



● ORIGINAL ARTICLE

Knowledge, Attitudes, Safety Awareness and Practice of Laser Dentistry Among Sudanese Dentists: A Cross-Sectional Survey

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Abstract

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BACKGROUND

Laser technology is increasingly integrated into dental practice worldwide, yet adoption in low-resource settings often lags behind favorable attitudes. No previous study has characterized Sudanese dentists' knowledge, attitudes, safety awareness and practice of laser dentistry.

METHODS

In this cross-sectional study, 413 Sudanese dentists completed a structured, self-administered online questionnaire between August 2023 and January 2024 through non-probability convenience sampling. Composite Knowledge (0–8), Attitude (4–20) and Safety-awareness (0–4) scores were derived; internal consistency was assessed using Cronbach's alpha. Associations were tested with chi-square/Fisher's exact and Mann-Whitney U/Kruskal-Wallis tests, and independent correlates of laser use by multivariable logistic regression ($p < 0.05$). Reporting followed STROBE.

RESULTS

Half of respondents (219, 53.0%) recognized that lasers treat both hard and soft tissue. Interest was high (346, 83.8%), yet only 77 (18.6%) used lasers. The commonest barrier ($n = 353$) was inadequate hands-on experience (245, 69.4%), followed by cost (90, 25.5%). Awareness of ocular (280, 67.8%) and cutaneous (263, 63.7%) hazards was moderate, but plume-inhalation awareness was low (133, 32.2%). Internal consistency was good to excellent (alpha 0.87–0.89). Independent correlates of laser use were prior safety training (aOR 19.9, 95% CI 7.2–55.1), higher knowledge score (aOR 1.55 per point, 1.23–1.96) and private-sector practice (aOR 2.88, 1.16–7.20); gender and qualification were not.

CONCLUSION

Positive attitudes were not matched by practical experience or comprehensive safety knowledge, particularly regarding plume inhalation. Structured undergraduate and postgraduate training with explicit plume-safety content is recommended.

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KEYWORDS

Lasers • Dentistry • Health knowledge, attitudes, practice • Dental education • Occupational



Introduction

Light Amplification by Stimulated Emission of Radiation (laser) became a working reality in 1960, when Maiman produced a coherent, monochromatic beam from a ruby crystal, building on Einstein's earlier description of stimulated emission.^{1,2} Different laser wavelengths interact differently with dental hard and soft tissue,³ and the technology has since diversified into several wavelength-specific systems: carbon dioxide, neodymium-doped yttrium aluminum garnet (Nd:YAG), erbium-based, and diode lasers.⁴⁻⁹

Laser-based approaches are now described across nearly every discipline of dentistry, spanning minimally invasive cavity preparation, caries detection, soft-tissue surgery, periodontal debridement, tooth whitening, and photobiomodulation for wound healing and pain control.⁴⁻⁹ The evidence for some applications remains mixed: systematic reviews report inconsistent improvement in clinical attachment level when lasers are added to non-surgical periodontal therapy,¹⁰ with comparable uncertainty for laser-assisted periodontal surgery,¹¹ a reminder that adoption should be guided by outcome evidence rather than novelty.

Despite this expanding evidence base, translation into everyday practice has been uneven outside high-income settings. Cross-sectional surveys from Saudi Arabia consistently show that familiarity outpaces use; comparable awareness-practice gaps have been reported from India and Pakistan, most often attributed to cost and insufficient hands-on training.¹²⁻²¹ Within Sudan, and across the wider region, comparable survey data on laser dentistry remain scarce.^{22,23} To our knowledge, no previous survey has examined Sudanese dentists' knowledge, attitudes and practice with regard to laser dentistry.

This gap is not merely academic. Curricular and policy decisions are difficult to make rationally without baseline data on practitioners' current knowledge, attitudes and self-reported barriers, and the absence of such data carries direct implications for patient safety, for the efficient use of scarce training and equipment resources in the Sudanese health system, and for alignment with international laser-safety standards.

The present study was therefore designed to assess Sudanese dentists' knowledge and awareness of laser applications, their attitudes toward safety and efficacy, and their current practice patterns and perceived barriers, and, extending beyond previous descriptive surveys, to identify the factors independently associated with laser use.

Materials and Methods

Study Design and Period

A cross-sectional, questionnaire-based study was conducted among dentists in Sudan between August 2023 and January 2024.

Setting and Participants

The target population comprised licensed dentists practicing in Sudan across government hospitals, private clinics, and academic institutions, from early-career practitioners to experienced specialists. Any licensed dentist practicing in Sudan who was willing to give informed consent was eligible; those who declined or did not complete the questionnaire were excluded.

Sampling and Sample Size

The questionnaire was distributed electronically as a self-administered Google Forms link. The sampling technique was non-probability convenience sampling, in which dentists were reached through professional networks and social media. Because recruitment relied on an openly shared link, the total number of dentists who were invited or who opened the form was not captured; a formal response rate and denominator, therefore, cannot be computed, and this is acknowledged as a limitation.

The minimum required sample size was estimated using the standard formula for a single proportion, $n = Z^2 pq / d^2$, where $Z = 1.96$ (the standard normal value for a 95% confidence level), $p = 0.5$ (the proportion assumed to give the maximum required sample in the absence of a prior estimate), $q = 1 - p = 0.5$, and $d = 0.05$ (the accepted margin of error). This yields $n = (1.96^2 \times 0.5 \times 0.5) / 0.05^2 = 384$, so a minimum of approximately 385 respondents was required. A total of 413 dentists provided complete responses and were included in the analysis, exceeding the calculated target.

Questionnaire

The questionnaire was developed for this study to assess the constructs specified in the study objectives and was informed by the content of previous surveys of dental professionals' knowledge, attitudes and practices regarding laser dentistry.^{12–21} Items were organized a priori according to the construct they were intended to measure. Demographic and professional items described participant characteristics; knowledge items assessed factual recognition of laser applications and types; attitude items assessed perceptions of laser safety and effectiveness; practice items assessed current use, interest, barriers to non-use, and support for undergraduate education; and safety-awareness items assessed recognition of ocular, cutaneous, dental-tissue and plume-related hazards. The analytic knowledge domain comprised eight factual items: one item on hard- and soft-tissue use, six items on applicability across dental specialties, and one item on identification of clinically used laser types. The attitude domain comprised four five-point Likert items addressing perceived benefits of laser treatment. The safety-awareness domain comprised four hazard-recognition items. The instrument was reviewed by three subject-matter experts for content and face validity and was piloted on 30 dentists, whose responses were not included in the final analysis. Internal consistency was acceptable at pilot (Cronbach's alpha 0.86) and good to excellent in the final sample (0.87 to 0.89 across the composite scales).

Variables and Scoring

Three composite scores were derived. The Knowledge score (range 0–8) summed correct responses to the eight factual knowledge items; the Safety-awareness score (range 0–4) summed affirmative recognition of the four specified hazards; and the Attitude score (range 4–20) summed the four five-point Likert items (coded 1 = strongly disagree to 5 = strongly agree). For descriptive interpretation, Knowledge and Safety-awareness scores were converted to percentages of the maximum obtainable score and classified using the commonly applied Bloom cut-off points: < 60% = poor, 60–79% = moderate, and ≥ 80% = good.^{24–26} These thresholds are used in KAP and health-professional survey research as pragmatic performance bands, with ≥ 80% representing a high level of mastery or adequacy, 60–79% an intermediate level, and < 60% an insufficient level. They are not presented as empirically validated clinical thresholds for laser dentistry. The same percentage

bands were applied descriptively to the Attitude score, with < 60% interpreted as less positive, 60–79% as moderately positive, and ≥ 80% as positive; attitude was also retained as a continuous score for analysis. The categorization was used for descriptive presentation only, whereas the continuous composite scores were retained for inferential analyses. Current practice was a single binary item and was analyzed as a proportion rather than as a scale.

Statistical Analysis

Data were cleaned before analysis: two biologically impossible age entries (3 and 4 years) were treated as missing for age summaries, and inconsistently coded experience schemes and duplicate specialty labels were harmonized. Categorical variables were summarized as frequencies and percentages, and continuous variables as mean ± SD. Internal consistency was assessed with Cronbach's alpha. Associations between categorical variables were tested with the Pearson chi-square test (Fisher's exact test where more than 20% of cells had expected counts below 5); differences in ordinal composite scores across groups were tested with the Mann–Whitney U test (two groups) or the Kruskal–Wallis test (more than two groups), as the scores were non-normally distributed. Factors independently associated with current laser use were identified using multivariable binary logistic regression, with results reported as adjusted odds ratios (aOR) with 95% confidence intervals; model calibration was assessed with the Hosmer–Lemeshow test. Analyses were performed in SPSS and Python, and two-sided $p < 0.05$ was considered statistically significant.

Ethics

Ethical clearance was obtained from the Alfajr College Research Ethics Committee under reference number AFC-REC-2023-07-15, dated 13 July 2023. Electronic informed consent was obtained from all participants, who were informed of the study's purpose, assured of confidentiality, and free to withdraw at any stage. All data were anonymized and stored securely.

Results

Participant Characteristics

A total of 413 dentists completed the questionnaire. The sample was predominantly female (268, 64.9%), with a mean age of approximately 32.6 ± 6.9 years. Most held a Bachelor of Dental Surgery (BDS) qualification (246,



59.6%) and worked as general practitioners (167, 40.4%); 266 (64.4%) had fewer than five years' experience. Respondents were distributed across government hospitals (154, 37.3%), private clinics (104, 25.2%), mixed settings (125, 30.3%) and academic institutions (30, 7.3%). Full characteristics are shown in Table 1, and the study's key knowledge, attitude and practice indicators are summarized in Figure 1.

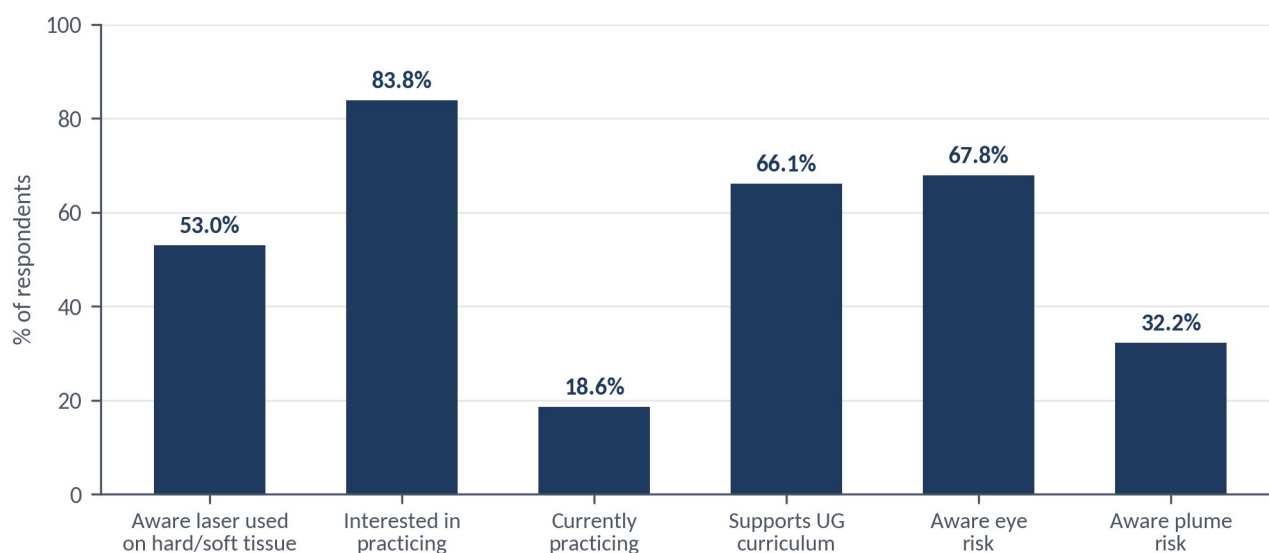
Table 1. Demographic and professional characteristics of the surveyed Sudanese dentists (N = 413).

Characteristic	Category	n (%)
Gender	Female	268 (64.9%)
	Male	145 (35.1%)
Qualification	BDS	246 (59.6%)
	MSc (Master's)	125 (30.3%)
	MD	35 (8.5%)

Characteristic	Category	n (%)
Professional status	PhD	7 (1.7%)
	General practitioner	167 (40.4%)
	Dental intern	135 (32.7%)
	Specialist	77 (18.6%)
Experience	Consultant	34 (8.2%)
	< 5 years	266 (64.4%)
	5–10 years	78 (18.9%)
	> 10 years	69 (16.7%)
Setting	Government hospital	154 (37.3%)
	Private clinic	104 (25.2%)
	Both	125 (30.3%)
	Academic	30 (7.3%)

Age (≥ 18 y): mean approximately 32.6 ± 6.9 years. Two biologically impossible age entries (3 and 4 years) were excluded from the age summary (see Strengths and Limitations).

Figure 1. Key knowledge, attitude and practice indicators among the surveyed Sudanese dentists (N = 413).



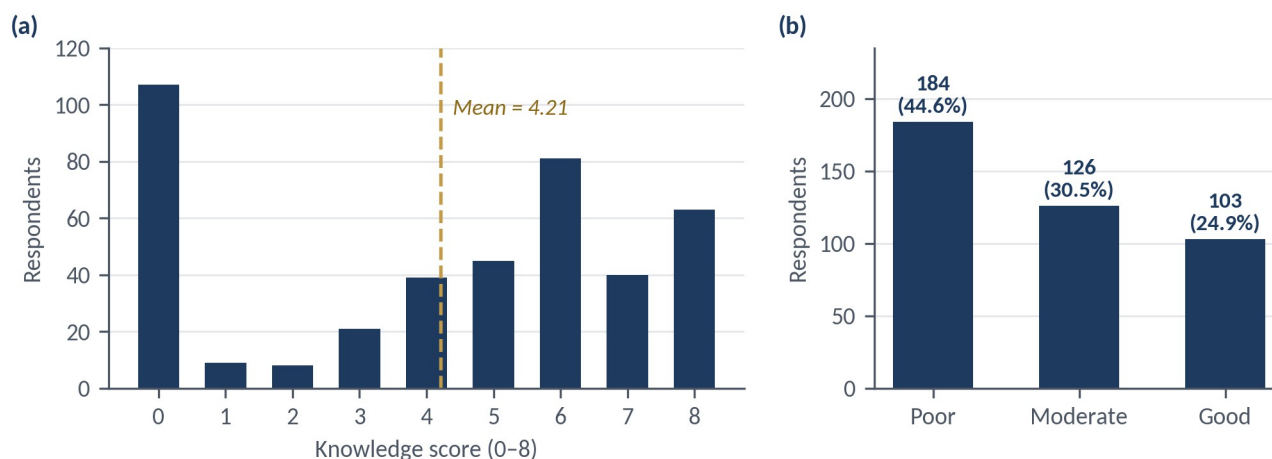
Values are the percentage of respondents endorsing each item: recognition that lasers treat hard and soft tissue, interest in practicing laser dentistry, current laser use, support for including laser education in the undergraduate curriculum, and awareness of ocular and laser-plume hazards.

Knowledge

Just over half of respondents (219, 53.0%) correctly identified that lasers can treat both hard and soft dental tissue, while 38.5% were uncertain. Perceived applicability varied by specialty (Table 2), being highest for periodontology (70.7%) and oral surgery (70.0%) and lowest for orthodontics (38.3%) and prosthodontics (40.7%). Fewer than half of respondents (42.1%) could identify the laser types used clinically (Table 2). The mean Knowledge score was 4.21 ± 2.94 of 8; by Bloom's classification, 44.6% were categorized as Poor, 30.5% as Moderate and 24.9% as Good (Figure 2).

Table 2. Proportion of dentists who considered lasers applicable, by knowledge item and dental domain (N = 413).

Item	Yes (%)
Laser used on hard and soft tissue	53.0
Periodontology	70.7
Oral surgery	70.0
Endodontics	59.6
Pedodontics	46.7
Orthodontics	38.3
Prosthodontics	40.7
Can identify laser types	42.1

Figure 2. Distribution of the composite Knowledge score across the sample (N = 413).

Panel (a) shows the frequency of each score from 0 to 8, with the dashed line marking the sample mean (4.21); panel (b) shows respondents classified by Bloom's cut-offs into Poor (< 60%), Moderate (60–79%) and Good ($\geq$ 80%) knowledge categories, with counts and percentages.

Attitudes

Attitudes were considerably more positive than actual practice. Most respondents agreed that laser treatment is associated with reduced pain, less bleeding, shorter treatment time with faster healing, and more conservative caries removal than conventional handpieces. The mean Attitude score was 16.67 ± 3.19 of 20, with the large majority (86%) classified as having a positive (Good) attitude.

Practice, Interest and Barriers

Interest in practicing laser dentistry was high (346, 83.8%), yet only 77 (18.6%) were currently using lasers. Among respondents who named a device ($n = 81$), the diode laser predominated (57, 70.4%). The barriers item was a single-choice question answered by 353 respondents; the most frequently cited barrier was inadequate hands-on experience (245, 69.4%), followed by cost (90, 25.5%), patient acceptance (9, 2.5%) and difficulty convincing the patient (9, 2.5%). These four categories account for the full set of responses (100%). Two-thirds of respondents (273, 66.1%) supported incorporating laser education into the undergraduate curriculum, while 5.6% were opposed.

Safety Awareness

Awareness of laser-associated hazards was inconsistent. Most respondents recognized risk to the eyes (280, 67.8%) and skin (263, 63.7%), and just over half recognized thermal damage to adjacent tooth structure (224, 54.2%). Awareness of laser-plume inhalation risk was markedly lower (133, 32.2%), with 53.8% uncertain.

Only 144 (34.9%) reported ever having received formal education on a laser safety protocol. The mean Safety-awareness score was 2.18 ± 1.62 out of 4.

Reliability

Internal consistency was good to excellent: Cronbach's alpha was 0.89 for the Knowledge scale, 0.88 for the Attitude scale and 0.87 for the Safety-awareness scale (0.92 for the combined knowledge-plus-safety items). No item, if removed, materially improved the reliability of its scale.

Factors Associated with Laser Use

In bivariate analysis, current laser use was strongly associated with prior safety training, practice setting, and knowledge and safety-awareness categories (all $p < 0.001$), and with interest in laser dentistry ($p < 0.001$), but not with gender ($p = 0.89$) or qualification ($p = 0.68$) (Table 3). Knowledge scores differed by qualification, experience and setting (Kruskal–Wallis, all $p < 0.001$); a difference by gender was also observed, but a subset of early-career respondents provided highly homogeneous response patterns (see Strengths and Limitations), so this particular difference should be interpreted with caution. In multivariable logistic regression (Table 4, Figure 3), prior safety training (aOR 19.9), a higher knowledge score (aOR 1.55 per point) and private-sector practice (aOR 2.88 vs government) were independently associated with laser use; gender, qualification and interest were not. The model was well calibrated (Hosmer–Lemeshow $p = 0.29$; McFadden pseudo- $R^2 = 0.51$).

Table 3. Bivariate associations between participant characteristics and current laser use.

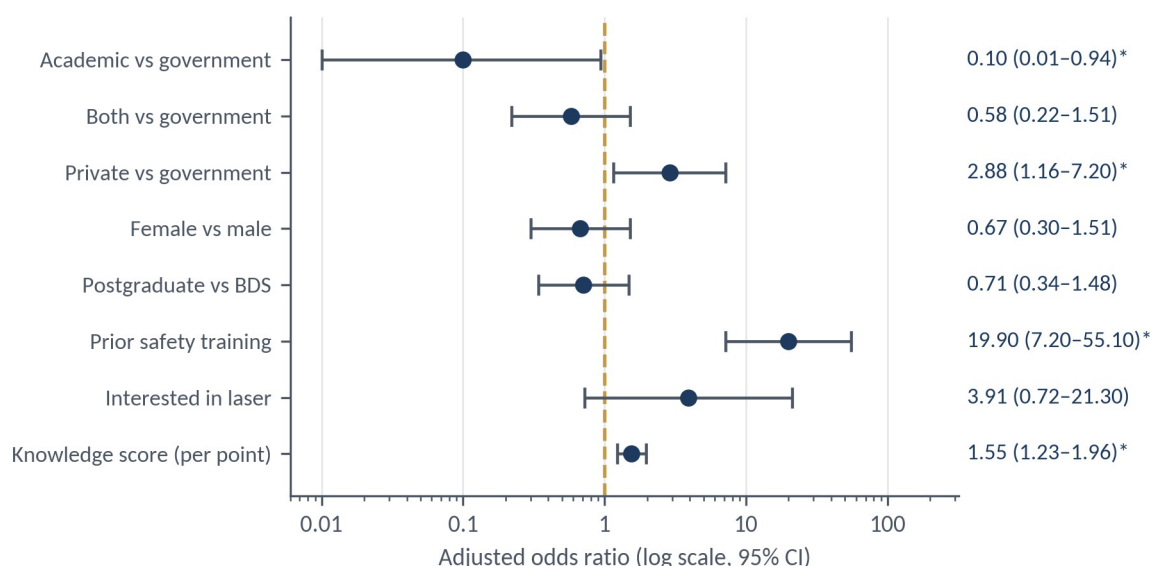
Predictor	Test	Chi-square	df	p value
Prior safety training	Pearson chi-square	143.43	2	< 0.001
Practice setting	Pearson chi-square	44.86	3	< 0.001
Knowledge category	Pearson chi-square	103.40	2	< 0.001
Safety-awareness category	Pearson chi-square	47.66	2	< 0.001
Interest in laser	Chi-square (corrected)	11.73	1	< 0.001
Gender	Chi-square (corrected)	0.02	1	0.89 (ns)
Qualification	Pearson chi-square	1.52	3	0.68 (ns)

Outcome: current laser use (yes/no). df, degrees of freedom; ns, not significant. Pearson chi-square statistics are reported for tables with more than two rows; for the 2 × 2 tables (interest, gender) the continuity-corrected (Yates) chi-square is reported. No table had more than 20% of cells with an expected count below 5, so Fisher's exact test was not required; where computed, Fisher's exact p values were consistent (interest p < 0.001; gender p = 0.89; qualification p = 0.68). All expected counts were adequate except a single small subgroup for qualification (PhD, n = 7), for which the result should be read with that caveat.

Table 4. Multivariable logistic regression identifying factors independently associated with current laser use (N = 413).

Predictor	aOR	95% CI	p value
Prior safety training (yes vs no)	19.9	7.2–55.1	< 0.001
Knowledge score (per +1 point)	1.55	1.23–1.96	< 0.001
Private vs government setting	2.88	1.16–7.20	0.023
Both vs government setting	0.58	0.22–1.51	0.26 (ns)
Academic vs government setting	0.10	0.01–0.94	0.044
Interested in laser (yes vs no)	3.91	0.72–21.3	0.11 (ns)
Female vs male	0.67	0.30–1.51	0.33 (ns)
Postgraduate vs BDS	0.71	0.34–1.48	0.36 (ns)

aOR, adjusted odds ratio; CI, confidence interval; ns, not significant. Reference categories: government setting, male, and BDS qualification. All predictors were entered simultaneously (N = 413). Model fit: McFadden pseudo-R² = 0.51; Hosmer–Lemeshow chi-square = 8.53, df = 7, p = 0.29. The academic-setting estimate rests on a small cell (n = 30) and has a wide confidence interval; it should be interpreted with caution as an unstable estimate.

Figure 3. Forest plot of adjusted odds ratios (with 95% confidence intervals) from the multivariable logistic regression model of factors independently associated with current laser use (N = 413).

Reference categories: government setting, male, BDS. The dashed reference line is set at an odds ratio of 1; an asterisk denotes p < 0.05. Values correspond to Table 4.

Discussion

This study characterizes Sudanese dentists' knowledge, attitudes, safety awareness and practice regarding laser dentistry, and its central finding mirrors a pattern reported repeatedly elsewhere: enthusiasm for laser

technology considerably outpaces its clinical use. In our sample, 346 (83.8%) expressed interest yet only 77 (18.6%) actually practiced, a gap comparable to that reported from Al-Kharj, Saudi Arabia, and from Coimbatore, Tanjore and across Pakistan.^{12,16,17,20} Taken together, this suggests that the awareness–practice gap

is a structural feature of dental systems with limited postgraduate laser-training infrastructure rather than a country-specific phenomenon.

The reasons Sudanese dentists gave for not practicing, principally inadequate hands-on experience and then cost, closely parallel barriers reported in comparable settings.^{12,19,20} Notably, our multivariable analysis reframes this descriptive picture: independent of other factors, it was prior safety training and higher knowledge, not demographic characteristics, that were associated with laser use. This is consistent with a training-limited rather than an attitude-limited adoption pathway and strengthens the case that equipment subsidy alone is unlikely to close the gap. This association should, however, be interpreted cautiously: the cross-sectional design cannot establish direction. It is at least as plausible that dentists who already use lasers subsequently obtain safety training as the reverse, so the relationship is likely bidirectional, and the estimates should be read as associations rather than causal effects. Cost may also remain an important barrier at the system level (for example, in equipment acquisition and maintenance) even though it did not emerge as an independent individual-level predictor of use.

Awareness of safety risks was uneven, and this may be the most clinically consequential finding. While most respondents recognized ocular and cutaneous hazards, only 133 (32.2%) identified laser-plume inhalation as a risk. Laser-generated plume can contain fine and ultrafine particulate matter and biological material, including cellular material and microorganisms, and occupational exposure is therefore an established safety concern requiring appropriate control measures.^{27,28} The low recognition of plume risk in this sample may therefore represent an important occupational-health knowledge gap. It warrants targeted educational attention, including explicit instruction on plume evacuation and local exhaust ventilation and appropriate respiratory and eye protection within laser-safety and infection-control training.^{27,28}

Two-thirds of respondents supported incorporating laser education into the undergraduate curriculum, consistent with recommendations emerging from the Saudi, Indian and Pakistani literature.^{13,20,21} This convergence across otherwise different education systems, healthcare structures and training infrastructures strengthens the case that curriculum reform, rather than isolated continuing-education

courses, may be the more durable long-term intervention. For Sudan and comparable low-resource settings, the practical implication is a phased strategy: introduce didactic laser content and simulation in the pre-clinical years; add supervised hands-on modules (soft-tissue diode applications first, given their lower cost and wide applicability) in the clinical years; prioritize accessible, low-cost postgraduate short courses; and make plume-safety instruction explicit throughout. Diode systems are already in documented clinical use in Sudan, including for the management of dentine hypersensitivity,²⁹ which makes them a practical entry point for such training. In the interim, shared-equipment arrangements between institutions and structured referral pathways could bridge the equipment-access gap. Finally, the low perceived applicability of lasers in orthodontics and prosthodontics may reflect genuinely narrower indications in those disciplines as much as unfamiliarity with emerging evidence, and disentangling the two would be a useful focus for future work.

Strengths and Limitations

Strengths. This is the first characterization of laser-dentistry knowledge, attitudes and practice among Sudanese dentists; the sample is reasonably large ($N = 413$) and spans career stages and practice settings; the composite scales showed good-to-excellent internal consistency; and the analysis extends beyond description to identify factors independently associated with laser use.

Limitations. First, the self-administered online design yields a self-selected sample, and because the response rate and denominator are not established, selection and non-response bias cannot be quantified; findings may over-represent dentists interested in laser technology. Second, all measures were self-reported and subject to social-desirability and recall bias, with potential information (misclassification) bias in items relying on respondent recall. Third, the cross-sectional design precludes causal inference, particularly for the training–use association, and residual confounding by unmeasured factors cannot be excluded. Fourth, data-quality checks identified two biologically impossible age entries (3 and 4 years), which were excluded; while isolated, these indicate that some self-reported fields require cautious interpretation. Fifth, a subset of early-career respondents provided highly homogeneous ('don't know' or 'neutral') response patterns; although these appear to be genuine independent submissions,

such straight-lining can attenuate or exaggerate group differences, and the observed gender difference in knowledge should therefore be read with caution. Finally, although the instrument underwent expert review and piloting, more extensive psychometric validation would strengthen future work; the findings pertain to dentists reachable through online professional networks and may not generalize to all dentists practicing in Sudan.

Conclusion

Sudanese dentists displayed generally positive attitudes toward laser dentistry and recognized many of its clinical advantages, but this enthusiasm was not matched by practical experience, specialty-specific knowledge, or comprehensive safety awareness, particularly regarding laser-plume inhalation. Independent of demographic factors, prior safety training and a higher knowledge score were the strongest correlates of laser use. This pattern parallels findings from Saudi Arabia, India and Pakistan, suggesting a shared structural gap between attitude and practice. Closing it will likely require coordinated curricular reform, accessible hands-on postgraduate training, and explicit plume-safety education, rather than equipment subsidy alone.

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Conflict of Interest

All authors declare that they have no competing interests.

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Availability of Data

The dataset analyzed is available from the corresponding author on reasonable request.

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