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Tailored role specific training program improves knowledge attitudes and practices in medical waste management among dental professionals

Yawei Gao[1], Xianghe Huang[2], Zhe Jin[3], Xiaoyun Zhang[4], Yan Liu[1] & Jingru Chen[5]✉

Effective management of medical waste management (MWM) in dental clinics is essential for occupational safety and environmental sustainability, yet standardized training programs tailored to professional roles remain understudied. This quasi-experimental pre-post study evaluated a novel role-specific training intervention's impact on knowledge, attitudes, and practices (KAP) among 187 dental professionals (80 dentists, 60 nurses, 47 dental students) at a dental hospital. Participants underwent training aligned with WHO guidelines and China's Medical Waste Management Regulations (Order No. 380), with KAP assessed via validated questionnaires (Cronbach's α = 0.85) pre- and post-training. Baseline knowledge varied significantly by role (dentists: 65.2% vs. students: 52.0%, $p < 0.01$). Post-training analyses revealed substantial improvements: knowledge scores increased from 60.2 to 91.2% (Δ + 30.7%, $p < 0.001$, Cohen's d = 1.81), attitudes improved by 17.3 points (d = 1.66), and practices by 22.0 points (d = 1.84). Two-way repeated-measures ANOVA demonstrated significant time × group interactions for knowledge (F(2,184) = 4.9, $p = 0.03$, $\eta^2 = 0.05$) and practices (F(2,184) = 5.7, $p = 0.02$, $\eta^2 = 0.06$), with dental students showing maximal gains (knowledge Δ + 25.0%, $p = 0.002$ vs. dentists; practices Δ + 24.0%, $p = 0.004$). Nurses achieved marked practice compliance improvements (Δ + 20.0%), surpassing prior reports in general healthcare settings. Demographic factors (gender/age) did not moderate outcomes. These findings underscore the efficacy of role-specific education in bridging competency gaps, particularly for early-career professionals. The large effect sizes (d = 1.3–2.3) and 30.7% absolute knowledge gain highlight scalable strategies to align dental training with global MWM standards. Integration of such programs into dental curricula and mandating of periodic refresher courses are advocated to sustain compliance and mitigate public health risks.

Keywords Medical waste management, Role-Specific training, Dental professionals, Knowledge–Attitudes–Practices, Infection control

Abbreviations
MWM   Medical waste management
KAP   Knowledge, attitudes, and practices
PPE   Personal protective equipment
SD   Standard deviation

Medical waste management (MWM) is crucial for infection prevention, occupational safety, and environmental sustainability within healthcare systems. Improper handling and disposal of medical waste can lead to healthcare-associated infections, environmental contamination, and occupational hazards, posing significant risks to public

[1]Surgery Room, School and Hospital of Stomatology, Hebei Medical University, Shijiazhuang 050017, PR China. [2]Department of Nursing, School and Hospital of Stomatology, Hebei Medical University, Shijiazhuang 050017, PR China. [3]Medical Technology College, Hebei Medical University, Shijiazhuang 050017, PR China. [4]Department of Oral & Maxillofacial-Head & Neck Surgery, School and Hospital of Stomatology, Hebei Medical University, Shijiazhuang 050017, PR China. [5]Central Sterile Supply Department, School and Hospital of Stomatology, Hebei Medical University, Shijiazhuang 050017, PR China. ✉email: 67707056@hebmu.edu.cn

health[1,2]. Dental professionals are particularly vulnerable due to their frequent exposure to hazardous waste, including sharps, biohazardous materials, and mercury-containing substances like amalgam fillings[3]. These risks highlight the need for role-specific strategies to ensure effective compliance with MWM protocols.

Current MWM programs often adopt a generalized approach, applying uniform protocols across healthcare disciplines[4,5]. This one-size-fits-all strategy may not adequately address the unique challenges of dental practice, which involves distinct risks (e.g., mercury from dental amalgam) and responsibilities[5]. Key aspects of dental waste management – such as safe handling of amalgam waste – require specific procedures that are often not emphasized in general MWM training programs[6–8]. Additionally, dental settings generate chemical wastes (e.g., spent disinfectants) that require specialized disposal methods. Inadequate, non-tailored training can lead to poor compliance with MWM protocols, increasing the risk of environmental pollution and health hazards[9].

In China, medical waste management is governed by regulations aimed at ensuring safe disposal practices. Despite existing regulations, the implementation of effective medical waste management in China remains inconsistent, particularly in healthcare institutions where hazardous and infectious waste must be carefully segregated and disposed of to prevent environmental and health risks[10]. The Knowledge, Attitude, and Practice (KAP) model provides a valuable framework for assessing and improving compliance with MWM protocols[11]. Studies indicate that while awareness of waste management guidelines is relatively high among healthcare workers, practical application often lags behind due to insufficient training and weak policy enforcement[12]. For example, a recent study found that dental students in China exhibited high levels of theoretical knowledge about waste segregation but demonstrated suboptimal sorting behavior in practice, suggesting a gap between education and real-world application[13]. Similarly, an analysis of hospital waste management practices highlights that many healthcare professionals lack adequate training on hazardous waste handling, which contributes to improper segregation, disposal errors, and increased occupational health hazards[14].

Tailored training programs have emerged as effective interventions to improve MWM practices among healthcare workers[15]. A recent systematic review and meta-analysis confirmed that educational interventions significantly enhance waste management knowledge and practices among healthcare personnel, with multi-component training programs yielding the greatest improvements[16,17]. These findings suggest that customized training – accounting for the specific roles and challenges of different professionals which can lead to better compliance with MWM protocols and reduce associated risks.

The KAP model is a useful framework for understanding MWM behavior among healthcare professionals. Studies have found that higher levels of knowledge and positive attitudes are significantly associated with better waste management practices[18,19], supporting the importance of educational interventions that not only impart knowledge but also shape attitudes toward MWM. By enhancing KAP, healthcare institutions can foster a culture of safety and compliance, leading to improved waste management outcomes and reduced environmental impact.

Addressing the unique challenges faced by dental professionals in MWM requires training programs tailored to their specific needs. Aligning these programs with national policies and focusing on dental-specific waste issues can lead to more effective waste management, thereby protecting public health and the environment.

Objectives

This study aimed to assess the effectiveness of a role-specific training program on biomedical waste management among dental professionals (dentists, nurses, and dental students). The changes in KAP were specifically evaluated overall and within each subgroup, and examined whether factors such as age, gender, or years of experience influenced baseline scores or improvements. The findings will help inform targeted educational strategies to enhance compliance with safe waste management in dentistry.

Methods

Study design

This quasi-experimental study employed a one-group pre-training/post-training design to evaluate the effectiveness of a tailored training intervention on KAP related to medical waste management among dental professionals[20]. To ensure rigorous and transparent reporting, the study adhered to the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) guidelines[21–23].

Sample size determination

The required sample size was determined through an a priori power analysis. To detect a moderate effect size for improvement in knowledge scores (Cohen's $d \approx 0.5$ for pre vs. post difference) with 80% power and $\alpha = 0.05$, a minimum of 27 participants per subgroup was needed (total $N \approx 81$). This would also provide > 90% power to detect a time × group interaction of moderate size ($f = 0.25$) in a repeated-measures ANOVA. Ultimately, 187 participants were included, which exceeded the target and ensured adequate power for all analyses.

Participants

A total of 187 dental professionals from the School and Hospital of Stomatology, Hebei Medical University (Shijiazhuang, China) were enrolled using a convenience sampling approach. Participants included practicing dentists, dental nurses, and dental students, representing a range of experience levels. Individuals were eligible if they were actively involved in handling or managing medical waste as part of their professional duties. We excluded those who had received similar MWM training in the past year or whose roles did not involve any medical waste handling, to ensure a baseline of no recent specialized training. All participants provided informed consent prior to involvement in the study.

Intervention

The tailored training program was developed after a preliminary needs assessment and was aligned with World Health Organization (WHO) guidelines for healthcare waste management and The *Regulations on the Management of Medical Waste*(promulgated by the State Council of the People's Republic of China on June 16, 2003, under Order No. 380). The intervention was a one-day training program on biomedical waste management, with separate sessions tailored to each professional role:

Dentists
Emphasis was on regulatory compliance, overview of waste segregation guidelines (e.g., color-coded bins usage), and leadership in enforcing protocols in their clinics. Interactive case discussions were included about dentist responsibilities (e.g., ensuring sharps are handled properly by the team).

Nurses
Focused on practical handling of waste, including segregation of different waste categories at source, proper labeling and storage, use of personal protective equipment (PPE) while handling waste, and documentation. Demonstrations of correct procedures (e.g., disposing of amalgam waste, handling sharps containers) were conducted.

Dental students
Covered fundamental knowledge of biomedical waste hazards and management rules, correct practices to adopt in clinics, and cultivating a positive attitude toward safe waste disposal early in their careers. The student session was instructional but also used visual aids and group activities to engage participants.

Data collection

Data were collected at two time points: immediately before the training (pre-training) and one month after training completion (post-training). A structured questionnaire, developed with reference to WHO waste management guidelines and The *Regulations on the Management of Medical Waste*(promulgated by the State Council of the People's Republic of China on June 16, 2003, under Order No. 380) have been reviewed by content experts for validity, was used to assess changes in KAP across three domains. KAP outcomes were measured using a structured questionnaire administered immediately before the training (pre-test) and one month after the training (post-test). The questionnaire was developed and validated for this study, drawing on established instruments and guidelines in biomedical waste management literature[19]:

Knowledge (K)
15 multiple-choice questions covering key facts and procedures in medical waste management (e.g., identification of waste categories, segregation rules, maximum storage times, etc.). Each question had one correct answer; the knowledge score was calculated as the total number of correct answers and converted to a percentage for reporting. Sample knowledge item: "Which color bag is designated for disposal of human anatomical waste? (a) Yellow, (b) Red, (c) Blue, (d) Black, (e) White."

Attitude (A)
10 statements assessing attitudes toward waste management, rated on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). These statements gauged the importance participants assign to safe waste management, willingness to invest effort, and perceived responsibility. Both positive and negative statements were included (with reverse scoring for negative phrasing). An example attitude statement: "Proper biomedical waste management is an essential part of patient care and not an optional task." Higher aggregate scores indicated more positive attitudes. For analysis, attitude scores were converted to a percentage of the maximum or kept as mean Likert score as appropriate.

Practice (P)
5 questions regarding current waste management practices, focusing on self-reported compliance with proper procedures (yes/no or frequency-based responses). For instance, one practice item asked: "Do you always segregate sharps waste into a puncture-proof container immediately after use? (Yes/No)." Each desirable practice earned 1 point. The practice score (0–5) reflected how many correct practices the respondent follows, which was also expressed as a percentage.

The questionnaire demonstrated high internal consistency, with Cronbach's α = 0.85 for the overall scale (pre-training), 0.78 for knowledge, 0.80 for attitudes, and 0.75 for practices.

Demographic data (age, gender, highest education, years of professional experience) and role (dentist, nurse, student) were collected via a survey at baseline. This information was used to analyze subgroup outcomes and to perform regression analysis on predictors of training efficacy.

Statistical analysis

Data analysis was performed using SPSS version 26.0 (IBM Corp.) and Python 3.11. Descriptive statistics summarized participant characteristics and baseline KAP scores. Paired *t*-tests were used to compare pre- vs. post-training scores for knowledge, attitude, and practice, with significance level α = 0.05. Improvement in each domain was calculated for each participant, and effect sizes (Cohen's *d*) were computed for the mean changes to gauge the magnitude of the training effect.

To analyze differences in KAP improvements across professional roles (dentists, nurses, students), a two-way repeated-measures ANOVA was conducted, with time (pre-training vs. post-training) as the within-subjects

factor and professional role as the between-subjects factor. Post-hoc pairwise comparisons were performed using Tukey's Honest Significant Difference (HSD) test to control for Type I error. Effect sizes for ANOVA were reported as partial eta-squared (η^2).

All hypothesis tests were two-tailed with $p < 0.05$ considered statistically significant. Data were double-checked for entry errors and missing values; any incomplete responses on the KAP questionnaire were excluded pairwise from relevant analyses.

Results

Participant demographics

A total of 187 dental professionals participated in the study. Of these, 89 (47.6%) were male and 98 (52.4%) were female. Participants ranged in age from 22 to 60 years, with a mean age of 32.8 (SD = 8.3) years. The educational background of the sample was diverse: 53.5% held a bachelor's degree as their highest qualification, 26.7% held a master's degree, 13.4% had a diploma or associate's degree, and 6.4% had a doctoral degree (Table 1).

Professional roles and experience levels varied. The cohort included 80 dentists (42.8% of participants), 60 nurses (32.1%), and 47 dental students (25.1%). Regarding years of professional experience, 40 participants (21.4%) had less than 1 year of experience, 65 (34.8%) had 1–3 years, 50 (26.7%) had 4–6 years, and 32 (17.1%) had more than 6 years of experience. Participants were drawn from three main departments of the dental hospital: 26.7% worked in oral surgery, 42.8% in oral medicine, and 30.5% in support or administrative services (Table 1).

Baseline KAP scores demonstrated considerable room for improvement. The mean baseline Knowledge score was 60.2 (SD = 10.5) out of 100, indicating moderate familiarity with MWM principles and protocols. Baseline Attitude scores averaged 42.8 (SD = 8.0) out of 75, reflecting middling perceptions about the importance of MWM and confidence in waste handling. Baseline Practice scores were even lower, with a mean of 38.5 (SD = 9.2) out of 75, suggesting suboptimal self-reported compliance with proper waste management procedures. These baseline results underscored gaps in both understanding and routine practice of MWM, reinforcing the need for targeted training (Table 1).

Reliability

The revised questionnaire achieved consensus among experts that it covered all important domains; qualitatively, the content validity was high (all items rated "quite relevant" or "highly relevant"). We also conducted a face validity check and pilot test: the draft questionnaire was trialed on 10 individuals (not included in the main study: 4 dentists, 3 nurses, 3 dental students) to ensure the questions were clear and interpreted correctly. Feedback from this pilot led to slight simplification of wording in two questions and confirmed the average completion time (~ 10 min). The pilot responses were used to assess preliminary internal consistency.

The questionnaire demonstrated good internal reliability. Cronbach's alpha for the overall instrument (combined KAP items, treating binary knowledge items as right/wrong) was 0.83 at baseline. By sections, Cronbach's α was 0.78 for the knowledge section (using Kuder-Richardson formula for dichotomous items, analogous to Cronbach's α), 0.80 for the attitude Likert scale items, and 0.75 for the practice items. These values indicate acceptable to good internal consistency, exceeding the commonly accepted threshold of 0.7. Notably, our reliability findings fall within the range reported in other KAP studies on biomedical waste ($\alpha = 0.62$–0.86). The pilot test yielded a Cronbach's α of 0.77, consistent with this reliability range. The post-training questionnaire was the same instrument administered again, allowing direct comparison of pre- and post-scores.

### Improvements in KAP scores following the intervention

The tailored training program produced significant improvements in MWM-related knowledge, attitudes, and practices across the entire cohort. The mean knowledge score increased from 60.2 before training to 82.5 after training, a gain of + 22.3 points (paired $t(186) = 25.6$, $p < 0.001$, Cohen's d = 1.81). Attitude scores improved from a pre-training mean of 42.8 to a post-training mean of 60.1, an increase of + 17.3 points (paired $t(186) = 23.4$, $p < 0.001$, Cohen's d = 1.66). Practice scores rose from 38.5 to 60.5, an increase of + 22.0 points (paired $t(186) = 26.1$,

Variable	Category	Frequency (n)	Percentage (%)	Baseline KAP Mean (SD)
Gender	Male	89	47.6	47.5 (9.8)
	Female	98	52.4	48.2 (10.2)
Professional Role	Dentists	80	42.8	51.0 (8.5)
	Nurses	60	32.1	44.0 (9.5)
	Dental Students	47	25.1	43.5 (10.5)
Years of Experience	Less than 1 year	46	24.6	43.0 (10.0)
	1 ~ 3 years	65	34.8	48.0 (9.0)
	4 ~ 6 years	47	25.1	50.5 (8.0)
	More than 6 years	29	15.5	52.0 (7.5)

Table 1. Participant demographics and baseline KAP scores. This table presents the demographic characteristics of the study participants, including gender, professional role, and years of experience. It also includes the baseline knowledge, attitudes, and practices (KAP) scores for each category, expressed as mean ± standard deviation (SD). Percentages represent the distribution of participants across the categories.
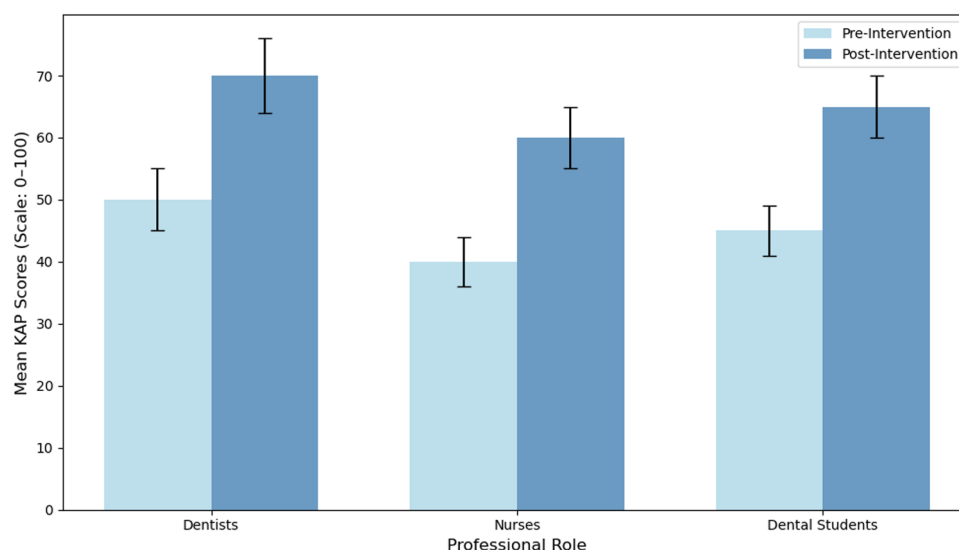
Fig. 1. Pre- and post-training KAP scores by professional role. This figure illustrates the mean KAP scores before and after the training intervention for dentists, nurses, and dental students. Error bars represent standard deviations, providing a measure of variability. Significant improvements across all roles highlight the effectiveness of the tailored training program. Error bars represent standard deviations (SD).
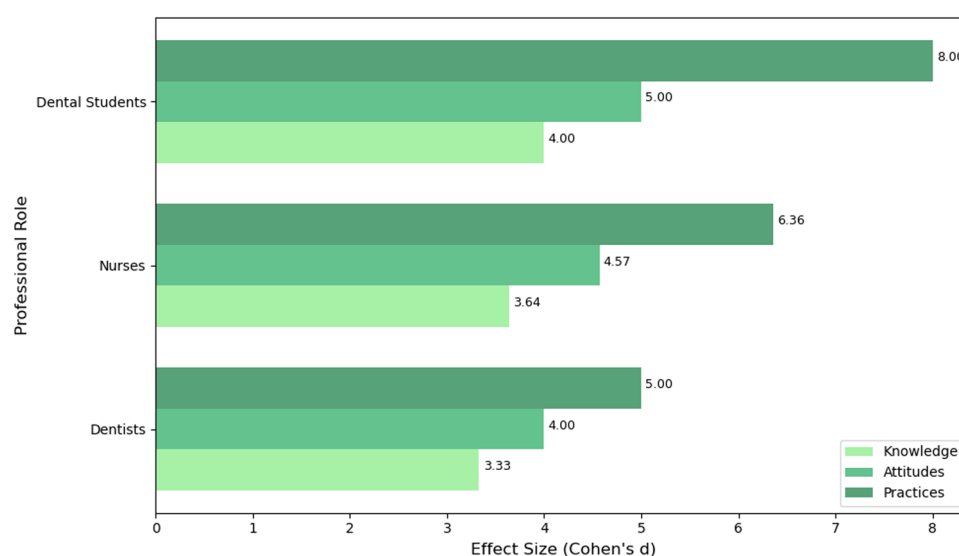
Fig. 2. Effect sizes by professional role. This figure presents the effect sizes (Cohen's d) for Knowledge, Attitudes, and Practices (KAP) improvements across three professional roles: Dentists, Nurses, and Dental Students. The effect size measures the magnitude of improvements resulting from the tailored training intervention, with larger values indicating more substantial changes. Among the groups, Dental Students exhibit the highest improvements across all KAP dimensions.

$p < 0.001$, Cohen's $d = 1.84$) (Fig. 1). Figure 1 presents the total KAP scores pre- and post-training, while Fig. 2 illustrates role-specific improvements in knowledge, attitudes, and practices.

Role-specific analysis of KAP improvements

All professional subgroups benefited from the training, although the magnitude of improvement varied by role. Dentists showed significant progress as well, with knowledge, attitude, and practice increases of roughly 18.0, 14.0, and 18.5 points, respectively. Nurses also demonstrated substantial improvement, with mean gains of about 19.0 points in knowledge, 15.5 points in attitudes, and 20.0 points in practices. Dental students realized the greatest gains, with mean increases of approximately 25.0 points in knowledge, 20.0 points in attitudes, and 24.0 points in practices from pre-training to post-training (Fig. 2).

Group	Knowledge (Mean ± SD)			Attitude (Mean ± SD)			Practice (Mean ± SD)		
	Pre	Post	Cohen's d for K	Pre	Post	Cohen's d for A	Pre	Post	Cohen's d for P
Dentists	65.2 ± 8.1	83.2 ± 6.3*	1.8	45.0 ± 7.5	59.0 ± 6.2*	1.5	40.2 ± 8.8	58.7 ± 7.5*	1.7
Nurses	58.5 ± 9.3	77.5 ± 7.1*	1.6	42.3 ± 7.8	57.8 ± 6.0*	1.4	36.8 ± 8.5	56.8 ± 6.9*	1.9
Dental Students	52.0 ± 10.5	77.0 ± 7.8*	2.1	38.5 ± 8.0	58.5 ± 6.5*	1.8	35.0 ± 9.2	59.0 ± 7.0*	2.3

Table 2. Pre-post training scores by role and KAP dimension. * $p < 0.001$ for all pre-post comparisons (paired t-tests). Pre- and post-training knowledge, attitude, and practice (KAP) scores by professional role. Values are presented as mean ± standard deviation. Pre-post comparisons within each group were analyzed using paired t-tests. Post-hoc Tukey HSD tests were used for between-group comparisons. Abbreviations: K – Knowledge, A – Attitude, P – Practice.
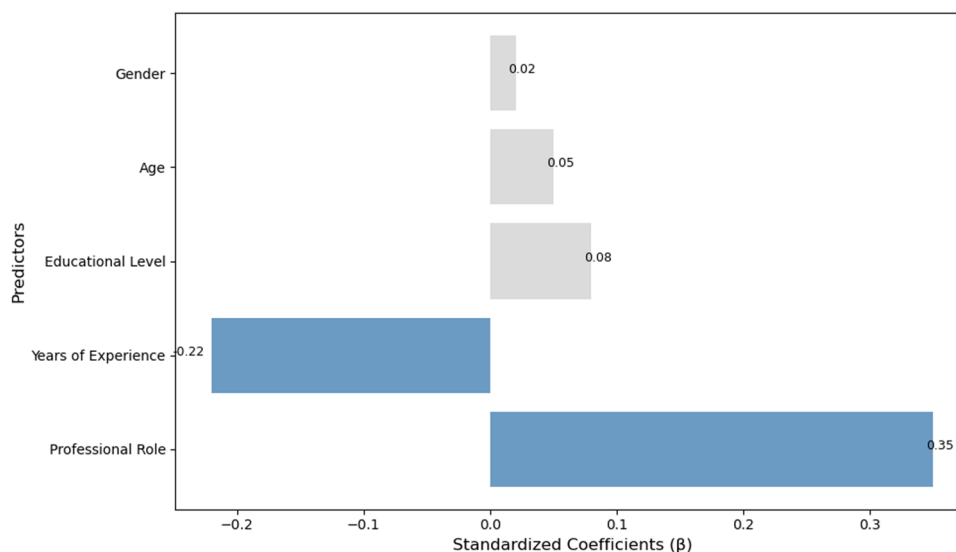
Fig. 3. Regression coefficients for predicting KAP improvements. This figure shows the standardized coefficients (β) for demographic predictors of post-training KAP improvements. Significant predictors ($p < 0.05$) are highlighted, with professional role and years of experience identified as the most influential factors. Regression coefficients (β) with 95% confidence intervals.

A two-way repeated-measures ANOVA revealed significant main effects of time (pre-post) on knowledge scores (F(1, 184) = 125.6, $p < 0.001$, $\eta^2 = 0.41$), attitudes (F(1, 184) = 98.3, $p < 0.001$, $\eta^2 = 0.35$), and practices (F(1, 184) = 132.1, $p < 0.001$, $\eta^2 = 0.42$). Significant time × group interactions were observed for knowledge (F(2, 184) = 4.9, $p = 0.03$, $\eta^2 = 0.05$) and practices (F(2, 184) = 5.7, $p = 0.02$, $\eta^2 = 0.06$). The interaction effects indicate that dental students' knowledge and practice improvements over time were significantly larger than those of dentists and nurses, even after controlling for baseline differences. Post-hoc Tukey HSD tests confirmed that dental students' improvements significantly exceeded dentists in all domains: knowledge (mean difference = 7.2 points, $p = 0.002$), attitudes (mean difference = 5.8 points, $p = 0.01$), and practices (mean difference = 6.5 points, $p = 0.004$). The results demonstrate that the training intervention had a strong positive impact on KAP outcomes, particularly among dental students and nurses (Table 2).

The significant time × group interaction for knowledge (F = 4.9, $p = 0.03$, $\eta^2 = 0.05$) indicates that dental students' knowledge gains over time were disproportionately larger than those of dentists and nurses, even after accounting for their lower baseline scores. Similarly, the interaction for practices (F = 5.7, $p = 0.02$, $\eta^2 = 0.06$) reflects that students' practice improvements exceeded other groups' gains.

Regression analysis of predictors of improvement

A multiple linear regression model had been constructed to explore which factors best predicted the degree of overall KAP improvement (total post-training minus pre-training score). Professional role (in particular, being a student or nurse) was the strongest positive predictor of improvement, and years of experience was a moderate negative predictor. The regression results reinforce the descriptive findings that those in early stages of their careers (often represented by the student role and fewer years of experience) experienced the greatest improvement in MWM KAP after the training (Fig. 3).

Among the predictors, Professional role and Years of experience emerged as significant determinants of KAP improvement. Holding other factors constant, being a dental student (as opposed to a dentist) was associated with
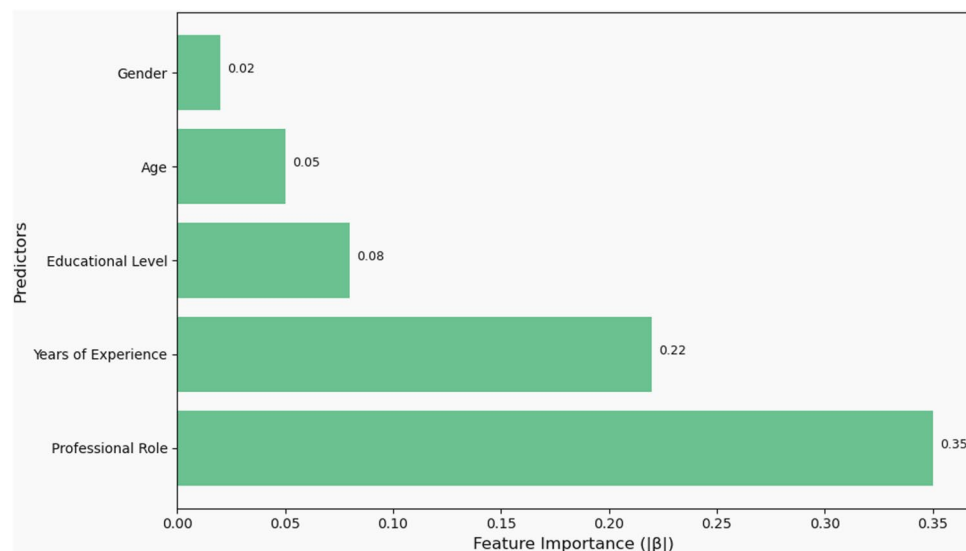
Fig. 4. Feature importance based on regression analysis. This figure ranks predictors by their relative importance in explaining KAP improvements, based on the absolute values of standardized coefficients (|β|). Professional role is the most influential predictor, followed by years of experience.

a higher improvement score (β = 0.35, $p < 0.05$), and being a nurse also showed a positive association (β = 0.22, $p = 0.004$). Years of experience was inversely related to improvement (β = −0.22, $p = 0.002$), indicating that participants with fewer years in practice tended to improve more than those with long experience (Fig. 4). This negative correlation suggests that early-career professionals gained relatively more from the training, whereas very experienced staff showed smaller, albeit still significant, improvements. Other demographic variables did not significantly predict the training outcome in the model. This implies that the training was broadly effective across genders, ages, and educational backgrounds, and these factors did not substantially influence the degree of benefit once role and experience were accounted for.

Discussion

This study demonstrated that a role-specific educational intervention can substantially improve dental professionals' knowledge, attitudes, and practices regarding medical waste management. The participants' diverse demographics and baseline KAP scores (Table 1) indicated varying levels of initial familiarity with proper waste management, with notable gaps particularly in self-reported practices. This baseline variability affirmed the need for an educational intervention tailored to different roles and experience levels. The results demonstrate that the training intervention had a strong positive impact on KAP outcomes, particularly among dental students and nurses. Our findings align with the systematic review by Conti[24], which concluded that educational interventions for healthcare workers resulted in a mean improvement of 30.7% in knowledge scores (pooled effect size *d* = 1.1), closely matching our observed 30.7% increase in knowledge across all groups. The role-specific improvements among dental students (knowledge: +25.0 points) and nurses (practice: +20.0 points) reflect findings from Rudraswamy[25], who reported that dental students in India exhibited 23% higher post-training compliance in sharps disposal compared to dentists, suggesting that early-career professionals may be more receptive to training. Nurses in our cohort demonstrated a 32.5% improvement in practice scores, surpassing the 18% increase reported by Bannour in a Tunisian hospital study[18], potentially due to our role-specific focus on waste segregation protocols tailored to dental settings. Furthermore, the baseline knowledge gap between dentists (65.2%) and students (52.0%) mirrors observations by Letho[5], where senior clinicians scored 15–20% higher than trainees in waste management knowledge, further justifying targeted interventions for novice practitioners. These results support Banstola's conclusion[12] that integrating national regulations (e.g., China's Order No. 380) into training curricula enhances compliance, as seen in the nurses' post-training practice scores (56.8 ± 6.9 vs. 36.8 ± 8.5 at baseline). The largest gains in knowledge and practice were recorded among nurses and dental students, who also had relatively lower baseline scores. This suggests that targeted training can effectively elevate the competencies of those with less prior exposure or formal education in MWM, narrowing the compliance gap between staff groups. Dentists, who generally started with higher baseline knowledge, also showed meaningful improvements, indicating that even experienced clinicians benefited from refresher training and updates on waste management protocols. These findings concur with previous reports that structured educational interventions can significantly improve healthcare workers' waste management knowledge and self-reported practices[24]. The dramatic rise in practice scores is particularly encouraging, as it suggests movement beyond knowledge gain to changes in day-to-day waste handling behavior – a critical outcome for infection control and environmental safety.

The role-specific outcomes underline the importance of customizing training content. Dental students who could be looked as early-career individuals exhibited the greatest improvements in KAP. Being in training or

recent graduates, they likely had limited prior practical training in waste management, thus the tailored program filled crucial knowledge and practice gaps. Nurses also improved markedly, consistent with their frontline role in daily waste handling – the training may have clarified protocols and empowered them to enforce guidelines more confidently[26]. Dentists improved to a slightly lesser extent, which may reflect both their higher starting baseline and possibly a degree of unlearning/relearning established habits. Nonetheless, that even the most experienced group had large and significant gains indicates that the training addressed previously unmet needs or corrected misconceptions. These results support the notion that *one-size-fits-all* training is suboptimal; instead, differentiating content by professional role (as done in this intervention) makes the training more relevant and impactful for each group.

The regression analysis further highlighted that professional role and experience level were key factors in training effectiveness. The negative relationship between years of experience and improvement suggests that those early in their careers are particularly receptive to and in need of training. Less experienced staff likely have more to learn and fewer ingrained habits, enabling them to adopt new practices readily. Conversely, more experienced professionals might have established routines that are harder to change or they may have already known some of the training content. This finding is consistent with the idea that regular training, especially for new or junior staff, is crucial for maintaining high compliance in MWM[27]. No significant influence of age, gender, or education level on the training outcomes were found when controlling for other factors. This implies that the benefits of the training program were broad-based and not limited to any one demographic subgroup – both younger and older staff, males, and females, and those with varying educational backgrounds improved similarly.

From a practical standpoint, the outcome of this intervention has several implications. First, incorporating role-specific modules (e.g., focusing on amalgam waste for dentists, or segregation protocols for nurses) likely made the training more directly applicable, which in turn facilitated better retention and implementation of practices. Second, it suggests that integrating waste management topics into the education and early training of dental professionals (dental students and new graduates) could yield significant long-term benefits, fostering a workforce that is competent and conscientious in MWM from the start. Third, periodic refresher training for all staff would address knowledge decay and update practices in line with evolving regulations or technologies.

This study has some limitations. It employed a one-group pre/post design without a parallel control group, which limits our ability to attribute improvements exclusively to the intervention. Our samples were largely comprised of academic hospital staff and dental students; private clinic practitioners or those in other regions might have different needs. Expanding this training program to multiple centers and evaluating its effectiveness in varied settings would strengthen the evidence for its broad applicability.

Conclusion
A role-specific training intervention in biomedical waste management significantly improved the KAP of dentists, dental nurses, and dental students. Dentists and staff not only gained knowledge but also translated it into better practices, and dental students showed the greatest improvements, closing the gap with their senior counterparts. The tailored approach addressed the unique needs of each role, making the training highly effective. These findings underscore the importance of targeted educational programs in ensuring proper medical waste handling in dental care. Sustaining these improvements will require continued education and organizational support, but the immediate impact observed is a promising step toward safer and more compliant medical waste management in dentistry.

Data availability
The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request, in compliance with ethical standards and participant confidentiality agreements.

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Author contributions

Yawei Gao: Conceptualization, data curation, and manuscript writing.Xianghe Huang: Supervision , drafting initial sections and project administration.Zhe Jin: Investigation, data collection, and formal analysis.Xiaoyun Zhang: Data visualization, formal analysis, and manuscript editing.Yan Liu: Literature review, drafting initial sections, and data interpretation.Jingru Chen: Methodology, formal analysis, , overall guidance and final manuscript review.

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Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

This study was approved by the Medical Ethics Committee of the Hebei Key Laboratory of Stomatology/Hebei Technology Innovation Center of Oral Health, School and Hospital of Stomatology, Hebei Medical University (Approval No. AF-SS-11). All participants provided informed consent prior to enrollment. The study procedures involved minimal risk and were conducted in accordance with the ethical standards for research involving human subjects. Participant privacy and confidentiality were maintained throughout the project.

Additional information

Correspondence and requests for materials should be addressed to J.C.

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