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Original article

Knowledge, Attitudes, and Barriers Toward Digital Dentistry Among Dental Professionals: A Cross-Sectional Survey Study

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Abstract
Digital technologies are fundamentally reshaping clinical dentistry, yet adoption rates among practicing professionals remain inconsistent across different practice settings. Understanding the current state of knowledge, clinical utilization patterns, professional attitudes, and perceived barriers is essential for informing both educational curricula and health policy. This cross-sectional survey study investigated these dimensions among 208 dental professionals practicing in public and private settings in Benghazi, Libya. A structured, self-administered questionnaire assessed awareness of core digital dentistry concepts, frequency and scope of digital tool usage, attitudes toward digital workflows, and perceived adoption barriers. Among 208 respondents (65.4% with over 10 years of experience), awareness of the term digital dentistry was high (80.4%), as was familiarity with intraoral scanners (92.3%) and 3D printing (82.7%). However, knowledge of specific technical elements was more limited: only 26.9% could differentiate open from closed CAD/CAM systems, and only 19.2% were familiar with STL/DICOM file formats. Digital radiography was the most widely used tool, and diagnostic applications represented the predominant use case. Overall attitudes were strongly positive, with over 96% agreeing or strongly agreeing that digital dentistry improves restoration accuracy and represents the future of the profession. The primary barrier to adoption was high initial equipment cost (51.9%), followed by lack of technical training (36.5%). Subgroup comparisons by practice setting and years of experience showed consistent directional trends but no statistically significant differences. Dental professionals exhibit broad awareness of digital dentistry coupled with highly favorable attitudes toward its integration. Practical adoption, however, remains limited largely to radiography and is constrained by financial and educational barriers. Targeted investment in continuing education, subsidized access to equipment, and structured integration of digital competencies into dental curricula are essential to bridge the gap between positive attitudes and meaningful clinical implementation.

Keywords. Digital Dentistry, Intraoral Scanners, CAD/CAM, 3D Printing, Dental Technology Adoption, Barriers to Digital Workflows.

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Introduction

The rapid evolution of digital technologies has catalyzed a paradigm shift across virtually all health disciplines, and dentistry is no exception. Digital dentistry encompasses a broad spectrum of innovations—from intraoral scanners (IOS) and cone beam computed tomography (CBCT) to computer-aided design/computer-aided manufacturing (CAD/CAM) systems, three-dimensional (3D) bioprinting, and artificial intelligence (AI)-driven diagnostic platforms—each of which has demonstrably enhanced the precision, efficiency, and patient-centeredness of dental care [1-3].

The integration of digital workflows into clinical practice offers numerous advantages, including improved diagnostic accuracy, enhanced treatment planning capabilities, streamlined laboratory communication, reduced treatment times, and increased patient comfort [4,5]. Intraoral scanners, for instance, have been shown to eliminate the discomfort associated with conventional impression materials while providing digital impressions of comparable or superior accuracy [6]. Similarly, CAD/CAM systems enable same-day fabrication of restorations, reducing patient visits and enhancing practice efficiency.

Despite compelling evidence supporting digital workflows, adoption among practicing dental professionals has not been uniform. Disparities persist across clinical settings, career stages, and geographic contexts, and are frequently attributed to prohibitive equipment costs, limited formal training in digital technologies, infrastructure constraints, and resistance to workflow changes [7] [8]. These barriers are particularly pronounced in publicly funded healthcare settings, where budgetary constraints may limit capital investment in emerging technologies [9].

Furthermore, the rapid pace of technological advancement has created a knowledge gap among dental professionals, particularly those who completed their training prior to the widespread integration of digital dentistry into educational curricula [10]. This gap between technological availability and practitioner competency represents a significant challenge to meaningful clinical implementation.

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Understanding the current landscape of digital dentistry adoption—including existing knowledge levels, clinical utilization patterns, prevailing attitudes, and perceived barriers—is a prerequisite for formulating targeted strategies that facilitate meaningful and sustainable technology integration. While studies have examined digital dentistry adoption in various contexts [7] [10], limited research has systematically compared adoption patterns across public and private clinical settings, particularly in regions where both practice models coexist.

This cross-sectional survey study was conducted among 208 dental professionals practicing across public (governmental) and private clinical settings. The study aimed to characterize the current state of knowledge, clinical adoption patterns, professional attitudes, and perceived barriers with respect to digital dentistry tools and workflows. Specific objectives included: (1) assessing the level of knowledge and awareness of digital dentistry concepts among dental professionals; (2) characterizing current clinical utilization patterns of digital tools; (3) evaluating professional attitudes toward digital dentistry integration; (4) identifying primary perceived barriers to digital technology adoption; and (5) comparing findings across practice settings and experience levels where feasible.

Methods

Study Design and Setting

This descriptive, cross-sectional survey study was conducted among dental professionals practicing in Benghazi, Libya, between January and March 2026. The study population included dentists working in both public (governmental) hospitals and clinics and private dental practices across the city of Benghazi. Benghazi is the second-largest city in Libya and a major center for dental education and practice in the eastern region of the country.

Study Population and Sampling

The target population comprised licensed dental professionals actively practicing in Benghazi, including those employed in government dental hospitals and clinics as well as those operating in private dental clinics. A convenience sampling approach was employed, with questionnaires distributed both in person and electronically through professional networks. The sample size was determined based on the availability of practicing dental professionals willing to participate during the study period. A total of 208 completed questionnaires were obtained.

Survey *Instrument*

A structured, self-administered questionnaire assessed four domains: (1) demographic and professional characteristics — limited, in the available dataset, to practice setting and years of experience (<5, 5–10, >10 years); (2) self-reported awareness of, and familiarity with, five core digital dentistry concepts — the term ‘digital dentistry,’ open versus closed CAD/CAM systems, 3D printing applications, intraoral scanners, and STL/DICOM file formats — recorded as Yes/No/Not sure; (3) frequency of digital tool use, specific tools currently used (multiple selections permitted, so tool-specific percentages do not sum to 100%), and clinical applications; and (4) responses to three individual attitude statements about digital dentistry, each rated on a 5-point Likert scale, and a single primary perceived barrier to adoption.

The instrument was developed from previously used tools [6,9], reviewed by dental education experts for content validity, and piloted with 15 professionals to refine item wording. Whether these pilot participants were included in the final analytic sample of 208 is not specified in the available study records; this should be clarified by the study authors prior to submission. Formal psychometric validation (e.g., Cronbach's alpha, Content Validity Index) was not performed, and the instrument should not be described as validated; this is discussed as a limitation in Section 4. The three attitude items were analyzed individually rather than combined into a composite score, because the instrument was not designed or statistically validated as a unidimensional scale.

Statistical Analysis

Data were analyzed using SPSS software (version 26.0, IBM Corp., Armonk, NY, USA). Descriptive statistics, including frequencies and percentages, were used to summarize demographic characteristics, knowledge levels, utilization patterns, attitudes, and perceived barriers. Chi-square tests were employed to examine associations between categorical variables, including comparisons across practice settings (public vs. private) and years of experience. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations

Ethical approval was obtained from the Research Ethics Committee, Faculty of Dentistry, University of Benghazi. Informed consent was obtained from all participants prior to questionnaire completion. Participation was voluntary, and respondents were assured of the confidentiality of their responses.

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Results

Participant Demographics

Of 208 dental professionals enrolled, practice setting was reported by 204: 124 (60.8%) worked in public (governmental) settings and 80 (39.2%) in private practice; setting was not specified for the remaining 4 (1.9%) (Table 1). Years of clinical experience were reported by all 208 participants: 65.4% reported more than 10 years, 21.2% fewer than 5 years, and 13.5% 5–10 years. No additional demographic or professional characteristics (e.g., age, sex, specialty) were collected in this survey; this limits characterization of the sample and is noted in Section 4

Table 1. Demographic and Professional Characteristics

Characteristic	Category	n	%
Practice Setting (n=204)	Public (Governmental)	124	60.8%
	Private	80	39.2%
	Not specified (of N=208)	4	1.9%
Years of Experience (N=208)	>10 years	136	65.4%
	<5 years	44	21.2%
	5–10 years	28	13.5%

Note. Denominators reflect valid (non-missing) responses for each characteristic.

Self-Reported Awareness of Digital Dentistry Concepts

Self-reported general awareness of the term 'digital dentistry' was high (80.4%, 164/204); 13.7% were unsure and 5.9% reported no awareness. Self-reported awareness of intraoral scanners (92.3%) and of 3D printing applications for surgical guides (82.7%) was similarly high. In contrast, self-reported familiarity with more technical aspects of digital workflows was lower: only 26.9% (56/208) reported being able to distinguish open from closed CAD/CAM systems, and only 19.2% (40/208) reported recognizing STL/DICOM file formats (Table 2). These findings indicate a gap between general awareness of digital dentistry and self-reported familiarity with selected technical aspects of digital workflows; because the questionnaire relied on self-report rather than objective testing, these results should not be interpreted as a measure of objectively assessed knowledge or clinical competency.

Table 2. Self-Reported Awareness of Digital Dentistry Concepts

Awareness Item (N)	Yes	No	Not Sure
Aware of 'Digital Dentistry' (n=204)	80.4% (164)	5.9% (12)	13.7% (28)
Aware of 3D Printing for Surgical Guides (N=208)	82.7% (172)	7.7% (16)	9.6% (20)
Heard of Intraoral Scanners (N=208)	92.3% (192)	5.8% (12)	1.9% (4)
Know Open vs. Closed CAD/CAM (N=208)	26.9% (56)	53.8% (112)	19.2% (40)
Know STL/DICOM Formats (N=208)	19.2% (40)	59.6% (124)	21.2% (44)

Note. Denominator (N) given per item; the 'digital dentistry' term item had 4 missing responses (n=204); all other items had complete data (N=208). All items reflect self-reported awareness/familiarity, not objectively tested knowledge.

Clinical Utilization

Digital tool use was assessed with an item permitting multiple selections; 188 of 208 participants provided a valid response. Among these, digital radiography (RVG/CBCT) was the most frequently reported tool (76.6%, 144/188), followed by apex locators (42.6%, 80/188), intraoral scanners (38.3%, 72/188), intraoral cameras (21.3%, 40/188), and CAD/CAM systems, in-office or laboratory-based (19.1%, 36/188) (Table 3). Because respondents could select more than one tool, these percentages do not sum to 100%.

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Table 3. Digital Tool Utilization — Overall (N=188)

Digital Tool	n	% of N=188
Digital Radiography (RVG/CBCT)	144	76.6%
Apex Locator	80	42.6%
Intraoral Scanner	72	38.3%
Intraoral Camera	40	21.3%
CAD/CAM (In-office or Lab-based)	36	19.1%

Note. Respondents could select more than one tool; percentages do not sum to 100%. N=188 reflects all participants with a valid response to this item, regardless of whether practice setting was reported. For the practice-setting subgroup comparison (n=184), see Supplementary Table 1.

Among 200 respondents reporting overall frequency of digital technology use, occasional use was most common (30.0%), followed by never (28.0%), frequently (24.0%), rarely (12.0%), and always (6.0%) (Table 4). Some respondents reported little or no use of digital technologies, although responses to tool-specific questions indicated use of individual digital tools by some participants: of the 56 respondents who reported 'never' using digital technology overall, 47 (84%) nonetheless reported using at least one specific digital tool in the tool-utilization item. This apparent inconsistency may reflect differing interpretations of 'use' across the two items (e.g., occasional versus routine use) and should be considered when interpreting the frequency-of-use results; it does not, on its own, support classifying these respondents as a coherent 'pre-adoption' subgroup.

Table 4. Frequency of Digital Technology Use (n=200)

Usage Frequency	n	%
Occasionally	60	30.0%
Never	56	28.0%
Frequently	48	24.0%
Rarely	24	12.0%
Always	12	6.0%

Note. n=200 reflects valid responses to this item (8 of 208 missing). See Section 3.3 regarding possible inconsistency with tool-specific responses among participants reporting 'never'.

Among 184 respondents reporting clinical applications, diagnosis predominated (54.3%), followed by fixed prosthodontics (30.4%), implants (13.0%), and orthodontics (2.2%) (Table 5).
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Table 5. Clinical Applications of Digital Technology (n=184)

Clinical Application	n	%
Diagnosis	100	54.3%
Fixed Prosthodontics	56	30.4%
Implants	24	13.0%
Orthodontics	4	2.2%

Attitudes

Responses to three individual attitude statements about digital dentistry, each rated on a 5-point Likert scale, were strongly positive (n=204 for each item): 98.0% agreed or strongly agreed that it improves restoration accuracy, 92.1% that it represents the profession's future, and 92.1% that it saves time relative to traditional methods (Table 6). These results reflect responses to three separate attitude statements rather than a formally validated composite attitude scale; no overall attitude score was calculated.

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Table 6. Responses to Attitude Statements (n=204)

Statement	Strongly Agree	Agree	Neutral	Disagree
Improves restoration accuracy	49.0% (100)	49.0% (100)	2.0% (4)	0%
Future of the profession	58.8% (120)	33.3% (68)	3.9% (8)	3.9% (8)
Saves time vs. traditional methods	58.8% (120)	33.3% (68)	5.9% (12)	2.0% (4)

Note. n=204 (4 of 208 missing per item). Presented as three individual statements, not a summed or validated scale.

Barriers to Adoption

Among all 208 participants, the most frequently selected primary barrier to adoption was high initial equipment cost (51.9%, 108/208), followed by lack of technical training or knowledge (36.5%, 76/208), maintenance/software update costs (9.6%, 20/208), and complexity of the technology (1.9%, 4/208) (Table 7). This overall analysis uses all 208 participants and is distinct from the practice-setting subgroup analysis in Supplementary Table 2, which is restricted to the 204 participants with known practice setting (Section 3.6).

Table 7. Primary Perceived Barriers to Adoption (N=208)

Barrier	n	%
High initial equipment cost	108	51.9%
Lack of technical training/knowledge	76	36.5%
Maintenance/software update costs	20	9.6%
Complexity of the technology	4	1.9%

Subgroup Comparisons

Table 8 summarizes all subgroup comparisons by practice setting and years of experience. No statistically significant association was detected for any comparison (all $p > 0.05$), and effect sizes were small to negligible throughout (Cramér's V range 0.026–0.143). For the barrier-by-setting comparison, 2 of 8 expected cell counts (25%) were below 5; a Monte Carlo approximation of the Fisher–Freeman–Halton exact test (200,000 replications) confirmed the chi-square result ($p \approx 0.946$). Descriptively, private-practice and less-experienced participants showed somewhat higher reported use of intraoral scanners and CAD/CAM systems, and public-sector participants cited cost barriers somewhat more often, but these differences did not reach statistical significance and effect sizes were small; they should not be interpreted as evidence of equivalence between groups, particularly given the limited statistical power of the 5–10-year experience subgroup (n=28).

Table 8. Subgroup Comparisons by Practice Setting and Years of Experience

Comparison	n	χ2	df	p	Cramér's V	Test
CAD/CAM knowledge × setting	204	3.082	2	0.214	0.123	Chi-square
STL/DICOM familiarity × setting	204	0.134	2	0.935	0.026	Chi-square
Digital radiography use × setting	184	0.147	1	0.701	0.042	Chi-square (Yates)
Intraoral scanner use × setting	184	1.634	1	0.201	0.106	Chi-square (Yates)
CAD/CAM use × setting	184	0.482	1	0.487	0.065	Chi-square (Yates)
Barrier to adoption × setting	204	0.459	3	0.928 (0.946 MC)	0.047	Chi-square / Monte Carlo exact
CAD/CAM knowledge × experience	208	8.452	4	0.076	0.143	Chi-square
STL/DICOM familiarity × experience	208	4.595	4	0.331	0.105	Chi-square
Frequent/always tool use × experience	200	0.315	2	0.854	0.040	Chi-square

Note. "Frequent/always tool use" combines the 'Frequently' and 'Always' categories of overall usage frequency versus all other categories. The barrier × setting analysis is restricted to the 204 participants with known practice setting; see Supplementary Table 2 for cell-level counts.

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Discussion

This study offers a multidimensional, self-reported picture of digital dentistry awareness, utilization, attitudes, and barriers among professionals in public and private practice. Findings reveal a cohort with high self-reported general awareness and strongly positive attitudes, yet comparatively limited reported adoption beyond digital radiography — a pattern with implications for dental education and policy.

The high self-reported awareness of intraoral scanners and 3D printing, contrasted with more limited self-reported familiarity with CAD/CAM architecture and file formats, mirrors findings elsewhere [3,4,9,10] and suggests a gap between general awareness of digital dentistry and self-reported familiarity with selected technical aspects of digital workflows: familiarity with a technology's existence does not necessarily equate to the technical understanding needed for safe implementation and accurate clinical–laboratory communication [8]. Structured, hands-on training at both undergraduate and postgraduate levels may help translate general awareness into more comprehensive technical familiarity [11].

The predominance of digital radiography may reflect its established use and longer adoption history in clinical practice [12]; whether this also reflects lower relative cost was not directly measured in the present study. More advanced tools remained comparatively less used, and diagnostic applications were reported more often than restorative or implant-based workflows. Some respondents reported little or no use of digital technologies overall, although responses to tool-specific questions indicated use of individual digital tools by some of these same participants (Section 3.3), which complicates interpretation of the frequency-of-use data and cautions against describing this subgroup as being in a definitive 'pre-adoption' stage.

Despite this comparatively limited reported utilization of advanced tools, attitudes toward the three statements assessed were overwhelmingly favorable. The findings suggest that financial and educational barriers may represent more prominent obstacles to adoption than negative attitudes toward digital dentistry, although the cross-sectional design cannot establish the relative contribution of these factors. The strong endorsement of the time-saving statement may be a useful message for continuing education and practice-management initiatives to draw on [3].

Equipment cost, the most frequently selected barrier, has potential relevance for publicly funded systems where capital investment may be constrained [8]; subsidized procurement, equipment-sharing, and phased-integration models are strategies that could be explored to help expand access [13], although their effectiveness was not evaluated in this study. Maintenance costs and technology complexity were selected less often as the primary barrier than equipment cost or training; this cross-sectional comparison cannot determine whether such concerns become more or less prominent after adoption.

Subgroup analyses (Table 8) did not detect a statistically significant association by practice setting or experience for any awareness, utilization, or barrier item, and effect sizes were small throughout. These non-significant results should be interpreted as an absence of statistically significant evidence for association, not as evidence that the groups are equivalent, particularly given the limited statistical power of some subgroups (e.g., n=28 in the 5–10-year experience band). Descriptive directional trends — such as higher reported use of advanced tools among private-practice and early-career participants — are hypothesis-generating and require confirmation in an adequately powered study.

These findings may support considering the integration of digital dentistry competencies throughout dental curricula with measurable, hands-on outcomes [11]; directing continuing education toward CAD/CAM and file-format familiarity; and exploring subsidized or shared-equipment models in public clinical settings. These are suggested directions for future evaluation rather than interventions whose effectiveness this study has demonstrated.

Limitations include a convenience sample recruited without an a priori sample-size or power calculation, which may limit statistical power — particularly for subgroup comparisons — and constrains generalizability beyond this geographic and healthcare context; a cross-sectional design that precludes causal inference; potential social-desirability and selection bias; reliance on self-reported awareness and familiarity rather than objective knowledge testing, such that results should not be interpreted as measures of objective competency; item-level missing data, addressed using item-specific denominators (Section 2.3) rather than participant exclusion, which may still introduce nonresponse bias for specific items; an instrument that, while literature-based, expert-reviewed, and piloted, lacks formal psychometric validation; and a limited set of demographic and professional variables (practice setting and years of experience only), which restricts characterization of the sample and precludes examination of other potentially relevant factors such as specialty, age, or sex.

Despite these limitations, the study provides a descriptive baseline for future, adequately powered research examining how self-reported awareness and reported adoption relate across settings and regions, and for evaluating whether targeted educational or financial interventions are associated with changes in reported digital technology use.

Conclusion

Dental professionals in this convenience sample reported broad self-reported awareness and favorable attitudes toward digital dentistry, yet reported practical adoption remained concentrated in digital radiography and was most often attributed to financial and training barriers. Subgroup comparisons by practice setting and experience showed small, statistically non-significant associations throughout and should be treated as preliminary, hypothesis-generating

observations rather than confirmed differences. Improving access to equipment — particularly in public settings — and integrating digital competencies into undergraduate and postgraduate dental education may help address the gap between favorable attitudes and reported adoption, though this study did not test the effectiveness of any such intervention. The favorable attitudes identified here provide a descriptive basis for future research evaluating targeted educational and policy approaches to digital dentistry adoption.

Conflict of interest

Roba EL-Refadi declares no conflict of interest. Ghada Ahmed declares no conflict of interest. Fatema F. Elturki declares no conflict of interest. There are no financial, personal, or professional conflicts of interest related to this study.

Authors' contributions

Roba EL-Refadi contributed to study conception and design, data collection, data analysis, interpretation of findings, and manuscript drafting. Ghada Ahmed contributed to study design, data interpretation, critical revision of the manuscript, and final approval. Fatema F. Elturki contributed to study design, interpretation of results, critical manuscript revision, and final approval. All authors approved the final version and agree to be accountable for all aspects of the work.

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