CAHIERS MAGELLANES-NS
Volume 06 Issue 2
2024

ISSN:1624-1940
http://magellanes.com/

KNOWLEDGE LEVEL OF DIGITAL DENTISTRY AMONG DENTISTS, DENTAL INTERNS, AND DENTAL STUDENTS IN SAUDI ARABIA

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Abstract

Background: The digitalization of general dentistry has significantly impacted numerous factors, including clinical considerations, student training, treatment options, patient motivation, laboratory procedures, practice administration, and dental research. As the popularity of 3D printing and Computer Aided. Designing/Computer Aided Manufacturing (CAD/CAM) technology has increased recently, obtaining dental students' and dentists' knowledge, and attitudes towards artificial intelligence in dentistry was important. The study aimed to assess the knowledge and awareness of digital dentistry among dentists, dental interns, and dental students in Saudi Arabia.

Methods: This study is a cross-sectional questionnaire survey in Saudi Arabia between July 2024 to November 2024. The study was recruit participants through an online survey. The inclusion criteria for this study were as follows: undergraduate dental students, dental interns, and dentists in Saudi Arabia and non-dental professionals were excluded from this study.

Results: The study results revealed varying levels of knowledge, awareness, and perception regarding digital dentistry. While 54% identified prosthodontics as the main field utilizing CAD/CAM technology, and a significant 77.7% recognized its effectiveness in fabricating various restorations, 57.1% exhibited a low overall knowledge of digital dentistry. Furthermore, though 50.7% reported using digital devices, satisfaction with CAD/CAM restorations was low, with only 27.5% expressing high satisfaction. A substantial majority (82.9%) advocated for increased educational emphasis on digital dentistry, and 90.5% wished to incorporate CAD/CAM technology into their practices.
Conclusion: Despite widespread recognition of the benefits of CAD/CAM technology and a strong desire to incorporate digital methods into practice, a significant portion of respondents demonstrated low knowledge levels and limited practical experience. High costs, inadequate training, and lingering reliance on traditional methods were identified as barriers to the effective implementation of digital dentistry.

ISSN:1624-1940
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Keywords: Awareness, Attitude, Digital Dentistry, CAD/CAM, Restorative Dentistry, Prosthodontics, Saudi Arabia

Introduction:

Digital dentistry (DD) has gained popularity in recent years and now plays a significant role in the evolution of dentistry. It increasingly contributes to stimulating innovation and enhancing student experiences in contemporary dental education [1]. The integration of computers into dental practice enables more precise, efficient, and rapid treatments for patients compared to traditional methods. Additionally, it enhances convenience by minimizing chairside time and the number of appointments, leading to more cost-effective treatments [2]. Furthermore, DD alleviates the workload for dentists and laboratory technicians, allowing for the treatment of a greater number of patients. Through oral scanning, DD data can be captured and stored within computer systems. Computer-aided design and computer-aided manufacturing (CAD/CAM) represent the most commonly utilized aspects of DD [3]. CEREC system (Chairside Economical Restoration of Esthetic Ceramic), the E4D DentistTM technology was released in 2008 which allows doing indirect dental prosthetic restorations in a single appointment [4-6]. Studies conducted in Saudi Arabia revealed that the vast majority of people (98.5%) thought digital dentistry would eventually replace traditional dental services and enhance the quality of dental procedures [7,8].
Research was done by Mahesh Suganna in 2024 to a diverse group of participants from the dental field. Nearly all participants (99.3%) said they were aware of digital technologies in dentistry. Many participants showed a positive attitude towards CAD/CAM technology and its advantages in time-saving and patient inflow. However, many participants have noted That high expenses, lack of knowledge, and a preference for conventional ways hurdle the adaptation [9,10]. A total of 178 individuals took part in a research study conducted in 2022. 73.6% of participants recognize that the CAD/CAM technology may be utilized in all areas of dentistry, whereas 23% are only aware of its application in prosthodontics. The vast majority of survey participants agreed that CAD/CAM manufactured restorations exceeded traditionally fabricated restorations. However, they have limited clinical knowledge and experience with CAD/CAM technology [11].
Although digital dentistry offers several benefits and conveniences, it is not widely used and integrated into everyday practice. Factors such as excessive equipment costs, inadequate training, unwillingness to shift from conventional ways, and perceived. The complexities of technology have been identified as impediments. This study seeks to evaluate digital dentistry knowledge and practices among undergraduate dental students, dental interns, and dentists in Saudi Arabia.
This study was designed to evaluate the knowledge and awareness of digital technology in dentistry among dentists, dental interns, and dental students in Saudi Arabia.

Materials and Methods:

Study design:

A cross-sectional study based on a structured questionnaire that was developed by authors, conducted between July 2024 and November 2024 in Saudi Arabia.

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Study setting: participants, recruitment, and sampling procedure:

An online survey was distributed among undergraduate dental students, dental interns, and dentists in Saudi Arabia.

Inclusion and Exclusion Criteria:

The study's inclusion criteria included Saudi Arabian dentists, dental interns, and dental students. This study excluded dental professionals, dental interns, dental students not from Saudi Arabia, and non-dental professionals.

Sample size:

From July 2024 to August 2024 was the beginning of data collecting. To determine the minimum number of responses required to provide a representative sample for the entire population. The sample size was calculated by using the Roasoft sample size calculator. Keeping an indicator percentage of 0.50, a margin of error of 5 %, and a confidence interval (CI) of 95%, the calculated sample size was 384.

Method for data collection and instrument (*Data collection Technique and Tools)*:

The survey tool was a self-administered anonymous questionnaire written in

English. This tool was created after studying relevant research performed in Saudi Arabia and elsewhere [6,11,12]. The final version of the questionnaire contained 20 questions divided into 3 primary sections. The initial section Begin with a brief summary of the study and the consent question. The subsequent section provided demographic information with Educational Qualification and Name of associated Institute. The third section posed questions about their knowledge and awareness regarding digital dentistry also with inclusion of questions regarding their Perception/Practice. Each question is expected to take 10 seconds, with a total time of approximately 5 minutes.

Scoring system:

The perception, awareness and level of knowledge of the participants… along with personal questions were evaluated using a total of (23) statements. (10) reports related to knowledge, (6) to awareness, (7) reports related to perception. (6) additional questions about demography.

Correct responses receive one point, while erroneous answers or "I don't know" receive zero points. We applied Likert scales (Dichotomous, Three-Point, and
Quality Scales) for scoring. The (50) point maximum score was split as follows:

The participants' results were determining their placement into three groups: 80.0%– 100.0%, 60.0%–79%, and 59.0%, which were the original Bloom's cut-off points.

Participants' knowledge was assessed using (10) questions with scores ranging from (23) points. Participants with scores (18 or more) were considered to have a **high level of knowledge**, those with scores ranging from (16-17) as having a **moderate level of knowledge**, and those with scores ranging from (15 or less) as a **low level of knowledge**.

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Participants' Awareness was assessed using (6) questions with scores ranging from (27) points. Participants with scores (21 or more) were considered to have a **high level of Awareness**, those with scores ranging from (19-20) as having a **moderate level of Awareness**, and those with scores ranging from (18 or less) as a **low level of Awareness**. Participants' perceptions and practices were assessed using (6) questions and these questions are out of scoring.

Pilot test:

The questionnaire was distributed to 20 individuals and asked to fill it out. This was done to test the simplicity of the questionnaire and the feasibility of the study. Data from the pilot study was excluded from the final data of the study.

Analyzes and entry method:

Data was entered on the computer using the "Microsoft Office Excel Software" program (2016) for Windows. Data was then transferred to the Statistical Package of Social Science Software (SPSS) program, version 20 (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.) to be statistically analyzed.

Results:

Table (1) illustrates various demographic information of the participants, a total of 844. The average age of the participants is 24.8 years, indicating a youthful demographic, with a significant proportion (56.4%) under the age of 25. Gender distribution is relatively balanced, with a slight female majority at 50.7%. Geographically, a predominant majority (56.9%) hail from the Southern region, suggesting a possible regional concentration in the data. Educationally, most participants are dental students (55.9%) or general dentists (27.5%), with a striking 75.6% having less than five years of practice, reflecting a relatively novice workforce in the field. Additionally, the overwhelming majority (79.4%) work in the governmental sector, highlighting the sector's significance in the employment landscape for dental professionals.

Table (1): Sociodemographic characteristics of participants (n=844)

Parameter		***No.***	***Percent (%)***
Age ***(Mean: 24.8, STD:4.7)***	less than 23	212	25.1
	23 to 24	264	31.3
	24 to 26	220	26.1
	more than 26	148	17.5
Gender	Female	428	50.7
	Male	416	49.3
Residential area	Northern region	70	8.3
	Southern region	480	56.9

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	Center region	70	8.3
	Eastern region	58	6.9
	Western region	166	19.7
Educational Qualification	Dental Student	472	55.9
	Dental Interns	98	11.6
	General Dentist	232	27.5
	Specialist	22	2.6
	Consultant	20	2.4
How long have you been practicing dentistry?	Less than Five years	638	75.6
	5-10 years	164	19.4
	11-15 years	16	1.9
	More than 15 years	26	3.1
Where are you Studying or Working?	Governmental Sector	670	79.4
	Private sector	174	20.6

As shown in figure 1, The provided figure illustrates the diverse applicability of CAD/CAM technology across various branches of dentistry. Notably, Prosthodontics / Restorative emerges as the primary area of utilization, with 456 instances recorded, accounting for approximately 61% of the total responses. In contrast, Orthodontics and Endodontics show significantly lower engagement rates at 20 and 14 instances respectively, representing merely 2.6% and 1.8% of the total. Interestingly, a significant proportion of respondents, 354 (approximately 46.5%), indicated that CAD/CAM can be employed across all the mentioned fields, highlighting a broad recognition of its versatility. This data underscores the predominant role of CAD/CAM in Prosthodontics while also pointing to opportunities for increased adoption in Orthodontics and Endodontics.

Figure (1): Illustrates where CAD/CAM can be used in dentistry among participants

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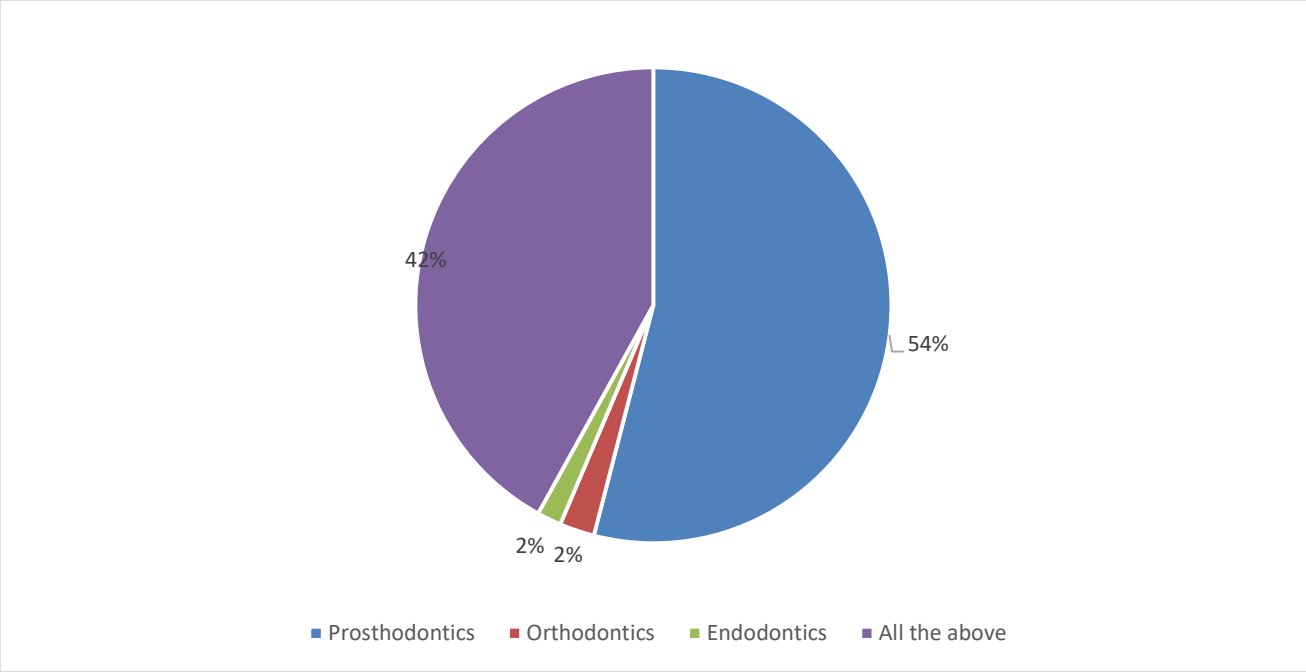

As illustrated in table (2), The data provides insight into the knowledge of digital dentistry among a sample of 844 dentists, highlighting their familiarity with CAD/CAM technologies and their applications within various dental specialties. Notably, a significant proportion of respondents (54.0%) recognized prosthodontics as the primary branch utilizing CAD/CAM, while a smaller fraction identified orthodontics and endodontics. The effectiveness of CAD/CAM systems is underscored by the overwhelming consensus (77.7%) on their application in fabricating crowns, bridges, inlays, veneers, and dentures. Furthermore, the understanding of the CAD/CAM process appears robust, with 78.4% acknowledging the complete workflow, indicating a solid comprehension of scanning, designing, and milling phases. The preference for zirconia as the primary material in crown preparations is evident, with 30.3% of participants selecting it, although 56.2% acknowledged the varied materials used in CAD/CAM systems. While many dentists recognized the advantages of CAD/CAM, such as reduced appointments and increased precision, awareness of potential drawbacks, particularly the need for extensive training and high equipment costs, varied. Overall, this data suggests a commendable level of awareness surrounding digital dentistry.

Table (2): Parameters related to knowledge of digital dentistry among dentists (n=844).

Parameter		***No.***	***Percent (%)***
CAD/CAM can be used in which branches of dentistry?	Prosthodontics	456	54.0
	Orthodontics	20	2.4
	Endodontics	14	1.7
	All the above	354	41.9

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Application of a CAD/CAM system in dentistry?	Crown and bridges, Inlay, onlay and veneers and dentures	656	77.7
	Helping in removing the plaque layer	18	2.1
	Sterilization of dental instruments	38	4.5
	All the above	132	15.6
The Process of a CAD/CAM consist of	Only the designing and milling phase	88	10.4
	Only the scanning and designing phase	50	5.9
	Scanning, designing and milling phase	662	78.4
	None of the above	44	5.2
The components of a CAD/CAM system include: (you can choose more than one option) *	CAI (Computer aided inspections)	636	75.4
	Computer which plans and calculates body form of restorations	586	69.4
	Numerically controlled milling machine	446	52.8
Which materials are the most frequently utilized in a CAD/CAM crown preparation system?	A- Zirconia	256	30.3
	B - Ceramic	90	10.7
	All of the above	474	56.2
	None of the above	24	2.8
what are the benefits of CAD/CAM system? (you can choose more than one option) *	Reduce number of appointments	668	79.1
	Digital Workflow	468	55.4
	More precise as compared to conventional methods	520	61.6
	I don't know	64	7.6
What is the main disadvantage of the CAD/CAM system?	A- Need for extended training	120	14.2
	B- High-cost equipment	246	29.1
	All of the above	440	52.1
	None of the above	38	4.5
What are the uses of CAD/CAM technology in dentistry? (you can choose more than one option) *	Intra-oral scanning	610	72.3
	Digital impressions	590	69.9
	Shade matching	366	43.4
	Computer-aided designing (by laboratory or specialist milling center)	524	62.1
	I don't know	62	7.3
What is the General perception of Digital dentistry you can mention? (you can choose more than one option) *	Easy to use, Less steps than analogue	628	74.4
	Less mistakes	506	59.9
	present Precise diagnosis and predictable treatment	396	46.9

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	Productive and efficient	430	50.9
	Standardized treatment outcomes between dentists	302	35.8
	More attractive for patients	10	1.2
	More attractive for dentists	6	0.7
Source of Digital Technologies in Dentistry knowledge? (you can choose more than one option) *	Books/articles	516	61.1
	Conference/webinar	408	48.3
	Workshops/courses	506	59.9
	Social media	408	48.3

Results may overlap

The data presented in figure (2) indicates that a significant majority of respondents, representing approximately 44%, identified "All of the above" as the main disadvantage of the CAD/CAM system. This indicates a consensus that both the need for extended training and the high cost of equipment are considerable barriers to the effective implementation of CAD/CAM technologies. In contrast, only 30% of participants expressed that "High-cost equipment" was the primary drawback, while a mere 10% pointed to the "Need for extended training." Notably, only 3% of respondents felt that there were no significant disadvantages associated with the system.

Figure (2): Illustrates main disadvantage of CAD/CAM system among participants.

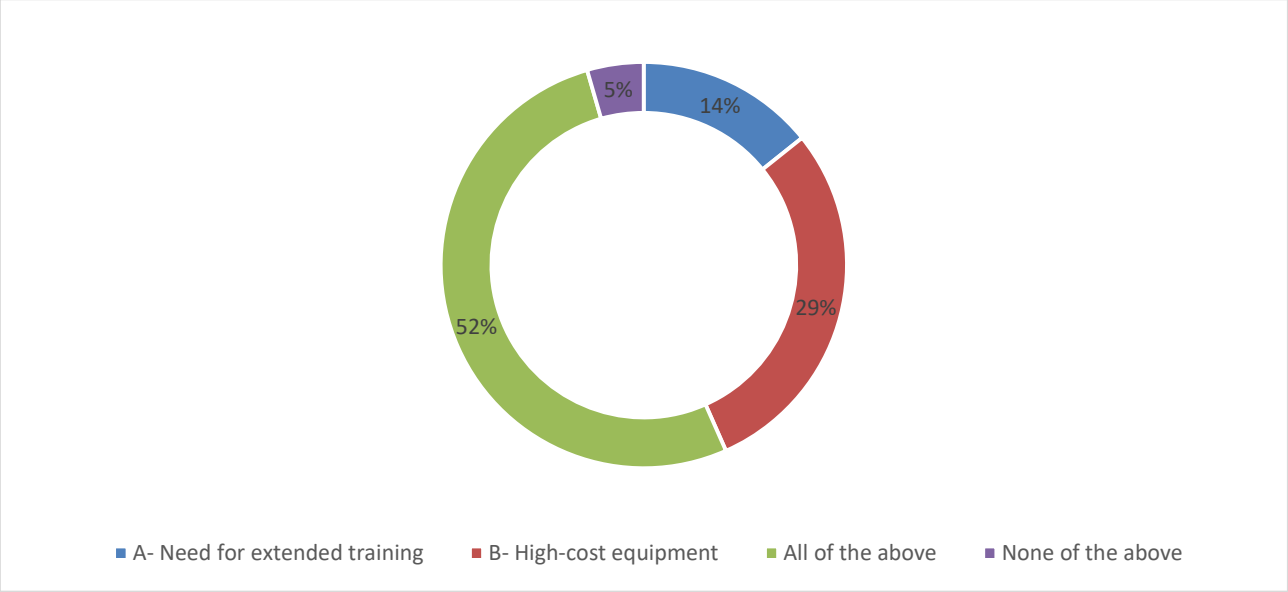

Table (3) reveals insights regarding dentists' awareness and use of digital dentistry technologies among a sample of 844 participants. Notably, a significant portion of dentists remains unfamiliar with various CAD/CAM systems, as indicated by the 37.4% who selected "none." In terms of material familiarity, a large majority recognize Emax and Zirconia, with percentages at 67.1% and 72.7%, respectively, showcasing a general awareness of common materials used in CAD/CAM applications. Half of the respondents (50.7%) reported having used digital devices in their practices, yet there appears to be a

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notable disparity in satisfaction levels concerning the fit and quality of CAD/CAM restorations, with only 27.5% expressing high satisfaction. Moreover, the results concerning educational background reveal that while 43.8% felt adequately educated in digital dentistry, a nearly equal percentage (41.7%) disagreed. Lastly, the data elucidates several challenges faced by practitioners, with cost considerations emerging as a primary barrier for 55.7% of the participants, followed by the learning curve and technological obsolescence.

Table (3): participants' awareness of digital dentistry among dentists (n=844).

Parameter		***No.***	***Percent (%)***
Which CAD/CAM system are you familiar with from the list below? (you can choose more than one option) *	Lava™	282	33.4
	Distributed control system (DCS) precident	228	27.0
	Chairside Economical Restoration of Esthetic Ceramic (CEREC)	288	34.1
	Procera	134	15.9
	None	316	37.4
With a CAD/CAM technology, which of the following materials are used? (you can choose more than one option) *	Emax	566	67.1
	Zirconia	614	72.7
	Metals	174	20.6
	Composite	180	21.3
	I don't know	112	13.3
Have you ever used any device of digital devices dentistry in your clinic before?	Yes	428	50.7
	No	324	38.4
	I do not know	92	10.9
If yes, how would you rate the marginal fit, axial contour, proximal contact, and occlusal contact of chair-side CAD/CAM restorations initially? (n=428)	Very satisfied	232	27.5
	Satisfied	146	17.3
	Slightly satisfied	40	4.7
	Not at all satisfied	10	1.2
Have you received sufficient undergraduate education in digital dentistry?	Yes	370	43.8
	No	352	41.7
	I don't know	104	12.3
	Not Applicable	18	2.1
Personal challenges experienced when using DTD (Digital Technologies in Dentistry)? (you can choose more than one option) *	Cost trap	470	55.7
	Learning curve	316	37.4
	Changing in professional profile	202	23.9
	Big data, data security and storage	230	27.3
	Keeping up with the latest technology	274	32.5

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	Assuming responsibility for a complex technical system	164	19.4
	I do not know	202	23.9

Results may overlap

The data presented in Table 4 highlights notable insights into dentists' perceptions and practices regarding digital dentistry among a cohort of 844 participants. A substantial majority, 82.9%, advocate for enhanced educational focus on digital dentistry in both undergraduate and graduate programs, indicating a pronounced recognition of its relevance in contemporary dental practice. Furthermore, an impressive 90.5% expressed a desire to integrate CAD/CAM technology into their daily operations, suggesting a strong inclination toward modernizing clinical workflows. The preference for CAD/CAM over traditional techniques is also evident, with 78.2% favoring digital methods, albeit with 15.2% uncertain about their stance. Noteworthy is the assertion that digital dentistry will influence clinical decision-making, with 74.4% agreeing to this premise. Additionally, 84.8% foresee a transformative impact of digital technologies on the profession, underscoring a collective anticipation of future advancements. However, it is also essential to address the 24.2% of respondents who reported that digital technologies are present yet underutilized at their workplaces, indicating potential barriers to full adoption.

Table (4): participants perception/practice of digital dentistry among dentists (n=844).

Parameter		***No.***	***Percent (%)***
You participated in any CAD/CAM workshops or training sessions	Yes	386	45.7
	No	458	54.3
You believe that undergraduate and graduate courses should include more information about digital dentistry	Yes	700	82.9
	No	68	8.1
	Not sure	76	9.0
You would like to integrate a CAD/CAM into your daily operations	Yes	764	90.5
	No	80	9.5
You would prefer to use CAD/CAM instead of traditional techniques.	Yes	660	78.2
	No	56	6.6
	Not sure	128	15.2
You do believe that using digital dentistry would change the way you make clinical decisions.	Yes	628	74.4
	No	88	10.4
	Not sure	128	15.2
You believe that dental practice will change in the future and that digital dentistry will benefit our profession.	Yes	716	84.8
	No	46	5.5
	Not sure	82	9.7

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Personal experiences when using DTD (Digital Technologies in Dentistry) *	DTD s exist at my workplace, but they aren't used	204	24.2
	Excellent value for money	276	32.7
	I enjoy discussing DTD with colleagues	246	29.1
	Pleasant working environment	348	41.2
	Simplify daily work	546	64.7

Results may overlap

The data presented in Table 5 reveals significant insights into knowledge level of digital dentistry among dentists, dental interns, and dental students in Saudi Arabia. Notably, a substantial majority, 57.1%, exhibit a low level of knowledge, indicating a concerning gap in understanding this critical aspect of digital dentistry. Conversely, only 25.4% of respondents demonstrate a high level of knowledge, while 17.5% possess a moderate level of awareness.

Table (5): Shows knowledge level of digital dentistry among dentists score results.

	Frequency	**Percent**
High level of knowledge	214	25.4
Moderate level of knowledge	148	17.5
Low level of knowledge	482	57.1
Total	844	100.0

The data presented in Table 6 highlights a concerning trend regarding the awareness of digital dentistry among dentists in Saudi Arabia. With a staggering 83.9% of participants indicating low awareness, it is evident that most dental professionals may not be sufficiently informed about the advancements and benefits of digital technologies in their field. In contrast, only 5.5% of dentists report a high level of awareness, while a mere 10.7% exhibit moderate awareness.

Table (6): Shows awareness level of digital dentistry among dentists in Saudi Arabia score results.

	Frequency	**Percent**
High level of awareness	46	5.5
Moderate awareness	90	10.7
Low awareness	708	83.9
Total	844	100.0

Table (7) shows that knowledge level of digital dentistry among dentists has statistically significant relation to age (P value=0.0001), residential area (P value=0.002), educational qualification (P value=0.0001), place of work (P value=0.022). It also shows statistically insignificant relation to gender, and years of practice.

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Table (7): Relation between knowledge level of digital dentistry among dentists and sociodemographic characteristics.

Parameters		***Knowledge level***		***Total (N=844)***	***P value****
		High or moderate knowledge	**Low level of knowledge**		
Gender	Female	192	236	428	0.241
		53.0%	49.0%	50.7%	
	Male	170	246	416	
		47.0%	51.0%	49.3%	
Age	less than 23	34	178	212	0.0001
		9.4%	36.9%	25.1%	
	23 to 24	128	136	264	
		35.4%	28.2%	31.3%	
	24 to 26	120	100	220	
		33.1%	20.7%	26.1%	
	more than 26	80	68	148	
		22.1%	14.1%	17.5%	
Residential area	Northern region	18	52	70	0.002
		5.0%	10.8%	8.3%	
	Southern region	208	272	480	
		57.5%	56.4%	56.9%	
	Center region	28	42	70	
		7.7%	8.7%	8.3%	
	Eastern region	20	38	58	
		5.5%	7.9%	6.9%	
	Western region	88	78	166	
		24.3%	16.2%	19.7%	
Educational Qualification	Dental Student	174	298	472	0.0001
		48.1%	61.8%	55.9%	
	Dental Interns	34	64	98	
		9.4%	13.3%	11.6%	
	General Dentist	130	102	232	
		35.9%	21.2%	27.5%	
	Specialist	16	6	22	
		4.4%	1.2%	2.6%	
	Consultant	8	12	20	
		2.2%	2.5%	2.4%	
How long have you been practicing dentistry?	Less than Five years	260	378	638	0.105
		71.8%	78.4%	75.6%	
	5-10 years	80	84	164	

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		22.1%	17.4%	19.4%	
	11-15 years	10	6	16	
		2.8%	1.2%	1.9%	
	More than 15 years	12	14	26	
		3.3%	2.9%	3.1%	
Where are you Studying or Working?	Governmental Sector	274	396	670	0.022
		75.7%	82.2%	79.4%	
	Private sector	88	86	174	
		24.3%	17.8%	20.6%	

****P value was considered significant if ≤ 0.05.***

Table (8) shows that awareness level of digital dentistry among dentists has statistically significant relation to gender (P value=0.0001), age (P value=0.014), educational qualification (P value=0.018), years of practice (P value=0.0001). It also shows statistically insignificant relation to residential area, and place of work.

Table (8): Awareness level of digital dentistry among dentists in association with sociodemographic characteristics.

Parameters		***Awareness level***		***Total (N=844)***	***P value****
		High or moderate awareness	**Low awareness**		
Gender	Female	42	386	428	0.0001
		30.9%	54.5%	50.7%	
	Male	94	322	416	
		69.1%	45.5%	49.3%	
Age	less than 23	28	184	212	0.014
		20.6%	26.0%	25.1%	
	23 to 24	44	220	264	
		32.4%	31.1%	31.3%	
	24 to 26	28	192	220	
		20.6%	27.1%	26.1%	
	more than 26	36	112	148	
		26.5%	15.8%	17.5%	
Residential area	Northern region	10	60	70	0.059
		7.4%	8.5%	8.3%	
	Southern region	86	394	480	
		63.2%	55.6%	56.9%	
	Center region	6	64	70	
		4.4%	9.0%	8.3%	
	Eastern region	14	44	58	
		10.3%	6.2%	6.9%	
	Western region	20	146	166	

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		14.7%	20.6%	19.7%	
Educational Qualification	Dental Student	66	406	472	0.018
		48.5%	57.3%	55.9%	
	Dental Interns	24	74	98	
		17.6%	10.5%	11.6%	
	General Dentist	34	198	232	
		25.0%	28.0%	27.5%	
	Specialist	6	16	22	
		4.4%	2.3%	2.6%	
	Consultant	6	14	20	
		4.4%	2.0%	2.4%	
How long have you been practicing dentistry?	Less than Five years	60	578	638	0.0001
		44.1%	81.6%	75.6%	
	5-10 years	58	106	164	
		42.6%	15.0%	19.4%	
	11-15 years	10	6	16	
		7.4%	0.8%	1.9%	
	More than 15 years	8	18	26	
		5.9%	2.5%	3.1%	
Where are you Studying or Working?	Governmental Sector	104	566	670	0.359
		76.5%	79.9%	79.4%	
	Private sector	32	142	174	
		23.5%	20.1%	20.6%	

****P value was considered significant if ≤ 0.05.***

Discussion:

Digital Dentistry is a forward-looking technology that has opened up new avenues in dental medicine. The latest advancements in CAD/CAM are continuously evolving, aiming to produce innovative products and systems that meet the highest quality standards [16]. These technologies enable the attainment of optimal clinical restorations characterized by high biocompatibility, the absence of secondary reactions, outstanding aesthetics, and enhanced collaboration between dentists and dental laboratories. Various surveys have been conducted worldwide to evaluate the knowledge and implementation of DD. For instance, a 2016 survey in the UK revealed that 55.6% of participants reported not using DD due to its associated costs [17]. Conversely, in the Netherlands, the adoption of DD is notably high, particularly among practice owners [18]. Local research in Saudi Arabia (SA) indicates that an overwhelming majority of individuals (98.5%) believe that DD enhances the quality of dental care and will ultimately replace conventional dental practices. Thus, we aimed in this study to assess the knowledge and awareness of digital dentistry among dentists, dental interns, and dental students in Saudi Arabia.

Our study findings indicate a disparity in knowledge, awareness, and perception of digital dentistry, paralleling several previous investigations into dental students and practitioners. For instance, Umer et al. [19] found that clinical-phase students demonstrated significantly greater familiarity with digital dentistry (DD) compared to their preclinical counterparts, with only half expressing positivity towards DD's contribution to patient satisfaction and operational efficiency. Our research echoes these

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observations, underscoring a substantial portion of the respondents (57.1%) with limited knowledge about digital dentistry. Furthermore, Radwan et al. [20] identified that among Generation X practitioners, a mere 10.1% actively utilized digital technologies, with barriers such as insufficient practitioner awareness and inadequate educational opportunities prevalent among lower-frequency users. Similarly, while a notable 77.7% in our study recognized CAD/CAM's efficacy for restorations, 24.2% acknowledged underutilization of these technologies, paralleling the barriers reported by Radwan et al. Our results align closely with Hall et al. [21], who noted that only 42.3% of participants were general practitioners, yet a substantial 75.9% possessed a positive perception of digital dentistry. Our survey similarly identified a pronounced desire for educational initiatives, with 82.9% advocating for a greater emphasis on digital dentistry, reinforcing the need for structured educational interventions noted in earlier studies. Lastly, Memon et al. [22] indicated that among their examined student populations, a staggering majority reported never having encountered CAD/CAM technologies, reflecting a significant knowledge deficit that aligns with our findings of only 27.5% high satisfaction with CAD/CAM restorations. Overall, these studies collectively reveal a critical need for enhanced educational resources and experiential learning opportunities to tackle existing knowledge gaps and promote the integration of digital dentistry within clinical practices, a sentiment echoed across the spectrum of dental education and practice environments. When comparing our study's findings regarding knowledge, awareness, and perception of digital dentistry to those of previous studies, several key aspects emerge that inform the broader understanding of the topic. Muhammad Farooq Umer et al. reported significant differences in knowledge levels among dental students, particularly noting that students in the clinical phase exhibited enhanced awareness of digital dentistry (DD) compared to their preclinical counterparts ($P<0.01$). This aligns with our study's finding, where a notable percentage of participants expressed low overall knowledge regarding digital methods. Furthermore, participants in Umer et al.'s study indicated a 73.3% negative viewpoint toward the practice of DD, contrasting with our respondents' ambivalence toward their satisfaction with CAD/CAM restorations despite recognizing its benefits. This dichotomy underscores a disconnection between theoretical knowledge and practical implementation, which is similarly echoed in Hawazen A Radwan et al.'s findings, where a noteworthy portion of General X indicated regular use of digital technologies, with 92% advocating for its inclusion in the undergraduate dental curriculum. Our study mirrors this desire for education, as 82.9% of respondents called for enhanced training, which could address the substantial awareness gaps recognized in both studies. In the context of practical engagement, Mohamed Ashraf Hall et al. found that only 50.7% of participants showed moderate knowledge regarding digital dentistry, which resonates with our report of 57.1% low awareness levels. Moreover, the emphasis on a higher perception of digital dentistry practice among participants (75.9%) in Hall et al.'s study aligns with our own findings, where interest in incorporating CAD/CAM technology was markedly high (90.5%). This suggests a shared enthusiasm across studies for advancements in dental practices, despite gaps in knowledge and satisfactory application. Moreover, L Memon et al. reported that a significant number of students, particularly from government institutions, lacked direct exposure to CAD/CAM technology (80.6% of government students had never used CAD/CAM). This corroborates our finding that 24.2% acknowledged underutilization of digital technologies. Importantly, Memon's study found limited recognition of the materials used in CAD/CAM applications and the functionality of digital impressions, further defining the scope of educational deficiencies that our results support. Notably, 50% of their respondents recognized the role of digital dentistry in future practices, paralleling our findings that indicate a willingness among practitioners to adopt CAD/CAM methodologies but highlight dissatisfaction with the current implementation. On the other hand, Madfa et al studied the level of knowledge among preclinical, clinical, and intern students at the College of Dentistry, Hail University,

ISSN:1624-1940
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and concluded that DD knowledge gradually increases with the study level [23]. Moreover, a study conducted in India among dental practitioners found that 96.7% of practitioners are aware of CAD/CAM technology in dentistry, and 87% believe that lack of knowledge, not high cost, is the major shortcoming of CAD/CAM [24]. Another study concluded that 74% of undergraduate students are unaware of the materials used to fabricate CAD/CAM prostheses [25]. Additionally, a 2024 study by Aldowah et al concluded that dental undergraduate students had limited knowledge about artificial intelligence (AI) as DD, and this type of DD must apply additional effort to prepare students for the era of AI as DD [26].

Conclusion:

In conclusion, this study underscored the critical need for enhanced education and training in digital dentistry among dental practitioners, interns, and students in Saudi Arabia. Despite widespread recognition of the benefits of CAD/CAM technology and a strong desire to incorporate digital methods into practice, a significant portion of respondents demonstrated low knowledge levels and limited practical experience. High costs, inadequate training, and lingering reliance on traditional methods were identified as barriers to the effective implementation of digital dentistry. Therefore, to maximize the potential of these innovative technologies, it is essential to develop structured educational programs and hands-on training opportunities that can empower future dental professionals with the necessary skills and confidence to utilize digital tools effectively, ultimately improving patient care and treatment outcomes in the dental field.

Acknowledgement:

Special thanks to the Deanship of Scientific Research (DSR) and the Faculty of Dentistry at King Abdulaziz University, Jeddah, for supporting this project.

Ethical approval

An informed consent was obtained from each participant after explaining the study in full and clarifying that participation is voluntary. Data collected were securely saved and used for research purposes only.

Funding

There was no external funding for this study.

Conflict of interests

The authors declare no conflict of interest.

Informed consent:

Written informed consent was acquired from each individual study participant.

Data and materials availability

All data associated with this study are present in the paper.

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