JHWCR JOURNAL OF HEALTH, WELLNESS AND COMMUNITY RESEARCH 3007-0570

https://doi.org/10.61919/s3jdvm94

Original Article

Digital Radiography Adoption in Pakistani Dental Practices: Trends, Barriers, and Practitioner Perspectives

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ABSTRACT

Background: Digital radiography has transformed dental diagnostics by enabling rapid image acquisition, improved image quality, and simplified storage and transmission. Although widely implemented in high-income countries, adoption in developing healthcare systems remains variable due to economic, educational, and infrastructural constraints. Understanding the extent of digital radiography use and the barriers affecting its integration into clinical practice is essential for guiding policy and professional training initiatives. Objective: To assess the prevalence of digital radiography use among dental practitioners in Pakistan and to evaluate associated barriers, training exposure, practitioner perceptions, and radiation safety practices. Methods: A descriptive cross-sectional survey was conducted between October and December 2025 among dental practitioners practicing in public hospitals, teaching institutions, and private clinics across Pakistan. Eligible participants included PMDC-registered dentists actively engaged in clinical practice. Data were collected using a validated 19-item online questionnaire assessing demographic characteristics, radiographic practices, training exposure, practitioner attitudes, and perceived barriers to adoption. Descriptive statistics and exploratory subgroup analyses were performed using IBM SPSS Statistics version 27. Results: Among 200 respondents, 87.5% reported using digital radiography, with intraoral digital sensors being the most common modality (70%). Improved image quality (76%) and faster workflow (74%) were the most frequently cited motivators for adoption. The main barriers included equipment cost (80%), lack of training (59%), and limited technical support (40%). Only 18.5% of practitioners had received formal training, and 47.5% reported not routinely using radiation safety measures. Conclusion: Digital radiography use among surveyed dentists in Pakistan is widespread; however, significant gaps remain in professional training and radiation safety compliance. Addressing financial barriers and strengthening educational programs may facilitate safer and more effective integration of digital imaging technologies in dental practice. Keywords: Digital radiography, Dental imaging, Technology adoption, Radiation safety, Dental practitioners, Pakistan.

"Cite this Article" | Received: 09 November 2025; Accepted: 23 February 2026; Published: 12 March 2026.

Author Contributions: Concept: AA; Design: FM; Data Collection: KS, ST, SH; Analysis: MF; Drafting: AA, MF. **Ethical Approval**: Ethical Approval was obtained by respective Institute**.** Informed Consent: Written informed consent was obtained from all participants; Conflict of Interest: The authors declare no conflict of interest; Funding: No external funding; Data Availability: Available from the corresponding author on reasonable request; Acknowledgments: N/A.

INTRODUCTION

Digital radiography has become an integral component of contemporary dental practice because radiographic imaging is essential at nearly every stage of patient care, including diagnosis, treatment planning, procedural guidance, and follow-up evaluation. Compared with conventional film-based methods, digital radiographic systems offer several practical and clinical advantages, including rapid image acquisition, immediate image display, image enhancement capabilities, simplified storage and retrieval, and easier electronic transfer of patient records. In addition, when exposure parameters are appropriately optimized, digital systems may reduce patient radiation dose relative to conventional film-based techniques. These advantages have supported a substantial transition toward digital imaging in many dental settings worldwide, particularly in environments with stronger financial, technical, and educational support systems (1–3).

Despite these advantages, the uptake of digital radiography remains uneven across healthcare contexts, particularly in low- and middle-income countries where adoption is influenced not only by clinical preference but also by affordability, infrastructure, technical support, and professional training. Evidence from high-income countries such as Sweden and Belgium indicates widespread penetration of digital intraoral and extraoral radiography across dental practices, although variation still exists according to clinic size, organizational model, and available technical resources (1–3). Similar findings have been reported from other settings, including Saudi Arabia and Brazil, where digital radiography is increasingly common in larger institutions and academically affiliated practices, yet smaller and resource-constrained clinics continue to experience slower transitions due to cost and operational barriers (5,6). These international patterns suggest that adoption of digital radiography is not merely a function of technological availability, but also of preparedness at the practitioner, institutional, and system levels.

In Pakistan, the transition appears to be progressing, but the available evidence remains limited in scope and methodologically fragmented. Existing local studies suggest growing awareness and use of digital radiographic technologies among dental professionals, yet they also highlight persistent deficiencies in training, safety practices, and equitable access across practice settings. A Karachi-based survey reported that although many practitioners had adopted some form of digital radiography, cost remained a major obstacle and radiation safety practices were inconsistent (4). More recent work on digital dentistry in Pakistan has similarly shown that although practitioners and trainees recognize the future value of digital technologies, actual implementation is constrained by financial limitations, variable technical competence, and unequal educational exposure (8). At the same time, broader evidence from cross-sectional studies in dentistry indicates that technology readiness, formal training, and institutional support are key determinants of successful digital integration, while lack of structured education can delay both adoption and competent use (9,10). Taken together, these findings suggest that in Pakistan the issue is no longer limited to whether digital radiography is known to clinicians, but whether it is being adopted in a manner that is safe, equitable, and professionally sustainable.

A further concern is that the existing Pakistani literature has largely been restricted to individual cities, specific institutions, or broader digital dentistry constructs rather than focused assessment of digital radiography use itself. As a result, important dimensions remain insufficiently described, including the extent of current use in different clinical settings, the types of digital imaging systems available in practice, the duration of implementation, practitioners' perceived facilitators and barriers, the level of formal training received, and adherence to radiation safety measures. This gap is important because digital radiography should not be evaluated solely as a technological upgrade; it also has implications for diagnostic quality, workflow efficiency, occupational safety, patient communication, and long-term practice modernization. In particular, if use expands in the absence of adequate training and radiation protection, the expected benefits of digital systems may not be fully realized and may instead expose gaps in professional preparedness and regulatory oversight (4,7).

Within a Population of dental practitioners actively engaged in clinical practice in Pakistan, the Exposure of interest is the use of digital radiography and related training and practice characteristics, while the Comparison of interest lies between differing levels of use, preparedness, and safety compliance across respondents and practice environments; the principal Outcomes include self-reported prevalence of digital radiography use, perceived barriers and facilitators, training exposure, software confidence, and radiation safety practices. Framed in this way, the study addresses a clinically and policy-relevant question: how widely is digital radiography being used by practicing dentists in Pakistan, what factors are encouraging or limiting its uptake, and to what extent is its use accompanied by appropriate professional training and radiation protection? Therefore, the objective of this study was to assess the self-reported use of digital radiography among dental practitioners in Pakistan and to examine associated trends, perceived barriers, practitioner perspectives, training status, and radiation safety practices (1–10).

METHODS

This study was conducted as a descriptive cross-sectional observational survey designed to assess the current use of digital radiography, associated training exposure, perceived barriers, and radiation safety practices among dental practitioners in Pakistan. A cross-sectional design was selected because it allows efficient assessment of technology utilization patterns, professional practices, and practitioner perceptions within a defined time frame. Such survey-based approaches are widely used in health services and dental technology adoption research to quantify prevalence, identify barriers, and evaluate professional attitudes in clinical practice environments (11–13).

Data collection was carried out between October and December 2025 across multiple clinical environments in Pakistan, including public sector hospitals, teaching hospitals affiliated with dental colleges, and private dental clinics. The survey targeted dental practitioners actively involved in clinical practice in urban and peri-urban areas. Participation was open to dentists working in different organizational settings, including public hospitals, academic teaching institutions, private solo practices, and private group or chain clinics. The survey was administered electronically to allow nationwide distribution and to facilitate participation from practitioners practicing in geographically dispersed locations.

Eligible participants were dental practitioners holding a Bachelor of Dental Surgery (BDS) degree from a Higher Education Commission (HEC) recognized institution and registered with the Pakistan Medical and Dental Council (PMDC). Participants were required to be actively engaged in routine dental clinical practice at the time of the survey. House officers, postgraduate trainees, and general dental practitioners who fulfilled these criteria were eligible for inclusion. Individuals who were undergraduate dental students, non-practicing graduates, foreign-qualified dentists without local PMDC registration, or paramedical personnel were excluded. Participants who declined to provide informed consent were not included in the study.

A non-probability sampling approach was used, combining convenience sampling with snowball recruitment. Initial participants were approached through professional networks, institutional contacts, and professional dental associations. The survey link was also disseminated through verified professional social media platforms commonly used by dental practitioners. Participants were encouraged to share the survey with colleagues who met the eligibility criteria, thereby facilitating broader recruitment across institutions and practice settings. Before accessing the questionnaire, participants were presented with an electronic informed consent statement outlining the purpose of the study, voluntary participation, confidentiality protections, and the option to withdraw at any stage. Only individuals who agreed to participate electronically were allowed to proceed to the questionnaire.

Data were collected using a structured online questionnaire developed specifically for this study based on a comprehensive review of the literature on digital dentistry and dental radiography adoption. Conceptual guidance was obtained from previously published studies evaluating digital technology adoption, radiographic practices, and professional attitudes toward digital imaging systems in dentistry (8–10). The initial questionnaire draft was reviewed by senior dental professionals with experience in oral radiology and dental public health to evaluate clarity, relevance, and content validity. Minor modifications were made to improve question wording and ensure alignment with the Pakistani clinical context. The finalized instrument consisted of 19 close-ended questions organized into five domains: demographic and professional characteristics, current radiographic practices, training and competency in digital radiography, practitioner perceptions and attitudes toward digital imaging, and perceived facilitators and barriers influencing adoption.

Demographic variables included gender, years of clinical experience, professional qualification, and primary practice setting. Radiographic practice variables assessed whether digital radiography was currently used in the respondent's practice and identified available imaging modalities including

intraoral digital sensors, digital panoramic systems, and cone-beam computed tomography (CBCT). Duration of digital radiography use was recorded to characterize implementation timelines. Training-related variables assessed whether respondents had received formal training in digital radiography and their level of self-reported confidence in using radiographic software. Radiation safety practices were assessed through self-reported use of protective measures such as lead aprons, thyroid collars, personal dosimeters, and other protective strategies. Perception-related variables captured practitioner attitudes toward digital radiography, perceived patient responses to digital imaging compared with conventional radiography, and perceived benefits including image quality, workflow efficiency, radiation dose considerations, and environmental impact. Participants were also asked to identify perceived barriers to adoption, including equipment cost, lack of training, maintenance concerns, electricity reliability, regulatory challenges, and perceived lack of advantage over conventional film. Several items allowed multiple responses to capture the range of perceived factors influencing adoption.

The questionnaire was distributed using Google Forms, which allowed anonymous participation and automated collection of responses. The survey required approximately five to seven minutes to complete. To enhance data integrity and minimize duplicate responses, the platform restricted multiple submissions from the same device and required completion of all mandatory fields before submission. Responses were automatically recorded in a secure database accessible only to the research team. Data were downloaded into a password-protected dataset prior to analysis. No personally identifying information was collected, thereby maintaining participant anonymity.

Potential sources of bias were considered during the design and implementation of the study. Recruitment across multiple institutional and practice settings was undertaken to increase diversity of respondents and reduce institutional clustering. Use of standardized close-ended questions minimized interviewer bias and ensured uniform data collection. The online format allowed anonymous participation, which may reduce social desirability bias in responses related to safety practices and professional training. Nonetheless, as with most self-reported surveys, the possibility of recall bias and response bias was acknowledged during interpretation. The questionnaire was structured to maintain neutral wording and avoid leading questions to further reduce response bias.

The required sample size was estimated using the World Health Organization sample size calculator for cross-sectional surveys. In the absence of reliable national prevalence estimates for digital radiography adoption among practicing dentists in Pakistan, an expected prevalence of 50% was used to produce the most conservative sample size estimate. With a 95% confidence level and a 5% margin of error, the minimum calculated sample size was 385 participants. Responses were collected until the end of the data collection period, resulting in a final analytic sample of 200 completed questionnaires.

Statistical analysis was performed using IBM SPSS Statistics version 27 (IBM Corp., Armonk, NY, USA). Data were screened for completeness and consistency prior to analysis. Because all survey questions were mandatory, the final dataset contained no missing values. Descriptive statistical methods were used to summarize the data. Categorical variables were presented as frequencies and percentages, while continuous variables were summarized using means and standard deviations where applicable. Exploratory subgroup analyses were conducted based on demographic characteristics including gender, professional qualification, years of clinical experience, and practice setting to examine potential differences in digital radiography use and related practices. Results of multiple-response questions were reported as proportions of the total sample, acknowledging that percentages may exceed 100% where participants selected more than one option.

Ethical approval for the study was obtained from the Research Ethics and Review Board of the PRIDE Center for Research and Learning Institute (Reference No. PRIDE/ERB/2025/012, dated 1 October 2025). The study adhered to ethical principles for research involving human participants. Participation was voluntary, electronic informed consent was obtained prior to data collection, and respondents were assured that all responses would remain anonymous and used exclusively for research purposes. Data

were stored securely and were accessible only to the investigators. The study design, survey administration procedures, and analytic approach were documented in detail to allow reproducibility by other researchers investigating digital radiography adoption in comparable clinical contexts (11–13).

RESULTS

The demographic and professional characteristics of the 200 participating dental practitioners are summarized in Table 1. Female practitioners constituted the majority of the sample, accounting for 124 participants (62%), while 76 participants (38%) were male. In terms of clinical experience, the largest proportion of respondents had relatively early-career experience. Specifically, 79 practitioners (39.5%) reported having 0–1 year of clinical experience, followed by 63 practitioners (31.5%) with 1–3 years of experience. Practitioners with 3–5 years of experience accounted for 28 respondents (14%), while 30 respondents (15%) had more than five years of professional experience.

Regarding practice setting, nearly half of the respondents were working in teaching hospitals (90 practitioners, 45%). Public hospitals accounted for 43 practitioners (21.5%), while 38 respondents (19%) worked in private solo practices and 29 respondents (14.5%) practiced in private group or chain clinics. In terms of professional qualification, the majority of respondents held a Bachelor of Dental Surgery (BDS) degree (147 practitioners, 73.5%), whereas 25 practitioners (12.5%) had obtained the Fellowship of the College of Physicians and Surgeons (FCPS) qualification. A further 17 practitioners (8.5%) held MDS or MS postgraduate degrees, while 11 participants (5.5%) reported other qualifications.

The availability and use of digital radiographic modalities in clinical practice are presented in Table 2. Overall, digital radiography was reported to be in use by 175 practitioners, representing 87.5% of the total sample, whereas 25 practitioners (12.5%) reported that digital radiography was either unavailable or not used in their primary practice.

Among the different imaging modalities, intraoral digital sensors were the most commonly available technology, reported by 140 respondents (70%). Digital panoramic radiography units were available in 66 practices (33%), while cone-beam computed tomography (CBCT) systems were reported by 24 practitioners (12%). These findings indicate that intraoral digital imaging constitutes the primary form of digital radiographic technology used in routine dental practice within the surveyed population.

Associations between professional characteristics and the use of digital radiography are presented in Table 3. When stratified by years of clinical experience, digital radiography use was highest among practitioners with 0–1 year of experience, with 72 out of 79 practitioners (91.1%) reporting digital use. Among practitioners with 1–3 years of experience, 54 of 63 respondents (85.7%) reported digital radiography use, while the corresponding proportions were 23 of 28 practitioners (82.1%) for those with 3–5 years of experience and 26 of 30 practitioners (86.7%) among those with more than five years of experience. Statistical testing indicated that the association between clinical experience and digital radiography use was not statistically significant ($\chi^2 = 3.41$, $p = 0.333$).

In contrast, a statistically significant association was observed between practice setting and the use of digital radiography ($\chi^2 = 9.12$, $p = 0.028$). The highest prevalence of digital radiography use was observed in teaching hospitals, where 83 out of 90 practitioners (92.2%) reported digital imaging in their practice. Private group or chain clinics also demonstrated relatively high adoption, with 26 out of 29 practitioners (89.7%) reporting digital radiography use.

Lower proportions were observed in public hospitals and private solo practices, where digital radiography use was reported by 35 of 43 practitioners (81.4%) and 31 of 38 practitioners (81.6%), respectively. These findings suggest that institutional settings with greater access to infrastructure and academic resources may facilitate higher levels of digital imaging adoption.

The reported motivations for adopting digital radiography among users are summarized in Table 4. Among the practitioners who reported using digital radiography, the most frequently cited motivator was improved image quality, reported by 152 respondents (76%). Faster clinical workflow and improved efficiency were reported by 148 practitioners (74%), indicating that operational advantages played a major role in adoption decisions. Ease of image storage and sharing was reported by 104 practitioners (52%), reflecting the perceived benefits of digital image archiving and communication systems. Additional motivations included reduced radiation exposure (77 practitioners, 38.5%), enhanced professional competitiveness in clinical practice (58 practitioners, 29%), and environmental benefits associated with elimination of chemical film processing (50 practitioners, 25%).

Training exposure, software confidence, and radiation safety practices are presented in Table 5. Only 37 practitioners (18.5%) reported having received formal training in digital radiography, whereas 135 practitioners (67.5%) reported no formal training. A further 28 respondents (14%) indicated that they planned to receive training in the future. With regard to software competency, 57 practitioners (28.5%) described themselves as very confident in using radiology software, while 109 practitioners (54.5%) reported being somewhat confident. However, 34 practitioners (17%) reported that they were not confident in using radiology software, highlighting variability in technical proficiency among practitioners.

Radiation safety practices also demonstrated considerable variation. The most commonly reported protective measure was the use of lead aprons, reported by 92 practitioners (46%). Thyroid collar use was reported by 25 practitioners (12.5%), while only five practitioners (2.5%) reported using personal radiation dosimeters. Notably, 95 practitioners (47.5%) reported that they did not routinely use any radiation safety measures during radiographic procedures. Because respondents were allowed to select multiple safety measures, the reported percentages do not sum to 100%.

Table 1. Demographic and Professional Characteristics of Participants (n = 200)

Variable	Category	n (%)
Gender	Male	76 (38)
	Female	124 (62)
Clinical Experience	0–1 year	79 (39.5)
	1–3 years	63 (31.5)
	3–5 years	28 (14.0)
	>5 years	30 (15.0)
Practice Setting	Teaching hospital	90 (45.0)
	Public hospital	43 (21.5)
	Private solo clinic	38 (19.0)
	Private group/chain	29 (14.5)
Highest Qualification	BDS	147 (73.5)
	FCPS	25 (12.5)
	MDS/MS	17 (8.5)
	Other	11 (5.5)

Table 2. Availability of Digital Radiographic Modalities (n = 200)

Imaging Modality	Available n (%)
Intraoral digital sensor	140 (70.0)
Digital panoramic unit	66 (33.0)
Cone-beam CT (CBCT)	24 (12.0)

Table 3. Association of Digital Radiography Use with Professional Characteristics

Variable	Category	Digital Use n (%)	No Digital Use n (%)	χ^2	p-value
Clinical Experience	0–1 year	72 (91.1)	7 (8.9)	3.41	0.333
	1–3 years	54 (85.7)	9 (14.3)		
	3–5 years	23 (82.1)	5 (17.9)		
	>5 years	26 (86.7)	4 (13.3)		
Practice Setting	Teaching hospital	83 (92.2)	7 (7.8)	9.12	0.028*
	Public hospital	35 (81.4)	8 (18.6)		
	Private solo clinic	31 (81.6)	7 (18.4)		
	Private group/chain	26 (89.7)	3 (10.3)		

Table 4. Reported Motivators for Adoption of Digital Radiography (n = 175)

Motivator	n (%)
Better image quality	152 (76.0)
Faster workflow	148 (74.0)
Easier storage and sharing	104 (52.0)
Reduced radiation exposure	77 (38.5)
Competitive advantage	58 (29.0)
Environmental benefits	50 (25.0)

Table 5. Training Status, Software Confidence, and Radiation Safety Practices (n = 200)

Variable	Category	n (%)
Formal Training in Digital Radiography	Yes	37 (18.5)
	No	135 (67.5)
	Planning training	28 (14.0)
Confidence with Radiology Software	Very confident	57 (28.5)

Variable	Category	n (%)
	Somewhat confident	109 (54.5)
	Not confident	34 (17.0)
Radiation Safety Measures*	Lead apron	92 (46.0)
	Thyroid collar	25 (12.5)
	Personal dosimeter	5 (2.5)
	No safety measures	95 (47.5)

Table 6. Reported Barriers to Adoption of Digital Radiography (n = 200)

Barrier	n (%)
High equipment cost	160 (80.0)
Lack of training	118 (59.0)
Maintenance/technical support	80 (40.0)
Electricity issues	50 (25.0)
Regulatory issues	24 (12.0)
No perceived advantage	22 (11.0)
Satisfaction with film radiography	12 (6.0)

The perceived barriers to adopting digital radiography are summarized in Table 6. The most frequently reported barrier was the high cost of digital radiography equipment, reported by 160 practitioners (80%). Lack of technical training was the second most common barrier, identified by 118 respondents (59%). Maintenance and technical support limitations were reported by 80 practitioners (40%), while electricity reliability issues were cited by 50 practitioners (25%). Additional barriers included regulatory challenges (24 practitioners, 12%), perceived lack of advantage compared with conventional radiography (22 practitioners, 11%), and satisfaction with traditional film-based systems (12 practitioners, 6%). These findings indicate that financial constraints and training limitations represent the most substantial obstacles to broader implementation of digital radiography in dental practice.

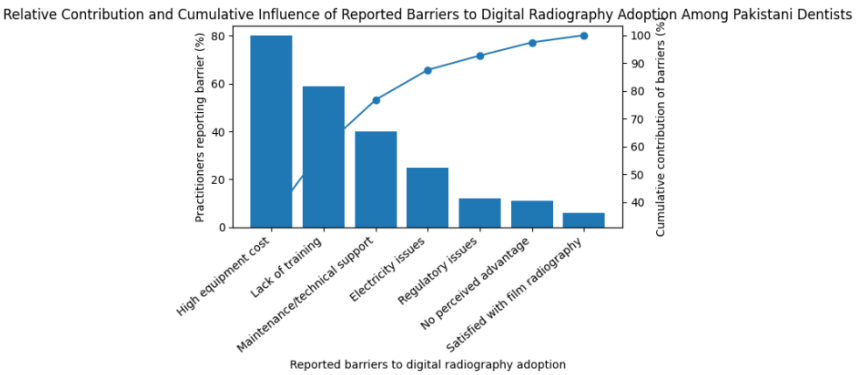

Figure 1 Relative Contribution and Cumulative Influence of Reported Barriers to Digital Radiography Adoption Among Pakistani Dentists

The distribution of perceived barriers demonstrates a highly concentrated constraint pattern, with the two leading factors—high equipment cost (80%) and lack of training (59%)—together accounting for approximately 49% of the cumulative barrier burden among respondents. When maintenance and

technical support limitations (40%) are included, the cumulative contribution rises to nearly 73%, indicating that financial and technical preparedness factors dominate the adoption landscape. Secondary barriers such as electricity instability (25%), regulatory challenges (12%), and perceived lack of advantage (11%) contribute comparatively smaller gradients, collectively increasing the cumulative influence on 94%. The lowest contributor, satisfaction with conventional film radiography (6%), suggests that resistance to technological change is relatively minor compared with structural constraints. Clinically, this distribution indicates that over three-quarters of the obstacles to digital radiography adoption are concentrated in economic and training-related factors, highlighting that policy interventions targeting equipment financing and professional training programs could potentially address the majority of barriers limiting broader implementation in Pakistani dental practices.

DISCUSSION

This study provides a contemporary overview of digital radiography use, perceived barriers, practitioner training, and radiation safety practices among dental practitioners in Pakistan. The findings demonstrate a high self-reported prevalence of digital radiography use (87.5%) among surveyed practitioners, with intraoral digital sensors representing the most commonly available modality. Although this prevalence is higher than earlier national estimates, important gaps persist in formal training and radiation safety practices. These findings suggest that while technological penetration may be progressing, professional preparedness and safety compliance have not advanced at the same pace.

The reported adoption rate of 87.5% exceeds several previously reported estimates from Pakistan. Earlier work by Hasan et al. documented digital radiography use in approximately two-thirds of surveyed dentists in Karachi, highlighting cost and safety concerns as major barriers to broader implementation (14). Similarly, Siddique et al. reported that fewer than half of respondents in their study actively used digital dental technologies, although their sample included dental students and early trainees, which may partly explain the lower reported prevalence (8). The higher proportion observed in the present study may reflect both temporal progress and the increasing availability of digital imaging systems in institutional and private practice settings over recent years. Internationally, adoption rates reported in countries such as Belgium and Sweden approach near-universal levels among dental practitioners, reflecting the influence of stronger infrastructure, formal training pathways, and integration of digital imaging within routine clinical workflows (1–3,15).

Despite the high reported use of digital radiography, the findings highlight an important distinction between technology availability and competent digital integration. Only 18.5% of practitioners reported receiving formal training in digital radiography, and 17% reported low confidence in using radiology software. This discrepancy suggests that many practitioners may rely primarily on informal clinical exposure rather than structured education when adopting digital imaging technologies. Similar patterns have been documented in other middle-income countries, where practitioners frequently adopt digital systems but lack formal instruction in image acquisition optimization, diagnostic interpretation, and digital image management (6,16). Evidence from technology adoption research indicates that professional training and technological readiness strongly influence both the quality of digital imaging practices and the sustainability of technology integration in clinical environments (10,17).

Radiation safety practices represent another critical concern highlighted by the findings. Nearly half of the respondents (47.5%) reported using no radiation protection measures during imaging procedures, while only 46% reported using lead aprons and an extremely small proportion (2.5%) reported using personal dosimeters. These results are consistent with earlier regional studies that have reported suboptimal adherence to radiation protection guidelines among dental practitioners. Hasan et al. reported that a substantial proportion of dentists in Karachi used inappropriate positioning practices during radiographic exposure (14), while Kasat et al. found that nearly half of dental practitioners in western India demonstrated inadequate radiation safety compliance (7). Similar deficiencies have also

been reported among Pakistani dental surgeons in more recent studies assessing knowledge and behavior related to dental X-ray equipment (11). Although digital radiography can potentially reduce radiation exposure compared with film-based systems when optimized correctly, inadequate safety protocols may undermine these advantages and expose patients and practitioners to unnecessary radiation risks.(18).

Financial constraints emerged as the most frequently reported barrier to digital radiography adoption, with 80% of respondents identifying equipment cost as a major obstacle. Lack of training (59%) and limited technical support (40%) were also commonly reported. These findings align closely with international evidence demonstrating that economic barriers remain the dominant obstacle to digital imaging adoption in resource-limited healthcare environments. Studies from Brazil and other developing settings have similarly identified cost of sensors, maintenance challenges, and technical fragility as major deterrents to widespread implementation of digital radiography (19,20). In addition to affecting practitioner adoption, financial constraints also appear to influence patient behavior, as 63% of respondents reported that cost was the most common reason patients declined radiographic investigations. These dual economic pressures suggest that both practitioner-level and patient-level financial considerations influence the utilization of digital radiography in routine dental practice.

Importantly, the overwhelmingly positive perception of digital radiography among practitioners indicates that resistance to technological change is not a major limiting factor. Nearly all respondents (96.5%) expressed positive attitudes toward transitioning fully from conventional film radiography to digital systems. This finding suggests that structural barriers such as financial limitations, training deficiencies, and infrastructure constraints are more influential than attitudinal resistance. Similar conclusions have been reported in surveys conducted in Saudi Arabia and other regions, where dentists expressed strong support for digital technologies despite facing practical obstacles to implementation (5,18). Addressing these structural barriers through targeted interventions may therefore accelerate the safe and effective adoption of digital radiography in clinical practice (21,22)

Several practical implications arise from the present findings. First, integration of digital radiography training within undergraduate dental curricula may help ensure that new graduates enter clinical practice with appropriate competencies in digital imaging. Second, structured continuing professional development programs focused on radiographic interpretation, image optimization, and radiation safety may help bridge the training gap among practicing dentists. Third, financial strategies such as government subsidies, equipment leasing models, or shared imaging facilities may help mitigate the economic barriers associated with acquiring digital imaging systems. Similar policy interventions have been recommended in other middle-income healthcare systems seeking to expand digital diagnostic technologies while maintaining equitable access (16,18).

The study has several limitations that should be considered when interpreting the findings. The use of convenience and snowball sampling limits the representativeness of the sample and restricts generalizability to the broader population of dental practitioners in Pakistan. The achieved sample size was smaller than the calculated target, which may reduce the precision of prevalence estimates. Additionally, all data were self-reported, which introduces the possibility of recall bias or social desirability bias, particularly for questions related to radiation safety practices and professional competence. Finally, the cross-sectional design captures a snapshot of current practices and cannot assess causal relationships or longitudinal trends in digital radiography adoption (23).

Future research should aim to address these limitations by conducting larger, nationally representative surveys incorporating probabilistic sampling strategies. Mixed-methods studies combining quantitative surveys with qualitative interviews may also provide deeper insights into organizational, economic, and cultural factors influencing digital radiography adoption. Additionally, observational audits of radiation safety practices could provide more objective assessments of compliance with established radiological protection standards. Such research would contribute to the development of evidence-based policies

aimed at strengthening the safe and effective integration of digital imaging technologies within dental healthcare systems (24).

CONCLUSION

This study demonstrates that digital radiography is widely used among surveyed dental practitioners in Pakistan, with intraoral digital sensors representing the most common imaging modality. Adoption appears to be driven primarily by improved diagnostic image quality and increased workflow efficiency. However, important challenges remain, particularly with regard to limited formal training in digital radiography and inadequate adherence to radiation safety practices. Financial barriers, lack of technical training, and limited technical support were identified as the principal obstacles to broader implementation. These findings highlight the need for targeted educational initiatives, strengthened radiation safety regulations, and financial strategies that facilitate access to digital imaging technologies in dental practice. Addressing these structural challenges may help ensure that the expanding use of digital radiography translates into improved diagnostic quality, patient safety, and sustainable modernization of dental healthcare systems.

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