BMC Oral Health

RESEARCH Open Access

Adoption of minimally invasive dentistry in Palestine: assessing practices and barriers – a cross-sectional study

Naji Arandi[1*] and Tarek Rabi[2]

Abstract

Aims This study explored the diagnostic and treatment practices of Palestinian general dentists related to minimally invasive dentistry (MID) and identified perceived barriers to its broader application.

Materials and methods A cross-sectional online survey collected data from general dentists on demographics, MID-related practices, and barriers. Descriptive and inferential statistics were used to evaluate current practices and their associations with dentist demographics and professional characteristics.

Results A substantial proportion of dentists applied MID-related principles. Preventive, nonoperative approaches are slightly more common for occlusal lesions and more clearly favored for approximal lesions. Approximately two-thirds adopted conservative cavity designs such as vertical slots or saucer-shaped preparations, whereas approximately half preferred selective removal for deep caries. Most dentists opted to repair rather than replace defective restorations. Clinical experience had a stronger influence on these practices than gender or workplace setting did, and the main barriers included limited training, restricted access to modern materials and technologies, and low patient awareness.

Conclusion Palestinian dentists demonstrated variability in the application of MID-related practices, with greater use reported among more experienced practitioners and those in private practice. Addressing educational, infrastructural and cultural barriers could support broader integration of evidence-based, minimally invasive approaches into routine care. These findings set the foundation for developing national policies, curricular reform, and continuing education, underscoring their importance in advancing evidence-based, minimally invasive care in Palestine.

Keywords Minimally invasive dentistry, Conservative dentistry, Caries, Management, Composite repair

*Correspondence:
Naji Arandi
naji.arandi@aaup.edu
[1]Department of Conservative Dentistry, Faculty of Dentistry, Arab American University, Jenin, Palestine
[2]Department of Conservative Dentistry, Faculty of Dentistry, Al-Quds University, Abu Dis, Palestine

© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc-nd/4.0/.

Introduction

Dental caries, a chronic, noncommunicable disease, results from the demineralization of dental tissues resulting from bacterial metabolism [1]. It affects billions of people worldwide, leading to pain, tooth loss, and substantial treatment costs, while also reducing quality of life [2–6]. As a major public health challenge, innovative prevention and management strategies are needed to address its individual and societal impacts [6–8].

In Palestine, dental caries are highly prevalent, particularly among children and adolescents. The decayed, missing, and filled teeth (DMFT) index measures caries experience in permanent teeth, whereas the dmft index applies to primary teeth. Higher scores on these indices reflect a greater burden of untreated or previously treated caries, indicating increased caries risk and severity. For example, a 2014 study in northern Palestine reported that 54.35% of adolescents aged 12–15 years had dental caries, with a mean DMFT score of 5.39, suggesting a moderate to high caries burden [9]. In the same year, another study reported that 76% of preschoolers aged 4–5 years had caries, with a mean dmft score of 2.46, indicating significant caries in primary teeth [10]. Similarly, research involving children aged 4–18 years in Nablus, Qalqiliyah, and Salfeit reported a caries prevalence of 95.5%, with mean dmft and DMFT scores of 3.88 and 3.44, respectively [4]. More recent data from Jerusalem highlight the severity of the issue, revealing that 97% of preschoolers had caries, with a mean dmft score of 6.6 [11]. These consistently high DMFT and dmft scores underscore the urgent need for effective caries prevention and management strategies—such as MID—in Palestine. This need is amplified by challenges unique to the Palestinian healthcare context, including limited resources, fragmented infrastructure, and disparities in access across regions such as the West Bank, Gaza, and East Jerusalem. These structural constraints likely impact the implementation of contemporary approaches such as MID and warrant closer examination of how dentists practice under such conditions.

Traditionally, caries treatment follows a surgical model, emphasizing cavity preparation and restoration to address symptoms, often involving extensive removal of enamel, dentin, and proximity to the pulp, without managing the underlying disease [12]. Today, the medical model prevails, recognizing caries as a biofilm-mediated condition driven by dietary factors and an imbalance between demineralization and remineralization [12]. This shift has spurred MID, which prioritizes tooth preservation through early detection, personalized risk assessments, remineralization therapies, and selective carious tissue removal to preserve dentin and pulp vitality [13–18]. For advanced caries with cavitation, MID employs conservative restorative approaches using bioactive materials, such as glass ionomer cement, to promote dentin remineralization and minimize pulpal risk, integrating medical and surgical strategies for comprehensive, patient-centered care [12, 15].

The global integration of MID reflects substantial variation between and within countries. In high-income settings such as the UK, Netherlands, and Australia, conservative, evidence-based approaches are increasingly emphasized, supported by clinical guidelines, continuing education, and favorable reimbursement structures [19–22]. In contrast, many low- and middle-income countries—including Brazil, Egypt, Russia, Jordan, Syria, and Saudi Arabia—continue to rely on traditional, surgically oriented methods owing to limitations in training, infrastructure, and resources [23–29]. These variations and challenges may also be relevant in Palestine, although no national-level data currently exist to assess how MID-related practices are applied by general dental practitioners—an evidence gap this study seeks to address. Understanding this gap is essential for informing targeted educational, institutional, and policy interventions that align local practices with global standards.

Despite the global endorsement of MID as the contemporary standard of care, there remains limited understanding of how its principles are applied by general dentists in Palestine. While prior studies in the region have examined caries prevalence and treatment outcomes, there is a notable absence of national-level research investigating dentists' clinical decision-making, use of MID-related techniques, and perceived barriers to their implementation. No national-level data currently exist on how Palestinian dentists diagnose, manage, or approach carious lesions within the framework of MID. This significant gap in the literature highlights the need for research that explores both the application of MID principles and the systemic challenges faced by practitioners operating in a resource-constrained context.

In Palestine, this research is timely given the high prevalence of caries, limited opportunities for continuing professional development in MID, and the absence of national clinical guidelines—factors that leave practitioners reliant on outdated protocols and underscore the need for national-level evidence to guide education, training, and policy.

This exploratory study addresses this gap by investigating how Palestinian dentists incorporate key MID principles into their daily practice, with a focus on current clinical decisions and perceived barriers. Specifically, it asks the following questions: What are the clinical practices related to MID, and what barriers do dentists in Palestine face in implementing them? Unlike prior studies focused on specific regions or subgroups, this national-level survey captures a broader range of perspectives across both the private and public sectors. The findings

aim to inform curriculum reform, continuing education, and policy strategies that support the wider integration of evidence-based, minimally invasive approaches in everyday dental practice.

This study is guided by Rogers' diffusion of innovation (DOI) theory, which explains the integration of new practices through perceived relative advantage, compatibility, complexity, trialability, and observability, as well as broader social and systemic influences [30]. In the context of MID, uptake depends on whether dentists recognize clear benefits, view complexity as manageable through training, perceive opportunities for trial techniques, and observe visible success among peers. In Palestine, factors such as limited resources, entrenched surgical traditions, and uneven access to education may shape these perceptions. Framing the study within DOI provides a conceptual basis for examining barriers to the implementation of MID and identifying strategies to accelerate its wider integration into practice.

Materials and methods

Study design and variables

This cross-sectional survey was designed to evaluate the diagnostic and treatment practices of Palestinian general dental practitioners in relation to MID and to assess perceived barriers to their implementation. The independent variables included demographic factors such as gender and years of clinical experience and were categorized into four groups (≤ 5 years, 6–9 years, 10–15 years, and ≥ 16 years) to reflect distinct career stages. The practice setting was classified as private practice versus public clinic. These variables were selected on the basis of their potential to influence clinical practices, as supported by existing research. Additionally, we investigated barriers to MID to better understand the challenges faced by practitioners in implementing minimally invasive approaches.

Study setting, recruitment, and data collection

This cross-sectional study was conducted in Palestine from May to December 2023 and was carried out in accordance with the STROBE [31] and CHERRIES guidelines [32]. Given their exploratory nature, participants were recruited via a convenience sampling approach, with initial contact made online through invitations distributed across professional social media platforms (Facebook and WhatsApp) and through personalized messages sent via personal networks (e.g., email or messaging) to ensure broad representation across all regions of Palestine and practice types. To enhance representativeness, a snowball sampling technique encouraged participants to share the survey with colleagues and friends. Hosted on Google Forms, the web-based questionnaire allowed participants to submit responses electronically, with access restricted to invited individuals via a nonpublic survey link; data collection was fully automated, as Google Forms directly recorded responses into a secure database, reducing the risk of transcription errors and ensuring data integrity. No incentives were offered; participation was voluntary and motivated by professional interest. The survey's introductory page informed participants that the 12 closed-ended questions would take approximately 10–15 min to complete. Only fully completed questionnaires were eligible for inclusion; responses with any missing answers were excluded from the analysis.

The target sample size was calculated via Raosoft software on the basis of an estimated population of 4,000 dentists in Palestine, a 5% margin of error, a 95% confidence level, and a 50% assumed response distribution, yielding a required sample of 350 to achieve a sample size sufficient for representativeness of the national dentist population while acknowledging that the convenience sampling approach limits full representativeness. To account for nonresponses, 700 general dentists were invited. The inclusion and exclusion criteria were as follows: general dentists currently practicing in Palestine were included, while specialists in conservative or restorative dentistry and dental students were excluded, as the study focused on the routine clinical practices of general practitioners.

Survey development and testing

This study employed a structured, standardized online questionnaire developed through a multistep process to ensure content validity, clarity, and technical functionality. The questionnaire was designed on the basis of a comprehensive literature review and refined to address the study's objectives effectively [23, 27, 28]. Two experts in MID and dental public health reviewed the initial draft and assessed its relevance, comprehensiveness, and alignment with the study's goals. Their insights were instrumental in refining the questionnaire, particularly in enhancing clarity and reducing measurement biases. A subsequent pilot study with 20 general dentists, representing diverse experience levels and practice settings, evaluated question clarity, navigation ease, and online performance. Pilot testing feedback prompted minor adjustments to ensure that the survey effectively captured the intended data. As dental education in Palestine is conducted primarily in English and all licensed dentists are trained via English-language curricula, no translation of the questionnaire was needed. Barriers to implementing MID were assessed with a single close-ended question asking participants to select the main barrier they perceived in their clinical practice from a predefined list of options. The barriers were therefore measured as categorical variables, without ranking or multiple selections. This forced-choice design was used to capture the

primary barrier perceived by each respondent, reduce overlap between categories, minimize respondent burden, and enable straightforward categorical analysis.

The survey comprises 12 questions and is divided into three sections: (1) demographic and professional characteristics (Questions 1–3), (2) diagnostic and treatment approaches (Questions 4–11), and (3) perceived barriers to implementing MID (Question 12), as detailed in Appendix A. A structured questionnaire format with predefined, closed-ended questions was used to ensure systematic data collection, reduce interpretation bias, and enhance comparability across respondents. To maintain respondent focus and reduce the cognitive load, each question was presented on a separate page via Google Forms. The participants could navigate between pages and revise their answers via the 'Back' button; however, no final review summary was provided before submission. Adaptive questioning was not used—all participants received the same 12 questions in a fixed order to ensure consistency. The sequence—beginning with demographics, followed by diagnostic practices, treatment decisions, and perceived barriers—was intentionally structured to reflect the logical flow of clinical decision-making, thereby enhancing comprehension.

The fixed-question order adopted in this study aligns with established practices in dental survey research. For example, Shah et al. [33] used a structured questionnaire to assess knowledge and attitudes toward MID among general dental practitioners in Saudi Arabia. Similarly, Al-Asmar et al. [28] investigated operative dentistry practices in Jordan via a structured survey format, whereas Stangvaltaite et al. [34] applied a structured questionnaire in a multinational study across France, Germany, and Norway to examine the management of pulp exposures during carious tissue removal. In addition, this design choice adheres to the CHERRIES guidelines [32], which recommend a fixed question sequence when it improves respondent comprehension and aligns with the logical progression of clinical reasoning.

To address consistency calibration, the survey's reliability was assessed through test–retest analyses, methods that are consistent with established approaches in dental research [23, 33, 35]. Forty general dentists completed the questionnaire twice, with a two-week interval between sessions. Test–retest reliability was determined via Pearson correlation coefficients and intraclass correlation coefficients (ICCs). Three clinically relevant items related to the MID exhibited excellent reliability: managing incipient enamel caries (Pearson $r = 0.81$, ICC = 0.81), treating approximal enamel lesions identified radiographically (Pearson $r = 0.94$, ICC = 0.94), and prioritizing patient complaints over the CRA (Pearson $r = 0.94$, ICC = 0.94). The results confirm strong reliability and demonstrate the survey's stability and precision in measuring MID practices.

Ethics statement

Ethical approval for this study was obtained from the Institutional Review Board (IRB) of Arab American University (Approval Number: J-2025/A/2/N), in accordance with the ethical principles outlined in the Declaration of Helsinki (1975), as revised in 2013. The data reported here were part of a larger dataset collected for a broader project assessing contemporary dental practice in Palestine. Before accessing the questionnaire on Google Forms, participants were presented with an introductory page describing the study's purpose—to assess MID adoption and barriers among Palestinian dentists—their rights and the voluntary nature of participation. The page included a consent statement: *"By clicking 'Proceed' below, you confirm that you understand the study's aims, that participation is voluntary, and that you may skip any question or withdraw at any time without consequence."* Participants clicked "Proceed" to begin, thereby providing informed consent. The introductory page also identified the principal investigator and provided contact information for inquiries. No identifying information was collected; all the responses were anonymous. Data were transmitted via secure Google Forms, stored in encrypted files accessible only to the principal investigator, and managed in compliance with data privacy regulations.

After submission, the responses were reviewed for completeness, and early terminated or incomplete surveys were excluded via the complete case analysis approach, which balances data integrity with voluntary participation. To prevent unauthorized access, all files were stored on Google Drive, accessible only to the principal investigator via password protection and two-factor authentication, with encryption applied to ensure confidentiality. These security measures were implemented to reduce social desirability bias and encourage honest responses without fear of judgment. The participants were informed on the introductory page that these data would be retained for 5 years after the study's completion for potential secondary analysis, after which they would be permanently deleted.

Statistical analysis

Data analysis was performed via descriptive and inferential statistics with a 95% confidence interval and a significance level of $p < 0.05$. All analyses were conducted via IBM SPSS Statistics Version 28 (IBM Corp., Armonk, NY, USA). Categorical variables—including gender, years of clinical experience, and practice setting—were summarized using frequencies and percentages.

Associations between demographic characteristics and categorical outcomes were evaluated via chi-square tests. To assess the relationships between demographic factors and treatment preferences, binary logistic regression was applied for dichotomous outcomes, and multinomial logistic regression was used for outcomes with more than two categories. Gender, experience, and workplace setting were included as covariates in all regression models to adjust for their known influence on clinical decision-making. These methodological choices align with the study's cross-sectional design and exploratory objectives.

Logistic regression was chosen because of the nominal and dichotomous nature of the outcomes, with no evident clustering to warrant mixed models or other approaches. Regression assumptions were reviewed to ensure appropriate model specification and convergence. Only predictors meeting the significance threshold of $p < 0.05$ are highlighted in the main text, whereas full model outputs (including nonsignificant findings) are provided in Appendix B for transparency.

Given the use of convenience sampling via online platforms and snowball recruitment, no specific analytical adjustments (e.g., sample weighting or clustering adjustments) were applied because of the absence of comprehensive demographic data for Palestinian dentists. The analyses assumed a simple random sample. Missing data were addressed via the complete case analysis approach, where only fully completed surveys were included in the final analysis. This approach was selected to maintain internal consistency and avoid imputation bias, as the proportion of missing responses was minimal and assumed to be random. Early terminated or partially completed responses were excluded from the dataset.

Results

Participant demographics

Among the 700 practitioners invited, 390 responded (55.7% response rate), but 40 incomplete submissions were excluded, leaving 350 fully completed surveys for analysis. Although the survey platform technically allowed participants to skip questions, only fully completed questionnaires were retained to ensure consistency and comparability across responses. The anonymous, online survey format precluded systematic tracking of nonparticipation reasons, leaving the causes of incomplete responses unclear. Excluding these responses ensured data quality; however, selection bias may have been introduced if noncompleters differed systematically from respondents. Given that incomplete submissions comprised only a small fraction (10%) of responses, their exclusion is unlikely to meaningfully alter the study's overall findings.

Table 1 Demographic characteristics of respondents

Demographic	Category	Frequency (*n*)	Percentage (%)
Gender	Male	195	56%
	Female	155	44%
Experience	≤ 5 years	77	22%
	6–9 years	84	24%
	10–15 years	87	25%
	≥ 16 years	102	29%
Workplace Setting	Private Practice	218	62%
	Public Clinic	132	38%

The study utilized a single-stage online questionnaire, eliminating the need for follow-up data collection. Table 1 summarizes the demographic characteristics of the respondents. The final sample consisted of 56% male participants ($n = 195$) and 44% female participants ($n = 155$). In terms of professional experience, 22% of the respondents had five years or less ($n = 77$), 24% had 6–9 years ($n = 84$), 25% had 10–15 years ($n = 87$), and 29% had 16 or more years of experience ($n = 102$). With respect to the workplace setting, 62% of the participants ($n = 218$) worked in private practice, whereas 38% ($n = 132$) were employed in public clinics.

Clinical application of MID-related practices

Table 2 summarizes the respondents' treatment preferences and diagnostic approaches. Only summary results are presented here to increase readability. A detailed distribution of responses for all survey questions, stratified by gender, years of experience, and practice setting, is provided in Appendix C.

Diagnostic and risk assessment practices

When asked about their initial diagnostic focus, most dentists prioritized the patient's chief complaint over performing a caries risk assessment (CRA). A marginal gender difference was observed, with female dentists being more likely to report using CRAs, although this difference did not reach statistical significance ($p = 0.065$). No notable differences were found across experience levels or workplace settings.

Visual–tactile examination, with or without radiographs, was the most common diagnostic method. The use of newer technologies (e.g., fluorescence or transillumination) was limited overall but significantly more common among dentists with over 16 years of experience and those in private practice ($p < 0.05$). Experience also significantly influenced reliance on radiographic methods, with early-career practitioners (≤ 5 years) and those with ≥ 16 years of experience being more likely than mid-career dentists to prefer this approach ($p = 0.016$).

Management of noncavitated carious lesions

For incipient enamel lesions, preventive, nonoperative approaches predominated, with an even stronger preference for approximal enamel lesions. No significant

Table 2 Overall MID responses

Question	Response	Total (%)
Do you focus on the patient's chief complaint or perform a caries risk assessment?	Focus on chief complaint	192 (55%)
	Do a caries risk assessment	158 (45%)
What diagnostic tools do you routinely use to detect carious lesions in your practice?	Visual and tactile examination	87 (25%)
	Visual-tactile and radiographic examination	105 (30%)
	Caries-Detector dyes	35 (10%)
	Dental explorers	17 (5%)
	Radiographic examination	70 (20%)
	Recent diagnostic tools	36 (10%)
What is your usual treatment approach for managing an incipient carious lesion confined to enamel, with no radiographic evidence of progression?	Preventive, nonoperative (noninvasive or microinvasive) therapies	193 (55%)
	Operative intervention	157 (45%)
What is your usual approach for managing approximal carious lesions confined to enamel, based on radiographic findings and with no visible signs of dentinal involvement?	Preventive, nonoperative (noninvasive or microinvasive) therapies	214 (61%)
	Operative intervention	136 (39%)
What preparation technique do you typically use for managing proximal lesions in your clinical practice?	Conventional class II cavity preparation	107 (31%)
	Vertical slot or saucer-shaped preparations	231 (66%)
	Tunnel preparation	12 (3%)
What is your typical approach for managing deep cavities?	Remove Soft and Hard Dentin	105 (30%)
	Remove Only Soft Infected Dentin	175 (50%)
	Stepwise caries removal	70 (20%)
What is your typical approach when managing defective restorations with localized defects—do you generally repair or replace them?	Repair	245 (70%)
	Replace	105 (30%)
What is your typical approach for managing restorations with marginal staining or minor defects that are asymptomatic?	Monitor and refurbish if needed	193 (55%)
	Replace them	157 (45%)

demographic differences were found. Dentists who favored operative management of occlusal lesions were less likely to do so for approximal enamel lesions (OR = 0.68, $p = 0.087$), suggesting a possible inclination toward preventive strategies at less accessible sites.

When managing proximal caries, most respondents favored conservative preparation techniques (vertical slot or saucer-shaped designs), with only a minority using traditional Class II or tunnel preparations. Treatment preferences in this context were consistent across all demographic variables.

Table 3 Perceived barriers to MID implementation

Question	Response	Count	%
What do you feel is the main barriers to adopt MID in your practice?	Lack of patient awareness or demand for minimally invasive techniques	32	9.1
	Limited training or knowledge in MID, including lack of access to continuing education	93	26.6
	High cost of materials and equipment	67	19.1
	Time constraints in clinical practice	17	4.9
	Uncertainty about long-term outcomes of minimally invasive treatments	22	6.3
	Insufficient reimbursement from insurance or financial incentives	11	3.1
	Lack of availability or access to appropriate technology and tools	56	16
	Cultural or traditional preferences for more conventional methods	44	12.6
	Concerns about the effectiveness of minimally invasive techniques in certain cases	5	1.4
	Lack of support from colleagues or the broader dental community	3	0.9

Approaches to cavity design and caries removal

For deep caries management, half of the respondents preferred the selective removal of soft dentin. The rest were split between complete excavation and stepwise removal, with no significant subgroup differences.

Management of defective restorations

In the context of defective restorations, most dentists prefer repair over replacement, including in cases involving marginal staining or minor asymptomatic defects. No significant associations with gender, experience, or workplace setting were detected.

Perceived barriers to MID

As shown in Table 3, dentists were asked to select a single main barrier. The most frequently reported obstacle was limited training or knowledge in MID—often linked to insufficient access to continuing education. Resource-related challenges, cultural or traditional preferences for conventional methods, low patient awareness, and uncertainty about outcomes were also noted, whereas time constraints, lack of reimbursement, concerns about effectiveness, and lack of professional support were less common.

Associations between demographics and MID-related practices

Multinomial logistic regression revealed no significant influence of gender, experience, or workplace setting on preferences for managing deep carious lesions or cavity preparation techniques. In contrast, experience significantly affects the choice of diagnostic tools. Dentists with ≤ 5 years of experience were significantly more likely to prefer radiographic examination than those with a

combination of visual–tactile and radiographic methods (OR = 3.38, $p = 0.012$). Those with ≥ 16 years of experience were significantly more likely to favor radiographic examination (OR = 2.51, $p = 0.033$) and substantially more likely to use recent diagnostic tools (OR = 5.87, $p = 0.010$). Gender showed a borderline trend, with females being less likely than males to use dental explorers (OR = 0.32, $p = 0.063$). The full results are presented in Table 4.

Binary logistic regression indicated no significant demographic influence on treatment preferences for incipient occlusal lesions, approximal enamel lesions, or defective restorations, although a strong overall preference for repair over replacement was evident ($p < 0.001$). As shown in Table 5, two associations approached or reached significance. Female dentists were marginally more likely to favor CRA over the chief complaint ($p = 0.052$). Dentists with ≥ 16 years of experience were significantly more likely to adopt a conservative approach for marginal staining or minor defects (OR = 1.88, $p = 0.037$), indicating stronger preservation-oriented preferences in this group.

Table 4 Multinomial logistic regression results for tools for caries detection

Tool	Predictor	*P* value	Odds Ratio (OR)	95% CI Lower	95% CI Upper
Dental Explorers	Gender: Female	0.063	0.319	0.096	1.062
Radiographic Examination	Experience: ≤ 5 years	0.012	3.378	1.312	8.694
Radiographic Examination	Experience: ≥ 16 years	0.033	2.510	1.079	5.839
Recent Diagnostic tools	Experience: ≥ 16 years	0.010	5.869	1.519	22.679

Reference Category: Visual-Tactile and Radiographic Examination

Table 5 Binary logistic regression results for prioritizing chief complaint vs. CRA and management of restorations with marginal defects

Binary logistic regression for chief complaint vs. CRA				
Predictor	P value	Odds Ratio (OR)	95% CI Lower	95% CI Upper
Gender: Female	0.052	1.531	0.996	2.354
Binary logistic regression for the management of restorations with marginal staining or minor marginal defects				
Predictor	P value	Odds Ratio (OR)	95% CI Lower	95% CI Upper
Experience: ≥ 16 years	0.037	1.881	1.039	3.404

Discussion

Palestinian dental practitioners apply MID-related practices in daily decision-making, although key barriers still limit broader use. Some clinicians apply MID, favoring preventive nonoperative approaches and repairs, but traditional methods remain prevalent. Barriers such as limited training, restricted CPD access, and resource shortages highlight the challenges associated with wider MID integration.

These findings converge on three interrelated themes that shape the implementation of MID in Palestine: (1) training and education gaps, particularly the limited integration of MID in undergraduate curricula and restricted opportunities for continuing professional development; (2) resource and cost constraints, including the high cost of materials, limited access to technologies, and the absence of supportive reimbursement systems; and (3) the influence of practice setting and cultural factors, where clinical experience, workplace context, and entrenched traditional preferences strongly influence uptake. The following sections expand on these themes.

Diagnostic and risk assessment practices

In our study, 55% of the dentists reported prioritizing the patient's chief complaint, whereas 45% incorporated CRAs into their clinical decision-making. CRA is a cornerstone of preventive, evidence-based caries management, as it enables clinicians to identify risk factors and tailor interventions accordingly [36–41]. Comparable trends have been reported in other countries: in Syria, 90% of dentists acknowledged the importance of CRA, but only 47.2% reported using it routinely [42]. In contrast, in the UK and Turkey, more consistent CRA adoption has been observed, supported by structured clinical guidelines and reimbursement frameworks [21, 43]. Reliance on symptoms over risk assessments is a common challenge in resource-limited contexts, including Palestine [25, 28, 33, 44–49].

CRA helps identify risk factors and guide interventions. However, its use is hampered by education gaps, time pressures, limited insurance, and entrenched routines. A borderline association emerged: female dentists were 1.5 times more likely to use CRA (OR = 1.531, 95% CI: 0.996–2.354, $p = 0.052$), suggesting a trend—although not statistically significant—toward more preventive, risk-based approaches.

Within the diffusion innovation framework, a CRA's limited uptake reflects perceived complexity and low trialability. Restricted CPD opportunities and the absence of peer modeling or guideline reinforcement further exacerbate this. The limited uptake of CRAs in Palestine reflects systemic constraints, including insufficient emphasis on undergraduate curricula, restricted CPD opportunities, and the absence of supportive insurance structures. These factors collectively hinder the standardization of CRA use and the transition toward a consistent, disease-centered model.

Recent consensus recommendations—including the EFCD (2023) position paper and the joint ORCA/EFCD consensus—underscore the role of individualized risk-based planning as a cornerstone of MID, further highlighting the importance of consistent CRA utilization for translating preventive strategies into routine practice [50, 51].

Management of carious lesions and restorations

30% of practitioners used a combination of visual–tactile and radiographic assessments, whereas 25% relied solely on visual–tactile methods. The use of advanced diagnostic tools was limited to only 10% of the respondents, indicating that most Palestinian dentists continue to depend on conventional techniques. Similar trends have been reported in Egypt and Saudi Arabia, where practitioners also reported minimal uptake of innovative technologies [23, 52].

Visual inspection is the main method for detecting occlusal caries, although accuracy varies with experience and may lead to misdiagnosis [53, 54]. Magnification aids such as loupes and operating microscopes have been proposed to enhance detection, although evidence indicates that they may not consistently improve accuracy [55–58]. While loupes may offer ergonomic benefits, their diagnostic value remains limited in resource-constrained settings.

Radiographs provide additional diagnostic value but detect only caries after significant progression. They cannot reliably distinguish between active and arrested lesions [59, 60]. For this reason, radiographs must be used alongside careful clinical examination. The use of sharp explorers is discouraged because of the risk of creating irreversible surface defects that compromise remineralization, whereas gentle tactile assessment with blunt probes is recommended [61–63]. Newer technologies—such as fiber-optic transillumination, quantitative light-induced fluorescence, and artificial intelligence-based tools—hold promise for earlier and more reliable detection [41, 53, 64–67]. However, their limited accessibility in Palestine underscores the importance of systemic investment in technology and training if dentists are to move beyond reliance on basic diagnostic methods (see Appendix D for representative examples).

When managing incipient enamel lesions on the occlusal surface, 55% of dentists in our study preferred preventive, nonoperative strategies, reflecting growing adoption of MID approaches. Similar findings have been reported in California (59%), whereas French and Thai dentists leaned more toward early operative interventions [68–70]. More conservative practices were observed in the UK, Russia, the Netherlands, and Kuwait, where the majority favored preventive strategies [20, 21, 27, 71]. These results align with a recent 21-country survey showing widespread overtreatment of enamel lesions: only about two-thirds delayed intervention until EDJ or beyond, while one in six intervened at E2 (lesions confined to the inner half of enamel). Guideline adherence was low, with just 22.7%–32.7% of responses meeting consensus recommendations, underscoring the persistence of early operative thresholds [72]. This preventive orientation among Palestinian dentists also parallels recent findings on restorative practices, where composite resins were the predominant choice for both small (83.7%) and large (60.4%) posterior cavities, underscoring a gradual transition away from traditional amalgam and toward more tooth-preserving, adhesive-based approaches [73].

For enamel-confined proximal lesions identified radiographically, 61% of our respondents also preferred nonoperative therapies, though 39% recommended immediate operative intervention. This aligns with Kuwait, Thailand, the UK, and the Netherlands but contrasts with Russia, where early operative treatment was more common [20, 21, 27, 68, 70, 71]. The multinational data similarly showed that dentists were more conservative with approximal than occlusal lesions, with nearly 70% choosing thresholds at the enamel–dentin junction or into the outer dentin. However, overtreatment remained substantial in certain regions—Colombian and Kazakh dentists frequently initiated treatment while lesions were still confined to enamel (outer or inner half), while Bangladesh and Portugal consistently demonstrated later, guideline-concordant thresholds [72].

Our findings suggest that Palestinian dentists are increasingly adopting preventive approaches for both occlusal and proximal enamel lesions. However, a considerable minority still favors early operative intervention. Interestingly, operators who preferred operative management of incipient occlusal lesions were less likely to adopt the same approach for enamel-confined approximal lesions, indicating a potential preference for preventive strategies at less accessible sites. Although not statistically significant, this contrasts with studies where early intervention choices were consistent across lesion types [20, 74]. The broader literature further emphasizes that such variations in intervention thresholds and treatment decisions may be influenced not only by lesion accessibility, but also by caries risk stratification, gender and specialization of practitioners, training background, patient expectations, economic incentives, and national health policies [72]. In the Palestinian context, the overlap between preventive lesion management and restorative material preference suggests a coherent though still transitional pattern toward MID, highlighting opportunities for curricular reinforcement and continuing professional development to consolidate these evolving practices [73].

Two-thirds favored conservative designs, but one-third still used traditional Class II forms, reflecting entrenched training and familiarity. Tunnel restorations, once promoted as a minimally invasive option, were chosen by only 3% of the dentists in our study and remain unpopular internationally because of structural compromise and marginal ridge fracture risks [75–77]. Comparable patterns have been reported internationally. In Russia, 39.8% of dentists continue to use conventional Class II preparations, whereas 60.2% favor minimally invasive designs, including saucer-shaped (38.6%) and tunnel preparations (21.6%) [27]. In the Netherlands, saucer-shaped designs are also predominant (59.1%), with tunnel preparations chosen by 4.7% of practitioners [20]. In Kuwait, nearly half of practitioners (49.2%) still preferred conventional Class II designs [71], whereas in the UK and USA, 49.8% and 54.1% of dentists, respectively, reported reliance on traditional forms despite guidelines recommending otherwise [21, 68]. In the UAE, 72.8% of practitioners preferred box preparations, with 20.6% using tunnel preparations [78].

Half of our respondents preferred selective caries removal for deep lesions, while 30% opted for complete excavation, and 20% opted for stepwise removal. Selective removal is widely supported in the literature for preserving pulp vitality [79–87], and international guidelines, including those of the American Dental Association, also reinforce this approach [87]. In the UK, Australia, Syria, and Norway, selective caries removal is widely embraced as the standard approach [21, 25, 29, 81, 88, 89]. In contrast, studies from France, Germany, Saudi Arabia, Egypt, and Spain report stronger preferences for complete excavation or stepwise methods, reflecting a continued emphasis on bacterial elimination and traditional philosophies [23, 79, 81, 90]. The near-even split reflects a transitional state of practice. Many recognize the benefits of selective removal, yet uncertainty and reliance on familiar methods sustain complete excavation and stepwise approaches. The findings underscore the need to reinforce selective caries removal in curricula, CPD, and national guidelines.

For defective restorations, 70% of the dentists in our study opted for repair rather than replacement, and 55% preferred to monitor or refurbish minor defects instead of replacing them. The results align with the global shift toward conservative strategies that extend the life of restorations and minimize unnecessary removal of the tooth structure. In Libya, for example, 68.9% of dentists reported repairing small defective composite restorations, whereas 29.5% chose replacement [91]. Similar preferences for repair have been reported in countries such as Australia, Norway, Germany, Greece, Switzerland, and the USA, reflecting broader international acceptance of repair as a minimally invasive alternative to replacement [92–96].

Despite positive trends, 45% of the respondents still favored replacement for minor asymptomatic defects. This highlights persistent variability in practice. This reliance on replacement may reflect lingering cultural expectations, limited confidence in repair outcomes, or the absence of clear clinical guidelines. Repairing defective restorations preserves tooth structure and slows the restorative cycle [97–102]. However, the limited observability of successful repairs and patient expectations for 'new' restorations may explain why many still prefer replacement.

Overall, Palestinian dentists are beginning to adopt repair-oriented approaches in line with MID principles, but training, guideline reinforcement, and patient education will be essential to support the wider diffusion of conservative management of defective restorations.

A gradual shift toward MID is occurring among Palestinian dentists, although traditional approaches remain common because of entrenched routines, training gaps, and systemic barriers. Preventive, nonoperative management was chosen by just over half of the respondents for early lesions (55% occlusal, 61% approximal), indicating recognition of a relative advantage, whereas the minority opting for operative care reflects limited compatibility with established routines and uncertainty about long-term outcomes. A similar pattern appeared in cavity preparation, where 66% favored conservative slot or saucer designs, but nearly one-third still relied on traditional Class II forms—suggesting that the familiarity and low observability of newer methods constrain wider diffusion. For deep caries, half adopted selective removal, while 30% persisted with complete excavation, underscoring how uncertainty reduces perceived advantage and reinforces reliance on conventional techniques. In contrast, restorative repair resulted in greater uptake, with 70% favoring repair and 55% refurbishing minor defects, reflecting compatibility with preservation principles. However, the persistence of replacement among a third of dentists points to cultural expectations and limited observability of successful repairs as barriers to full diffusion. These patterns illustrate diffusion dynamics. Preventive and repair choices show recognition of advantages, whereas traditional preparations and replacements reflect limited observability and cultural expectations that reinforce conventional techniques. As only one main barrier was recorded per respondent, the mapping to DOI constructs should be interpreted as indicative rather than definitive; concurrent influences across categories may be underrepresented.

Training and education gaps and resource constraints

The most frequently cited barrier was limited training/CPD in MID (26.6%), followed by high costs of materials and equipment (19.1%) and limited access to appropriate technologies (16%), with cultural preferences for traditional methods reported by 14%. These constraints align with DOI constructs: training deficits increase perceived complexity and reduce trialability; resource scarcity diminishes relative advantage and compatibility—especially in public clinics; and low patient awareness restricts observability. In Palestine, these barriers are compounded by systemic issues. To our knowledge, no studies have evaluated the integration of MID into the national dental curriculum, but undergraduate education likely continues to emphasize traditional methods, with limited attention to minimally invasive approaches. Opportunities for CPD—particularly in the public sector—are constrained by logistical and financial challenges.

Influence of clinical experience, practice setting, and cultural factors

Clinical experience significantly shaped MID-related practices. Dentists with ≤5 years of experience and those with ≥16 years of experience were more likely than their mid-career peers were to rely on radiographs (≤5 years: OR = 3.38, 95% CI 1.31–8.69, $p = 0.012$; ≥16 years: OR = 2.51, 95% CI 1.08–5.84, $p = 0.033$). Interestingly, the ≥16-year group also reported greater use of recent diagnostic innovations (OR = 5.87, 95% CI 1.52–22.68, $p = 0.010$) and a greater preference for conservative management of marginal staining or minor defects (OR = 1.88, 95% CI 1.04–3.40, $p = 0.037$). These patterns suggest both the impact of recent training among early graduates and the adaptability of highly experienced clinicians.

Gender had no significant influence on most clinical decisions, although a borderline, nonsignificant trend favored CRA use among female dentists (OR = 1.53, 95% CI 0.996–2.35; $p = 0.052$). International studies report similar findings: experience, rather than demographics, was the key driver in Saudi Arabia [33] and the Netherlands [20]. In contrast, in the US [68] and UK [21], younger dentists with recent evidence-based training leaned more strongly toward conservative care.

While these findings reflect routine general practice, the exclusion of restorative specialists is a limitation. Specialists typically receive more advanced training in minimally invasive techniques and may adhere more closely to evidence-based protocols or alternative philosophies [23, 27, 28]. Including their perspectives in future research would provide a fuller picture of how MID practices are applied across clinical specializations and highlight training disparities or system-level barriers that general practitioner surveys may overlook.

Workplace setting had minimal overall influence on MID practices in this study. However, systemic challenges in the public sector—restricted resources, fewer CPD opportunities, and limited autonomy—likely constrain wider uptake. In Palestine, where untreated oral disease is prevalent, these barriers limit the potential of MID as a cost-effective preventive strategy.

Regional disparities (West Bank, Gaza, East Jerusalem; rural vs. urban) may further shape access to training and materials, although our data did not permit stratified analysis. Future research should investigate these variations to inform location-specific strategies for broader MID implementation.

Overall, the findings converge on three interrelated themes shaping MID application in Palestine: (1) training and education gaps, where limited emphasis on MID in undergraduate curricula and restricted CPD opportunities perpetuate reliance on traditional methods; (2) resource and cost constraints, including high material costs, limited access to technologies, and the absence of supportive reimbursement systems, which restrict implementation, especially in public clinics; and (3) the influence of practice setting and cultural factors, whereby clinical experience, private sector resources, and entrenched traditional preferences strongly shape uptake. Together, these themes explain the variability in practice and underscore the systemic educational, infrastructural, and cultural influences that shape MID adoption in Palestine.

These interrelated themes can be more fully understood through Rogers' diffusion of innovation framework, which offers a structured lens for interpreting how barriers and facilitators shape MID adoption. The relative advantage of MID was evident in the strong preference for preventive strategies and restorative repair, yet uncertainty about long-term outcomes limited its perceived benefit for deep lesions. Compatibility was constrained by entrenched surgical traditions, reimbursement systems, and public-sector resource limitations, whereas inadequate training contributed to perceptions of complexity and hindered the uptake of diagnostic innovations such as CRAs. Opportunities for trialability were scarce in public clinics, and observability was weak owing to the absence of role models and peer networks demonstrating successful MID integration. Notably, higher uptake among experienced dentists suggests that accumulated professional experience and networks may accelerate diffusion, whereas systemic constraints in the public sector weaken perceptions of relative advantage and compatibility, slowing adoption overall.

Strategies to enhance MID diffusion

Within the diffusion of the innovation framework, the barriers identified in this study map onto core constructs

such as complexity, trialability, observability, and compatibility. Limited CPD access increases perceived complexity, scarce opportunities in public clinics restrict trialability and observability, and the absence of supportive reimbursement systems undermines compatibility. Addressing these dimensions is essential for embedding MID more consistently into routine practice.

Policy and practice implications

The results highlight the need for coordinated reforms across education, professional development, and health policy to support the wider integration of MID in Palestine. Several actionable priorities emerge: Undergraduate dental education should embed MID principles throughout preclinical and clinical training. Structured teaching of caries risk assessment, selective caries removal, and restoration repair would ensure that new graduates adopt evidence-based, conservative practices from the outset. The integration of international consensus statements and clinical guidelines into the curriculum could further align training with global standards. Limited access to CPD was the most frequently reported barrier in this study. Hands-on workshops and accredited CPD courses on MID techniques and diagnostic tools are essential. They should equip practitioners at all career stages with practical skills and confidence. Tailored CPD strategies could also address the distinct needs of early-career versus senior practitioners, reinforcing trialability and reducing perceived complexity. Cost-related barriers—including the high price of bioactive restorative materials and the limited availability of advanced diagnostic devices—constrain implementation, particularly in public clinics. Targeted subsidies, institutional investments, or public–private partnerships could improve access to affordable, high-quality materials and technologies, thereby strengthening the relative advantage of MID approaches. The development of context-appropriate national clinical guidelines for caries management would standardize practice, promote consistency, and reduce reliance on outdated, invasive methods. Moreover, insurance reforms and reimbursement structures should incentivize preventive and conservative treatment options, encouraging dentists to align economic decisions with evidence-based care. Together, these reforms address the educational, infrastructural, and systemic barriers identified in this study and create an enabling environment for the routine application of patient-centered, minimally invasive care.

Limitations

As an exploratory study, this research has several limitations that should be considered when interpreting the findings. Reliance on self-reported data may have introduced response bias, as social desirability could lead participants to overreport the use of MID-related practices, potentially inflating the prevalence of certain approaches. The extent of such bias is unquantifiable without objective validation.

The sampling approach may also have introduced bias. Convenience sampling via digital platforms and snowball recruitment likely overrepresented younger and more technologically connected practitioners while potentially excluding older dentists or those with limited internet access. The absence of comprehensive national demographic data or accessible dental workforce registries in the distinct territories of Palestine prevented comparison of our sample's demographic profile with that of the broader dentist population. This limitation restricts the assessment of representativeness and introduces the potential for selection bias.

The barrier question was designed as a forced-choice item. This format identified the primary obstacle perceived by each respondent but may have underrepresented the coexistence of multiple barriers in daily practice.

The cross-sectional design further restricts causal inference. Reliance on self-reported data at a single time point prevents conclusions about temporal relationships or cause–effect dynamics.

The exclusion of specialists in conservative or restorative dentistry narrowed the scope to general practitioners. Although appropriate for the study aim, this may have limited the diversity of perspectives, as specialists often receive advanced training in MID and could demonstrate greater adherence to evidence-based practices.

In addition, external factors such as patient preferences, financial constraints, and institutional protocols were not assessed. These influences may also shape the adoption of MID and contribute to variability in practice patterns, adding uncertainty to the precision of our estimates.

Certain methodological limitations should also be noted. The statistical analyses assumed a simple random sample despite nonrandom recruitment, which may overestimate significance and warrants caution in interpretation. The multiple statistical comparisons conducted may have increased the risk of Type I errors, particularly for marginally significant associations. Although adjustments such as Bonferroni correction were considered, they were deemed unnecessary for this exploratory study focused on predefined outcomes.

Together, these limitations suggest that future research should employ stratified sampling across key geographic regions (West Bank, Gaza, and East Jerusalem) to systematically evaluate regional disparities. Combining surveys with clinical audits would help validate self-reported practices, whereas longitudinal designs could track changes over time. Implementing more stringent

statistical thresholds (e.g., $p < 0.01$) or correction methods could reduce false positives, and incorporating qualitative methods (e.g., interviews, focus groups) would further contextualize the barriers and facilitators of MID adoption in Palestine's unique healthcare environment.

Conclusion

This study demonstrated that the application of MID practices among Palestinian general dental practitioners is variable, with clinical experience exerting the strongest influence, whereas gender and workplace setting had limited effects. Many dentists incorporate preventive and conservative approaches, yet traditional methods persist owing to training gaps, resource constraints, and systemic barriers. As the first national-level investigation on this topic in Palestine, these findings highlight critical gaps that must be addressed to advance evidence-based, patient-centered caries management. Future efforts should include longitudinal monitoring to track changes in MID uptake, stratified sampling across regions to identify geographic disparities, and mixed-method designs that integrate qualitative perspectives from practitioners, patients, and institutions. Together, these strategies clarify the evolving trajectory of MID adoption and inform policy, education, and clinical practice in Palestine.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12903-025-07042-7.

Appendix A

Appendix B

Appendix C

Appendix D

Acknowledgements
Not applicable.

Authors' contributions
N.Z.A designed the study, collected the data, interpreted the data, performed the statistical analyses, and drafted and wrote the manuscript. T.R assisted in designing the study, collecting the data, and drafting the manuscript. All authors reviewed and approved the final version.

Funding
None.

Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval for this study was obtained from the Institutional Review Board (IRB) of Arab American University, Palestine (Approval Number: J-2025/A/2/N). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Informed consent was obtained from each participant prior to their inclusion in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 5 March 2025 / Accepted: 23 September 2025
Published online: 14 October 2025

References

1. Giacaman R, Fernández C, Muñoz-Sandoval C, León S, García-Manríquez N, Echeverría C, et al. Understanding dental caries as a non-communicable and behavioral disease: management implications. Frontiers in Oral Health. 2022;3:1–10.
2. Aly NM, Ihab M, Ammar N, Quritum M, Moussa H, El Tantawi M. Impact of dental caries and Self-perceived oral health on daily lives of children and mothers in rural egypt: a household survey. BMC Oral Health. 2024;24:1–10.
3. Kaya MS, Akyuz S, Guclu B, Diracoglu D, Yarat A. Masticatory parameters of children with and without clinically diagnosed caries in permanent dentition. Eur J Paediatr Dent. 2017;18:116–20.
4. Rogers HJ, Tariq U, Olsson L, Riaz SA, Miah MR. Caries prevalence, clinical consequences and self-reported pain experienced by children living in the West bank. Eur Arch Paediatr Dent. 2019;20:333–8.
5. Muhammad T, Srivastava S. Tooth loss and associated self-rated health and psychological and subjective wellbeing among community-dwelling older adults: A cross-sectional study in India. BMC Public Health. 2022;22:7.
6. Dunleavy G, Verma N, Raghupathy R, Jain S, Hofmeister J, Cook R, et al. Inequalities in oral health: estimating the longitudinal economic burden of dental caries by deprivation status in six countries. BMC Public Health. 2024;24:3239.
7. James A, Janakiram C, Meghana RV, Kumar VS, Sagarkar AR. Impact of oral conditions on oral health-related quality of life among Indians- a systematic review and Meta-analysis. Health Qual Life Outcomes. 2023;21:1–18.
8. Baniasadi K, Armoon B, Higgs P, Bayat AH, Mohammadi Gharehghani MA, Hemmat M, et al. The association of oral health status and socio-economic determinants with oral health-related quality of life among the elderly: a systematic review and meta-analysis. Int J Dent Hyg. 2021;19:153–65.
9. Mahfouz M, Abu Esaid A. Dental caries prevalence among 12–15 year old Palestinian children. Int Sch Res Notices. 2014;2014:1–4.
10. Azizi Z. The prevalence of dental caries in primary dentition in 4- to 5-year-old preschool children in Northern Palestine. Int J Dent. 2014;2014:1–5.
11. Kateeb E, Lim S, Amer S, Ismail A. Behavioral and social determinants of early childhood caries among Palestinian preschoolers in Jerusalem area: a cross-sectional study. BMC Oral Health. 2023;23:152.
12. Walsh LJ, Brostek AM. Minimum intervention dentistry principles and objectives. Aust Dent J. 2013;58(Suppl 1):3–16.
13. Yon MJY, Gao SS, Chen KJ, Duangthip D, Lo ECM, Chu CH. Medical model in caries management. Dent J. 2019;7:37.
14. Perrone BR, Bottesini VC, Duarte DA. Minimal intervention dentistry: what is its clinical application and effectiveness in different continents? – a scoping review. Journal of Conservative Dentistry and Endodontics. 2024;27:134–9.
15. Philip N, Suneja B. The revolutionary evolution in carious lesion management. J Conserv Dent. 2023;26:249–57.
16. Leal SC, Dame-Teixeira N, De Brito Barbosa C, Kominami PAA, Raposo F, Nakagawa EMT, et al. Minimum intervention oral care: defining the future of caries management. Braz Oral Res. 2022;36:1–11.
17. Desai H, Stewart CA, Finer Y. Minimally invasive therapies for the management of dental caries—a literature review. Dent J. 2021;9:1–27.
18. Alyahya Y. A narrative review of minimally invasive techniques in restorative dentistry. Saudi Dent J. 2024;36:228–33.
19. Nguyen TM, Tonmukayakul U, Calache H. Evaluation of an intervention to promote minimally invasive dentistry (MID) in an Australian community dental agency—a pilot study. Int J Dent Hyg. 2022;20:627–34.
20. Laske M, Opdam NJM, Bronkhorst EM, Braspenning JCC, Van Der Sanden WJM, Huysmans MCDNJM, et al. Minimally invasive intervention for primary caries lesions: are dentists implementing this concept? Caries Res. 2019;53:204–16.
21. Mirsiaghi F, Leung A, Fine P, Blizard R, Louca C. An investigation of general dental practitioners' understanding and perceptions of minimally invasive dentistry. Br Dent J. 2018;225:420–4.

22. Henneberg S, Henriksen J, Christensen L, Markvart M, Rosing K. Inconsistent decision making in dental caries diagnosis and treatment: a case-based questionnaire survey. Health Sci Rep. 2024;7:e2278.
23. Elkady DM, Khater AGA. Knowledge and attitudes toward evidence-based cariology and restorative dentistry among Egyptian dental practitioners: a cross-sectional survey. BMC Oral Health. 2023;23:622.
24. Arotiba G, Loto A, Ijarogbe O, Ajayi Y, Umesi D, Menakaya I. Minimum intervention dentistry in resource challenged practice environments. Afr J Oral Health. 2019;9:1–17.
25. Algarni AA, Alwusaydi RM, Alenezi RS, Alharbi NA, Alqadi SF. Knowledge and attitude of dentists toward minimally invasive caries management in Almadinah Almunawwarah province, KSA. J Taibah Univ Med Sci. 2024;19:10–7.
26. Mania TV, Domingues NB, Raggio DP. Dental professionals' knowledge towards minimal intervention dentistry regarding caries management in the public health service in Vitória Da Conquista, Brazil. Pesqui Bras Odontopediatr Clin Integr. 2024;24:1–11.
27. Drachev SN, Galieva AS, Yushmanova TN, Polivanaya EA, Stangvaltaite-Mouhat L, Al-Mahdi R, et al. Restorative treatment decisions for carious lesions: do Russian dentists and dental students apply minimal intervention dentistry? BMC Oral Health. 2021;21:638.
28. Al-Asmar AA, Al-Hiyasat AS, Pitts NB. Reframing perceptions in operative dentistry relating evidence-based dentistry and clinical decision making: a cross-sectional study among Jordanian dentists. BMC Oral Health. 2022;22:637.
29. Alghorani R, Alhaffar MBA, Milly H, Banerjee A. Management of deep carious lesions among Syrian dentists: a cross-sectional study. BMC Oral Health. 2025;25:440.
30. García-Avilés JA. Diffusion of innovation. Int Encycl Media Psychol. 2020;1–8.
31. von Elm E, Altman DG, Egger M, Pocock S, Gøtzsche PC, Vandenbroucke J. Strengthening the reporting of observational studies in epidemiology (StroBE) statement: guidelines for reporting observational studies. Int J Med Students. 2014;2:36–7.
32. Eysenbach G. Improving the quality of web surveys: the checklist for reporting results of internet E-surveys (CHERRIES). J Med Internet Res. 2004;6:1–6.
33. Shah AH, Sheddi FM, Alharqan MS, Khawja SG, Vohra FM, Akram Z, et al. Knowledge and attitude among general dental practitioners towards minimally invasive dentistry in Riyadh and AlKharj. J Clin Diagn Res. 2016;10:90–4.
34. Stangvaltaite L, Schwendicke F, Holmgren C, Finet M, Maltz M, Elhennawy K, et al. Management of pulps exposed during carious tissue removal in adults: a multi-national questionnaire-based survey. Clin Oral Investig. 2017;21:2303–9.
35. Schwendicke F, Meyer-Lueckel H, Dörfer C, Paris S. Attitudes and behaviour regarding deep dentin caries removal: a survey among German dentists. Caries Res. 2013;47:566–73.
36. Fontana M, González-Cabezas C. Noninvasive caries risk-based management in private practice settings may lead to reduced caries experience over time. J Evid Based Dent Pract. 2016;16:239–42.
37. Usha C. Caries risk assessment: a critical look. Journal of Operative Dentistry & Endodontics. 2018;3:22–7.
38. Fontana M, Gonzalez-Cabezas C. Minimal intervention dentistry: part 2. Caries risk assessment in adults. Br Dent J. 2012;213:447–51.
39. Schwendicke F, Splieth CH, Bottenberg P, Breschi L, Campus G, Doméjean S, et al. How to intervene in the caries process in adults: proximal and secondary caries? An EFCD-ORCA-DGZ expert Delphi consensus statement. Clin Oral Investig. 2020;24:3315–21.
40. Schwendicke F, Splieth C, Breschi L, Banerjee A, Fontana M, Paris S, et al. When to intervene in the caries process? An expert Delphi consensus statement. Clin Oral Investig. 2019;23(10):3691–703.
41. Abdelaziz M. Detection, diagnosis, and monitoring of early caries: the future of individualized dental care. Diagnostics. 2023;13:3649.
42. Alakkad D, Al-Shiekh MN, Karkoutly M, Laflouf M. Knowledge, attitudes, and practices among Syrian dentists towards minimal invasive dentistry and chemomechanical caries removal: a cross-sectional study. BDJ Open. 2025;11:55.
43. Akgül S, Yıkılgan İ, Ömürlü H. Dentists' decision to conduct CRA in adult patients in turkey: a questionnaire-based survey. J Adv Oral Res. 2020;11:77–82.
44. Volgenant CMC, Giacaman RA, Persoon IF, Doméjean S, De Soet H. Caries risk assessment by dental students and dentists in the netherlands: a survey study to assess knowledge and implementation. Caries Res. 2025;7:1–11.
45. Elagra M, Alzaid H, Alsabeh M, Altoub N, Binhowaimel S. Caries-related treatment decisions of general dental practitioners in Riyadh, Saudi Arabia. Saudi J Oral Sci. 2020;7:174–80.
46. Fang X, Hua F, Chen Z, Zhang L. Caries risk assessment-related knowledge, attitude, and behaviors among Chinese dentists: a cross-sectional survey. Clin Oral Investig. 2023;27:1079–87.
47. Doméjean S, Léger S, Simon A, Boucharel N, Holmgren C. Knowledge, opinions and practices of French general practitioners in the assessment of caries risk: results of a national survey. Clin Oral Investig. 2017;21:653–63.
48. Tagliaferro EP, da Silva S, Rosell SRC, Valsecki Junior FL, Riley A, Gilbert JL. Caries risk assessment in dental practices by dentists from a Brazilian community. Braz Oral Res. 2020;35:1–9.
49. Nie E, Jiang R, Islam R, Li X, Yu J. Evaluation of caries risk assessment practices among dental practitioners in Guangzhou, China: a cross-sectional study. Front Oral Health. 2024;5:1458188.
50. Neuhaus KW, Kühnisch J, Banerjee A, Martignon S, Ricketts D, Schwendicke F, et al. Organization for caries Research–European federation of Conservative dentistry consensus report on clinical recommendations for caries diagnosis. Paper II: caries lesion activity and progression assessment. Caries Res. 2024;58:511–20.
51. Huysmans MC, Fontana M, Lussi A, Jablonski-Momeni A, Banerjee A, Ricketts D, et al. European organisation for caries research and the European federation of conservative dentistry consensus report on clinical recommendations for caries diagnosis: paper III – caries diagnosis at the individual level. Caries Res. 2024;58:521–32.
52. Radwan W, AlNasser AA, Aloqab H, Al-Saggaf K, Almuhtab NA, Alnasyan B. Knowledge and use of caries detection methods among dental students and dental practitioners in Riyadh, Saudi Arabia. Int J Dent. 2020. https://doi.org/10.1155/2020/8825890.
53. McComb D, Tam LE. Diagnosis of occlusal caries: part I. Conventional methods. J Can Dent Assoc. 2001;67:454–7.
54. El-Housseiny AA, Jamjoum H. Evaluation of visual, explorer, and a laser device for detection of early occlusal caries. J Clin Pediatr Dent. 2001;26:41–8.
55. Neuhaus KW, Jost F, Perrin P, Lussi A. Impact of different magnification levels on visual caries detection with ICDAS. J Dent. 2015;43:1559–64.
56. Wilde S, de Campos PH, Marcondes APM, Moura-Netto C, Novaes TF, Lussi A, et al. Optical magnification has no benefits on the detection of occlusal caries lesions in permanent molars using different visual scoring systems: an in vitro study. J Clin Exp Dent. 2020;12:e479–87.
57. Sasirekha G, Chandrasekhar R, Vinay C, Uloopi KS, Rojaramya KS, Chaitanya P. In vitro evaluation of reliability and validity of international caries detection and assessment system II coding for occlusal caries using magnification. Int J Clin Pediatr Dent. 2023;16:S138–41.
58. Mitropoulos P, Rahiotis C, Kakaboura A, Vougiouklakis G. The impact of magnification on occlusal caries diagnosis with implementation of the ICDAS II criteria. Caries Res. 2012;46:82–6.
59. Wenzel A. Radiographic modalities for diagnosis of caries in a historical perspective: from film to machine-intelligence supported systems. Dentomaxillofac Radiol. 2021;50:20210010.
60. Tranæus S, Shi XQ, Angmar-Månsson B. Caries risk assessment: methods available to clinicians for caries detection. Community Dent Oral Epidemiol. 2005;33:265–73.
61. Hamilton JC, Stookey G. Should a dental explorer be used to probe suspected carious lesions? J Am Dent Assoc. 2005;136:1526–32.
62. Ekstrand KR, Ricketts DNJ, Longbottom C, Pitts NB. Visual and tactile assessment of arrested initial enamel carious lesions: an in vivo pilot study. Caries Res. 2005;39:173–7.
63. Kühnisch J, Dietz W, Stösser L, Hickel R, Heinrich-Weltzien R. Effects of dental probing on occlusal surfaces - a scanning electron microscopy evaluation. Caries Res. 2006;41:43–8.
64. Chan EK, Wah YY, Lam WYH, Chu CH, Yu OY. Use of digital diagnostic aids for initial caries detection: a review. Dent J. 2023;11:232.
65. Choo-Smith LP, Dong CCS, Cleghorn B, Hewko M. Shedding new light on early caries detection. J Can Dent Assoc (Tor). 2008;74:913–8.
66. Pretty IA, Maupomé G. A closer look at diagnosis in clinical dental practice: part 5. Emerging technologies for caries detection and diagnosis. J Can Dent Assoc (Tor). 2004;70:540.
67. Kühnisch J, Aps JKM, Splieth C, Lussi A, Jablonski-Momeni A, Mendes FM, et al. ORCA-EFCD consensus report on clinical recommendation for caries diagnosis. Paper I: caries lesion detection and depth assessment. Clin Oral Investig. 2024;28:227.
68. Rechmann P, Doméjean S, Rechmann BMT, Kinsel R, Featherstone JDB. Approximal and occlusal carious lesions: restorative treatment decisions by California dentists. J Am Dent Assoc. 2016;147:328–38.

69. Muller-Bolla M, Aïem E, Coulot C, Velly AM, Doméjean S. Restorative thresholds for primary and permanent molars in children: French dentist decisions. Int J Paediatr Dent. 2021;31:299–310.
70. Ramayasinpong K, Nakornchai S, Jirarattanasopha V. Decision making on caries management in children and adolescents among Thai dentists. Int J Paediatr Dent. 2025. https://doi.org/10.1111/ipd.13297.
71. Khalaf ME, Alomari QD, Ngo H, Doméjean S. Restorative treatment thresholds: factors influencing the treatment thresholds and modalities of general dentists in Kuwait. Med Princ Pract. 2014;23:357–62.
72. Hatipoğlu Ö, Taha N, Karobari MI, Aldhelai TA, Ayyad DM, Madfa AA, et al. Variations in dentists' thresholds for restorative treatment of active non-cavitated carious lesions: a multinational cross-sectional study. J Dent. 2025. https://doi.org/10.1016/j.jdent.2025.106092.
73. Arandi NZ. Current trends in placing posterior composite restorations: perspectives from Palestinian general dentists: a questionnair study. J Int Soc Prev Community Dent. 2024;14:112–20.
74. Kopperud SE, Tveit B, Opdam NJM. Occlusal caries management: preferences among dentists in Norway. Caries Res. 2016;50:40–7.
75. Nicolaisen S, Von Der Fehr FR, Lunder N, Thomsen I. Performance of tunnel restorations at 3–6 years. J Dent. 2000;28:383–7.
76. Hörsted-Bindslev P, Heyde-Petersen B, Simonsen P, Baelum V. Tunnel or saucer-shaped restorations: a survival analysis. Clin Oral Investig. 2005;9:25–30.
77. Wiegand A, Attin T. Treatment of proximal caries lesions by tunnel restorations. Dent Mater. 2007;23:1461–7.
78. Suliman A, Abdo A, Elmasmari H. Restorative treatment decisions on approximal caries among practicing dentists in the college of dentistry clinics, Ajman University, united Arab Emirates. Open Dent J. 2020;14:97–102.
79. Crespo-Gallardo I, Martín-González J, Jiménez-Sánchez MC, Cabanillas-Balsera D, Sánchez-Domínguez B, Segura-Egea JJ. Dentists knowledge, attitudes and determining factors of the conservative approach in teeth with reversible pulpitis and deep caries lesions. J Clin Exp Dent. 2018;10:e1205-15.
80. Koopaeei MM, Inglehart MR, McDonald N, Fontana M. General dentists', pediatric dentists', and endodontists' diagnostic assessment and treatment strategies for deep carious lesions: a comparative analysis. J Am Dent Assoc. 2017;148:64–74.
81. Schwendicke F, Stangvaltaite L, Holmgren C, Maltz M, Finet M, Elhennawy K, et al. Dentists' attitudes and behaviour regarding deep carious lesion management: a multi-national survey. Clin Oral Investig. 2017;21(1):191–8.
82. Weber CM, Alves LS, Maltz M, Doctor O. Treatment decisions for deep carious lesions in the. Public Health Service South Brazil. 2011;71:265–70.
83. Yao Y, Luo A, Hao Y. Selective versus stepwise removal of deep carious lesions: a meta-analysis of randomized controlled trials. J Dent Sci. 2023;18:17–26.
84. Figundio N, Lopes P, Tedesco TK, Fernandes JCH, Fernandes GVO, Mello-Moura ACV. Deep carious lesions management with stepwise, selective, or non-selective removal in permanent dentition: a systematic review of randomized clinical trials. Healthcare. 2023;11:2338.
85. Barros MMAF, De Queiroz Rodrigues MI, Muniz FWMG, Rodrigues LKA. Selective, stepwise, or nonselective removal of carious tissue: which technique offers lower risk for the treatment of dental caries in permanent teeth? A systematic review and meta-analysis. Clin Oral Investig. 2020;24:521–32.
86. González-Gil D, Flores-Fraile J, Vera-Rodríguez V, Martín-Vacas A, López-Marcos J. Comparative meta-analysis of minimally invasive and conventional approaches for caries removal in permanent dentition. Med. 2024;60:402.
87. Dhar V, Pilcher L, Fontana M, González-Cabezas C, Keels MA, Mascarenhas AK, et al. Evidence-based clinical practice guideline on restorative treatments for caries lesions: A report from the American dental association. J Am Dent Assoc. 2023;154:551–e56651.
88. Chai BYY, Tay BYX, Chow CYT, Fuss J, Krishnan U. Treatment preferences for deep caries lesions among Australian dentists. Aust Dent J. 2020;65:83–9.
89. Patel S, Fine P, Shukla M, Blizard R, Leung A. An investigation into the management of the deep carious lesion by general dental practitioners in the UK. Br Dent J. 2022.
90. Elrashid AH, Alsulaiman NA, Alqahtani AM, Algholamy FM, Alobaida AM. Management preference of deep carious lesion in permanent mature teeth among dentists in Riyadh City. Saudi J Oral Sci. 2022;9:17–22.
91. Elsharkasi MM, Platt JA. Knowledge, attitude, and practice of resin composite repair among Libyan practitioners. Sci J Univ Benghazi. 2021;34:271–6.
92. Kanzow P, Hoffmann R, Tschammler C, Kruppa J, Rödig T, Wiegand A. Attitudes, practice, and experience of German dentists regarding repair restorations. Clin Oral Investig. 2017;21:1087–93.
93. Kanzow P, Dieckmann P, Hausdörfer T, Attin T, Wiegand A, Wegehaupt FJ. Repair restorations: questionnaire survey among dentists in the canton of Zurich, Switzerland. Swiss Dent J. 2017;127:300–11.
94. Khanna R, Han J, Liang E, Lee CY, Manakil J. The current attitudes and practices of dentists in Australia towards composite repair: a cross-sectional survey study. Aust Dent J. 2024;70:49–57.
95. Kattan W, Urquhart O, Comnick C, McQuistan MR, Guzmán-Armstrong S, Kolker J, et al. Repair versus replacement of defective direct restorations: A cross-sectional study among US dentists. J Am Dent Assoc. 2021;152:927–35.
96. Maria A, Charikleia P, Panagiotis L. Attitudes of Greek dentists towards repair of conservative restorations. An online survey. Int Dent J. 2017;67:351–9.
97. Kanzow P, Wiegand A. Retrospective analysis on the repair vs. replacement of composite restorations. Dent Mater. 2020;36:108–18.
98. Blum IR, Lynch CD, Wilson NHF. Factors influencing repair of dental restorations with resin composite. Clin Cosmet Investig Dent. 2014;6:81–7.
99. Lechte C, Schlarmann F, Biermann J, Wiegand A, Kanzow P. Repair of partially defective restorations: systematic review and meta-analysis of patient acceptance. J Dent. 2024;159:105361.
100. Loomans BAC, Ozcan M. Intraoral repair of direct and indirect restorations: procedures and guidelines. Oper Dent. 2016;41:S68–78.
101. Blum IR, Özcan M. Reparative dentistry: possibilities and limitations. Curr Oral Health Rep. 2018;5:264–9.
102. Moncada G, Martin J, Fernández E, Hemnel MC, Mjör IA, Gordan VV. Sealing, refurbishment and repair of class I and class II defective restorations a three-year clinical trial. J Am Dent Assoc. 2009;140:425–32.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.