ASSESSING THE ROLE OF 3D PRINTING AND DIGITAL DENTISTRY IN DENTAL EDUCATION AND PRACTICE: A COMPARATIVE STUDY AMONG GENERAL DENTIST AND ENDODONTIST

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KEYWORDS

Digital Dentistry, Precision, 3D printing, Education, Practice

ABSTRACT

Background: The integration of 3D printing and digital dentistry has revolutionized dental education and clinical practice by enhancing precision, efficiency, and customization in various procedures, including surgical guides, implants, and prosthetics. However, the level of adoption and practical application of these technologies varies among dental professionals. This study aims to assess the knowledge, utilization, and impact of 3D printing and digital dentistry among general dentists and endodontists.

Methods: A cross-sectional study was conducted among 500 participants, including undergraduate and postgraduate dental students, general dentists, and endodontists in Saudi Arabia. A structured questionnaire was used to gather data on participants' familiarity with and use of 3D printing and digital dentistry technologies. The questionnaire covered demographics, awareness levels, application, perceived benefits, challenges, and training needs. Data were analyzed using SPSS software (version 26.0), with descriptive statistics presented as frequency and percentage distributions. Comparative analysis was performed using the chi-square test to examine differences among participant groups, with a significance level set at 5% ($p < 0.05$).

Results: The findings indicate that while awareness of 3D printing and digital dentistry is increasing, significant variations exist in hands-on experience among different professional groups. Endodontists and dental practitioners reported higher utilization rates than undergraduate students. The primary benefits identified included improved precision, customization, and reduced procedural time. However, challenges such as high costs, technical skill requirements, and limited access to training programs were noted as barriers to widespread adoption.

Conclusion: The study highlights the growing recognition of 3D printing and digital dentistry within dental education and practice. However, the limited hands-on experience among students should be improved.

1. Introduction:

The introduction of 3D printing and digital dentistry has brought a transformative shift to the field of dental medicine, enabling unparalleled precision and customization in the fabrication of surgical guides, implants, and prosthetic devices. These cutting-edge technologies have greatly influenced both dental education and clinical practice by offering new opportunities to enhance patient care and treatment outcomes[1,2]. The use of 3D printing facilitates the production of highly precise and patient-specific dental components, while digital dentistry—encompassing CAD/CAM systems and digital impressions—optimizes workflow efficiency and procedural accuracy[3,4]. The incorporation of these advancements represents a major technological leap, allowing for the creation of customized dental solutions with remarkable accuracy and reliability[5]. The ability to generate highly detailed, patient-specific models has streamlined various aspects of dental care, ranging from diagnostics and treatment

planning to execution and follow-up[6].

Among these innovations, 3D printing has become a particularly valuable tool in modern dentistry. Its capability to fabricate intricate structures with minimal error has revolutionized the design and manufacturing of dental prosthetics and implants[7]. This technology enables the rapid production of precise dental components tailored to the unique anatomical needs of each patient, thereby enhancing treatment customization and overall clinical outcomes[8]. Meanwhile, digital dentistry integrates a variety of advanced tools, including computer-aided design (CAD) and computer-aided manufacturing (CAM), which facilitate the creation of digital impressions and models[9]. These digital solutions have significantly improved the accuracy and efficiency of dental procedures, reducing dependency on conventional techniques that often involve manual adjustments and measurements. By adopting digital technologies within clinical workflows, dental professionals can achieve greater consistency, predictability, and efficiency in their practice[10]. Despite the numerous advantages of 3D printing and digital dentistry, their adoption varies across dental institutions and practices. Several factors, including accessibility to advanced equipment, availability of training, and financial constraints, influence the extent to which these technologies are implemented. Therefore, it is essential to evaluate how these innovations are currently integrated into dental education and clinical practice while identifying potential challenges that may hinder their widespread use[11].

This cross-sectional study aims to assess the current utilization and perception of 3D printing and digital dentistry among dental students and practitioners. By collecting data on their experiences, knowledge, and attitudes toward these technologies, the study seeks to provide insights into their level of adoption and practical applications[12]. The findings will help identify areas where additional training and resources may be required, contributing to the continuous improvement of dental education and clinical workflows. In conclusion, the rapid advancement of 3D printing and digital dentistry presents significant opportunities for enhancing precision and treatment outcomes in dentistry. Understanding how these technologies are currently perceived and integrated into dental practice and education will be crucial for optimizing their application and maximizing their benefits[13]. This study will provide valuable insights into the impact of these innovations and offer recommendations for their effective implementation in the field.

2. Materials And Method

This cross-sectional study aimed to evaluate the adoption and impact of 3D printing and digital dentistry in both dental education and clinical practice. To ensure a diverse participant pool, the study was conducted across multiple dental institutions and professional settings, encompassing undergraduate and postgraduate dental students as well as practicing dental professionals. The total sample size was determined to be 500. The study was conducted in Saudi Arabia. The study was conducted from 1/08/2024 to 1/2/2025 among different academic levels, including undergraduate and postgraduate programs, alongside dental practitioners with varying degrees of professional experience. Ethical considerations were strictly adhered to, ensuring participant confidentiality and rights protection. Prior to data collection, informed consent was obtained from all participants, and the study received ethical approval from the institutional review board of the respective institutions. A combination of random sampling and purposive selection was employed to ensure representation across different educational and professional backgrounds. Data collection was carried out using a structured questionnaire designed to assess participants' knowledge, familiarity, and utilization of 3D printing and digital dentistry technologies. The questionnaire comprised multiple sections, covering demographic details, awareness levels, practical applications, perceived advantages and challenges, as well as training and educational needs. Its development was guided by a comprehensive literature review and expert input to ensure relevance and clarity. Before final implementation, a pilot study was conducted with a small group of participants to refine the questionnaire for better clarity and effectiveness. Depending on participant preference, the finalized version was distributed electronically and in print. The collected data were analyzed using statistical software to identify trends and patterns

in technology adoption. Descriptive statistics were applied to summarize demographic information and assess the prevalence of 3D printing and digital dentistry use. Comparative analysis was conducted to explore differences in technology adoption and perceptions among undergraduate students, postgraduate students, dental practitioners, and academicians. Frequency and percentage distributions were used to present descriptive statistics, while inferential analysis was performed using the chi-square test to compare responses across participant groups. Statistical analysis was conducted using SPSS software (version 26.0), with a significance level set at 5% ($\alpha = 0.05$). A p-value of less than 0.05 was considered statistically significant.

3. Results

Demographic Characteristics (Table 1)

The study sample primarily comprised undergraduate students (50%), followed by postgraduate students (20%), dental practitioners (20%), and endodontists (10%). Among practitioners and academicians, the majority (16.2%) had over six years of experience, while a smaller proportion (2.8%) had between 4-6 years.

Knowledge and Awareness (Table 2)

A significant percentage of undergraduate students (33.5%) reported being unfamiliar with 3D printing technology, while familiarity increased among postgraduate students (35%), dental practitioners (45%), and endodontists (56%). A similar trend was observed for digital dentistry techniques, with greater awareness among experienced professionals. The p-values indicate statistically significant differences in awareness levels across different groups.

Usage and Application (Table 3)

While 3D printing technology was widely adopted among dental practitioners (67%) and endodontists (78%), its use was significantly lower among undergraduate (9.6%) and postgraduate students (24%). Among those who had used 3D printing, applications varied, with surgical guides being the most common. Additionally, the use of digital dentistry techniques was highest among endodontists (30% using them often), whereas a considerable portion of undergraduates (50%) never utilized them.

Perceived Benefits and Challenges (Table 4)

Respondents acknowledged several advantages of 3D printing in dentistry, such as high precision (40% of endodontists), customization, and reduced procedure time. However, cost was a major challenge, with 40% of undergraduate students citing high initial costs as a barrier. Learning curve and time constraints were additional concerns.

Training and Education (Table 5)

The majority of undergraduate students (90%) and postgraduate students (77%) reported not having received formal training in 3D printing and digital dentistry. In contrast, a higher percentage of dental practitioners (56%) and endodontists (78%) had undergone formal training. The statistically significant p-value (0.031) indicates a noteworthy difference in training exposure across groups, with professionals being more likely to receive formal education in digital dentistry compared to students.

Sources of Training

Among those who received training, the most common source was the dental school curriculum, particularly for undergraduate students and postgraduates. Continuing education courses were attended by a smaller percentage of respondents, with only 3.2% of undergraduates and 5% of dental practitioners utilizing this option. Workshops and seminars were a prominent training avenue for dental practitioners (30%) and endodontists (40%), while on-the-job training and other forms of education were entirely absent across all groups.

Interest in Further Training

A significant proportion of respondents expressed a strong interest in additional training on 3D printing and digital dentistry. Most undergraduate students (90%), postgraduate students (79%), dental practitioners (85%), and endodontists (74%) were "very interested" in further training. Only a small fraction of participants showed little or no interest, suggesting a general enthusiasm for expanding knowledge and skills in this domain.

Belief in 3D Printing as a Future Standard in Dentistry

A substantial proportion of respondents agreed that 3D printing and digital dentistry would become standard in future dental practice. Among them, 50% of undergraduate students, 55% of postgraduate students, 55% of dental practitioners, and 64% of endodontists strongly agreed with this notion. Only a small percentage (8% of undergraduates and 10% of postgraduates) disagreed, while none of the dental practitioners or endodontists opposed the idea. The p-value (0.32) suggests no significant variation in responses across groups.

Required Resources for Effective Implementation

Access to equipment was identified as the most crucial requirement, with 50% of undergraduates, 39% of postgraduates, 49% of dental practitioners, and 68% of endodontists highlighting this need. Training programs and technical support were also considered essential by a notable percentage of respondents across all groups. Financial support was less frequently mentioned, with only 10% of undergraduates and 3% of postgraduate students and dental practitioners citing it as a need. Peer collaboration and other resources were not reported as significant requirements by any group.

Table 1: Assessment of Demographic Details

Questionnaire	Options	Frequency (N)	Percentage (%)
1. What is your current level of education/professional status?	Undergraduate Student	250	50
	Postgraduate Student	100	20
	Dental Practitioner	100	20
	Endodontist	50	10
2. How many years of experience do you have in the dental field? (Applicable for dental practitioner and academician)	Less than 1 year	25	5
	1-3 years	30	6
	4-6 years	14	2.8
	More than 6 years	81	16.2

Graph 1: Demographic Details

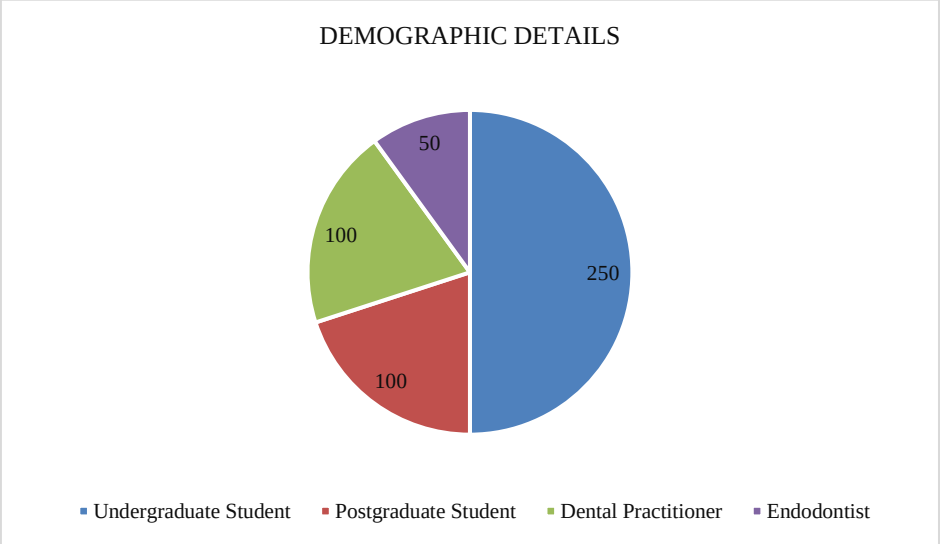

Table 2: Assessment of Knowledge and Awareness

Questionnaire	Options	Undergraduate students		Post graduate students		Dental practitioner		Endodontist		P-value
		Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)	
How familiar are you with 3D printing technology in dentistry?	Not familiar	80	33.5	16	16	11	11	2	4	0.045*
	Somewhat familiar	55	15.5	15	15	10	10	10	20	
	Familiar	65	26	35	35	45	45	28	56	
	Very familiar	50	20	34	34	34	34	10	20	
How familiar are you with digital dentistry techniques (e.g., CAD/CAM, digital impressions)	Not familiar	50	20	13	13	22	22	2	4	0.034*
	Somewhat familiar	85	34	19	19	28	28	2	4	
	Familiar	65	26	39	39	31	31	23	46	
	Very familiar	50	20	29	29	19	19	23	46	

Table 3: Assessment of Usage and Application

Questionnaire	Options	Undergraduate students		Post graduate students		Dental practitioner		Endodontist		P-value
		Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)	
Have you ever used 3D printing technology in your dental practice/studies	Yes	23	9.6	24	24	67	67	39	78	0.026*
	No	227	90.4	76	76	33	33	11	22	
If yes, what applications have you used 3D printing for	Surgical guides	13	4.2	14	14	31	31	19	38	0.12
	Dental implants	10	4	10	10	21	21	10	20	
	Prosthetics (e.g., crowns, bridges, dentures)	2	0.8	1	1	11	11	4	8	
	Orthodontic appliances	0	0	0	0	2	2	3	6	
	Models for treatment planning	0	0	0	0	2	4	3	6	
	Others	0	0	0	0	0	0	0	0	
How often do you use digital dentistry techniques in your	Never	125	50	60	60	20	20	10	20	0.047*
	Rarely	50	20	10	10	15	15	7	14	
	Sometimes	25	10	10	10	20	20	7	14	

practice/studies	Often	25	10	10	10	20	20	15	30	
	Always	25	10	10	10	25	25	11	22	

Table 4: Assessment of Perceived Benefits and Challenges

Questionnaire	Options	Undergraduate students		Post graduate students		Dental practitioner		Endodontist		P-value
		Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	
What do you perceive as the main benefits of using 3D printing in dentistry	High precision	50	20	20	20	35	35	20	40	0..46
	Customization for individual patients	50	20	20	20	35	35	15	30	
	Reduced procedure time	25	10	20	20	20	20	10	20	
	Improved patient outcomes	50	20	15	15	5	5	5	10	
	Cost-effectiveness	50	20	15	15	5	5	0	0	
	Others	25	10	20	20	5	5	0	0	
What do you perceive as the main challenges of using 3D printing in dentistry	High initial cost	100	40	40	40	40	35	20	40	0.14
	Learning curve/technical skills required	50	20	20	20	20	35	5	10	
	Time-consuming process	25	10	20	20	20	20	20	40	
	Lack of training/resources	50	20	15	15	5	5	5	10	
	Integration with existing workflows	25	10	5	5	15	5	0	0	
	Others	0	0	0	0	0	0	0	0	

Table 5: Assessment of Training and Education

Questionnaire	Options	Undergraduate students		Post graduate students		Dental practitioner		Endodontist		P-value
		Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	
Have you received any formal training on 3D printing and digital dentistry	Yes	25	10	23	23	56	56	39	78	0.031*
	No	225	90	77	77	44	44	11	22	
If yes, where did you receive your training	Dental school curriculum	15		15		21		11		0.13
	Continuing education courses	8	3.2	3	3	5	5	8	16	
	Workshops/seminars	2	0.8	5	5	30	30	20	40	

	On-the-job training	0	0	0	0	0	0	0	0	
	Other	0	0	0	0	0	0	0	0	
How interested are you in receiving further training on 3D printing and digital dentistry	Not interested	5	2	2	2	0	0	0	0	0.078
	Somewhat interested	5	2	3	3	0	0	0	0	
	Interested	15	6	16	16	15	15	13	26	
	Very interested	225	90	79	79	85	85	37	74	

Table 6: Future Perspectives

Questionnaire	Options	Undergraduate students		Post graduate students		Dental practitioner		Endodontist		P-value
		Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	
Do you believe that 3D printing and digital dentistry will become a standard practice in the future of dental care	Strongly agree	125	50	55	55	65	55	32	64	0.32
	Agree	75	30	25	25	25	25	14	28	
	Neutral	25	10	10	10	10	10	4	8	
	Disagree	20	8	10	10	0	0	0	0	
	Strongly disagree	5	2	0	0	0	0	0	0	
What additional resources or support would you need to effectively incorporate 3D printing and digital dentistry into your practice/studies	Access to equipment	125	50	39	39	49	49	34	68	0.063
	Training programs	50	20	29	29	19	19	10	20	
	Technical support	50	20	29	29	29	29	6	12	
	Financial support	25	10	3	3	3	3	0	0	
	Peer collaboration	0	0	0	0	0	0	0	0	
	Other	0	0	0	0	0	0	0	0	

4. Discussion

The integration of 3D printing and digital dentistry has revolutionized both dental education and clinical practice. These advancements have significantly improved precision, efficiency, and patient outcomes while also reshaping the learning experience for dental students and practitioners[14]. In dental education, 3D printing and digital technologies have enhanced the training of students by providing realistic simulation models for preclinical practice. Traditional teaching methods often rely on typodonts and extracted teeth, which may not fully replicate patient-specific anatomy. However, 3D-printed models allow students to practice on customized, anatomically accurate replicas, thereby improving their diagnostic and procedural skills[15]. Moreover, digital dentistry tools such as CAD/CAM systems, digital impressions, and virtual simulations enable students to gain hands-on experience with modern workflows, preparing them for real-world clinical scenarios. From a clinical perspective, 3D printing has transformed the fabrication of dental prosthetics, surgical guides, and orthodontic appliances[15]. The ability to design and print customized restorations within a short period has enhanced treatment efficiency and reduced patient chairside time. Digital workflows, including intraoral scanning and CAD/CAM milling, have improved accuracy and minimized errors associated

with conventional impression techniques. Furthermore, the application of 3D-printed surgical guides has optimized implant placement and complex surgical procedures, increasing the predictability of outcomes and reducing complications[16]. Another significant impact of these technologies is cost-effectiveness. While the initial investment in digital equipment may be high, the long-term benefits include reduced material wastage, lower laboratory costs, and increased workflow efficiency[17]. Additionally, digital records facilitate seamless communication between dental professionals, laboratories, and patients, enhancing collaboration and case management. Despite these advantages, certain challenges must be addressed. The high cost of acquiring and maintaining digital equipment can be a barrier for some dental institutions and private practices. Additionally, a learning curve is associated with adopting new digital workflows, requiring adequate training for students and practitioners. Furthermore, ensuring the biocompatibility and long-term stability of 3D-printed materials remains an ongoing area of research[18,19].

This study offers valuable insights into the implementation and impact of 3D printing and digital dentistry in dental education and clinical practice. The findings reveal a growing awareness of these technologies among dental students and professionals, with many recognizing their ability to enhance precision in procedures such as surgical guides, implants, and prosthetics. However, there is a noticeable variation in exposure and hands-on experience, particularly between undergraduate students, postgraduate students, and practicing dentists. These results align with previous research highlighting the transformative role of digital technologies in dentistry, emphasizing their potential to improve treatment accuracy, reduce procedural duration, and enhance patient satisfaction[20,21]. While our study supports these advantages, it also identifies a significant gap in comprehensive training, which has been recognized as a key challenge to the widespread adoption of these innovations[17,18]. The integration of 3D printing and digital dentistry into dental curricula is essential for equipping future professionals with the necessary skills[22]. The findings emphasize the importance of not only introducing these technologies in theoretical coursework but also incorporating practical training to enhance proficiency. For practicing dentists, continuous education and skill development in digital tools could improve clinical efficiency, particularly in procedures that require high precision[23,24]. Despite its contributions, this study has certain limitations. As a cross-sectional study, it provides a snapshot of current perceptions and practices without capturing their evolution over time[25]. Additionally, self-reported data may introduce bias, as participants might overestimate their familiarity with or usage of these technologies. Moreover, the study was conducted within a specific geographical region, which may limit the generalizability of the findings to other educational systems or locations[26,27]. The recent study done by Saeidi et al[28], states the significance of digital technologies in our dentistry which helps our budding dentist to explore more in the field of dentistry and AI is one such technology which shows the impact of AI in cancer treatment and innovation will help the digital technologies to move forward with great impact[29].

5. Conclusion

The study highlights the growing recognition of 3D printing and digital dentistry within dental education and practice. However, the limited hands-on experience among students should be improved. While there is clear enthusiasm for these technologies, there is also a pressing need for enhanced training and education to fully realize their potential. As these tools continue to evolve, they will likely become integral components of modern dental practice, offering unprecedented levels of precision and customization in patient care.

Conflict of Interest: Nil.

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