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Knowledge, awareness, and practices of digital prosthodontic technologies among dental professionals in the Southern Region of Saudi Arabia

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Abstract

INTRODUCTION. Workflows in prosthodontics have been revolutionized by digital technologies, such as computer-aided design / computer-aided manufacturing (CAD / CAM), intraoral scanners, and three-dimensional printing (3D). However, a persistent gap between awareness and adoption persists primarily because of financial and educational barriers. Evidence on digital prosthodontics is scarce in the Southern region of Saudi Arabia, where digital health is a national priority under Vision 2030.

PURPOSE. This study assessed the knowledge, awareness, and practices (KAP) of digital prosthodontics in dental professionals in Saudi Arabia and compared general dentists and specialists in terms of their adoption of these technologies.

MATERIALS AND METHODS. A cross-sectional online survey was conducted from May to August 2025 with a validated self-administered questionnaire. Eligible participants included interns, general dentists, specialists, and faculty members across public, private, and academic sectors in the Southern region of Saudi Arabia. Data were analyzed using descriptive statistics and Pearson's chi-square test, and associations between professional level and KAP outcomes were assessed. A p -value of < 0.05 was considered significant.

RESULTS. A total of 204 dental professionals participated; most were younger than 25 years (51.0%) and affiliated with universities or academic institutions (79.9%). Awareness of specific digital technologies was high for CBCT-based implant planning (89.7%), CAD/CAM systems (88.2%), and intraoral scanners (88.2%). However, knowledge of integrated workflows was moderate, with 54.4% reporting some knowledge and 55.4% unable to identify complete workflow components. Clinical adoption remained limited, with only 25.5% reporting use of digital prosthodontic technologies in practice. The main barriers were high initial cost (65.7%) and lack of training or skills (56.9%). Specialists demonstrated significantly higher awareness, knowledge, confidence, and adoption than general dentists ($p < 0.001$ for key comparisons). Most participants expressed interest in structured training (79.9%) and supported curricular integration (72.1%).

CONCLUSION. Dental professionals in the Southern Region of Saudi Arabia showed high awareness of common digital prosthodontic technologies but only moderate workflow knowledge, with adoption remaining limited and specialist-driven. High costs and insufficient training were the main barriers, highlighting the need for competency-based education, accessible continuing professional development, and institutional support to strengthen digital readiness, expand implementation, and align prosthodontic practice with national digital health priorities and international standards.

CLINICAL SIGNIFICANCE. Addressing the gap between awareness and clinical adoption of digital prosthodontics is essential for modernizing prosthodontic practice. Expanding competency-based training, improving access to digital technologies, and reducing cost-related barriers may enhance workflow efficiency, patient-centered care, and equitable access to digital prosthodontic services beyond specialist settings.

Keywords: adoption barriers, CAD/CAM, dental education, digital prosthodontics, digital workflows, Intraoral scanners

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Знания, осведомленность и практика применения цифровых технологий в ортопедической стоматологии среди стоматологов Южного региона Саудовской Аравии

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Резюме

ВВЕДЕНИЕ. Цифровые технологии, такие как системы автоматизированного проектирования и автоматизированного изготовления (CAD / CAM), интраоральные сканеры и 3D-печать, произвели революцию в рабочих процессах ортопедической стоматологии. Однако сохраняется значительный разрыв между осведомленностью о цифровых технологиях и их практическим внедрением, что преимущественно обусловлено финансовыми и образовательными барьерами. Данные о применении цифровых технологий в ортопедической стоматологии в Южном регионе Саудовской Аравии ограничены, несмотря на то что цифровое здравоохранение является одним из национальных приоритетов в рамках программы Vision 2030.

ЦЕЛЬ. Целью настоящего исследования являлась оценка знаний, осведомленности и практики применения цифровых технологий в ортопедической стоматологии среди специалистов стоматологического профиля в Саудовской Аравии, а также сравнение врачей-стоматологов общей практики и специалистов по уровню внедрения данных технологий.

МАТЕРИАЛЫ И МЕТОДЫ. С мая по август 2025 г. было проведено поперечное онлайн-исследование с использованием валидированного вопросника для самостоятельного заполнения. В исследование включали врачей-интернов, врачей-стоматологов общей практики, специалистов и преподавателей, работающих в государственных и частных учреждениях, а также в академическом секторе Южного региона Саудовской Аравии. Анализ данных проводили с использованием методов описательной статистики и критерия χ^2 Пирсона; оценивали взаимосвязи между профессиональным уровнем участников и показателями знаний, осведомленности и практического применения цифровых технологий. Статистически значимыми считали различия при $p < 0,05$.

РЕЗУЛЬТАТЫ. В исследовании приняли участие 204 специалиста стоматологического профиля; большинство участников были моложе 25 лет (51,0 %) и представляли университеты или академические учреждения (79,9 %). Высокий уровень осведомленности был отмечен в отношении отдельных цифровых технологий, включая планирование имплантации на основе конусно-лучевой компьютерной томографии (89,7 %), системы CAD/CAM (88,2 %) и интраоральные сканеры (88,2 %). Вместе с тем знания об интегрированных цифровых рабочих процессах были умеренными: 54,4 % участников сообщили о наличии определенных знаний, а 55,4 % не смогли определить компоненты полного цифрового рабочего процесса. Практическое применение цифровых технологий в ортопедической стоматологии оставалось ограниченным: только 25,5 % участников сообщили об их использовании в клинической практике. Основными препятствиями являлись высокая первоначальная стоимость оборудования и программного обеспечения (65,7 %), а также недостаток обучения и практических навыков (56,9 %). Специалисты продемонстрировали статистически значимо более высокий уровень осведомленности, знаний, уверенности и практического применения цифровых технологий по сравнению с врачами общей практики (для ключевых сравнений $p < 0,001$). Большинство участников выразили заинтересованность в структурированных программах обучения (79,9 %) и поддержали интеграцию цифровых технологий в образовательные программы (72,1 %).

ЗАКЛЮЧЕНИЕ. Специалисты стоматологического профиля Южного региона Саудовской Аравии продемонстрировали высокий уровень осведомленности о распространенных цифровых технологиях в ортопедической стоматологии, однако знания об интегрированных рабочих процессах оставались умеренными, а практическое внедрение технологий – ограниченным и преимущественно характерным для специалистов. Основными барьерами являлись высокая стоимость и недостаток обучения, что подчеркивает необходимость компетентностно-ориентированного образования, доступных программ непрерывного профессионального развития и институциональной поддержки. Реализация этих мер позволит повысить уровень цифровой готовности специалистов, расширить внедрение цифровых технологий и обеспечить соответствие ортопедической стоматологической практики национальным приоритетам цифрового здравоохранения и международным стандартам.

КЛИНИЧЕСКАЯ ЗНАЧИМОСТЬ. Устранение разрыва между осведомленностью и практическим внедрением цифровых технологий в ортопедической стоматологии имеет важное значение для модернизации клинической практики. Расширение компетентностно-ориентированного обучения, повышение доступности цифровых технологий и снижение финансовых барьеров могут способствовать повышению эффективности рабочих процессов, развитию пациент-ориентированного подхода и обеспечению более равного доступа к цифровым услугам в ортопедической стоматологии, в том числе за пределами специализированных учреждений.

Ключевые слова: барьеры внедрения, CAD/CAM, стоматологическое образование, цифровая ортопедическая стоматология, цифровые рабочие процессы, интраоральные сканеры.

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INTRODUCTION

Modern dental practice has been revolutionized by digital technologies, which have altered the processes of diagnosis, treatment planning, and restoration fabrication [1]. Prosthodontics is a field focused on restoring oral function, aesthetics, and health in patients with missing or deficient teeth and maxillofacial structures [2]. Advancements in prosthodontics have considerably enhanced precision, efficiency, and patient-centered outcomes, and digital workflows are increasingly recognized as essential to contemporary prosthodontic care [3].

Computer-aided design/computer-aided manufacturing (CAD/CAM), intraoral scanners (IOSs), cone-beam computed tomography (CBCT), and three-dimensional (3D) printing are among the digital tools that have gradually replaced traditional analog methods. Collectively, these technologies improve the accuracy and reproducibility of fixed, removable, and implant prosthodontics. Additionally, applications such as virtual articulators and digital occlusal analysis expand the diagnostic and treatment planning capabilities [4–7]. These innovations are widely recognized for their ability to enhance workflow efficiency and patient outcomes [8; 9].

However, a persistent gap between awareness of digital technologies and their integration into routine clinical practice persists despite these advancements. Surveys conducted across different countries consistently indicate that despite the strong willingness of most clinicians to adopt digital approaches, obstacles, such as the high cost of equipment, steep learning curves, and absence of standardized training continue to exist [10–13]. These findings suggest that clinicians are amenable to innovation. However, the likelihood of widespread adoption is limited by educational and systemic constraints. This challenge is especially pertinent in Saudi Arabia, where digital health has been regarded as a strategic priority in the modernization of healthcare delivery under Vision 2030 [14; 15].

However, the adoption of digital dentistry remains limited, practitioners and faculty members responsible for clinical instruction have inequitable access to advanced technologies and limited opportunities for practical training [16; 17]. Collectively, these observations indicate that the integration of digital dentistry in Saudi Arabia is hampered by persistent structural barriers, such as insufficient institutional investment and inadequate hands-on exposure.

Furthermore, existing Saudi studies frequently conduct preliminary examination of digital dentistry or focus on isolated technologies, such as CAD/CAM or IOSs, rather than assessing the integration of digital tools within prosthodontic workflows [18; 19]. This

narrow scope results in a critical evidence gap: the specific manner in which dental professionals in Saudi Arabia interact with digital prosthodontics in the fixed, removable, and implant subspecialties and the extent to which adoption is influenced by role, experience, and practice setting. Efforts to reform curricula, expand professional training, and design supportive policies are at risk of being fragmented or poorly targeted in the absence of such evidence.

Therefore, this study aimed to assess awareness, knowledge, and practice related to digital prosthodontics among dental professionals in the Southern Region of Saudi Arabia. It also compared general dentists and specialists across these domains to identify differences in familiarity, understanding, clinical adoption, perceived barriers, and training needs.

MATERIALS AND METHODS

Study Design, Setting, and Ethical Approval

A structured self-administered online questionnaire was employed in this cross-sectional analytical study to assess the clinical practices, knowledge, and awareness of digital prosthodontics in dental professionals in the southern region of Saudi Arabia. The study adhered to the STROBE guidelines for observational research [20]. All responses were password protected, anonymized, and processed in accordance with the Declaration of Helsinki [21]. The study protocol was reviewed and approved by the Institutional Research Ethics Committee of the College of Dentistry, Najran University (R: 202602-076-042752-093124) on 17 March 2026.

Eligible participants included interns, general dentists, prosthodontists, and other specialists across public, private, and academic sectors. Undergraduate students who had not yet commenced their internship were excluded. Participation was voluntary, and electronic informed consent was obtained before access to the survey.

Sample Size and Power Calculation

The Saudi Commission for Health Specialties reported that the number of dentists in the Southern region of Saudi Arabia in 2023 was approximately 43,000 [22]. The Raosoft calculator (Raosoft, Inc., Seattle, WA, USA), indicated that a minimum sample size of 381 was required to achieve a 95% confidence interval and 5% margin of error. A total of 228 responses were collected, and 24 were excluded because of incompleteness or inconsistency, yielding 204 valid responses. The margin of error was 6.85%. Although exceeding the standard 5%, it was considered acceptable for exploratory cross-sectional surveys in dentistry. The attained sample size offers adequate statistical power to identify medium effect sizes.

Participants and Recruitment

A non-probability convenience sampling method was employed. The survey link was distributed through professional dental networks, academic institutions, and social media platforms (e.g., WhatsApp, Twitter/X, Telegram, and Facebook) to ensure broad reach across diverse practice settings. This approach has been widely used in exploratory surveys of healthcare professionals in the absence of a probability-based framework [10; 19]. Data were collected anonymously from May to August 2025 utilizing Google Forms.

Survey Instrument Development and Validation

The questionnaire was derived from previously validated instruments on digital dentistry adoption [10–13; 16; 18; 19] and tailored to emphasize prosthodontics. Content validity was evaluated by a panel comprising two prosthodontics faculty members and one health education specialist, who assessed each item for clarity, relevance, and necessity using a 4-point Likert scale. The recommended thresholds for the Content Validity Index were achieved ($I-CVI \geq 0.78$; $S-CVI/Ave \geq 0.80$) [23]. A pilot study involving 30 dental practitioners, including interns, general dentists, and specialists, was conducted to assess questionnaire clarity, comprehensibility, flow, and completion time. Minor modifications were made based on participant feedback. The final instrument demonstrated good internal consistency, with a Cronbach's alpha of 0.8 [24]. Formal construct validity testing was not performed because the questionnaire was adapted from previously validated instruments and intended for exploratory assessment.

Questionnaire Parts

To address the multicultural and diverse academic backgrounds of Saudi Arabia's dental workforce, the structured questionnaire was developed in English and comprised 26 items distributed across four domains. The **first** domain included **6 demographic and professional items** covering age, gender, qualifications, clinical experience, specialty, and practice setting.

The **second** domain consisted of 3 **awareness** items, defined as participants' recognition of digital prosthodontics and familiarity with specific digital technologies. Questions assessed awareness of digital prosthodontics, familiarity with digital technologies, and sources of information. The **third** domain included 8 **knowledge** items, defined as participants' understanding of digital prosthodontic workflows, clinical applications, and benefits. Questions addressed workflow components, CAD/CAM-fabricable prostheses, advantages of intraoral scanners, applications of 3D printing, implant planning tools, digital denture workflows, and virtual articulators. The **fourth** domain comprised 9 **practice** items, defined as the self-reported clinical use and implementation of digital prosthodontic technologies. Questions evaluated technology utilization, clinical indications, duration of use, confidence levels, perceived barriers, training preferences, and opinions regarding curricular integration.

Data Management and Statistical Analysis

All collected data were coded, entered into Microsoft Excel, and analyzed using IBM SPSS Statistics (version 25.0; IBM Corp., Armonk, NY, USA). Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize demographic and professional characteristics, as well as responses related to knowledge, awareness, and practice of digital prosthodontics. For comparative analysis, dental students were grouped with general dentists under the "general dentistry" category. Associations between categorical variables (e.g., professional level and knowledge, awareness, and practice parameters) were assessed using Pearson's Chi-square (χ^2) test. For questions allowing multiple responses, Chi-square analysis was not performed. A $p < 0.05$ was considered statistically significant, while $p < 0.001$ were regarded as highly significant. All graphical representations were generated using Microsoft Excel to ensure clarity of data presentation.

RESULTS

The survey included 204 dental professionals and students from diverse academic and clinical backgrounds. The findings are presented according to awareness, knowledge, and practice of digital prosthodontics and their associations with professional level. Percentages describe response distributions, and statistically significant associations ($p < 0.05$) are highlighted. The study population was predominantly young (< 25 years, 51.0%), with a higher proportion of females (53.4%) than males. Nearly half of the participants reported less than one year of clinical experience (47.5%), reflecting the inclusion of undergraduate students, while early-career practitioners were represented in the 1–5-year category. Over half (52.0%) held a basic dental degree (BDS/DDS), and specialists constituted 40.7% of the sample. Universities and academic institutions were the most common practice settings (79.9%) (Table 1).

More than half of the participants (57.8%) were aware of the term digital prosthodontics. Awareness of specific digital technologies was generally high, particularly CBCT-based implant planning (89.7%), CAD/CAM systems (88.2%), and intraoral scanners (88.2%). Awareness was lower for guided surgery systems (64.2%), 3D printing/additive manufacturing (56.9%), digital dentures (51.5%), virtual articulators (49.0%), and digital occlusal analysis (36.3%). Knowledge was most commonly acquired through undergraduate training (24.5%), self-study or colleagues (22.5%), online courses and social media (17.2%), and continuing education activities (16.7%) (Table 1). Specialists were significantly more likely than general practitioners to report awareness of digital prosthodontics (91.6% vs. 34.7%, $p < 0.001$). In addition, specialists more frequently identified postgraduate studies and continuing education activities as their primary sources of knowledge, whereas general practitioners more commonly reported undergraduate training and self-directed learning ($p < 0.001$) (Table 2).

Table 1. Demographic and professional characteristics of study participants ($n = 204$)

Characteristics	Variable	<i>n</i>	%
Age	< 25	104	51.0
	25–34	24	11.8
	35–44	54	26.5
	45–54	18	8.8
	55	4	2.0
Gender	Male	95	46.6
	Female	109	53.4
Clinical Experience	< 1 year	97	47.5
	1–5 years	24	11.8
	6–10 years	31	15.2
	11–15 years	34	16.7
	> 15 years	18	8.8
Highest qualification	Student	10	4.9
	BDS/DDS	106	52.0
	Master's	9	4.4
	Board-certified specialist	59	28.9
	PhD	20	9.8
Practice Settings (Multiple Choices) [†]	Government clinic	41	20.1
	Hospital dental unit	31	15.2
	Private practice	63	30.9
	University/academic institution	163	79.9
Specialty	Student	10	4.9
	General Dentist	111	54.4
	Specialist	83	40.7

Note. [†] Multiple-response question, so the total percentages may exceed 100%.

Knowledge of digital prosthodontics was moderate, with 54.4% of participants reporting some knowledge of digital technologies. However, understanding of complete digital workflows remained limited, as more than half of the respondents (55.4%) were unable to identify their components. Among workflow elements, 3D printing/milling machines (38.7%) and intraoral scanners (38.2%) were the most frequently recognized. Porcelain veneers (67.2%) and surgical guides (56.4%) were the most commonly identified prostheses that can be fabricated using CAD/CAM systems. Reduced chairside time (46.6%) was the most frequently recognized advantage of intraoral scanners, while fabrication of implant surgical guides (44.6%) was the most commonly identified application of 3D printing. Knowledge of virtual articulators was limited, with 44.1% of participants selecting “I don't know”. Specialists were significantly more likely than general practitioners to report having knowledge of digital prosthodontic technologies (80.7% vs. 36.4%, $p < 0.001$). Significant associations with professional level were also observed for knowledge of the advantages of intraoral scanners, applications of 3D printing, the role of virtual articulators, implant planning tools, and the benefits of digital denture workflows (all $p < 0.001$) (Table 3).

Despite moderate awareness and knowledge, only 25.5% of participants reported using digital prosthodontic technologies in clinical practice. Among the available technologies, 3D printing (78.9%), CAD/CAM systems (65.7%), CBCT-guided implant planning (58.8%), and intraoral scanners (48.5%) were the most commonly reported. Crown and bridge restorations (63.7%), surgical guide fabrication (60.8%), and implant-supported prostheses (58.8%) were the principal clinical applications.

Table 2. Awareness of digital prosthodontics and sources of information by professional level (Chi-square Test)

Questions	Answers	<i>n</i> (%)	General dentistry (<i>n</i> = 121)	Specialist (<i>n</i> = 83)	χ^2	<i>p</i>
Are you aware of the term digital prosthodontics?	Yes	118 (57.8)	42	76	65.3	<0.001*
	No	86 (42.2)	79	7		
Which of the following digital technologies are you aware of in prosthodontics? (Multiple Choices) [†]	Intraoral scanners (IOS)	180 (88.2)	Not calculated			
	CAD/CAM systems	180 (88.2)				
	3D printing/additive manufacturing	116 (56.9)				
	Digital dentures	105 (51.5)				
	Virtual articulators	100 (49.0)				
	CBCT-based implant planning	183 (89.7)				
	Guided surgery systems	131 (64.2)				
	Digital occlusal analysis	74 (36.3)				
Where did you gain most of your knowledge about digital prosthodontics?	Undergraduate training	50 (24.5)	47	3	105	<0.001*
	Postgraduate studies	29 (14.2)	5	24		
	Self-study/colleagues	46 (22.5)	41	5		
	Continuing education (workshops/conferences)	34 (16.7)	5	29		
	Online courses/social media	35 (17.2)	13	22		
	I don't have any knowledge	10 (4.9)	10	0		

Note. [†] Multiple-response question, so the total percentages may exceed 100%; χ^2 not calculated; * Statistically significant.

Most participants reported 1–3 years of experience with digital tools (64.2%) and rated their confidence as moderate (score 3; 50.0%). The most frequently reported barriers were high initial cost (65.7%) and lack of training or skills (56.9%). Nevertheless, most participants expressed interest in structured training (79.9%) and supported the integration of digital prosthodontics into dental curricula (72.1%). Significant as-

sociations with professional level were observed for the use of digital prosthodontic technologies, duration of use, confidence in using digital tools, interest in structured training, and support for curricular integration (all $p < 0.05$). Specialists reported substantially greater adoption of digital prosthodontic technologies and higher levels of confidence than general practitioners (all $p < 0.001$) (Table 4).

Table 3. Knowledge of digital prosthodontic workflows, applications, and benefits by professional level (Chi-square test)

Questions	Answers	n (%)	General dentistry (n = 121)	Specialist (n = 83)	χ ²	p
Do you have any knowledge of digital prosthodontic technologies?	Yes, I have some knowledge	111 (54.4)	44	67	39.1	<0.001*
	No, I don't have knowledge	93 (45.6)	77	16		
Which of the following technologies are components of a complete digital prosthodontic workflow? (Multiple Choices)†	Intraoral scanner (IOS)	78 (38.2)	Not calculated			
	CAD software	45 (22.1)				
	3D printing/milling machine	79 (38.7)				
	Articulating paper	15 (7.4)				
	I don't know	113 (55.4)				
Which of the following prostheses can be fabricated using CAD/CAM systems? (Multiple Choices)†	Complete dentures	88 (43.1)	Not calculated			
	Metal-ceramic crowns	73 (35.8)				
	Porcelain veneers	137 (67.2)				
	Surgical guides	115 (56.4)				
	Space maintainers	13 (6.4)				
	I don't know	38 (18.6)				
What are the main advantages of using intraoral scanners compared to conventional impressions?	Improved patient comfort	36 (17.6)	4	32	93.3	<0.001*
	Improved soft tissue recording	14 (6.9)	9	5		
	Real-time visualization	21 (10.3)	0	21		
	Reduced chairside time	95 (46.6)	74	21		
	I don't know	38 (18.6)	34	4		
What are typical clinical applications of 3D printing in prosthodontics?	Fabrication of full metal crowns	5 (2.5)	0	5	44.0	<0.001*
	Fabrication of implant surgical guides	91 (44.6)	47	44		
	Printing custom trays	9 (4.4)	0	9		
	Printing of diagnostic wax-ups	18 (8.8)	8	10		
	Provisional restorations	14 (6.9)	14	0		
	Real-time occlusal correction	8 (3.9)	5	3		
	I don't know	59 (28.9)	47	12		
What is the role of virtual articulators in prosthodontics?	Predicting occlusal interferences	32 (15.7)	15	17	16.7	<0.001*
	Recording vertical dimension	5 (2.5)	5	0		
	Simulating mandibular movements	77 (37.7)	36	41		
	I don't know	90 (44.1)	65	25		
Which digital tools are most commonly used in implant planning and placement workflows?	CBCT imaging	89 (43.6)	41	48	37.6	<0.001*
	Guided surgery software	10 (4.9)	0	10		
	IOS for scanning edentulous arches	90 (44.1)	65	25		
	I don't know	15 (7.4)	15	0		
What are the main benefits of digital denture workflows compared to conventional methods?	Accurate recording of soft tissues in function	47 (23.0)	34	13	16.3	<0.001*
	Better reproducibility	40 (19.6)	25	15		
	Fewer clinical visits	53 (26.0)	31	22		
	Fully automated occlusal design	5 (2.5)	5	0		
	Real-time occlusion tracking	19 (9.3)	5	14		
	I don't know	40 (19.6)	21	19		

Note. † Multiple-response question, so the total percentages may exceed 100%; χ^2 not calculated; * Statistically significant.

Table 4. Practice of digital prosthodontics and perceived barriers by professional level (Chi-square test)

Questions	Answers	<i>n</i> (%)	General dentistry (<i>n</i> = 121)	Specialist (<i>n</i> = 83)	χ^2	<i>p</i>
Do you use any digital prosthodontic technologies in your clinical practice?	Yes	52 (25.5)	0	52	102	<0.001*
	No	152 (74.5)	121	31		
Which of these technologies do you currently use in your clinical practice? (Multiple Choices)†	Intraoral scanner (IOS)	99 (48.5)	Not calculated			
	CAD /CAM	134 (65.7)				
	3D printing	161 (78.9)				
	CBCT-guided implant planning	120 (58.8)				
	Digital denture workflows	34 (16.7)				
	Virtual articulator	46 (22.5)				
	Digital occlusal analysis	46 (22.5)				
If using any digital tools, for which indications? (Multiple Choices)†	Crown/bridge restorations	130 (63.7)	Not calculated			
	Complete dentures	74 (36.3)				
	Implant-supported prostheses	120 (58.8)				
	Surgical guide fabrication	124 (60.8)				
	Temporaries /provisional prostheses	112 (54.9)				
	Occlusal adjustments	53 (26.0)				
	Endodontics (guided)	9 (4.4)				
How long have you been using digital tools in your practice?	1–3 years	131 (64.2)	88	43	9.86	0.007*
	4–6 years	43 (21.1)	18	25		
	>6 years	30 (14.7)	15	15		
Please rate your confidence in using digital tools in prosthodontics	1	15 (7.4)	5	10	43.0	<0.001*
	2	18 (8.8)	10	8		
	3	102 (50.0)	82	20		
	4	64 (31.4)	24	40		
	5	5 (2.5)	0	5		
What are the main barriers you face in adopting digital prosthodontics? (Multiple Choices)†	High initial cost	134 (65.7)	Not calculated			
	Lack of training /skills	116 (56.9)				
	Lack of institutional support	46 (22.5)				
	Lack of awareness about benefits	32 (15.7)				
	Resistance from colleagues	23 (11.3)				
	Time constraints	39 (19.1)				
	Incompatibility with current workflows	25 (12.3)				
	Technology is too complex	33 (16.2)				
	No perceived advantage over traditional methods	13 (6.4)				
	I didn't use it	9 (4.4)				
Would you be interested in receiving structured training in digital prosthodontic tools?	Yes	163 (79.9)	91	72	6.18	0.046*
	No	6 (2.9)	6	0		
	Not sure	35 (17.2)	24	11		
Preferred method of training	In-person workshops	87 (42.6)	47	40	6.12	0.295
	Industry training sessions	5 (2.5)	5	0		
	Online courses	25 (12.3)	15	10		
	Self-paced learning /video tutorials	19 (9.3)	10	9		
	University-based CPD programs	49 (24.0)	33	16		
	None	19 (9.3)	11	8		
Do you believe digital prosthodontics should be fully integrated into dental curricula?	Yes	147 (72.1)	75	72	15.8	<0.001*
	No	5 (2.5)	5	0		
	Not sure	52 (25.5)	41	11		

Note. [†] Multiple-response question, so the total percentages may exceed 100%; χ^2 not calculated; * Statistically significant.

Overall, the findings indicate moderate awareness and knowledge of digital prosthodontics among participants, but limited clinical adoption. Specialists consistently demonstrated higher levels of awareness, knowledge, confidence, and utilization of digital technologies than general dentists, suggesting an important role for postgraduate education and professional training in facilitating adoption. High initial costs and insufficient training were the most frequently reported barriers, whereas strong interest in structured training programs and broad support for curricular integration highlight opportunities to enhance the implementation of digital prosthodontics in dental education and clinical practice.

DISCUSSION

This study provides regional evidence on awareness, knowledge, and clinical adoption of digital prosthodontics among dental professionals in the Southern Region of Saudi Arabia. The main finding was a clear awareness-to-practice gap: participants demonstrated high awareness of commonly used technologies, particularly CBCT-based implant planning, CAD/CAM systems, and intraoral scanners, yet clinical implementation remained limited. This pattern is consistent with previous Saudi and international studies indicating that digital transformation in dentistry depends not only on recognition of digital tools, but also on workflow competence, access to equipment, confidence, training, and institutional support [16–19; 25].

Although awareness of major digital technologies was high, knowledge of integrated digital prosthodontic workflows was only moderate. More than half of the participants were unable to identify the components of a complete digital workflow, and substantial uncertainty persisted regarding virtual articulators and implant-planning workflows. This distinction is important because digital prosthodontics requires more than familiarity with individual devices; it depends on understanding how intraoral scanning, CAD software, CAM or additive manufacturing, CBCT-based planning, virtual articulation, laboratory communication, and clinical verification are integrated into a complete treatment pathway [4; 6; 7]. Similar knowledge gaps have been reported in relation to advanced digital and computer-assisted dental technologies, supporting the need for structured training beyond basic exposure to digital tools [26; 27].

Despite relatively favorable awareness and moderate knowledge, only one-quarter of participants reported using digital prosthodontic technologies in clinical practice. This confirms that awareness alone is insufficient to ensure adoption. The most frequently reported barriers were high initial cost and lack of training or skills, followed by institutional and workflow-related limitations. These factors are interrelated: high equipment costs restrict access in undergraduate clinics, continuing education settings, and general practice environments, while limited access reduces hands-on exposure, clinical confidence, and readiness for implementation. Without structured educational pathways

and institutional investment, digital prosthodontics may remain concentrated in specialist, academic, or better-resourced settings [14; 16; 18; 19; 28].

Specialists demonstrated significantly higher awareness, knowledge, confidence, and adoption of digital prosthodontics than general dentists. This professional disparity likely reflects differences in postgraduate education, exposure to complex prosthodontic and implant cases, and access to advanced technologies. Specialists were more likely to understand the clinical benefits of intraoral scanners, applications of 3D printing, the role of virtual articulators, and digital implant-planning workflows, and they also reported higher levels of clinical use and confidence. Similar patterns have been reported in studies showing greater digital readiness and technology adoption among specialists, postgraduate trainees, faculty members, and clinicians working in more resource-supported environments [14; 18; 29; 30]. Therefore, the observed gap should be interpreted as a training and access disparity rather than simply a difference in willingness to adopt digital dentistry.

The strong interest in structured training and curricular integration represents one of the most actionable findings of this study. Most participants supported formal training and the integration of digital prosthodontics into dental curricula, indicating readiness for educational reform. Saudi dental education may therefore benefit from a competency-based model in which foundational skills in intraoral scanning, CAD/CAM principles, CBCT-based planning, 3D printing concepts, digital laboratory communication, and workflow design are introduced at the undergraduate level, followed by case-based training in guided implant planning, digital dentures, virtual articulation, digital occlusal analysis, and workflow troubleshooting during internship, postgraduate training, and continuing professional development [31–34]. From a policy perspective, wider implementation will require institutional strategies such as shared digital laboratories, university-based simulation centers, subsidized continuing education, and public-private partnerships to reduce cost-related barriers and expand access beyond specialist or tertiary-care settings [15; 28; 34].

Clinically, limited adoption of digital prosthodontics may restrict access to workflows that can improve efficiency, reproducibility, communication, and patient experience. Digital impressions and CAD/CAM restorations have demonstrated value in fixed prosthodontics, while digital denture workflows may improve reproducibility and reduce clinical adjustments [4; 8; 35–37]. Artificial intelligence represents an emerging extension of these workflows, with applications increasingly being explored in radiographic interpretation, implant planning, prosthesis design optimization, margin detection, shade selection, occlusal analysis, and workflow automation [38]. Although AI adoption was not directly assessed in this study, the observed gap between awareness and implementation is relevant to future AI integration. Dental curricula and continuing education programs should therefore include foundational

AI literacy, ethical considerations, data quality principles, and critical appraisal of AI-assisted decision-support systems to prevent AI from following the same pattern observed with other digital technologies.

STRENGTHS, LIMITATIONS, AND FUTURE DIRECTIONS

This study is among the early regional assessments of awareness, knowledge, and practice related to digital prosthodontics in the Southern Region of Saudi Arabia, with direct comparison between general dentists and specialists. The survey instrument was tested and validated, confirming its reliability. However, several limitations should be acknowledged. Convenience sampling and voluntary participation may have introduced selection bias, while reliance on self-reported data may be affected by recall or social desirability bias. The cross-sectional design also prevents causal inference. In addition, the predominance of younger participants and respondents affiliated with academic institutions may limit the generalizability of the findings to more experienced clinicians and those practicing primarily in private settings. The relatively small number of participants reporting clinical use of digital prosthodontic technologies also limited the feasibility of multivariable regression analysis to identify independent predictors of adoption. Future studies should include larger and more diverse samples across academic, public, and private sectors. Longitudinal research, objective skill-based assessments, and evaluations of curricular reforms, continuing education programs, institutional support, and cost-effectiveness would provide stronger evidence regarding strategies to improve digital prosthodontic adoption.

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CONCLUSION

Dental practitioners in the Southern Region of Saudi Arabia demonstrated high awareness of common digital prosthodontic technologies but only moderate knowledge of integrated workflows, with clinical adoption remaining limited and largely specialist-driven. High costs and insufficient training were the main barriers, while competency-based education, accessible continuing professional development, and institutional support may strengthen digital readiness, expand implementation, and align prosthodontic practice with national digital health priorities and international standards.

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AUTHOR'S CONTRIBUTION

The author contributed to the conception and design of the study, data collection, critical revision of the manuscript for important intellectual content, and final approval of the version to be published.

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