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Knowledge, attitudes, and practices regarding digital dentistry among Turkish dentists: a cross-sectional study

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Digital technologies are increasingly integrated into dental practice, yet their adoption may vary according to professional and institutional factors. This cross-sectional study evaluated dentists' knowledge, attitudes, and practices (KAP) regarding digital dentistry and factors associated with clinical adoption in Turkiye. A total of 225 dentists completed an online questionnaire. Mean knowledge, attitude, and practice scores were 11.2 ± 4.1, 24.4 ± 2.7, and 12.2 ± 5.3, respectively. Public hospital dentists demonstrated lower knowledge and practice scores, while practice scores were also lower among university hospital dentists than among those working in private-sector settings. Knowledge and attitude were positively correlated with practice (ρ = 0.311 and ρ = 0.250, respectively; both $p < 0.001$). In multivariable analyses, male sex, older age, and private clinic/corporate dental chain employment were independently associated with higher practice scores, whereas public hospital employment was independently associated with lower practice scores. Overall, favourable attitudes towards digital dentistry did not consistently correspond to clinical adoption, indicating differences between attitudes and reported clinical practice. These findings highlight associations between professional and practice-setting characteristics and the clinical use of digital technologies.

Keywords Digital dentistry, Knowledge, attitudes, and practices, Dentists, Technology adoption, Practice setting, Digital health

Digital technologies have increasingly transformed dental practice by reshaping clinical workflows from diagnosis and treatment planning to treatment delivery. Digital dentistry encompasses a wide range of technologies, including computer-aided design/computer-aided manufacturing (CAD/CAM), cone-beam computed tomography (CBCT), intraoral scanners, three-dimensional (3D) printing, and artificial intelligence, which can improve efficiency, accuracy, and patient experience across different stages of dental care[1]. Their applications extend across dental specialties, including digital impressions and CAD/CAM workflows in restorative and prosthetic dentistry, CBCT-guided surgical planning in implant dentistry, digital modelling in orthodontics, and patient-specific 3D-printed solutions in oral and maxillofacial surgery[2]. Guided techniques have also expanded applications in endodontics and microsurgery, particularly for the localisation of calcified canals and the management of complex procedures[3]. Collectively, these developments reflect the increasing integration of digital technologies into contemporary dental practice.

Despite these advances, the adoption of digital technologies among dentists remains heterogeneous in terms of knowledge, attitudes, and clinical practices[4]. High costs, insufficient training, limited technical support, and difficulties in adapting to new workflows have been identified as important barriers to their effective clinical integration[5,6]. Importantly, these barriers may differ across practice settings because access to digital infrastructure, training opportunities, and institutional support is not necessarily uniform. Such differences may be associated with variation in the clinical adoption of digital technologies across practice settings. Understanding the factors associated with digital technology use is therefore important for developing strategies that support effective implementation across different practice settings.

The Knowledge-Attitude-Practice (KAP) model provides a useful framework for examining factors related to technology adoption among healthcare professionals[5,7]. Although the literature on digital dentistry has

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extensively addressed the technical characteristics and clinical performance of individual technologies, evidence focusing on their adoption from the clinician perspective remains more limited[1,8]. Previous studies have reported variation in dentists' knowledge, perceptions, and use of digital technologies[2,4,5]; however, evidence integrating KAP domains with demographic, professional, and practice-setting factors remains limited, particularly regarding which factors are independently associated with the clinical use of digital technologies. Examining these relationships may help distinguish favourable perceptions of digital dentistry from factors associated with their translation into routine clinical practice.

In Turkiye, where digital technologies are increasingly incorporated into dental practice, comprehensive evidence on dentists' knowledge, attitudes, and practices and their variation across different professional and institutional settings remains limited. Identifying factors associated with clinical adoption may provide relevant evidence for workforce development, educational planning, and institutional strategies aimed at supporting the broader implementation of digital dental technologies. Accordingly, this study aimed to evaluate dentists' knowledge, attitudes, and practices regarding digital dentistry in Turkiye, examine the relationships among these domains, and identify demographic, professional, and practice-setting factors independently associated with the clinical adoption of digital technologies.

Methods

This web-based cross-sectional study, based on the Knowledge, Attitudes, and Practices (KAP) model, was conducted among dentists actively practising in Turkiye between 1 January 2026 and 30 April 2026. Ethical approval for the study was obtained from the Clinical Research Ethics Committee of Marmara University Faculty of Dentistry (Protocol No: 2025-67). All procedures were performed in accordance with the Declaration of Helsinki. All participants were informed about the purpose of the study, and electronic informed consent was obtained prior to completing the questionnaire. The study was reported in accordance with the STROBE Statement.

Study sample

The questionnaire was completed anonymously to ensure participant confidentiality. Participants were recruited using a snowball sampling approach through the authors' professional networks and professional social media platforms (WhatsApp, Telegram, Instagram, and Facebook). The questionnaire was administered online using Google Forms, and participants were encouraged to disseminate the survey link within their professional networks; participation was voluntary.

All Turkish dentists working in public, private, and academic institutions, including general dentists, specialists, and postgraduate trainees (residents and doctoral students), regardless of age or years of professional experience, were eligible for inclusion. For the classification of practice settings, "private practice" referred to independently operated dental practices, whereas "private clinic/corporate dental chain" referred to private clinics or corporate dental organisations. Participants were required to be actively practising in a clinical setting in Turkiye, hold a degree in dentistry, and voluntarily agree to participate. Only participants who completed the questionnaire fully and consistently were included in the final analysis; questionnaires with missing or inconsistent responses were excluded. Efforts to minimise bias included anonymous data collection, standardised online administration, and inclusion of only fully completed questionnaires.

Questionnaire and study variables

The questionnaire was developed and adapted from instruments used in previous studies[2,9]. Items were selected from these instruments based on their relevance to the knowledge, attitude, and practice domains addressed in the present study. Rather than reproducing a single existing questionnaire, relevant items and domains were adapted and organised to reflect the objectives and scope of the present study. The draft questionnaire was subsequently reviewed by two experienced dental academics to assess the relevance, clarity, and appropriateness of the items, and modifications were made based on their feedback. The responses designated as correct for the knowledge items were based on the scientific literature consulted during questionnaire development. The questionnaire comprised 26 items across four sections. The first section recorded demographic and professional characteristics, including age, sex, year of graduation, years of professional experience, practice setting, professional status, and field of specialisation. The second section assessed knowledge of digital dentistry concepts, commonly used digital technologies, digital impression accuracy, dental 3D-printing materials, applications of digital technologies, and the advantages of CAD/CAM systems. The third section assessed attitudes towards digital dental technologies using seven items with response scales appropriate to each question. The fourth section assessed practices related to digital dental technologies, including the use of digital systems, frequency of use, areas of clinical application, and approaches to investment in digital technologies. The questionnaire items and response distributions are provided in the Supplementary information.

Pilot study and reliability assessment

A pilot study was conducted with 40 practitioners to refine the questionnaire and evaluate its internal consistency using Cronbach's alpha coefficient; a value of at least 0.70 was considered acceptable. Pilot participants were not included in the final analytic sample. The overall Cronbach's alpha coefficient obtained in the pilot study was 0.776, indicating acceptable internal consistency.

Scoring of the KAP domains

For the knowledge domain, correct responses were assigned 1 point, whereas incorrect, uncertain, and "I do not know" responses were assigned 0 points. For multiple-response items, each correctly selected option contributed 1 point, yielding a maximum knowledge score of 20. For the attitude domain, the seven items were scored

from 0 to 4, with higher scores indicating a more positive attitude towards digital dentistry; negatively worded items were reverse-coded, yielding a maximum attitude score of 28. For the practice domain, items were scored according to predefined scoring criteria appropriate to their response format, with higher scores indicating greater use of digital technologies; the maximum practice score was 24. The maximum total KAP score was therefore 72.

Sample size calculation

The sample size was calculated a priori using G*Power software (version 3.1.9.7). Based on the effect size reported in a previous cross-sectional study evaluating knowledge, attitudes, and practices related to digital dentistry among dental professionals, a medium effect size ($f = 0.25$) was assumed, as reported by Abdulai and Suradi[10]. With a significance level of $\alpha = 0.05$ and a statistical power of 80% ($1 - \beta = 0.80$), the minimum required sample size was calculated as 200 participants. A total of 225 dentists were included, exceeding the minimum required sample size.

Descriptive and comparative statistics

Data were analysed using JASP and IBM SPSS Statistics (version 25). Categorical variables were presented as frequencies and percentages (n, %), whereas continuous variables were summarised using means and standard deviations, medians and interquartile ranges (Q25–Q75), and ranges, as appropriate. Distributional assumptions were assessed using the Shapiro–Wilk test and Q–Q plots, and homogeneity of variance was evaluated using Levene's test. Differences in knowledge, attitude, practice, and total KAP scores according to participant characteristics were analysed using independent-samples t-tests, Mann–Whitney U tests, one-way analysis of variance (ANOVA), or Kruskal–Wallis tests, as appropriate. Effect sizes were reported using Cohen's d, rank-biserial correlation, partial eta-squared ($\eta^2 p$), or epsilon-squared (ε^2), according to the statistical test applied. Bonferroni-adjusted post-hoc comparisons were performed where appropriate. Statistical significance was set at $p < 0.05$.

Regression analysis

Variables associated with knowledge, attitude, and practice scores were further evaluated using multivariable linear regression models. Variables with $p < 0.25$ in univariable analyses were considered eligible for inclusion in the multivariable models. Spearman's rank correlation coefficient was used to assess associations between quantitative and ordinal variables. To minimise multicollinearity, age, year of graduation, and years of professional experience, which were highly correlated (|Spearman's ρ| > 0.80), were not entered simultaneously into the same regression model. Accordingly, year of graduation was retained in the knowledge model, years of professional experience in the attitude model, and age in the practice model. Multicollinearity was further assessed using the variance inflation factor (VIF), and VIF values were < 10 in all models. Model diagnostics indicated that the assumptions of linear regression were adequately satisfied. Unstandardized regression coefficients (B) with 95% confidence intervals (CI) were reported. Statistical significance was set at $p < 0.05$.

Results

Descriptive statistics

A total of 225 dentists were included in the final analysis. Of the participants, 118 (52.4%) were female and 107 (47.6%) were male. Most participants were aged 25–34 years ($n = 129$, 57.3%), graduated in or after 2020 ($n = 82$, 36.4%), and had 0–5 years of professional experience ($n = 84$, 37.3%).

Regarding practice setting, 75 participants (33.3%) worked in university hospitals, followed by private practice ($n = 63$, 28.0%) and private clinics or corporate dental chains ($n = 60$, 26.7%). In terms of professional status, 81 participants (36.0%) were general dentists, 77 (34.2%) were specialist dentists, and 67 (29.8%) were postgraduate trainees (residency/PhD). Additionally, 82 participants (36.4%) reported having no specialty training, while the remaining participants represented various dental specialties (Table 1).

KAP scores — overview

The mean knowledge, attitude, and practice scores were 11.2 ± 4.1, 24.4 ± 2.7, and 12.2 ± 5.3, respectively, out of maximum possible scores of 20, 28, and 24. The mean total KAP score was 47.9 ± 8.9 out of a maximum of 72 (Table 2).

Analysis of knowledge scores

The mean knowledge score was 11.2 ± 4.1 out of 20. Knowledge scores did not differ significantly by sex, age, years of professional experience, or professional status ($p > 0.05$). However, significant differences were observed according to year of graduation ($p = 0.013$), practice setting ($p < 0.001$), and field of specialisation ($p < 0.001$).

Bonferroni-adjusted post-hoc comparisons showed that dentists who graduated between 2010 and 2014 had significantly higher knowledge scores than those who graduated between 2005 and 2009 (12.7 ± 4.3 vs. 9.6 ± 3.7, $p = 0.024$). Dentists working in public hospitals had significantly lower knowledge scores (7.9 ± 3.7) than those working in private practice (11.1 ± 3.9, $p = 0.019$), private clinics/corporate dental chains (11.4 ± 4.0, $p = 0.005$), and university hospitals (12.5 ± 3.9, $p < 0.001$); no significant differences were observed among the latter three settings. Regarding field of specialisation, restorative dentistry specialists had significantly higher knowledge scores (15.3 ± 3.9) than oral and maxillofacial surgeons (7.5 ± 2.1, $p < 0.001$), oral diagnosis and radiology specialists (9.2 ± 3.8, $p = 0.007$), and dentists with no specialty training (11.0 ± 4.1, $p = 0.009$). Prosthodontists also had significantly higher knowledge scores (13.1 ± 4.7) than oral and maxillofacial surgeons ($p = 0.038$). No other pairwise comparisons were statistically significant (Table 2).

Variables	$n = 225$	%
Gender		
Female	118	52.4
Male	107	47.6
Age		
< 25	9	4.0
25–34	129	57.3
35–44	58	25.8
≥ 45	29	12.9
Year of graduation		
≤ 2004	24	10.7
2005–2009	28	12.4
2010–2014	40	17.8
2015–2019	51	22.7
≥ 2020	82	36.4
Years of experience		
0–5	84	37.3
6–10	51	22.7
11–15	44	19.6
16–20	21	9.3
> 21	25	11.1
Practice setting		
Private practice	63	28.0
Private clinic/corporate dental chain	60	26.7
Public hospital	27	12.0
University hospital	75	33.3
Professional status		
General dentist	81	36.0
Specialist dentist	77	34.2
Postgraduate student (residency/PhD)	67	29.8
Field of specialisation		
No specialty	82	36.4
Restorative dentistry	22	9.8
Endodontics	18	8.0
Prosthodontics	17	7.6
Orthodontics	17	7.6
Pediatric dentistry	27	12.0
Oral and maxillofacial surgery	15	6.7
Oral diagnosis and radiology	13	5.8
Periodontology	14	6.2

Table 1. Distribution of participants according to demographic and professional characteristics.

Analysis of attitude scores

The mean attitude score of the participants was 24.4 ± 2.7 out of a maximum of 28. Attitude scores were significantly higher among male dentists compared with females (24.8 ± 2.9 vs. 24.1 ± 2.6, $p = 0.032$). In addition, attitude scores varied significantly according to years of professional experience ($p = 0.047$), although no pairwise post-hoc comparisons reached statistical significance. No statistically significant differences were identified according to age, year of graduation, practice setting, professional status, or field of specialisation ($p > 0.05$) (Table 2).

Analysis of practice scores

The mean practice score of the participants was 12.2 ± 5.3 out of a maximum of 24. Practice scores differed significantly according to sex, age, year of graduation, years of professional experience, practice setting, professional status, and field of specialisation (all $p < 0.05$). Male dentists demonstrated significantly higher practice scores than females (14.7 ± 4.9 vs. 10.0 ± 4.8, $p < 0.001$). Practice scores were generally higher among older and more experienced dentists, with the highest scores observed among dentists aged ≥ 45 years (15.9 ± 3.8) and those with 16–20 years of professional experience (16.5 ± 4.9). Bonferroni-adjusted post-hoc comparisons showed that dentists working in private practice (14.2 ± 4.0) and private clinics/corporate dental chains (15.1 ± 5.2) had significantly higher practice scores than those working in public hospitals (7.8 ± 4.0) and

Variables	Knowledge score		Attitude score		Practice score		KAP score	
	Mean ± SD	*p*	Mean ± SD	*p*	Mean ± SD	*p*	Mean ± SD	*p*
Total	11.2 ± 4.1		24.4 ± 2.7		12.2 ± 5.3		47.9 ± 8.9	
Gender		0.840[1] (rrb = 0.018)		0.032[1]* (rrb = 0.187)		< 0.001[1]* (rrb = 0.535)		< 0.001[4]* (d = 0.658)
Female	11.2 ± 3.9		24.1 ± 2.6		10.0 ± 4.8		45.3 ± 8.0	
Male	11.4 ± 4.4		24.8 ± 2.9		14.7 ± 4.9		50.9 ± 9.0	
Age		0.325[2] (ε^2=0.020)		0.241[2] (ε^2=0.024)		< 0.001[2]* (ε^2=0.211)		0.063[2] (ε^2=0.042)
< 25	11.1 ± 1.2		23.9 ± 2.1		8.3 ± 5.7		43.3 ± 6.7	
25–34	11.6 ± 4.2		24.5 ± 2.6		10.6 ± 4.7		46.7 ± 8.7	
35–44	10.8 ± 4.2		24.9 ± 2.9		14.7 ± 5.6		50.3 ± 9.5	
≥ 45	10.7 ± 4.3		23.5 ± 2.9		15.9 ± 3.8		50.0 ± 8.2	
Year of graduation		0.013[2]* (ε^2=0.073)		0.490[2] (ε^2=0.020)		< 0.001[3]* (η^2p = 0.208)		0.010[3]* (η^2p = 0.075)
≤ 2004	10.2 ± 4.3		24.0 ± 2.8		15.7 ± 3.8		49.9 ± 8.0	
2005–2009	9.6 ± 3.7		25.0 ± 2.5		15.1 ± 4.2		49.6 ± 7.4	
2010–2014	12.7 ± 4.3		24.2 ± 3.0		14.7 ± 5.2		51.5 ± 8.5	
2015–2019	12.2 ± 4.8		24.3 ± 3.1		11.3 ± 5.2		47.9 ± 10.8	
≥ 2020	10.9 ± 3.4		24.6 ± 2.5		9.6 ± 4.9		45.1 ± 7.8	
Years of experience		0.324[2] (ε^2=0.027)		0.047[2]* (ε^2=0.056)		< 0.001[3]* (η^2p = 0.217)		0.002[3]* (η^2p = 0.096)
0–5	11.0 ± 3.3		24.6 ± 2.5		9.6 ± 4.9		45.2 ± 7.7	
6–10	11.7 ± 4.6		23.7 ± 3.2		11.5 ± 5.2		46.9 ± 9.8	
11–15	12.5 ± 4.7		25.1 ± 2.6		14.2 ± 4.8		51.8 ± 9.1	
16–20	10.3 ± 4.2		25.3 ± 1.9		16.5 ± 4.9		52.1 ± 7.7	
> 21	10.1 ± 4.1		23.5 ± 3.1		15.4 ± 3.8		49.0 ± 8.1	
Practice setting		< 0.001[2]* (ε^2=0.120)		0.060[2] (ε^2=0.043)		< 0.001[2]* (ε^2=0.278)		< 0.001[3]* (η^2p = 0.169)
Private practice	11.1 ± 3.9		24.2 ± 2.9		14.2 ± 4.0		49.6 ± 7.5	
Private clinic / corporate dental chain	11.4 ± 4.0		25.3 ± 2.6		15.1 ± 5.2		51.9 ± 8.1	
Public hospital	7.9 ± 3.7		24.3 ± 2.9		7.8 ± 4.0		40.1 ± 7.1	
University hospital	12.5 ± 3.9		23.9 ± 2.5		9.8 ± 4.9		46.2 ± 9.1	
Professional status		0.646[2] (ε^2=0.005)		0.161[2] (ε^2=0.021)		< 0.001[2]* (ε^2=0.174)		< 0.001[3]* (η^2p = 0.070)
General dentist	10.9 ± 4.1		24.3 ± 3.0		13.4 ± 5.9		48.5 ± 9.6	
Specialist dentist	11.7 ± 4.8		24.9 ± 2.5		13.7 ± 4.4		50.3 ± 8.4	
Postgraduate student (residency/PhD)	11.3 ± 3.3		24.1 ± 2.6		9.1 ± 4.4		44.5 ± 7.5	
Field of specialisation		< 0.001[2]* (ε^2=0.181)		0.228[2] (ε^2=0.061)		0.003[3]* (η^2p = 0.177)		0.011[3]* (η^2p = 0.124)
No specialty	11.0 ± 4.1		24.3 ± 3.0		13.5 ± 5.9		48.8 ± 9.8	
Restorative Dentistry	15.3 ± 3.9		24.6 ± 3.5		12.7 ± 5.0		52.6 ± 10.1	
Endodontics	11.7 ± 3.7		24.4 ± 2.1		11.2 ± 5.5		47.3 ± 7.3	
Prosthodontics	13.1 ± 4.7		24.0 ± 2.6		15.9 ± 1.9		53.0 ± 8.3	
Orthodontics	11.9 ± 4.6		23.1 ± 2.3		10.9 ± 2.1		45.9 ± 5.2	
Pediatric dentistry	11.0 ± 3.0		24.1 ± 2.7		7.1 ± 4.8		42.2 ± 8.4	
Oral and maxillofacial surgery	7.5 ± 2.1		24.8 ± 1.5		12.4 ± 5.1		44.8 ± 7.3	
Oral diagnosis and radiology	9.2 ± 3.8		25.0 ± 1.9		11.3 ± 3.4		45.5 ± 5.3	
Periodontology	9.9 ± 1.3		26.6 ± 2.3		13.2 ± 4.6		49.6 ± 5.9	

Table 2. Comparison of knowledge, attitude, practice, and total KAP scores according to participants' demographic and professional characteristics. Data are presented as mean ± standard deviation. *p* values represent overall between-group comparisons using independent-samples t-tests, Mann–Whitney U tests, one-way analysis of variance (ANOVA), or Kruskal–Wallis tests, as appropriate. Effect sizes are reported as Cohen's d, rank-biserial correlation ($r_{r\beta}$), partial eta-squared (η^2p), or epsilon-squared (ε^2), according to the statistical test applied. Bonferroni-adjusted post-hoc comparisons were performed following significant overall tests, where appropriate; statistically significant pairwise comparisons are reported in the Results. Statistical significance was set at $p < 0.05$.

university hospitals (9.8 ± 4.9) (all $p < 0.001$). Among specialties, prosthodontists exhibited the highest practice scores (15.9 ± 1.9), whereas pediatric dentists had the lowest scores (7.1 ± 4.8) (Table 2).

Correlation analysis

Spearman correlation analysis revealed positive correlations between knowledge and practice scores ($\rho = 0.311$, $p < 0.001$) and between attitude and practice scores ($\rho = 0.250$, $p < 0.001$). In addition, age and years of professional experience were positively correlated with practice and total KAP scores, whereas year of graduation was negatively correlated with these scores (Table 3). As practice scores constitute a component of the total KAP score, the strong correlation observed between these variables was expected and should therefore be interpreted with caution.

Regression analysis

Multivariable linear regression analyses were performed to identify factors independently associated with knowledge, attitude, and practice scores. Unstandardized regression coefficients (B) with 95% confidence intervals (CI) are reported throughout. Male sex was independently associated with higher practice scores (B = 1.87, 95% CI: 0.47–3.27, $p = 0.009$). Compared with participants aged < 25 years, those aged 35–44 years (B = 4.38, 95% CI: 1.14–7.63, $p = 0.008$) and ≥ 45 years (B = 5.19, 95% CI: 1.77–8.61, $p = 0.003$) had significantly higher practice scores (Table 4).

Regarding year of graduation, participants who graduated between 2010 and 2014 (B = 2.53, 95% CI: 0.47–4.60, $p = 0.016$) and between 2015 and 2019 (B = 2.67, 95% CI: 0.62–4.71, $p = 0.011$) had significantly higher knowledge scores than those who graduated in or before 2004. Participants with 6–10 years (B = − 1.73, 95% CI: −3.04 to − 0.42, $p = 0.010$), 11–15 years (B = − 1.63, 95% CI: −3.20 to − 0.05, $p = 0.043$), and > 21 years of professional experience (B = − 2.86, 95% CI: −4.65 to − 1.07, $p = 0.002$) had significantly lower attitude scores than those with 0–5 years of experience.

Working in private clinics/corporate dental chains was independently associated with higher practice scores compared with private practice (B = 1.76, 95% CI: 0.09–3.42, $p = 0.038$), whereas working in public hospitals was independently associated with lower practice scores (B = − 3.86, 95% CI: −6.01 to − 1.70, $p < 0.001$).

Regarding field of specialisation, restorative dentistry specialists had significantly higher knowledge scores than participants without specialty training (B = 2.70, 95% CI: 0.56–4.84, $p = 0.014$), whereas oral and maxillofacial surgeons had significantly lower knowledge scores (B = − 3.07, 95% CI: −5.27 to − 0.87, $p = 0.007$).

All three regression models were statistically significant. The knowledge model explained 41.1% of the variance ($R^2 = 0.411$, adjusted $R^2 = 0.347$, $p < 0.001$), the attitude model explained 26.1% ($R^2 = 0.261$, adjusted $R^2 = 0.165$, $p < 0.001$), and the practice model explained 57.7% ($R^2 = 0.577$, adjusted $R^2 = 0.525$, $p < 0.001$) (Table 4).

Discussion

This study evaluated dentists' knowledge, attitudes, and practices (KAP) regarding digital dentistry technologies and examined associations between demographic and professional factors and these domains. Significant positive associations were identified between knowledge and practice and between attitude and practice, whereas no significant association was observed between knowledge and attitude. Several demographic and professional characteristics were independently associated with knowledge, attitude, and practice scores, with the strongest associations observed for clinical practice.

The overall pattern observed in the present study was broadly consistent with findings reported in recent studies conducted in different countries. Hall et al.[4] reported moderate knowledge and awareness levels among Egyptian dentists despite generally positive perceptions towards digital systems. Similarly, Zhu et al.[2] demonstrated a significant association between knowledge of digital technologies and clinical utilisation behaviours. Previous surveys have also shown that awareness or positive perceptions of digital technologies do

		KAP	Knowledge	Attitude	Practice	Age	Year of graduation
Knowledge	ρ	0.683***	–	–	–	–	–
	p	< 0.001	–	–	–	–	–
Attitude	ρ	0.493***	0.102	–	–	–	–
	p	< 0.001	0.179	–	–	–	–
Practice	ρ	0.824***	0.311***	0.250***	–	–	–
	p	< 0.001	< 0.001	< 0.001	–	–	–
Age	ρ	0.188*	−0.135	0.028	0.457***	–	–
	p	0.013	0.076	0.716	< 0.001	–	–
Year of graduation	ρ	−0.231**	0.070	−0.015	−0.466***	−0.841***	–
	p	0.002	0.359	0.839	< 0.001	< 0.001	–
Years of experience	ρ	0.238**	−0.056	0.028	0.475***	0.840***	−0.967***
	p	0.001	0.463	0.716	< 0.001	< 0.001	< 0.001

Table 3. Spearman's correlations among knowledge, attitude, practice, total KAP scores, age, year of graduation, and professional experience. Spearman's rank correlation analysis was performed on 225 paired observations. *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$ were considered statistically significant.

	Knowledge		Attitude		Practice	
	B [95% CI]	*p*	B [95% CI]	*p*	B [95% CI]	p
Gender						
Female	Ref		Ref		Ref	
Male	–	–	0.78 [−0.17, 1.74]	0.109	1.87 [0.47, 3.27]	**0.009***
Age						
< 25	Ref		Ref		Ref	
25–34	–	–	–	–	2.25 [−0.66, 5.18]	0.129
35–44	–	–	–	–	4.38 [1.14, 7.63]	**0.008***
≥ 45	–	–	–	–	5.19 [1.77, 8.61]	**0.003***
Year of graduation						
≤ 2004	Ref		–	–	–	–
2005–2009	0.23 [−1.95, 2.41]	0.836	–	–	–	–
2010–2014	2.53 [0.47, 4.60]	**0.016***	–	–	–	–
2015–2019	2.67 [0.62, 4.71]	**0.011***	–	–	–	–
≥ 2020	1.67 [−0.48, 3.83]	0.128	–	–	–	–
Years of experience						
0–5	–	–	Ref		–	–
6–10	–	–	−1.73 [−3.04, −0.42]	**0.010***	–	–
11–15	–	–	−1.63 [−3.20, −0.05]	**0.043***	–	–
16–20	–	–	−1.17 [−3.11, 0.76]	0.233	–	–
> 21	–	–	−2.86 [−4.65, −1.07]	**0.002***	–	–
Practice setting						
Private practice	Ref		Ref		Ref	
Private clinic / corporate dental chain	−0.66 [−2.22, 0.88]	0.395	0.59 [−0.58, 1.77]	0.323	1.76 [0.09, 3.42]	**0.038***
Public hospital	−1.95 [−3.99, 0.08]	0.060	1.03 [−0.49, 2.55]	0.184	−3.86 [−6.01, −1.70]	**< 0.001***
University hospital	1.22 [−0.64, 3.09]	0.198	−0.86 [−2.28, 0.56]	0.234	−0.908 [−3.01, 1.19]	0.395
Professional status						
General dentist	Ref		Ref		Ref	
Specialist dentist	–	–	4.23 [−0.89, 9.36]	0.105	0.79 [−6.81, 8.40]	0.837
Postgraduate student (residency/PhD)	–	–	2.69 [−2.56, 7.94]	0.313	−0.585 [−8.30, 7.13]	0.881
Field of specialisation						
No specialty	Ref		Ref		Ref	
Restorative dentistry	2.70 [0.56, 4.84]	**0.014***	−2.49 [−7.74, 2.75]	0.349	−0.56 [−8.33, 7.20]	0.885
Endodontics	0.25 [−1.92, 2.42]	0.819	−2.39 [−7.73, 2.94]	0.377	−1.05 [−8.87, 6.76]	0.790
Prosthodontics	0.78 [−1.36, 2.93]	0.473	−3.53 [−8.81, 1.75]	0.188	0.56 [−7.20, 8.33]	0.886
Orthodontics	0.95 [−1.25, 3.17]	0.394	−3.32 [−8.63, 1.98]	0.218	−2.26 [−10.12, 5.59]	0.569
Pediatric dentistry	0.34 [−1.74, 2.44]	0.742	−1.66 [−6.99, 3.67]	0.539	−2.80 [−10.64, 5.04]	0.482
Oral and maxillofacial surgery	−3.07 [−5.27, −0.87]	**0.007***	−2.31 [−7.56, 2.93]	0.385	0.32 [−7.47, 8.11]	0.935
Oral diagnosis and radiology	−0.62 [−3.11, 1.87]	0.622	−2.38 [−7.76, 3.00]	0.384	−0.03 [−7.93, 7.87]	0.994
Periodontology	−2.28 [−4.65, 0.08]	0.058	−0.38 [−5.71, 4.95]	0.888	0.73 [−7.13, 8.60]	0.854

Table 4. Multivariable linear regression analyses of knowledge, attitude, and practice scores regarding digital dentistry. Multivariable linear regression analyses were performed for knowledge ($R = 0.641$, $R^2 = 0.411$, adjusted $R^2 = 0.347$, $F = 6.441$, $p < 0.001$), attitude ($R = 0.511$, $R^2 = 0.261$, adjusted $R^2 = 0.165$, $F = 2.722$, $p < 0.001$), and practice ($R = 0.759$, $R^2 = 0.577$, adjusted $R^2 = 0.525$, $F = 11.107$, $p < 0.001$). B, unstandardized regression coefficient; CI, confidence interval. Reference categories were female sex, age < 25 years, graduation year ≤ 2004, 0–5 years of professional experience, private practice, general dentist, and no specialty. *$p < 0.05$ was considered statistically significant.

not necessarily correspond to their routine clinical use, with substantial variation in adoption across technologies and clinical settings[11–14]. In the present study, attitude scores were relatively high compared with their maximum possible score, whereas knowledge and practice scores were more moderate, suggesting that favourable perceptions do not necessarily correspond to the implementation of digital technologies in routine practice. This discrepancy between favourable attitudes and actual utilisation has also been observed for chairside CAD/CAM and emerging AI-based applications, where interest in or positive perceptions of a technology may exceed its current level of clinical use[12,13]. The wider variation observed in practice scores may also be associated with broader structural and institutional factors in addition to individual perceptions.

High equipment costs, limited educational opportunities, inadequate technical support, and steep learning curves have been consistently identified as barriers to the clinical integration of digital technologies[15–18]. Lower practice scores among public hospital dentists may be related to differences in access to digital infrastructure and implementation opportunities across practice settings; however, these factors were not directly assessed in the present study. Although the present study did not assess these factors directly, previous evidence suggests that educational strategies, institutional investment, and sustainable financing models may be relevant considerations for supporting digital implementation in the public sector[19].

The positive correlation between knowledge and practice scores indicates an association between theoretical knowledge of digital dentistry technologies and their clinical implementation, consistent with the core assumptions of the KAP model[2]. This pattern is consistent with previous studies showing that greater knowledge is associated with increased utilisation of digital technologies[2,20]. A recent study comparing dentists across different clinical environments similarly identified positive relationships among knowledge, attitudes, and practice, while also indicating that infrastructure and resource availability may be associated with differences in the extent to which knowledge corresponds to clinical use[14].

The positive association between attitude and practice scores is consistent with behavioural models of technology adoption, in which favourable perceptions are associated with the adoption of new technologies in clinical practice[21]. Similar findings have been reported in previous KAP studies in dentistry, where positive attitudes were associated with greater technology utilisation[7]. Nevertheless, studies of chairside CAD/CAM and AI-based technologies indicate that willingness to adopt or positive perceptions may coexist with comparatively lower levels of actual use, emphasising the importance of practical training and access to technology[12,13].

The absence of a significant relationship between knowledge and attitude represents one of the most notable findings of the present study. Although traditional KAP theory assumes that increased knowledge contributes to the development of positive attitudes[22], the present findings suggest that this relationship may be more complex within the context of digital dentistry. Attitudes towards digital technologies may be associated with factors beyond theoretical knowledge alone[8]. The relatively narrow distribution of attitude scores may also indicate a potential ceiling effect. In this regard, Acharya et al.[23] similarly reported limited practical implementation despite high awareness levels regarding three-dimensional printing technologies, further suggesting that theoretical knowledge alone may not fully correspond to the clinical adoption of digital technologies. This interpretation is also compatible with broader technology-adoption research in dentistry, which identifies characteristics of the technology, the clinical environment, professional networks, and practitioner-related factors as interacting influences on adoption decisions[24].

Male participants demonstrated higher attitude, practice, and total KAP scores, whereas knowledge scores did not differ by sex. However, after adjustment for demographic and professional factors, male sex remained independently associated only with practice scores. Previous studies have reported inconsistent findings regarding sex differences in digital technology adoption[4,25], suggesting that additional factors may underlie these differences. The lack of a consistent pattern across studies suggests that sex-related differences should be interpreted cautiously and may partly reflect differences in professional exposure, training, workplace resources, or technology-specific experience rather than sex itself.

Differences in practice scores according to age and professional experience constitute another important finding. In the unadjusted analyses, practice scores tended to be higher among older and more experienced dentists. In the multivariable model, dentists aged 35–44 years and ≥ 45 years had significantly higher practice scores than those aged < 25 years. Previous studies have similarly reported a positive association between professional experience and digital technology utilisation[2,5]. However, adoption patterns appear to vary according to the technology assessed, suggesting that chronological age or years in practice alone may not adequately explain digital engagement[11,26]. This pattern may be associated with greater cumulative exposure to clinical technologies, greater purchasing capacity, or increased opportunities to incorporate digital systems into established workflows; however, these factors were not directly assessed in the present study.

Practice setting was significantly associated with both knowledge and practice levels. Dentists working in public hospitals demonstrated significantly lower knowledge scores than those in private practice, private clinics/corporate dental chains, and university hospitals, which did not differ significantly from one another. For practice scores, both public hospital and university hospital dentists scored significantly lower than those in private practice and private clinics/corporate dental chains, suggesting that differences in the conditions for translating digital knowledge into routine clinical use may exist across practice settings[4,6]. A study conducted in Hungary similarly reported that dentists in universities and private clinics demonstrated higher levels of digital workflow knowledge and utilisation compared with those in public institutions[27]. The higher practice levels observed in private-sector settings may be associated with greater investment capacity, easier access to digital infrastructure, and stronger incentives for technology adoption, although these potential explanatory factors were not directly measured in the present study. Importantly, in the multivariable analysis, employment in a private clinic/corporate dental chain remained positively associated with practice scores, whereas public hospital employment remained negatively associated with practice scores. However, given the unequal and relatively small sample sizes of some practice-setting subgroups, these findings should be interpreted cautiously and regarded as exploratory rather than as definitive evidence of differences between practice settings. Further studies directly assessing infrastructure, training opportunities, institutional support, and access to digital technologies are needed to clarify the factors underlying these differences.

Regarding specialty-based differences, restorative dentistry specialists demonstrated the highest knowledge scores, whereas prosthodontists exhibited the highest practice scores in the present sample. Given the relatively small and unequal numbers of participants across some specialty groups, these comparisons should be regarded as exploratory and interpreted with caution[28]. Surveys specifically examining CAD/CAM use have documented its incorporation into routine restorative and prosthodontic workflows, while studies in orthodontics have

similarly demonstrated growing use of intraoral scanners alongside continuing educational and technical challenges[12,26]. The expanding clinical use of 3D printing across dental disciplines further illustrates how adoption may differ according to the relevance of a particular technology to specialty-specific workflows[29]. Lower practice scores among pediatric dentists may be related to specialty-specific challenges in implementing digital technologies. Recent evidence in pediatric dentistry has highlighted barriers such as limited training, cost, and difficulties in integrating digital workflows into child-focused clinical care[30]. Nevertheless, because few studies have directly compared digital technology adoption across all dental specialties, the lower practice scores observed among pediatric dentists in the present sample should be interpreted cautiously rather than as evidence of systematically lower adoption within pediatric dentistry. In the multivariable analysis, restorative dentistry remained positively associated with knowledge scores, whereas oral and maxillofacial surgery was negatively associated with knowledge scores compared with participants without specialty training. Overall, the exploratory findings of the present study suggest potential variation in digital dentistry integration across specialties; however, larger and more balanced specialty-specific samples are needed to confirm these patterns.

Multivariable analyses further demonstrated that demographic and professional characteristics were more strongly associated with practice than with knowledge or attitudes. The practice model explained 57.7% of the variance, compared with 41.1% for knowledge and 26.1% for attitude. Collectively, the multivariable results demonstrate associations between several demographic and professional characteristics and digital dentistry practice. This interpretation is consistent with contemporary models of dental technology adoption, in which clinician characteristics, perceived benefits, training, resources, and the practice environment interact rather than acting as isolated determinants[13,24].

Several limitations should be acknowledged. The cross-sectional design precludes causal inference, and self-reported data may be subject to social desirability bias. The online recruitment method and voluntary participation may have introduced selection bias, particularly because dentists with greater interest in or familiarity with digital dentistry may have been more likely to participate. Moreover, the use of non-probability snowball sampling means that the study sample may not fully represent the overall population of dentists in Turkiye. Accordingly, the findings should be generalized to the broader dentist population with caution. In addition, some specialty- and practice-setting subgroups included relatively small and unequal numbers of participants, which may have limited the precision and generalisability of the subgroup findings. Accordingly, these subgroup comparisons should be regarded as exploratory and interpreted with caution rather than as definitive evidence of differences between specialties or practice settings. The study also did not directly assess the availability of or access to specific digital technologies within participants' workplaces. Therefore, differences in practice scores across practice settings may partly reflect differences in access to digital infrastructure rather than differences in knowledge or attitudes alone, and these findings should be interpreted with caution. Furthermore, the study assessed self-reported practices rather than objectively verified use of digital technologies, and therefore the reported practice scores may not fully reflect the actual use of these technologies in clinical practice. Strengths of the study include the inclusion of dentists from diverse specialties and practice settings, the application of multivariable analyses, and the use of the KAP framework for a comprehensive assessment. Future multicentre longitudinal studies should directly assess access to digital infrastructure, training opportunities, and institutional support to better understand the factors underlying differences in digital dentistry practice across healthcare settings.

Conclusions

Implementation of digital dentistry varied across professional and institutional settings in Turkiye. Although dentists generally demonstrated favourable attitudes towards digital technologies, lower practice levels among public hospital dentists were associated with practice setting; however, access to digital infrastructure was not directly assessed in this study. These findings highlight associations between individual and professional characteristics and the clinical use of digital technologies. Expanding practice-oriented education together with targeted investment in digital infrastructure may help support broader adoption of digital dentistry across different healthcare settings.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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References

1. Lam, W. Y. H. et al. Digital dentistry in clinical practice: a scoping review of current capabilities and future directions. *Int. Dent. J.* **76** (1), 109296 (2026).
2. Zhu, F. et al. Attitude, and practice regarding digital dental technologies among dentists in Jiangsu Province. *Healthcare (Basel).* **13** (3), 234 (2025).
3. Yousif, E. et al. A. 3D-printed patient-specific implants in maxillofacial reconstruction: a systematic review and meta-analysis of clinical outcomes and workflow efficiency. *Cureus* **17** (12), e98224 (2025).
4. Hall, M. A., Karawia, I., Mahmoud, A. Z. & Mohamed, O. S. Knowledge, awareness, and perception of digital dentistry among Egyptian dentists: a cross-sectional study. *BMC Oral Health.* **23** (1), 963 (2023).
5. Hatamleh, M. M., Saleh, S. A., Radwan, O. I. & Shamma, H. R. A. Adoption and challenges of digital dentistry among dentists and dental technicians: A cross-sectional study. *J. Prosthodont.* **34** (9), 913–917 (2025).
6. Radwan, H. A., Alsharif, A. T., Alsharif, M. T., Aloufi, M. R. & Alshammari, B. S. Digital technologies in dentistry in Saudi Arabia: Perceptions, practices and challenges. *Digit. Health.* **9**, 20552076231197095 (2023).

7. Sri, H., Maiti, S. & Sasanka, K. Knowledge, attitude, and practice of digital dentures among dentists. *J. Adv. Pharm. Technol. Res.* **13** (Suppl 2), S519–S524 (2022).
8. Schwendicke, F., Samek, W. & Krois, J. Artificial intelligence in dentistry: chances and challenges. *J. Dent. Res.* **99** (7), 769–774 (2020).
9. Mühlemann, S., Sandrini, G., Ioannidis, A., Jung, R. E. & Hämmerle, C. H. F. The use of digital technologies in dental practices in Switzerland: a cross-sectional survey. *Swiss Dent. J.* **129** (9), 700–707 (2019).
10. Abdulaı, D. & Suradı, R. Assessment of dental student's knowledge and attitudes toward digital dentistry. *Eurasian Dent. Res.* **3** (3), 63–68 (2025).
11. van der Zande, M. M., Gorter, R. C., Aartman, I. H. & Wismeijer, D. Adoption and use of digital technologies among general dental practitioners in the Netherlands. *PloS ONE.* **10** (3), e0120725 (2015).
12. Nassani, M. Z. et al. A Survey of dentists' perception of chair-side CAD/CAM technology. *Healthcare (Basel).* **9** (1), 68 (2021).
13. Barnawi, N. A. et al. Dentists' perception and use of AI and robotics in the care of persons with disabilities. *Sci. Rep.* **15** (1), 27551 (2025).
14. Bhatnagar, S., Pai Khot, A. J., Dhokar, A., Juvekar, T. C. & Desai, V. B. Knowledge, attitude, and practice of digital dentistry among dentists in rural and urban clinical settings in Western India: a descriptive cross-sectional study. *Front. Oral Health.* **7**, 1800833 (2026).
15. Schnitzler, C. & Bohnet-Joschko, S. Technology readiness drives digital adoption in dentistry: insights from a cross-sectional study. *Healthcare (Basel).* **13** (10), 1155 (2025).
16. van der Zande, M. M., Gorter, R. C. & Wismeijer, D. Dental practitioners and a digital future: an initial exploration of barriers and incentives to adopting digital technologies. *Br. Dent. J.* **215** (11), E21 (2013).
17. Alnafaiy, S. M. et al. Digital technology implementation in prosthodontics postgraduate programs in Saudi Arabia: a multi-institutional survey of program directors. *BMC Oral Health.* **24** (1), 1136 (2024).
18. Shin, Y. J. et al. Perceptions of benefits, barriers, and educational strategies for digital dentistry in Southeast Asia: A multi-country cross-Sectional pilot survey. *Community Dent. Health.* **43** (2), 152–159 (2026).
19. Emami, E., Kengne Talla, P., Inquimbert, C. & Giraudeau, N. Facilitators of and Barriers to Global Digital Oral Health: Mixed Methods Study. *J. Med. Internet Res.* **28**, e76236 (2026).
20. Al-Ibrahim, I. K., Madfa, A. A., Alotaibi, A. H. & Alshammari, A. S. Knowledge and experience of Saudi dental practitioners with intraoral scanners. *Open Dentistry J.* **19**(1) (2025).
21. Davis, F. D. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Q.* 319–340 (1989).
22. Launiala, A. How much can a KAP survey tell us about people's knowledge, attitudes and practices? Some observations from medical anthropology research on malaria in pregnancy in Malawi. *Anthropol. Matters* **11**(1) (2009).
23. Acharya, A., Chodankar, R. N., Patil, R. & Patil, A. G. Assessment of knowledge, awareness, and practices toward the use of 3D printing in dentistry among dental practitioners and dental technicians: A cross-sectional study. *J. Oral Biol. Craniofac. Res.* **13** (2), 253–258 (2023).
24. Matthews, D. C. et al. Factors influencing adoption of new technologies into dental practice: A qualitative study. *JDR Clin. Trans. Res.* **1**, 77–85 (2016).
25. Afshar, M. K., Afshar, M. K., Elmamooz, N. & Ahmadi, A. G. Assessment of knowledge and attitudes toward digital dentistry among final-year dental students in Southeast Iran: a cross-sectional study. *Pesqui Bras. Odontopediatria Clin. Integr.* **26**, e250016 (2026).
26. Krastev, T. et al. The Utilisation of CAD/CAM technology amongst Austrian dentists: a pilot study. *Int. Dent. J.* **73** (3), 430–434 (2023).
27. Németh, O., Uhrin, E., Girasek, E., Boros, J. & Győrffy, Z. The impact of digital healthcare and teledentistry on dentistry in the 21st Century: a survey of Hungarian dentists. *BMC oral health.* **23** (1), 1025 (2023).
28. Mangano, F., Shibli, J. A. & Fortin, T. Digital dentistry: new materials and techniques. *Int. J. Dent.* **2016** 5261247 (2016).
29. Hegedüs, T. et al. User experience of 3D printing in dentistry: A transnational questionnaire survey. *J. Dent.* **163**, 106200 (2025).
30. Qamar, Z. et al. Knowledge, attitude and practice (KAP) of dentists regarding the use of digital workflow in pedo-prosthetic rehabilitation: a comparative study across three countries. *J. Clin. Pediatr. Dent.* **50** (2), 58–66 (2026).

Author contributions

G.D. and N.K.D. conceptualized and designed the study and determined the methodology. N.K.D. performed the data curation. G.D. and N.K.D. interpreted the data and drafted the original manuscript. B.K. supervised the study and critically revised the manuscript. All authors read and approved the final version of the manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

Ethical approval for the study was obtained from the Clinical Research Ethics Committee of Marmara University Faculty of Dentistry (Protocol No: 2025-67). All procedures were performed in accordance with the Declaration of Helsinki. All participants were informed about the purpose of the study. Electronic informed consent was obtained from all participants prior to completing the questionnaire.

Additional information

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