive measures including policies to reduce the consumption of free sugars and promote the use of fluoride, both for caries prevention. Furthermore, the plan emphasizes the necessity of strengthening health systems to better integrate oral health services, developing robust national information systems to enable data-driven policy decisions, and restructuring professional training in oral health. By addressing these key areas, the WHO aims to significantly reduce the global burden of dental caries and improve overall oral health outcomes (Ben Yahya, 2024).

The traditional clinical approach of caries lesions frequently focus on the repaired damage caused by the dental caries disease by means of surgical operative interventions, rather than centering on the lesions etiology, the individual risk factors prevention and the patient education for prevention. This approach, do not allow to the disease progression prevention and often results in the increased loss of the affected tooth (Khallaf et al., 2021) All dental restorations, despite often being referred to as “permanent restorations” have a limited lifespan. Once a tooth has been restored, it typically enters a cycle of repeated interventions known as the "restoration cycle", which can ultimately lead to progressive loss of dental tissues. To mitigate this outcome, the principles of minimal intervention, also known as minimally invasive dentistry (MID) have been developed (Alam et al., 2023). This attitude represents a paradigm shift from the traditional philosophy of "extension for prevention"—which advocated for the removal of additional tooth structure to prevent future caries—towards the modern concept of "prevention of extension." MID emphasizes early detection, risk assessment, and the use of preventive and minimally invasive restorative methods, thereby reducing the need for extensive future interventions and preserving oral health over the long term (Al-Asmar et al., 2022).

MID is an approach that emphasizes the importance of individualized patient assessment. This can be achieved through the systematic identification of disease indicators, risk factors, and protective factors unique to each patient. By integrating this comprehensive assessment, clinicians are able to develop tailored treatment and prevention strategies that address the specific needs and risks of each individual (Khallaf et al., 2021)

Recent research has revealed considerable variation in the reported prevalence of dental caries depending on the diagnostic criteria employed, specifically when comparing the

WHO criteria with the International Caries Detection and Assessment System II (ICDAS II). The WHO criteria are limited to the identification of tooth cavitated lesions whereas ICDAS II enables the detection of both cavitated and non-cavitated (incipient) lesions, thereby providing a more comprehensive and earlier assessment of dental caries activity. The study of Rai and colleagues (2025) showed that the prevalence of dental caries was significantly higher when assessed using ICDAS II, with a particularly concerning proportion of non-cavitated carious lesions identified. These findings highlights the potential of ICDAS II to serve as a more sensitive and effective tool for early detection of caries, allowing for timely interventions and improved preventive strategies compared to the traditional WHO criteria (Rai et al., 2024).

The International Caries Detection and Assessment System (ICDAS) and the International Caries Classification and Management System (ICCMS) are evidence-based frameworks that play a pivotal role in achieving more accurate and conservative management of dental caries lesions. ICDAS allows a methodical analysis of caries progression, ranging from the earliest enamel changes to advanced cavitated lesions. Compared to conventional indices, such as the Decayed, Missing, and Filled Teeth (DMFT) index, ICDAS demonstrates greater sensitivity and specificity, thereby facilitating earlier diagnosis, planning and the implementation of personalized preventive actions (Pitts et al., 2013).

ICCMS builds upon the ICDAS classification by providing structural clinical care that incorporates each patient's unique risk factors. By staging lesions according to ICDAS criteria, ICCMS guides clinicians in selecting appropriate interventions, with a primary focus on minimizing invasive procedures. The system empathizes the remineralization of affected tooth structures and the conservation of natural dentition whenever possible. Beyond clinical practice, ICCMS can be applied in community-based programs and public health policies, serving as a base for equitable and sustainable oral health strategies (Ismail et al., 2015).

The adoption of ICDAS and ICCMS represents a paradigm in the perception, understanding, and management of dental caries lesions and of dental caries disease. Considering the high prevalence of caries in several populations, prioritizing prevention and continuous monitoring yields not only clinical benefits, but also significant social and economic advantages. By shifting the focus from restorative to preventive care, these methodologies support improved oral health outcomes at both individual and population

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levels (Martignon et al., 2019).

This integrative review aims to categorize and critically appraise both qualitative and quantitative, nowadays research methodologies employed for the evaluation of dental caries using both the International Caries Detection and Assessment System (ICDAS) and the International Caries Classification and Management System (ICCMS). By providing a comprehensive understanding of the latest evidence of the topic ICDAS and ICCMS, this review seeks to syntheses diverse perspectives and research types of these frameworks in both clinical and public health contexts.

2. Material and Methods

This integrative review followed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA 2020) guidelines (Page et alii., 2021; Equator network, 2023).

The research question based on PICOS strategy was: *What are the nowadays aims and methodologies for caries diagnosis and management and, the main quantitative outcomes of cross-sectional/longitudinal or in vivo studies using both ICDAS and ICCMS?*

2.1 - Eligibility, inclusion and exclusion criteria

Only in vivo studies - including clinical or exposure research- conducted on permanent teeth of humans aged 18 years or older and using both ICDAS and ICCMS for caries diagnosis and management, were included. Additionally, only full-text articles written in English and published within the last seven years (from 2019 up to March 2025) were considered for this planned study.

To assess the qualitative (aims, diagnosis and management methods) and the quantitative (frequency, prevalence or incidence rates) data outcomes, randomized clinical trials (RCTs) or the non-randomized-exposure, cross-sectional/longitudinal (NREs) studies were collected and analyzed as the PICOS framework (Table 1).

Other types of published research than those contemplated in inclusion criteria such as, those with distinct methodology, such as case reports, in vitro, systematic reviews or meta-analysis, studies performed in non-human teeth, in animals, in children or in primary teeth, and those with incomplete abstracts, or with no full-text available, or not written in English language, were excluded.

Table 1

PICOS strategy applied for the integrated analysis

IDENTIFIED	APPLIED
Population (P):	In Vivo, randomized clinical trials (RCT) or Non-randomized-exposure research in permanent teeth of humans with 18th or more than 18th years old.
Intervention/Exposure (I):	Use of ICDAS and ICCMS for caries detection, classification, risk assessment, and management.
Comparison (C):	Other tools than ICDAS/ICCMS for caries detection, evaluation and management.
Outcome (O):	Qualitative data (Aims, diagnosis and management methods) and quantitative data (frequency, prevalence or incidence) of cross-sectional or longitudinal studies (Non-randomized-exposure studies) and randomized clinical trials (RCTs).

2.2 - Search Strategy and Data Collection Process

2.2.1 - Search Engines, actions, key and MeSH terms

A methodological search was performed by one team member (M.R.) across PubMed, B-on and Web of Science platform from 27th November of 2024 up to 12th March of 2025. The search strategy applied the key search terms “ICDAS” AND/ OR “ICCMS” in combination with the two main Medical Subjects Headings (MeSH), “Dental Caries” and “Diagnosis”. These terms were combined by Boolean operators (“OR” and “AND”) to ensure relevance to the research question. The detailed search strategy is presented in Table 2. Key search terms were included in the title and/or in the abstract and were appropriately adapted for each database.

2.2.2 - Study Screening and Selection

The articles identified using the key search terms were imported into the reference manager, EndNote 21.5 to check for duplicates. Screening of the articles, based on the inclusion and exclusion criteria, was independently carried out by two examiners (M.R and P.M-M). The remaining articles were assessed for both quantitative and qualitative data.

2.2.3 - Qualitative and quantitative data collection

Qualitative data collection included detailed information on the timing (*when*) and

location (*where*) of each study, the characteristics of the study population (*who*), the nature of the exposure or intervention (*what*), the existence of a control or comparator group, as well as the rationale and methodology (*how*) employed in each study, and main objective of the study (*why*).

Quantitative data collection encompassed the total number of participants (N) and sample size, the main instrument or tool used to assess exposure, the main outcome measures and their corresponding agreement statistics, and any additional quantitative results reported within the individual studies.

Table 2

Search strategy used in each electronic database.

Actions	Search	Terms from tree structures
PubMed		
	(((Dental Caries) AND (Diagnosis)) OR (ICDAS)) OR (ICCMS)	(("dental caries"[MeSH Terms] OR ("dental"[All Fields] AND "caries"[All Fields]) OR "dental caries"[All Fields]) AND ("diagnosable"[All Fields] OR "diagnosi"[All Fields] OR "diagnosis"[MeSH Terms] OR "diagnosis"[All Fields] OR "diagnose"[All Fields] OR "diagnosed"[All Fields] OR "diagnoses"[All Fields] OR "diagnosing"[All Fields] OR "diagnosis"[MeSH Subheading])) OR "ICDAS"[All Fields] OR "ICCMS"[All Fields]
#2	(((Dental Caries) AND (Diagnosis)) OR (ICDAS)) OR (ICCMS) Filters: from 2019 - 2025	(("dental caries"[MeSH Terms] OR ("dental"[All Fields] AND "caries"[All Fields]) OR "dental caries"[All Fields]) AND ("diagnosable"[All Fields] OR "diagnosi"[All Fields] OR "diagnosis"[MeSH Terms] OR "diagnosis"[All Fields] OR "diagnose"[All Fields] OR "diagnosed"[All Fields] OR "diagnoses"[All Fields] OR "diagnosing"[All Fields] OR "diagnosis"[MeSH Subheading])) OR "ICDAS"[All Fields] OR "ICCMS"[All Fields] AND (2019:2025[pdat])
#3	(((Dental caries) AND (Diagnosis)) AND (ICDAS)) AND (ICCMS)	("dental caries"[MeSH Terms] OR ("dental"[All Fields] AND "caries"[All Fields]) OR "dental caries"[All Fields]) AND ("diagnosable"[All Fields] OR "diagnosi"[All Fields] OR "diagnosis"[MeSH Terms] OR "diagnosis"[All Fields] OR "diagnose"[All Fields] OR "diagnosed"[All Fields] OR "diagnoses"[All Fields] OR "diagnosing"[All Fields] OR "diagnosis"[MeSH Subheading]) AND "ICDAS"[All Fields] AND "ICCMS"[All Fields]

Table 2 - (Continues)

Search strategy used in each electronic database.

Actions	Search	Terms from tree structures
#4	((Dental caries) AND (Diagnosis)) AND (ICDAS)) AND (ICCMS) Filters: from 2019 - 2025	("dental caries"[MeSH Terms] OR ("dental"[All Fields] AND "caries"[All Fields]) OR "dental caries"[All Fields]) AND ("diagnosable"[All Fields] OR "diagnosi"[All Fields] OR "diagnosis"[MeSH Terms] OR "diagnosis"[All Fields] OR "diagnose"[All Fields] OR "diagnosed"[All Fields] OR "diagnoses"[All Fields] OR "diagnosing"[All Fields] OR "diagnosis"[MeSH Subheading]) AND "ICDAS"[All Fields] AND "ICCMS"[All Fields]) AND (2019:2025[pdat])
#5	((ICDAS[Title/Abstract]) OR (ICDAS[Title/Abstract]) OR II"[Title/Abstract])) AND (ICCMS[Title/Abstract])	("ICDAS"[Title/Abstract] OR "ICDAS"[Title/Abstract] OR II"[Title/Abstract]) AND "ICCMS"[Title/Abstract]
#6	((ICDAS[Title/Abstract]) OR (ICDAS[Title/Abstract]) OR II"[Title/Abstract])) AND (ICCMS[Title/Abstract]) Filters: from 2019 - 2025	("ICDAS"[Title/Abstract] OR "ICDAS"[Title/Abstract] OR II"[Title/Abstract]) AND "ICCMS"[Title/Abstract]) AND (2019:2025[pdat])
B-on		
#1	(AB ICDAS) AND (AB ICCMS) as Topic	
#2	(AB ICDAS) AND (AB ICCMS) Filter: 01/01/2019 - 11/03/2025	
Web of Science		
#1	(ICDAS AND ICCMS [Title, abstract, keywords]); ICDAS AND ICCMS as Topic	
#2	(ICDAS AND ICCMS [Title, abstract, keywords]); ICDAS AND ICCMS Filters: year 2019-2025	
AB: Abstract		

2.3 - Reporting and Quality - Risk of Bias of each in vivo research

Consultant and quality by risk of bias assessments were performed for each included study. For consultant assessment two distinct tools were employed: Strengthening the Reporting of Observational Studies in Epidemiology (STROBE 2007) checklist (von Elm et al., 2007), which comprises 22 items, was used for non-randomized-exposure (NREs) cross-sectional/longitudinal studies, non, and the Consolidated Standards of Reporting Trials (CONSORT 2020) checklist (Ortiz et al., 2021), consisting of 25 items, was applied

to RCTs. Each item on these checklists was scored as “0” if the criterion was not met and “1” if it was fulfilled. Items that were not applicable were marked as “NA.”.

Item scores for each study were summed to generate a total reporting score out of 22, which was then expressed as a percentage, with 100% equating to the highest possible score (Vandenbroucke et al., 2007, 2014). The researchers (M.R. and P.M-M.) established reporting cut-off thresholds to facilitate the classification of each study. Studies with reporting scores below 50% were categorized as having ‘poor reporting’ and were excluded from the review. Studies with reporting scores between 50% and 74% were considered to have moderate reporting quality, while studies scoring above 75% were classified as having high reporting quality. Both moderate and high reporting quality studies were included in the synthesis, as their reporting was deemed sufficiently robust for inclusion (Vandenbroucke et al., 2007, 2014).

The risk of bias was assessed using the revised Cochrane risk-of-bias tool for randomized trials Cochrane RoB 2 tool (Cochrane Methods Bias, 2019; Sterne et al., 2019) according to five domains. Overall risk of bias of the RCTs included were assigned as: Low risk of bias (study is assigned in 5 domains as low risk); as Some Concerns (study is assigned in at least one domain as some concerns but without any of the remaining domains assigned as high-risk); or as High-risk of bias (study is assigned in at least one of the 5 domains as high-risk or for several domains as some concerns).

The risk of bias in non-randomized observational studies-of Exposure (ROBINS-E) tool provides a structured approach to assessing the risk of bias in observational epidemiological studies according to seven domains (Cochrane Methods Bias, 2024; Higgins et al., 2024). Overall risk of bias of the NREs included were assigned as: Low risk of bias (The study is judged to be at low risk of bias for all domains for this result), Moderate risk of bias (The study is judged to be at low or moderate risk of bias for all domains.), Serious risk of bias (The study is judged to be at serious risk of bias in at least one domain, but not at critical risk of bias in any domain), Critical risk of bias (The study is judged to be at critical risk of bias in at least one domain). When no information on which to base a judgement about risk of bias for that domain is classified as “No information”.

2.4 - Data Synthesis

Data synthesis was conducted following integrative review methodologies. After the

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initial screening and selection process, data extraction was performed independently by two reviewers (M.R. and P.M.M.) to ensure accuracy and minimize bias. Extracted data included both quantitative and qualitative information relevant to the research question.

Studies were assessed for methodological similarity to determine their suitability for grouping and synthesis, when possible. A thematic synthesis was performed to summarize findings across studies.

The quality and risk of bias of the included studies were evaluated as part of the synthesis process, providing a comprehensive understanding of nowadays evidence on caries diagnosis and management using ICDAS and ICCMS, respectively in adult permanent teeth.

3. Results

3.1 - Study Selection and Flow Diagram

A total of 52 articles were identified through the initial search strategy (Figure 1). During the screening process, 22 duplicate records were removed. Of the remaining 30 articles, 25 were excluded for not meeting the predefined inclusion criteria. Specifically, 14 articles were excluded due to being published in languages other than English (8 in Spanish, 5 in German, and 1 in French). Additionally, 5 studies were excluded due to differing methodologies from those eligible for this review, comprising 2 in vitro studies, 2 review articles, and 1 case report. A further 6 studies were excluded due to including participants under the age of 18.

Following these exclusions, 5 studies met all inclusion criteria and were included in this integrative review.

The included studies represented diverse methodologies. Two were cross-sectional surveys conducted among practicing dentist (Al-Asmar et al., 2022; Ramayasinpong et al., 2025), while two were questionnaire-based studies assessing dental students. (Jablonski-Momeni et al., 2022; Yin et al., 2021). One study was a RCT evaluating different caries management protocols (Khallaf et al., 2021).

A thematic synthesis of the findings is provided in Annex 1. This synthesis includes detailed information of each included NREs and RCT study, including author and year, study objectives, methodology, population, statistical methods, main outcomes, limitations, and conclusions.

3.2 - Quality and Risk of Bias assessment of the included in vivo studies

The STROBE checklist, which has 22 essential items, was used to evaluate the completeness and transparency of reporting in the included studies. Four NREs studies were assessed, and overall, a high level of adherence to the STROBE criteria was observed- particularly in sections such as the title and abstract, background, study objectives, and participant descriptions. However, certain elements, including the reporting of potential sources of bias and the management of confounding factors, were less commonly reported. A detailed assessment to each STROBE items for all NREs studies is provided in Table 3.

To assess the completeness of reporting in the including RCT, the CONSORT 2020

checklist was applied. This checklist consists of 25 items, the majority of which were reported with high level of compliance, including items related to participants, interventions, blinding, among others. Nevertheless, certain aspects, such as protocol registration and funding disclosures, were omitted, as shown in Table 4.

The final consulting score for each study was 83% for the RCTs (Khallaf et al., 2021), 87% (Al-Asmar et al., 2022), 83% (Jablonski-Momeni et al., 2022), 80% (Yin et al., 2021) and 74% (Ramayasinpong et al., 2025).

Figure 1

PRISMA 2020 Flow Diagram (Page et al., 2021)

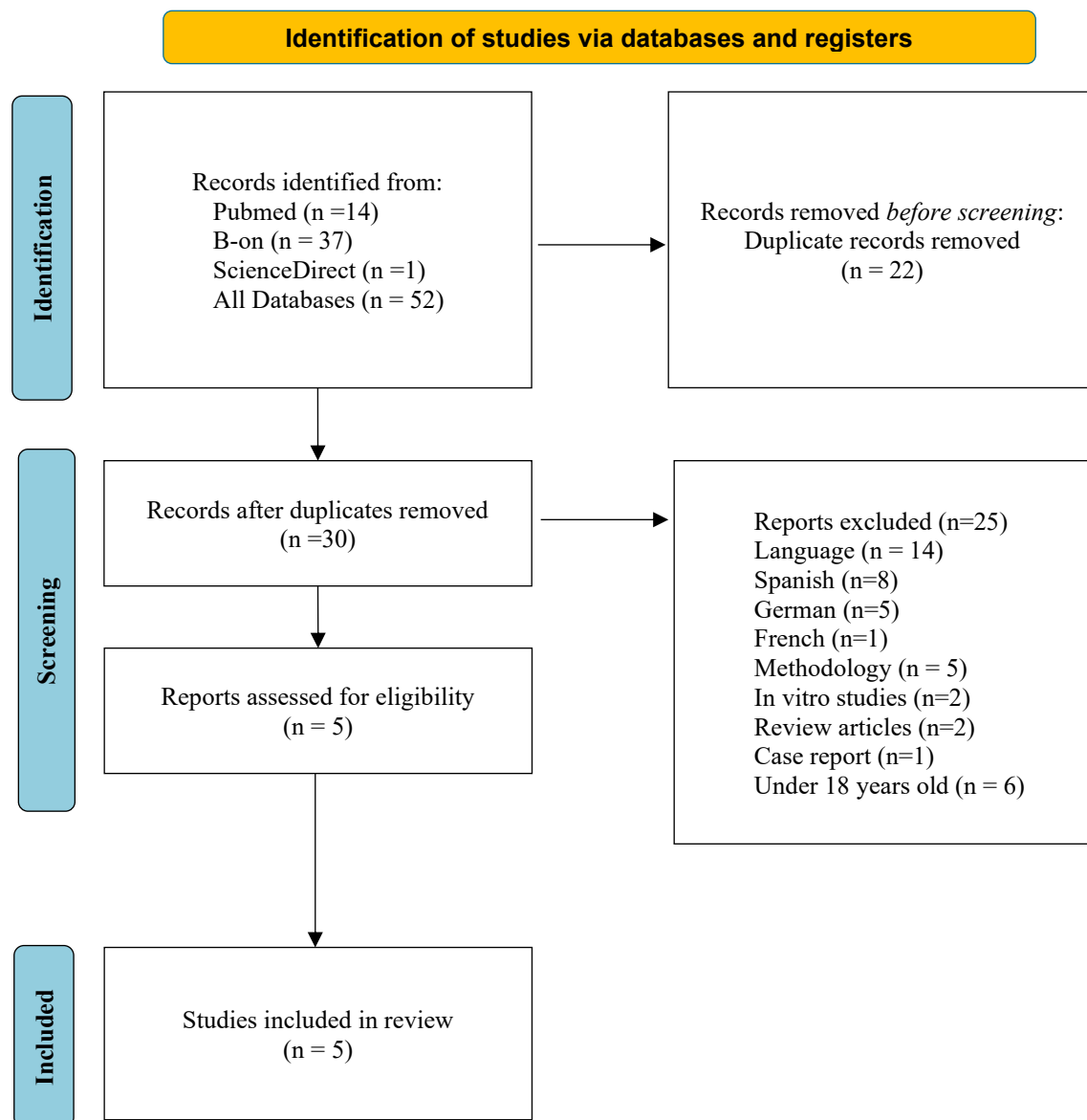


Table 3
STROBE reporting of the NREs- observational studies included. (EQUATOR Network, 2023)

STROBE Checklist	Items	(Yin et al., 2021)	(Al- Asmar et al., 2022)	(Jablonski- Momeni et al., 2022)	(Ramayasinpo ng et al., 2025)
Title and abstract	1	(a)	1	1	1
		(b)	1	1	1
Introduction					
Background/rationale	2	1	1	1	1
Objectives	3	1	1	1	1
Methods					
Study Design	4	1	1	1	1
Setting	5	1	1	1	1
Participants	6	1	1	1	1
Variables	7	1	1	1	1
Data sources/ Measurement	8	1	1	1	1
Bias	9	1	1	1	0
Study size	10	0	1	0	0
Quantitative Variables	11	1	1	1	1
Statistical Methods	12	(a)	1	1	1
		(b)	1	1	1
		(c)	1	1	0
		(d)	0	1	0
		(e)	0	0	0
Results					
Participants	13	(a)	1	1	1
		(b)	0	0	0
		(c)	0	0	0
Descriptive Data	14	(a)	1	1	1
		(b)	1	1	0
Outcome Data	15	1	1	1	1
Main results	16	(a)	1	1	1
		(b)	1	1	1
		(c)	0	0	0
Other Analyses	17	1	1	0	1
Discussion					
Key results	18	1	1	1	1
Limitations	19	1	1	1	0
Interpretation	20	1	1	1	1
Generalizability	21	1	1	1	1
Other Information					
Funding	22	2	0	1	1

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Table 4
CONSORT reporting for the RCT included. (EQUATOR Network, 2019)

CONSORT 2020 items	No	(Khallaf et al., 2021)
Title and abstract		
Title and abstract	1a	1
	1b	1
Introduction		
Background and objectives	2a	1
	2b	1
Methods		
Trial design	3a	1
	3b	0
Participants	4a	1
	4b	1
Interventions	5	1
Outcomes	6a	1
	6b	0
Sample size	7a	1
	7b	0
Randomization:		
Sequence generation	8a	1
	8b	1
Allocation concealment mechanism	9	1
Implementation	10	1
Blinding	11a	1
	11b	NA
Statistical methods	12a	1
	12b	1
Results		
Participant flow (a diagram is strongly recommended)	13a	1
	13b	1
Recruitment	14a	1
	14b	0
Baseline data	15	1
Numbers analyzed	16	1
Outcomes and estimation	17a	1
	17b	1
Ancillary analyses	18	1
Harms	19	1
Discussion		
Limitations	20	1
Generalizability	21	1
Interpretation	22	1
Registration	23	1
Protocol	24	0
Funding	25	0

The ROBINS-E tool (Higgins et al., 2024) was applied to assess the risk of bias across the four included NREs included, as summarized in Table 5. The evaluation covered all seven ROBINS-E domains: confounding, exposure measurement, selection of participants, post-exposure interventions, missing data, outcome measurement, and selection of reported results. Overall, three NRE were judged to have a very high risk of bias, while one study was assessed as having a high risk of bias.

Table 5
Risk of bias of the non-randomised- exposure (NREs) studies included, by ROBINS-E tool. (Cochrane Methods Bias, 2024)

Study / ROBINS-E Domain	Confounding	Exposure Measurement	Selection of Participants	Post-exposure Interventions	Missing Data	Outcome Measurement	Selection of Reported Result	Overall Risk of Bias
(Yin et al., 2021)	High Risk	Some Concerns	Very High Risk	High Risk	Some Concerns	Low Risk	Low Risk	Very High Risk
(Al-Asmar et al., 2022)	High Risk	Some Concerns	Very High Risk	High Risk	Some Concerns	High Risk	Low Risk	Very High Risk
(Jablonski- Momeni et al., 2022)	High Risk	Some Concerns	Very High Risk	High Risk	Some Concerns	High Risk	Some Concerns	Very High Risk
(Ramayasing et al., 2025)	Some Concerns	Low Risk	High Risk	High Risk	Some Concerns	Low Risk	Low Risk	High Risk

The risk of bias in the included RCT study was assessed using the RoB-2 tool (Sterne et al., 2019), which comprises 5 domains. Each domain was evaluated according to the specific criteria and signaling questions provided by the tool, and an overall judgment was determined based on the highest risk identified across any domain. Overall, the RCT included in this study was judged to have low risk of bias (Table 6).

Table 6

Risk of bias of the randomized clinical trial (RCT), by RoB-2 tool. (Cochrane Methods BIAs, 2019)

Study / Rob-2 Domain	Bias arising from the randomization process	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall risk of bias
(Khallaf et al., 2021)	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk

3.3 - Qualitative outcomes of the included studies

Qualitative information extracted from the five NREs and RCT included publications—such as the study period, study setting, characteristics of the study population, objectives, study design (including whether the study was controlled and/or included a comparator), as well as the rationale and methodology employed—is summarized in Table 7.

3.4 - Quantitative results of the included studies

The key quantitative data, including the total population and sample size, the primary outcome, instruments applied, outcome values, as well as measures of agreement are detailed in Table 8. Additional quantitative findings reported across the five included studies are also summarized within this table.

Table 7*Qualitative outcomes of the included (n=5) studies*

REFERENCE	WHEN?	WHERE?	WHO? (population on study)	WHAT? (exposure or intervention)	Has control? Comparator?	HOW?	WHY?
(Yin et al., 2021)		Dental institutions across Malaysia (	Final-year Dental Students	Exposure: Assessed knowledge and training experience of students in ICDAS and ICCMS systems	Compared knowledge/satisfaction by sex (male/female) and institution type (private/public)	Self-administered questionnaire	Evaluate how sex, institution type, and educational satisfaction relate to students' knowledge of ICDAS and ICCMS
(Khallaf et al., 2021)	July 2021; follow-up was 12 months.	Faculty of Dentistry, Cairo University, Egypt.	Dental students	Exposure: Caries risk assessment using CAMBRA. Intervention: ICCMS protocol.	CAMBRA group (control) vs ICCMS group (intervention)	Randomized controlled trial with three caries risk subgroups per model	Evaluate if ICCMS is more or equally effective as CAMBRA in preventing new dental caries and modifying treatment plans.
(Al-Asmar et al., 2022)	During COVID-19-	Jordan	Jordanian dentists	Exposure: Current clinical decision-making practices in operative dentistry	No control group; Comparisons made between subgroups (gender, years of experience, training background)	Survey (SurveyMonkey website)	Explore the alignment between evidence-based dentistry and actual clinical decision-making in caries management
(Jablonski-Momeni et al., 2022)		Two dental schools in Germany	Dental students at different stages of their education (6th and 7th semesters)	Exposure: Students' knowledge of caries lesion assessment using ICDAS/ICCMS systems	Control: Reference standard created by expert consensus; Comparison between Centre 1 (preclinical) and Centre 2 (clinical experience)	Written questionnaire on 12 clinical cases (photos, radiographs, histories)	Assess students' accuracy in caries diagnosis, risk assessment, and treatment planning using ICCMS
(Ramayasinpong et al., 2025)	August 2022 to November 2022	Thailand	Thai Dentists	Exposure: Use of different caries management techniques (preventive vs. operative)	No control group; Comparisons between: Clinical decisions across different scenarios	Web-based questionnaire Google Forms.	Assess Thai dentists' adherence to ICCMS guidelines and identify factors influencing decision-making regarding caries management..

Table 8

Quantitative outcomes of the included (n=5) studies

Reference	Population n (Number)	Population - Sample	Main outcome instruments or Tool	Main outcomes values (%)	Main outcomes- values agreement	Other data
(Yin et al., 2021)	616 dental students	440 dental students	Self-constructed questionnaire Three sections: demographic info, satisfaction with education, and knowledge of ICDAS and ICCMS	Knowledge of ICDAS: 95.3% were aware of ICDAS. 87.7% received adequate training. 82.3% were confident in classifying caries using ICDAS. Knowledge of ICCMS: Only 35.5% were aware of ICCMS. 57.7% were unsure about the adequacy of their ICCMS training. Only 27.5% were confident in making a treatment plan using ICCMS. ICDAS Knowledge (Mean scores out of 5): Awareness of ICDAS- 4.6 Adequate training- 4.3 Satisfaction with training - 4.3 Confidence in classifying caries- 4.2 Ability to communicate using ICDAS- 4.3 ICCMS Knowledge (Mean scores out of 5): Awareness of ICCMS- 3.2 Adequate training- 3.0 Satisfaction with training- 3.0 Understanding lesion codes - 3.0 Communication ability- 3.0 Confidence in making treatment plans - 2.9 Confidence in treating patients using ICCMS - 2.9	Comparison - Statistically Significant Male vs Female – Satisfaction with pediatric lectures P = 0.017 Preparedness to treat patients P = 0.033 Satisfaction with ICDAS training P = 0.039 Private vs Public – Satisfaction with clinical hours P = 0.000 Preparedness to treat patients P = 0.014 Knowledge by sex or institution type (ICDAS/ICCMS) - Not significant Correlation between satisfaction and ICCMS knowledge- Higher satisfaction = better ICCMS knowledge Correlation between satisfaction and ICDAS knowledge- Not significant	Gender: 312 (70.9%) female; 126 (28.6%) male, 2 unspecified Institutions: 231 (52.5%) from private institutions, 209 (47.5%) from public institutions.

Table 8 - (Continues)*Quantitative outcomes of the included (n=5) studies*

Reference	Population n (Number)	Population - Sample	Main outcome instruments or Tool	Main outcomes values (%)	Main outcomes- values agreement	Other data
(Khallaf et al., 2021)	104 dental students	52 in ICCMS group, 52 in CAMBRA group. Subdivided into risk levels: ICCMS: Low (17), Moderate (17), High (18) CAMBRA: Low (18), Moderate (17), High (17)	ICDAS-II scoring system for lesion assessment. CAMBRA chart for risk assessment	Caries Incidence: High Caries-Risk Group Significance (CAMBRA): P = 0.002 (Significant increase at 1 year) Significance (ICCMS): P = 0.227 (No significant change) Moderate Caries Significance (CAMBRA): P = 0.013 Significance (ICCMS): P = 0.665 Low Caries Significance (CAMBRA): P = 0.593 Significance (ICCMS): P = 1.000	NS difference in ICDAS scores between ICCMS and CAMBRA groups at: Baseline: P = 0.317; 6 months: P = 0.164; 1 year: P = 0.287 Within-Group Comparisons CAMBRA High-risk group: SI in ICDAS score at 1 year compared to baseline and 6 months P = 0.002; Moderate-risk group: SI in ICDAS score at 1 year P = 0.013: Low-risk group :P=0.593 ICCMS Group: High-risk, moderate and low risk groups NS changes P = 0.227, P = 0.665, P = 1.000 respectively. ICDAS Score Distribution Agreement: Baseline P = 0.310 (NS) 6 months P = 0.061 (NS); 1 year P = 0.301 (NS);	64.4% female, 35.6% male

Table 8 - (Continues)

Quantitative outcomes of the included (n=5) studies

Reference	Population n (Number)	Population - Sample	Main outcome instruments or Tool	Main outcomes values (%)	Main outcomes- values agreement	Other data
(Al-Asmar et al., 2022)	5811 dentists	4000 dentists	Questionnaire (validated by 10 restorative specialists before distribution); Chi-square tests	50.8% focus on chief complaint only Diagnostic Preferences: Clinical examination only: 7.8% Clinical examination + radiographs: 63.5% Clinical examination + radiographs + additional diagnostic tools: 28.8% Treatment Decisions: 50.8% of dentists focus only on the patient's chief complaint rather than performing a full-mouth risk assessment. 65.2% treat lesions confined to enamel operatively rather than using preventive measures. 80.5% manage incipient lesions with preventive treatment. 74.8% treat deep dentinal caries conservatively by selectively removing soft infected dentin. 67.2% routinely replace old failed restorations instead of repairing them. 81.5% keep and polish old, stained restorations	Focus on chief complaint =50.8% P = 0.004 ; Caries detection method (Clinical only) =7.8% P < 0.001; Treatment of incipient non-cavitated lesions (non-operative) =80.5% P < 0.001; Treatment of discolored fissures (Preventive) =33% P = 0.008; Treatment of lesions confined to enamel (Operative) =65.2% P = 0.001; Restoring arrested asymptomatic lesion (on patient demand) =58.8% P = 0.002; Radiographically detected proximal enamel caries (Operative) =55.2% P < 0.001; Treatment of deep dentinal lesions =74.8% P = 0.003; Old failed restorations (Replace) =67.2%P = 0.032	Gender: 57% Female, 43% Male Country of Graduation: 60.8% Jordan; 20.8% Arab/Asian; 13.2% West EU/USA; 5.2% East EU Experience: 26.2% <5 yrs; 26.8% 5–10 yrs; 26.2% 11–20 yrs; 20.8% >20 yrs Training: 68.2% General; 8% Conservative; 12.8% Endo; 11% Prosto Workplace 76% Private; 9.8% University; 9.2% Minister of health, 5% Royal medical services

Table 8 - (Continues)*Quantitative outcomes of the included (n=5) studies*

Reference	Population n (Number)	Population - Sample	Main outcome instruments or Tool	Main outcomes values (%)	Main outcomes- values agreement	Other data
(Jablonski -Momeni et al., 2022)	59 (27 from Centre 1, 32 from Centre 2)	46 students participated (26 from Centre 1, 20 from Centre 2)	Structured written questionnaire based on 12 clinical cases	ICCMS combined code Centre 1: 48.4%, Centre 2: 67.9% Caries risk assessment Centre 1: 51.3%, Centre 2: 57.9% Treatment option Centre 1: 40.7%, Centre 2: 67.5%	Kappa-Indicates level of agreement with expert standard: ICCMS code Centre 1: $\kappa = 0.175$ (slight), Centre 2: $\kappa = 0.432$ (moderate) Caries risk Centre 1: $\kappa = 0.178$ (slight), Centre 2: $\kappa = 0.315$ (fair) Treatment option Centre 1: $\kappa = 0.073$ (slight), Centre 2: $\kappa = 0.361$ (fair-moderate)	Centre 1 showed higher underestimation: ICCMS (73%), Risk (80%), Tx (84%) Centre 2 showed mixed estimations: ICCMS (51%), Risk (92%), Tx (77%) Missing Data: ICCMS code: Centre 1: 2.9%, Centre 2: 3.75% - Caries risk: Centre 1: 2.9%, Centre 2: 1.67% - Treatment option: Centre 1: 1%, Centre 2: 1.67%

Table 8 - (Continues)

Quantitative outcomes of the included (n=5) studies

Reference	Population n (Number)	Population - Sample	Main outcome instruments or Tool	Main outcomes values (%)	Main outcomes- values agreement	Other data
(Ramayasi npong et al., 2025)	442 dentists	Web-based questionnaire with validated clinical/radiog raphic images. Kappa statistic scores between 0.8–1 (expert agreement); intraexaminer reliability Kappa = 0.8– 0.9	Occlusal Caries (Primary Dentition) ICDAS 2: 39.6% sealant; 37.3% observe; 23.0%surgical ICDAS 3: 53.9% sealant; 13.6% observe; 29.2%TPOC ICDAS 4: 42.5% sealant/TPOC; 57.5% restoration Occlusal Caries (Permanent Dentition) ICDAS 2: 34.4% sealant; 28.5% observe; 23.3%TPOC;13.8%restoration ICDAS 3: 46.8% sealant; 12.0% observe; 35.7%TPOC;5.4%restoration ICDAS 4: 37.8% sealant/TPOC; 60.2% restoration Approximal Caries (Primary Dentition) RA 1: 69.6% non-surgical (65.6% fluoride varnish;4.0%resin infiltration) RA2: 78.0% non-surgical (51.8% fluoride varnish; 26.2% resin) RA3: 12.4% non-surgical; 87.3% restoration RB4: 99.5% restoration Approximal Caries (Permanent Dentition) RA1: 70.8% non-surgical (56.8% fluoride; 14.0% resin) RA2: 68.3% non-surgical (43.9 fluoride; 24.4% resin) RA3: 20.8% non-surgical; 79.2% restoration RB4: 97.7% restoration	Agreement with ICCMS Guidelines Occlusal Caries – Primary Dentition: ICDAS 2: 39.6%; ICDAS 3: 53.9%; ICDAS 4: 42.5% Occlusal Caries -Permanent Dentition: ICDAS 2: 34.4%; ICDAS 3: 46.8%; ICDAS 4: 39.6% Approximal Caries – Primary Dentition: RA1: 69.6%; RA2: 78.0%; RA3: 12.4%; RB4: 99.5% Approximal Caries-Permanent Dentition: RA1: 70.8%; RA2: 68.3%; RA3: 19.0%; RB4: 97.7%	Gender: female (77.4%) Years of experience: 39.6% > 11 years ago 34.8% < 5 years 25.6% 6-10 years ago. Specialties: Pediatric, operative, and advanced general dentistry (38.5%); General practice (30.3%); Government establishment(48.9 %) Workplace: 36.0% practiced in private clinics or hospitals; 12.7% were in academic settings; 2.5% administrative roles.	

4. Discussion

This integrative review synthesized both qualitative and quantitative evidence from five studies published between the years 2019 and 2025, examining research methodologies employed for the evaluation of dental caries through both the ICDAS and the ICCMS frameworks. Collectively, the findings underscore the importance of balancing detection with management: while ICDAS enables highly detailed detection and staging of caries lesions, ICCMS provides structured, evidence-based guidance for minimally invasive caries management.

A consistent theme emerging from the included studies is the identification of a persistent gap between the evidence-based recommendations proposed by ICCMS and the levels of implementation or knowledge observed in current practice. Two studies focusing on dentists reported only partial adherence to ICCMS guidelines. In Thailand, Ramayasinpong et al. (2025) found that only about one third to half of the dentists followed the non-invasive treatments recommended by ICCMS for early occlusal lesions, whereas adherence was notably higher (around 70%) for the management of incipient approximal lesions (Ramayasinpong et al., 2025). Similarly, Al-Asmar et al. (2022) in Jordan reported that approximately 50% of dentists considered only patients' main complaints without conducting the ICCMS recommended risk assessment, and around 65% still choose to treat enamel-confined lesions operatively (Al-Asmar et al., 2022). Despite the strong preventive emphasis of the ICCMS, these studies highlighted that many professionals still rely on traditional surgical interventions for early caries, especially for occlusal surfaces lesions. On the other hand, the same study found that over 80% of Jordanian dentists applied preventive modalities in managing incipient caries lesions (Al-Asmar et al., 2022).

In the studies involving dental students, a pattern of greater familiarity with the detection aspects than the management aspects of caries was observed. Yin et al. (2021) reported that final-year dental students in Malaysia exhibited significantly greater knowledgeable of ICDAS (caries detection) compared to ICCMS (caries management), suggesting that education and training on caries management component remains inadequate or insufficiently retained (Yin et al., 2021). Jablonski-Momeni et al. (2022) reported that, during case-based caries management exercises, dental students in Germany had low agreement with the expert decisions, frequently underestimating lesion severity and

selecting less invasive treatments options than those recommended by experts (Jablonski-Momeni et al., 2022). These students exhibited tendencies toward underdiagnosis and undertreatment, while many practicing dentists appeared to overtreat early lesions. Both scenarios reflect a divergence from the evidence-based application of the ICDAS/ICCMS frameworks. Khallaf et al., 2021 demonstrated that a caries management protocol based on the ICCMS achieved comparable efficacy in preventing new carious lesions over one year when compared to CAMBRA approach. Notably, the ICCMS group did not showed significant progression in caries scores, even among high-risk patients over the 12 months follow-up, while the CAMBRA group showed some progression in patients classified as high or moderate-risk (Khallaf et al., 2021).

Taken together, these findings underscore that ICDAS and ICCMS are effective tools for early detection and conservative management of dental caries. But their overall impact is limited by the level of adherence and proficiency in these systems among current and future clinicians.

A consistent theme emerging from the studies included in this review, is the urgent need to enhance education and training on ICDAS and ICCMS. Across diverse geographical regions and study designs- including observational studies and RCTs- there is consensus that adoption of these frameworks remains suboptimal. For instance, among dentists in Thailand and Jordan, those who were recent graduates or had received advanced training were more likely to follow the ICCMS recommendations, suggesting that up-to-date educational curricula positively influence compliance (Ramayasinpong et al., 2025). Both practitioner-focused studies highlighted a persistent gap between evidence and clinical practice: Thai dentists had difficulty moving away from traditional "drill and fill" approaches (Ramayasinpong et al., 2025), while a substantial proportion of Jordanian dentists continued to restore enamel lesions that, according to evidence-based protocols, could be managed non-invasively (Al-Asmar et al., 2022). Studies involving students similarly indicate that current undergraduate training may not be adequately prepare future dentists; one study explicitly recommends incorporating more systematic and comprehensive ICDAS/ICCMS content into curricula, alongside improved pedagogical approaches, to increase diagnostic accuracy and treatment planning capabilities (Jablonski-Momeni et al., 2022).

The variability in findings between studies can be partly attributed to differences in

populations and clinical settings, including geographic regions such as Southeast Asia versus Middle East as well as cultural contexts involving European versus Asian student's cohorts. For example, Ramayasinpong et al. (2025) observed higher adherence to ICCMS guidelines in the management of approximal lesions compared to occlusal lesions, potentially reflecting more uniform teaching of proximal caries management or heightened clinician concern regarding occlusal discolorations in pediatric cases. In contrast, Al-Asmar et al. (2022) found that half of surveyed dentists would surgically intervene on radiographic proximal enamel lesions, a discrepancy likely influenced by regional healthcare systems structures and patient expectations.

This integrative review identified several methodological weaknesses within the included studies, as evidenced by the reporting assessments-specifically, the STROBE checklist for NREs and CONSORT 2020 for the included RCT- in addition to risk of bias assessment using ROBINS-E and RoB 2 tools for the four observational (cross-sectional) studies and the RCT, respectively.

In the four observational (cross-sectional) studies, several key STROBE checklist items were either not addressed or insufficiently reported. Notably, most studies did not justify the sample size calculation or did not describe procedures to minimize sources of bias or control for confounding factors in their methods sections. Consequently, substantial risk of bias- especially selection bias and information bias- were detected. For example, one studies employed a convenience sample of professionals rather than random sampling, which limits the representativeness of the sample and introduces selection bias (Ramayasinpong et al., 2025). In another case, data collection relied entirely on self-administered questionnaires, a limitation explicitly acknowledged by the authors who noted the presence of self-completion bias and potential selection bias associated with the online survey format (Al-Asmar et al., 2022; Yin et al., 2021). Furthermore, two studies employed fictitious scenarios or static images rather than direct clinical observation, raising bias concerns due to underestimation or overestimation of the actual severity of carious lesions (Jablonski-Momeni et al., 2022; Ramayasinpong et al., 2025). None of the cross-sectional articles adjusted for extra-study factors beyond subgroups comparisons; Therefore, differences attributed to variables such as training type or professional experience may have been influenced by other unmeasured variables. Consistent with these limitations, the ROBINS-E assessment indicated that all observational studies had a high or very high risk of bias across several critical domains, predominantly due to

insufficient control for confounding and inadequate sampling methods.

The quality of reporting in the included RCT was evaluated using the CONSORT 2020 checklist and the RoB 2 tool. It should be noted that this review applied the CONSORT 2020 guidelines, as the more recent CONSORT 2025 (Hopewell et al., 2025) which expands the checklist to 30 items, including new items on patient and public involvement, data sharing, harms, and intervention delivery—was published after the review process had been completed.

According to CONSORT2020, the included RCT reported relatively higher methodological quality compared to the NRE-observational studies. However, some reporting deficiencies were identified, such as the lack of a statement regarding a preregistered study protocol, omission of formal sample size calculation, and absence of a funding disclosure—reporting elements that are recommended for transparency. Additionally, although the randomization process was clearly described and resulted in comparable groups (with RoB 2 confirming a low risk of bias in this domain), neither participants nor examiners were blinded, potentially introducing performance or detection bias. The authors themselves acknowledged certain limitations, including a small sample size, short duration of follow-up (12 months), and restriction of the participating sample to dental students. This narrow participant profile may not be representative of the broader patient population, thus limiting the generalizability of the results (Khallaf et al., 2021).

Given these limitations, subtle differences or potential long-term effects between the interventions tested (ICCMS versus CAMBRA) could have been missed. Therefore, findings indicating "no difference" between interventions should be interpreted carefully.

The collective evidence presented in this report carries significant implications for both clinical practice and dental education. Clinically, the findings highlight that although tools such as ICDAS and ICCMS are available to facilitate early caries detection and management, their full benefits can only occur when they are applied consistently and correctly. The observation that many dentists still restore early-stage carious lesions that are amenable to remineralization highlights a gap and the need for integration of ICCMS principles into routine practice. Greater adherence to ICCMS protocols has the potential to lead to more conservative treatment and individualized patient care, preserving tooth structure and mitigating the so-called "restorative cycle."

Early detection of non-cavitated lesions using ICDAS—which often reveals a substantially

higher caries prevalence than the WHO criteria (Khallaf et al., 2021) - provides an opportunity for non-operative interventions. When combined with risk factor control according to ICCMS guidelines, this approach can effectively interrupt disease progression, resulting in considerable long-term benefits for patients. However, the mere availability of these systems is not enough, and do not guarantee their implementation; sustained behavioral change in clinical decision-making is crucial. Initiatives such as ongoing professional development and revised clinical guidelines that reinforce preventive, risk-based care may be required to support this paradigm shift.

Some limitations of this integrative review report should be acknowledged. First, the evidence base is limited by the inclusion criteria (in vivo human studies employing both ICDAS and ICCMS, published between 2019 and 2025 years), resulting in a relatively small and heterogeneous sample. Secondly, the diversity of study designs introduces variable levels of evidence and potential sources of bias, warranting cautious interpretation of direct comparisons. Moreover, all included studies were originated from specific countries (Egypt, Thailand, Malaysia, Germany, Jordan), and their results may not be generalizable to other regions, especially given differences in educational backgrounds and healthcare systems. Third, the reliance on self-reported questionnaire data may not accurately reflect actual clinical behavior, and the sole RCT included featured a short follow-up period and a narrowly defined patient cohort. While the integrative review report approach provides a broad overview, it does not enable the establishment of causality or magnitude of precise effect sizes to the extent afforded by focused systematic reviews or meta-analysis.

To enhance the evidence base supporting the use of ICDAS and ICCMS in clinical settings, further research is warranted. Large-scale, longitudinal studies examining long-term outcomes - such as caries incidence, restoration rates, and tooth survival – comparing practices that implement ICDAS/ICCMS with those using traditional management strategies would provide stronger more robust data regarding the effectiveness of ICCMS in improving oral health outcomes over time. Additionally, qualitative research is needed to explore the barriers clinicians encounter in adopting minimally invasive approaches for early lesions, as well as the practical challenges associated with individualized risk assessments.

Future research should also address optimal educational strategies for teaching ICDAS and ICCMS, with a focus on determining which methods improve most effectively

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student skills and whether these competencies persist in clinical practice. Finally, expanding research efforts to include diverse populations and settings- particularly high-risk communities and public health programs- will be critical for evaluating the performance and adaptability of ICDAS and ICCMS across a range of clinical and public health environments.

5. Conclusion

This integrative report successfully fulfilled its primary objectives by synthesizing qualitative and quantitative evidence on the use of the ICDAS and ICCMS systems in the detection and management of dental caries. The analysis revealed a continued predominance of restorative approaches among dental professionals, with a tendency toward surgical intervention for early caries lesions that could otherwise be considered and managed through preventive actions. Additionally, the review identified notable deficiencies in dental student's proficiency with the ICCMS, underscoring shortcomings in both teaching and assimilation of these concepts during dental education and their academic training.

Crucially, the evidence indicates that the ICCMS is effective in the early detection and management of caries lesions, enabling better control of disease progression. However, the integration of ICDAS and ICCMS into everyday clinical practice remains inadequate. Barriers such as resistance to protocol change, lack of training, and institutional challenges hinder widespread implementation.

The findings of this study reported substantial practical implications: Educational implications- the clear need to strengthen undergraduate curricula and continuing professional development programs with a focus on ICDAS and ICCMS. This will ensure that emerging dental practitioners develop robust competencies in risk assessment, early diagnosis, and preventive care- and Health policies recommendations as integrating ICDAS and ICCMS into national oral health guidelines and public health programs is suggested. Targeted incentives for professional training and adherence to these evidence-based frameworks are essential steps towards standardizing practice and enhancing dental care quality at a population level.

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Annexes

Annex 1

Main description of the in vivo, NREs and RCTs (n=5) included in this integrative review, namely the authors/year, aims, methodology, population, statistics, main results, limitations and conclusions

Author/Y ear	Objective	Methodology	Population	Statistics	Main Result	Study Limitations	Conclusion
(Ramay asinpon g et al., 2025)	Investigate Thai dentists' adherence to ICCMS guidelines for managing caries in children, adolescents and explore influencing factors.	Web-based questionnaire assessing treatment preferences for different caries stages. Included demographic info and clinical scenarios with static images.	442 Thai dentists (respondents via dental school alumni Line groups).	Descriptive statistics, chi-square tests, bivariate and multivariate logistic regression (significance at $p < 0.05$).	Low adherence to ICCMS in occlusal caries; better agreement for enamel approximal lesions. Key factors: graduation year, postgrad education, work setting.	Convenience sample, static images without full clinical context, possible participation bias, only complete responses analyzed.	Thai dentists still favor invasive approaches for early occlusal caries. Greater ICCMS adherence seen in approximal lesions. Education and setting influenced decisions.
(Jablons ki- Momeni et al., 2022)	Evaluate undergraduate dental students' diagnostic and management ability using ICCMS via case-based survey.	Cross-sectional case-based survey among 46 students from two German universities, comparing decisions with expert consensus.	46 dental students (6th and 7th semesters) from Germany.	Kappa statistics for agreement; binomial tests for bias (under/overestimation).	Low agreement with experts, especially among less experienced students. Many underestimated lesion severity and chose less invasive treatment than recommended.	Small sample, limited generalizability, case-based (not clinical), activity of lesions not assessed.	Undergraduate students need improved ICCMS training to enhance diagnostic accuracy and evidence-based decision-making.

Author/Year	Objective	Methodology	Population	Statistics	Main Result	Study Limitations	Conclusion
(Al-Asmar et al., 2022)	Investigate operative dentistry practices in Jordan and assess alignment with evidence-based caries management principles (ICCMS).	Web-based survey sent to all licensed dentists in Jordan via their Dental Association, focusing on diagnostic and treatment decision-making practices.	4000 Jordanian dentists (68.8% response rate from 5811 invited).	Descriptive stats and chi-square tests for associations between practice patterns and demographics (experience, training, etc.).	Half of dentists prioritize chief complaint over full assessment. Many still use surgical treatment for enamel lesions. Preventive approaches more common for incipient lesions.	Self-report bias, limited qualitative data, possible selection bias due to online format.	Gaps exist between evidence and clinical practice. ICCMS-based approaches should be reinforced through updated education and policy.
(Khallaf et al., 2021)	Evaluate differences between ICCMS and CAMBRA caries risk assessment models on treatment planning in young adult patients.	Randomized clinical trial with 104 dental students divided into ICCMS and CAMBRA groups. Caries risk assessed per model and incidence followed at 6 and 12 months.	104 Egyptian young adult dental students (17–22 years old).	Chi-square test for group comparisons at each time point (baseline, 6 months, 12 months). Relative risk also reported.	No significant difference in new caries between ICCMS and CAMBRA at any time point. ICCMS group more stable over time, especially for high/moderate-risk groups.	Small sample, short follow-up, student patients may not represent general population, not blinded.	ICCMS and CAMBRA were equally effective in preventing new caries over one year, but ICCMS was more comprehensive.
(Yin et al., 2021)	Examine associations between sex, type of institution, and satisfaction with education on students' knowledge of ICDAS and ICCMS in managing caries in children.	Cross-sectional survey of final-year dental students using a structured questionnaire distributed through all dental schools in Malaysia.	440 final-year dental students in Malaysia (70.9% female).	Independent t-tests for knowledge and satisfaction by sex/institution. Spearman correlation between satisfaction and knowledge.	Male students more satisfied with education. No sex or institution effect on ICDAS/ICCMS knowledge. Students had better knowledge of ICDAS than ICCMS.	Self-reported data, no clinical assessment, limited to Malaysian students.	Curricula should improve teaching of ICCMS. Better education satisfaction may relate to greater perceived clinical readiness.