Greenfort International Journal of Applied Medical Science
Abbreviated Key Title: Grn Int J Apl Med Sci
ISSN 3048-6904(P) | ISSN 2584-2420(O)
Journal homepage: https://gijams.in

Research Article DOI: 10.62046/gijams.2026.v04i02.003

Amalgam Management among Clinical Dental Students of BAU Dental Clinic: A Knowledge, Attitude and Practice Survey

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Received: 19.10.20265 | Revised: 30.12.2025 | **Accepted:** 17.02.2026 | **Published:** 19.04.2026

Abstract: This research paper provides a systematic review and detailed methodological framework for a study investigating the Knowledge, Attitude, and Practice (KAP) regarding dental amalgam management among clinical-year students at the Bilad Al Rafidain University (BAU) Dental Clinic. Dental amalgam, a mercury-based restorative material, remains prevalent due to its durability and cost-effectiveness. However, its approximate 50% elemental mercury content raises significant occupational health and environmental concerns, particularly during handling, placement, removal, and disposal. While placed restorations are considered safe for patients, improper management poses risks of chronic mercury exposure for dental personnel and contributes to environmental mercury pollution via wastewater. This paper synthesises contemporary literature on amalgam's safety profile, environmental impact, and established Best Management Practices (BMPs) as per the American Dental Association (ADA) and World Health Organization (WHO). It elaborates on the proposed cross-sectional KAP study's methodology, including sample selection from BAU's Year 4 and Year 5 dental students, a mixed-methods questionnaire, and quantitative analysis using SPSS software. The anticipated findings are discussed, highlighting the critical role of targeted education, enforced clinical protocols, and robust waste management infrastructure in dental curricula to mitigate risks. This paper serves as both a foundational review and a detailed research proposal aiming to bridge the gap between established guidelines and clinical practice in an educational setting.

Keywords: Amalgam, clinical, dental students, management.

Citation: Muhanad Ali Kashmola *et al.* Amalgam Management among Clinical Dental Students of BAU Dental Clinic: A Knowledge, Attitude and Practice Survey. Grn Int J Apl Med Sci, 2026 Mar-Apr 4(2): 50-58.

INTRODUCTION

Dental amalgam has been a fundamental material in restorative dentistry for over 150 years. Its use can be traced back to Tang Dynasty China, but it was introduced into Western dentistry in the early 19th century, with its popularity soaring after the development of reliable alloys [1].

Modern dental amalgam is a metallic compound formed by mixing liquid elemental mercury (approximately 50% by weight) with a powdered alloy consisting primarily of silver (30-40%), tin, copper, and sometimes zinc. The resulting mass is plastic for a short period, allowing condensation into a prepared cavity, where it hardens into a durable intermetallic compound [2].

Its key advantages include high compressive strength, excellent longevity in stress-bearing posterior regions, marginal sealing via slight expansion, low technique sensitivity in moist environments, and relatively low cost. Despite the rise of adhesive, tooth-coloured alternatives like composites and ceramics, amalgam remains a globally significant material, particularly in public health dentistry and specific clinical scenarios where moisture control is challenging [3].

The primary challenge associated with dental amalgam stems from its mercury content. Mercury is a potent neurotoxin and cell poison with documented adverse effects on human health and ecosystems. This creates a paradoxical situation: while set amalgam restorations are widely regarded as safe for patients based on extensive risk assessments [4], the lifecycle of amalgam within the dental clinic presents measurable risks.

Despite the existence of clear Best Management Practices (BMPs) promulgated by bodies like the ADA and WHO—encompassing preventive measures, chair-side protocols, and mandatory recycling—compliance in clinical settings, including dental schools, is often inconsistent. Barriers include lack of detailed

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knowledge, misconceptions, clinical time pressures, inadequate infrastructure, and insufficient regulatory enforcement [5].

Therefore, a baseline assessment of the current Knowledge, Attitude, and Practice (KAP) among dental students (the future practitioners) and their clinical supervisors is not merely academic but a critical public health and environmental imperative. Understanding the specific gaps in BAU's educational clinic provides the essential evidence needed to design targeted interventions, refine curricula, enforce safety protocols, and ultimately foster a culture of responsible amalgam management.

Aims of the study

This study aims to:

1. Conduct a systematic and critical review of contemporary scientific literature on dental amalgam
2. Assess the level of knowledge regarding amalgam composition, mercury hazards, and BMPs among final-year dental students and lecturers.
3. Explore attitudes and perceptions concerning personal and environmental risks, and the perceived importance of adherence to guidelines.

Chemical Composition, Physical Properties and Evolution

Modern dental amalgams are categorized by their copper content. Low-copper amalgams (commonly used before the 1970s) had higher tin content, forming a gamma-2 phase (Sn7-8Hg) which was prone to corrosion and creep. The introduction of high-copper amalgams (>10% copper) was a major advancement. These alloys, either as single composition or admixed (blended), significantly reduce or eliminate the gamma-2 phase, resulting in superior clinical performance: higher early strength, better resistance to corrosion and marginal breakdown, and lower creep [6].

The shift to pre-capsulated alloys was another critical safety innovation, eliminating the need to handle bulk mercury and ensuring a consistent, safe mercury-to-alloy ratio while minimizing vapor release during mixing [7].

Physical properties underpinning its clinical use include:

1. High Compressive Strength: Exceeds 300 MPa after 24 hours, suitable for withstanding occlusal forces [2].
2. Dimensional Change: A slight setting expansion (5-15 µm/cm) aids in marginal sealing.
3. Creep: Modern high-copper amalgams exhibit low creep, reducing the risk of marginal ditching.
4. Corrosion Resistance: The formation of a protective layer of tin and copper oxides on the surface improves longevity [6].

However, amalgam manipulation and its waste management in the dental office, if not strictly regulated, contribute to the risk of occupational exposure as well as environmental pollution. A potential health risk to oral health personnel from mercury exposure exists if working conditions are not properly organized. The application of proper mercury hygiene protocol together with monitoring of mercury vapours in the dental clinics will significantly reduce mercury exposure (Burke, 2004). Moreover, mercury used in dentistry may contaminate the environment via the disposal of waste products from dental clinics. Nevertheless, according to Environmental Protection Agency less than one percent of the mercury released into the environment comes from amalgam [8].

Equipment is available to collect the wastes generated during dental amalgam placement and removal. Appropriate collection and recycling technology is also available to reduce mercury pollution to the environment [9]. Thus, the mercury exposure risk might not be an issue if a standard protocol of handling amalgam is followed accordingly. There are a lot of recommendations in the management of amalgam.

The ADA has established guidelines for the protection of dental healthcare workers and the environment. They also have established the best management practice for the management of amalgam. These recommendations should be practiced as to minimize the harms to the dental health workers and to others. Barrier technique is one of the most commonly practiced amalgam handling method where facemasks, face shields, gloves, and protective eyewear are worn by the operator. However, no standard mask will filter mercury vapour or amalgam particulates smaller than 10 µm. Filtration protection varies for different masks [10]. At least, preventive measure should be taken. Although mercury in the form of dental amalgam is very stable, amalgam should not be disposed into the general waste, infectious waste “yellow bag,” pharmaceutical waste or sharps container.

Amalgam also should not be rinsed down the drain. These precautions are important because some communities incinerate municipal garbage, medical waste, and sludge from wastewater treatment plants. If amalgam waste ends up in one of these incinerated waste streams, the mercury can be released to the environment due to the extremely high temperature used in the incineration process. Increasingly, local communities are endorsing restrictions on the incineration of wastes containing mercury. Amalgam waste if is kept separate from other waste can actually be safely recycled. Recycling is one of the best

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practices for amalgam waste management for dental clinics (World Health Organization [11].

The Safety Debate: Patient vs. Occupational Health Perspectives

Patient Safety and Restorative Efficacy

Recent comprehensive reviews by major health bodies continue to support the safety of amalgam restorations for the general population. The European Food Safety Authority [4] concluded that exposure to mercury from dental amalgam is unlikely to cause systemic toxic effects in patients, except for rare local hypersensitivity reactions. The World Health Organization [11] acknowledges its cost-effectiveness and durability as key advantages in oral health care.

The shift in concern has led not to bans based on health risks to patients, but to environmental considerations, culminating in the Minamata Convention on Mercury, which includes provisions to phase down (not phase out) the use of dental amalgam with measures like promoting alternatives, encouraging BMPs, and not using amalgam in deciduous teeth [12].

Occupational Health Risks for Dental Personnel

Occupational exposure remains the primary health concern. Studies continue to show elevated urinary or hair mercury levels in dentists and assistants compared to controls, correlating with years of practice and poor mercury hygiene [13].

The removal of old amalgam restorations generates the highest levels of mercury vapour and particulate aerosol. While improved clinic ventilation and high-volume evacuators (HVE) are effective, adherence is variable. Research by Stone et al. (2020) confirmed that even with HVE, measurable mercury vapour is released during removal, underscoring the need for respiratory protection (e.g., masks rated for vapours) and stringent protocols. Chronic effects are well-documented, and preventative occupational health strategies are paramount [10].

Environmental Impact and the Mercury Cycle

Dental amalgam is a significant, preventable point source of mercury pollution. Although contributing a small percentage to total global emissions, its release is highly concentrated and controllable. The Minamata Convention specifically targets dental amalgam, requiring Parties to implement measures such as setting national objectives to phase down its use, promoting mercury-free alternatives, and mandating the use of amalgam separators [12].

Amalgam separators are now a legal requirement in many countries (e.g., the EU, USA). Their effectiveness is high, with modern devices capable of capturing over 95% of amalgam particles [14]. Once captured, the amalgam waste must be recycled by certified handlers to recover precious metals and safely contain mercury, closing the material loop and preventing environmental release [9].

Best Management Practices (BMPs)

Contemporary BMPs integrate occupational safety and environmental protection [11,15]:

i. **Work Area Hygiene:** Use pre-dosed capsules. Work in well-ventilated areas. Avoid carpeting.
ii. **Personal Protective Equipment (PPE):** Wear appropriate gloves, protective eyewear, and masks. Note that surgical masks do not filter mercury vapour; respirators may be needed for high-risk tasks.
iii. **Patient Management:** Use rubber dam isolation and HVE during all amalgam procedures, especially removal.
iv. **Waste Management:** Implement a strict, colour-coded, and labeled system for segregating all amalgam waste (scrap, capsules, traps, filters, teeth). Never dispose of amalgam in sharps containers, infectious waste, or general garbage.
v. **Technology Mandate:** Install and maintain ISO 11143-certified amalgam separators.
vi. **Recycling Contract:** Establish a service agreement with a licensed hazardous waste/recycling company.
vii. **Staff Training:** Implement regular, mandatory training for all clinical staff on mercury hygiene and BMPs.

Knowledge, Attitude, and Practice (KAP) Studies in Dental Communities

Recent KAP studies from various regions consistently reveal significant gaps. A study in Saudi Arabia found good knowledge but poor practice regarding amalgam waste management among dentists [16].

Research in India highlighted a lack of awareness about amalgam separators and recycling facilities among dental students [17].

A systematic review by Khan et al. [18] concluded that while awareness of mercury toxicity is generally high, practical implementation of BMPs is globally suboptimal, influenced by factors like cost, lack of facilities, and insufficient regulatory pressure. This underscores the critical need for studies within specific educational institutions to identify localised barriers and tailor interventions effectively. Dental students' KAP is particularly crucial, as it predicts future professional behaviour [3].

Study Design and Setting

This study will employ a descriptive, analytical, cross-sectional design using a survey methodology. A cross-sectional design is appropriate for determining the prevalence and relationship between knowledge, attitudes, and practices at a single point in time [19].

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The study will be conducted at the Bilad Al Rafidain University (BAU) College of Dentistry and its associated Dental Clinic. The clinic setting is chosen as it is the primary environment where amalgam manipulation and waste generation occur, making it the most relevant context for assessing practice-related questions.

Study Population, Sample Size, and Sampling Technique

1. **Target Population:** All final-year clinical dental students (Year 4 and Year 5) at the BAU.
2. **Inclusion Criteria:**

For Students: Currently enrolled in Year 4 or Year 5 of the BDS program at BAU, with active clinical rotation privileges in the restorative dentistry clinic and having completed at least one academic year of clinical training.

3. **Exclusion Criteria:**

Students with less than one year of clinical experience in restorative dentistry.

4. **Sampling Technique:** A census sampling method will be used for the student population, aiming to include all eligible Year 4 and Year 5 students.
5. **Sample Size Justification:** As the study aims for a complete picture within the specific educational institution, a census of the target student cohorts is justifiable [20].

Data Collection Tool: Questionnaire Development and Validation

The primary instrument will be a structured, self-administered questionnaire. Its development will follow a multi-stage process to ensure validity and reliability:

1. **Literature Review & Drafting:** Items will be generated based on a thorough review of existing KAP studies on amalgam management [17,21], ADA/WHO BMP guidelines [15,17], and core educational texts [6].
2. **Content Validity:** The initial draft will be reviewed by a panel of 3-5 experts, including a dental public health specialist, an operative dentistry professor, and an environmental health expert. They will assess the questionnaire for clarity, relevance, comprehensiveness, and appropriateness of each item using a formal content validity index (CVI) assessment. Revisions will be made based on their feedback [22].
3. **Pilot Testing:** The revised questionnaire will be pilot-tested on a small group (10-15 individuals) from a similar but non-participating cohort (e.g., Year 3 students). This will assess the time required for completion, clarity of instructions, and identification of ambiguous questions. Internal consistency reliability for the knowledge scale will be calculated using Cronbach's Alpha, with a target of >0.70 considered acceptable [23].
4. **Final Questionnaire Structure:** The final tool will comprise six sections:

- **Section A: Demographic Information** (Age, gender, academic year/position, years of clinical experience).
- **Section B: Knowledge Assessment** (15-20 close-ended, multiple-choice or True/False/Don't Know questions). Topics: amalgam composition, mercury toxicity pathways, symptoms of chronic exposure, key BMPs (e.g., use of capsules, separators, proper disposal methods), environmental impact.
- **Section C: Attitude Assessment** (10-12 items using a 5-point Likert scale from 'Strongly Disagree' to 'Strongly Agree'). Topics: perceived personal risk, perceived environmental responsibility, belief in the effectiveness of BMPs, attitude towards phasing down amalgam.
- **Section D: Practice Assessment** (10-15 items). Mix of Likert-scale questions (frequency: Never, Rarely, Sometimes, Often, Always) and multiple-choice questions regarding actual behaviours: use of PPE during amalgam work, use of HVE and rubber dam, disposal methods for different types of amalgam waste, maintenance of amalgam separators, engagement with recycling services.
- **Section E: Open-Ended Question** (Qualitative Component): "In your opinion, what are the major barriers preventing ideal amalgam waste management in this clinic, and what suggestions do you have for improvement?"
- **Section F: Training Exposure** (Yes/No and open comment): Questions about prior formal training or instruction received on mercury hygiene and amalgam waste management.

Variables and Measurement

1) **Independent Variables:** Demographic factors (Year of study/Position, Years of experience, Gender), Training exposure.
2) **Dependent Variables:**
   - ✓ *Knowledge Score:* Summative score from Section B. Each correct answer = 1 point; incorrect/'Don't Know' = 0. Total score will be calculated and can be categorised (e.g., Poor, Fair, Good).
   - ✓ *Attitude Score:* Mean score from Likert items in Section C (coded 1-5). Higher scores indicate more positive/safety-conscious attitudes.
   - ✓ *Practice Score:* A composite score derived from Section D, with higher scores indicating better adherence to BMPs. Specific practice indicators (e.g., % who always use capsules, % who segregate scrap amalgam) will also be analysed separately.

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Data Processing and Statistical Analysis Plan

Data analysis will be performed using IBM SPSS Statistics (Version 28.0 or later).

1. **Descriptive Statistics:** Frequencies, percentages, means, and standard deviations will describe demographic characteristics and summarize scores for knowledge, attitude, and practice scales.
2. **Inferential Statistics:**
   - **Comparative Analysis:** Independent samples t-test will compare mean knowledge, attitude, and practice scores between Year 4 and Year 5 students.
   - **Association Analysis:** Pearson's correlation coefficient will be used to examine the relationship between knowledge scores and practice scores, and between attitude scores and practice scores.
   - **Predictive Analysis:** Multiple linear regression analysis may be explored to determine if demographic variables (year, experience) and knowledge/attitude scores are significant predictors of practice scores.
   - **Chi-square tests** will be used to assess associations between categorical variables (e.g., training exposure vs. correct disposal practice).
3. **Qualitative Analysis:** Responses from the open-ended question (Section E) will be analyzed using thematic analysis [24]. Responses will be transcribed, coded line-by-line to identify initial concepts, and then grouped into overarching themes (e.g., "Barriers: Lack of Infrastructure," "Barriers: Time Pressure," "Suggestions: Improved Training"). These themes will be presented descriptively with supporting verbatim quotes to add depth and context to the quantitative findings.

Ethical Considerations

Prior to commencement, ethical approval will be sought from the BAU Institutional Review Board (IRB) or Research Ethics Committee. Key ethical principles will be adhered to:

1) **Informed Consent:** A written information sheet explaining the study's purpose, procedures, risks (minimal), benefits, and confidentiality measures will be provided. Participation will be voluntary, and written consent will be obtained from each participant.
2) **Anonymity and Confidentiality:** Questionnaires will be anonymous. No personally identifiable information will be collected on the survey form. All data will be stored securely on a password-protected computer, accessible only to the research team.
3) **Right to Withdraw:** Participants will be informed they can withdraw from the study at any point without providing a reason and without any academic or professional penalty.

RESULTS

The survey assessing the Knowledge, Attitude, and Practice (KAP) regarding amalgam management among clinical dental students at BAU Dental Clinic yielded the following key findings:

Knowledge Assessment

A significant proportion of participants demonstrated correct knowledge regarding the basic composition of dental amalgam, with 96% correctly identifying it as a mixture of mercury and other metals. However, knowledge regarding specific exposure pathways and risks was more variable. While most recognized the danger of mercury vapour from spills (88% correct) and leaky capsules (83% correct), fewer were aware of exposure risks from direct skin contact with freshly mixed amalgam (83% incorrect) or from malfunctioning amalgamators (73-77% correct). Notably, only 35% correctly identified that mercury vapour is released during the placement of amalgam, indicating a critical gap in understanding exposure during routine procedures.

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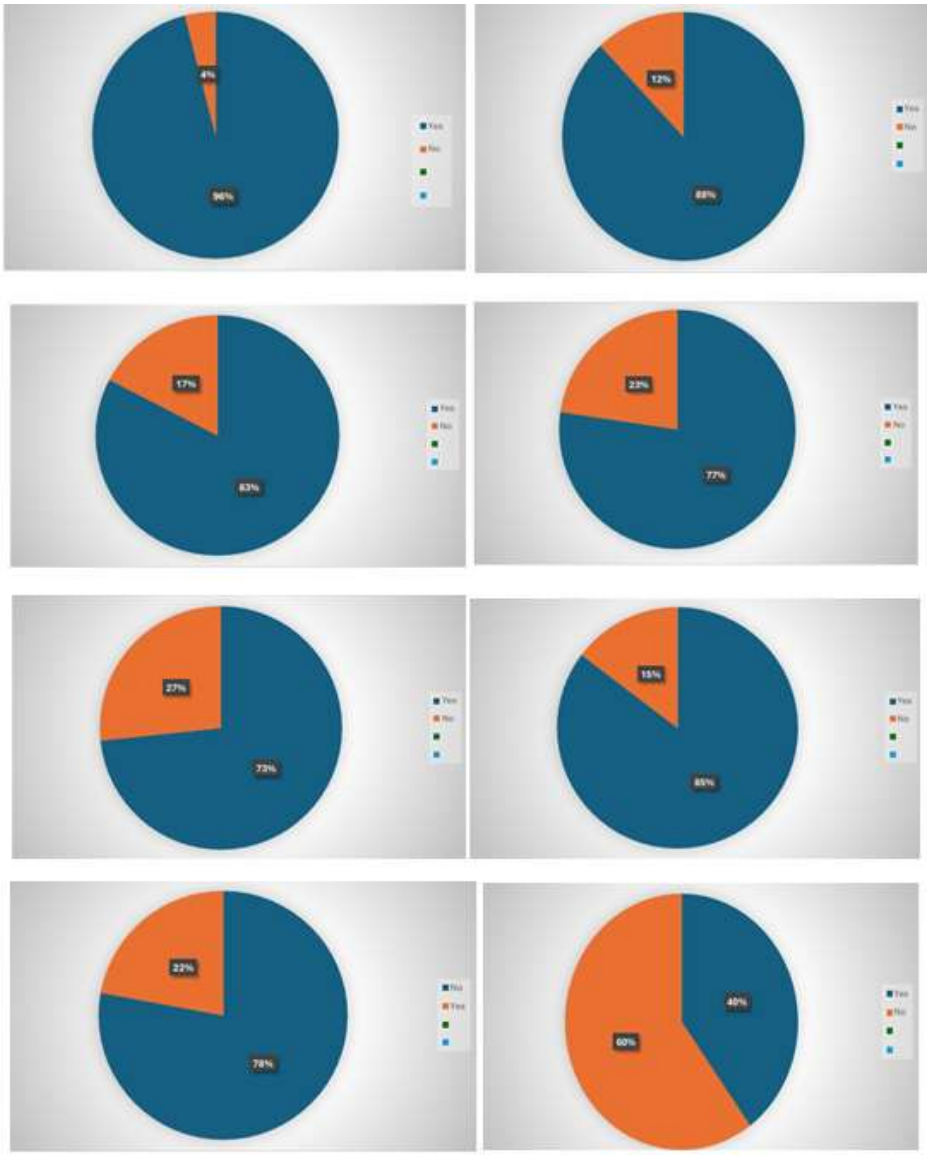

Figure 1: Participants' Knowledge about Source of Mercury Vapour: Spillage, Leaky Capsules, Direct Contact, Faulty Amalgamator, During Removal, During Placement, During Polishing and During Storage

Practice Assessment

Reported adherence to Best Management Practices (BMPs) showed room for improvement. While key practices like wearing gloves and masks were reportedly followed "all the time" by most, only 7% reported always storing amalgam scrap in a closed container—a fundamental waste containment practice. Alarmingly, 12% reported the incorrect practice of pouring amalgam waste from the filter into the sink, which leads directly to environmental contamination. In waste segregation, 20% of respondents correctly identified that non-contact amalgam scrap, extracted teeth with amalgam, and waste from chair filters should all be placed in a closed container.

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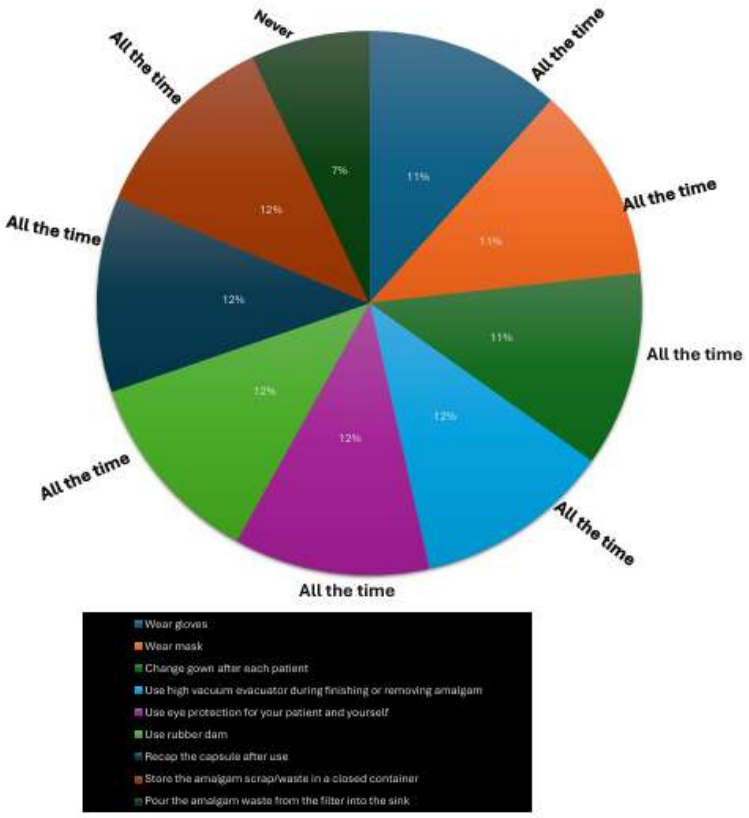

Figure 2: Participants' Practices Regarding Amalgam Waste Handling and Disposal

Attitude Assessment

Attitudes reflected high concern and a desire for improved management. A majority (82-85%) "totally agreed" that amalgam is hazardous to patients and that mercury management should be formally taught in all Iraqi dental schools. Furthermore, 79% totally agreed that every dental clinic should have periodic mercury vapour checks. However, only 15% totally agreed that amalgam use should be prohibited in Iraq, suggesting support for its controlled use rather than an outright ban. Regarding personal and institutional protocol, 77% totally agreed that they follow the prescribed BAU clinic protocol, and 77% also believed this protocol is in accord with ADA recommendations.

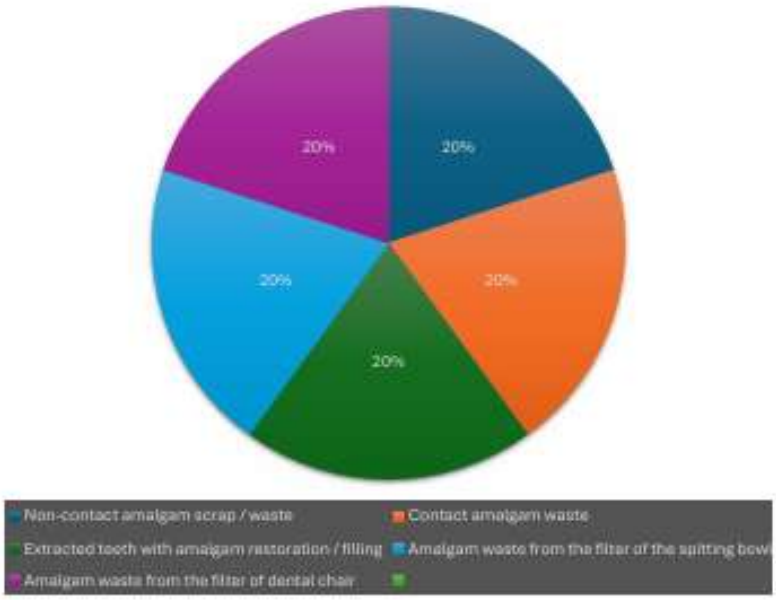

Figure 3: Participants' Attitudes Regarding Amalgam Risks and Need for Education

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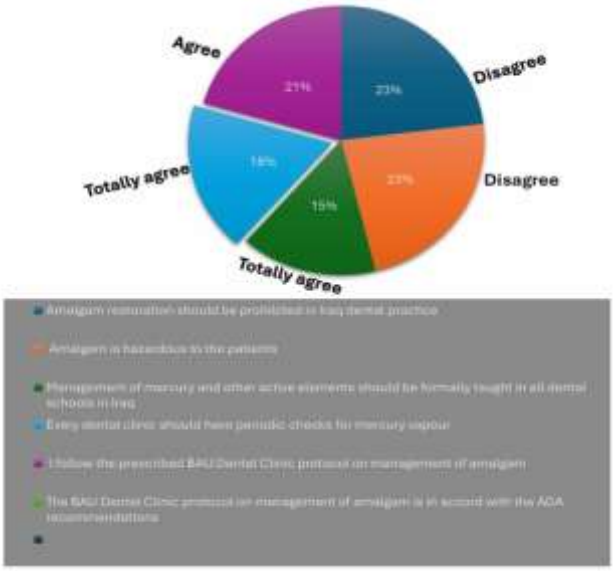

Figure 4: Participants' Attitudes Regarding Clinic Protocols and Recommendations

DISCUSSION

The results indicate a disconnect between knowledge, attitude, and practice, a common finding in KAP studies [19]. While foundational knowledge is strong and attitudes are largely safety-conscious, self-reported practices reveal significant lapses, particularly in waste management.

The high recognition of amalgam's mercury content (96%) contrasts with poorer knowledge about specific occupational exposure pathways, such as during placement (35% correct). This suggests that the curriculum or training may emphasize material science over practical occupational hygiene. This gap is critical, as placement and polishing are frequent activities, and unawareness increases the risk of chronic low-level exposure [25].

The practice findings are the most concerning. The low rate of consistent use of closed containers for amalgam scrap (7%) and the improper disposal of filter waste into sinks (12%) are major breaches of ADA and WHO BMPs [11,15]. These practices directly contribute to environmental mercury pollution, as wastewater treatment plants cannot remove all mercury, and it may enter the aquatic ecosystem [8]. This indicates either a lack of available infrastructure (sealed containers, amalgam separators), insufficient enforcement of protocols, or a failure of training to translate knowledge into habit. The positive attitudes are encouraging. The strong consensus on the need for formal education and periodic vapour monitoring presents a clear mandate for institutional change. The belief that the BAU protocol aligns with ADA guidelines, coupled with the admitted practice gaps, suggests that the *existing* protocol may not be fully implemented, accessible, or practical in the clinical environment. The qualitative barriers hinted at in the survey (e.g., time pressure, lack of facilities) align with global findings [17,21].

CONCLUSION

In conclusion, BAU dental students possess the fundamental knowledge and positive attitudes necessary for safe amalgam management. However, significant gaps in detailed risk knowledge and, most importantly, in the consistent application of safe disposal practices, pose a risk to occupational health and the environment. These gaps likely stem from systemic issues such as training deficiencies, inadequate clinical infrastructure, and insufficient protocol enforcement rather than a lack of concern.

This KAP study at BAU Dental Clinic reveals that while awareness of dental amalgam's mercury content is high and attitudes towards safety and environmental responsibility are largely positive, critical deficiencies exist in both detailed knowledge of exposure risks and, most notably, in the practical implementation of safe amalgam waste management protocols. The disparity between expressed attitudes and reported practices highlights a significant gap between theoretical understanding and clinical execution. The improper disposal practices documented particularly the disposal of amalgam waste into sinks and the inconsistent use of sealed storage, present tangible risks for environmental mercury contamination and indicate a failure of current clinical systems or training to ensure compliance with established Best Management Practices.

Recommendation

1. Assessment of Knowledge and Adherence to Amalgam Waste Management Protocols among Dental Students and Practitioners.
2. A Gap Analysis: Knowledge vs. Practice in Dental Amalgam Safety Measures at University Clinics.
3. Compliance with Best Management Practices for Amalgam: A Survey of Dental Students' Clinical Habits.

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Acknowledgement: None
Conflict of Interest: The authors declare no conflict of interest.
Source of Fund: None

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