Dentists' Awareness, Knowledge and Experiences on the Use of 3D Print Technologies in Dentistry

Diş Hekimlerinin 3D Yazıcı Teknolojilerinin Diş Hekimliğinde Kullanımına Yönelik Farkındalıkları, Bilgileri ve Deneyimleri

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ABSTRACT

INTRODUCTION: This study evaluates the awareness and knowledge levels of dentists about 3D printing systems and the frequency of application of these systems in their clinical practice.

MATERIAL and METHODS: Data collection was carried out through a 19-question survey created through Google Forms. While the first 5 questions in this survey measure demographic characteristics such as gender, age, professional title, professional experience, and the institution, the other 14 questions consist of technical questions that measure the knowledge and experience of dentists about 3D printing technologies.

RESULTS: A survey of 358 dentists revealed 61.5% were general dentists, 22.9% were research assistants, and 15.6% were specialists. Knowledge of 3D printer technology was significantly higher among those in public hospitals and with ≤5 years of experience (P<0.05). While 75% did not use 3D printers, 12% used them several times a month, 8% several times a week, and 4% several times a day.

CONCLUSION: The level of knowledge about 3D printing technologies is higher in dentists who have five years or less of professional experience. It has been determined that the high-cost systems of 3D printing technology are the main factors limiting the use of the systems in dentistry practice.

Keywords: *3D Printing, Additive Manufacturing, Dentists, Surveys, Questionnaires*

ÖZ

GİRİŞ: Amaç: Bu çalışma, diş hekimlerinin 3D baskı sistemleri hakkındaki farkındalık ve bilgi düzeylerini ve bu sistemlerin klinik uygulamalarda kullanım sıklığını değerlendirmektedir.

YÖNTEM ve GEREÇLER: Veri toplama, Google Forms aracılığıyla oluşturulan 19 soruluk bir anket ile gerçekleştirilmiştir. Bu anketin ilk 5 sorusu, cinsiyet, yaş, mesleki unvan, mesleki deneyim ve çalışılan kurum gibi demografik özellikleri ölçerken, diğer 14 soru, diş hekimlerinin 3D baskı teknolojileri hakkındaki bilgi ve deneyimlerini ölçen teknik sorulardan oluşmaktadır.

BULGULAR: 358 diş hekimi arasında yapılan ankette, katılımcıların %61,5'i genel diş hekimi, %22,9'u araştırma görevlisi ve %15,6'sı uzman diş hekimi olarak belirlenmiştir. 3D yazıcı teknolojisi bilgisi, kamu hastanelerinde çalışanlar ve meslekte 5 yıl veya daha az deneyime sahip olanlar arasında anlamlı derecede yüksektir (P<0.05). Katılımcıların %75'i 3D yazıcı kullanmadığını, %12'si ayda birkaç kez, %8'i haftada birkaç kez ve %4'ü günde birkaç kez kullandığını bildirmiştir.

SONUÇ: 3D baskı teknolojileri hakkındaki bilgi düzeyi, meslekte beş yıl veya daha az deneyime sahip diş hekimlerinde daha yüksektir. 3D baskı teknolojisinin pahalı sistemlerinin, diş hekimliği uygulamalarında bu sistemlerin kullanımını sınırlayan ana faktörler olduğu belirlenmiştir.

Anahtar Kelimeler: *3D Baskı, Katmanlı Üretim, Diş Hekimleri, Anketler, Soru Formları*

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INTRODUCTION

Technological advancements have led to significant transformations in various fields, including dentistry, in recent years. The integration of digital technologies into dental applications has accelerated diagnostic and treatment processes while enhancing their precision. One of the most critical aspects of this technological evolution is 3D printing technology, which is increasingly being utilized in dentistry.[1]

3D printing is a technology that operates on the principle of additive manufacturing, enabling the production of patient-specific dental structures using computer-aided design (CAD) software. This method offers several advantages in dental applications, providing faster, more cost-effective, and patient-friendly solutions compared to traditional techniques. The use of 3D printing technology in dentistry is particularly concentrated in prosthodontics, orthodontics, oral surgery, dental implantology and endodontics.[2-9]

Today, 3D printers are used in prosthodontics to produce patient-specific restorations, making laboratory processes faster and more cost-effective. In orthodontics, 3D printing plays a crucial role, particularly in the production of clear aligners and customized bracket designs. Compared to traditional methods, patient data can be stored digitally and reproduced when needed, minimizing the necessity for physical storage.[4-7]

In oral surgery and dental implantology, 3D printing technologies enable the creation of patient-specific anatomical models, allowing for more precise preoperative planning and making surgical procedures more predictable.[8]

Despite these advantages, the extent to which 3D printing technology has been adopted in dental practice, the level of knowledge among dentists, and the potential barriers to its use remain unclear. Various studies have reported that dentists' awareness of 3D printing technologies varies significantly and that factors such as high costs and technical knowledge requirements may influence adoption rates.[10]

This study aims to assess dentists' knowledge and awareness of 3D printing technologies across a broad participant group, identify trends in its usage, and determine the barriers to its implementation. The findings are expected to contribute to the more effective integration of 3D printing technologies into dental education and clinical applications.

MATERIAL and METHODS

This study was conducted to measure the level of knowledge and awareness of dentists in Türkiye about 3D printing technologies. Data collection was carried out through a 19-question questionnaire created through Google Forms®. While the first 5 questions in this questionnaire measure demographic characteristics such as gender, age, professional title, professional experience, and institution of employment, the other 14 questions consist of technical questions that measure dentists' knowledge about 3D printing technologies.

A table summarizing the questionnaire items is provided in Table 1. The questions were developed based on a review of the literature and expert opinions from academics specializing in digital dentistry and 3D printing technologies. The questionnaire included questions regarding the level of knowledge, clinical application experience, and potential challenges in using 3D printing technologies in dental practice.

Table 1: Survey Questions on Dentists' Awareness and Knowledge of 3D Printing Technologies

Question Number	Survey Question
1	What is your gender?
2	What is your age?
3	What is your professional title? (General Practitioner, Research Assistant, Specialist)
4	How many years of professional experience do you have?
5	In which type of institution do you currently work? (State Hospital, Private Clinic, University Hospital)
6	Have you ever heard of 3D printing technologies in dentistry? (Yes/No)
7	Have you had the opportunity to use or observe 3D printing technologies? (Yes/No)
8	Do you have a 3D printer in your clinic? (Yes/No)
9	Do you use CAD/CAM systems in your clinic? (Yes/No)
10	What do you think is the best material for 3D printers? (Thermoplastic material, Light cure resin, Sintered powder, No idea)
11	In which applications do you use 3D printing technologies in your clinic? (Diagnostic Model Production, Prosthetic Restorations, Surgical Guide, Orthodontic Applications, No idea)
12	Do you think 3D printing technologies will be used more in the future? (Yes/No)
13	Would you like to attend a course/seminar to increase your knowledge about 3D printing technologies? (Yes/No)
14	What is the biggest barrier to using 3D printing technologies? (Expensive systems, Lack of sufficient practice, Complex technical information, Being unaware of 3D printers)
15	How often do you use 3D printers? (A few times a day, A few times a week, A few times a month, Never)
16	What factors do you think affect the efficiency of 3D printing in dentistry? (Cost efficiency, Ease of diagnosis and treatment, Prognosis, Technical aspects, Patient response)
17	Have you received any formal training on 3D printing technologies? (Yes/No)
18	Would you recommend the use of 3D printing technologies to your colleagues? (Yes/No)
19	What additional training or support would you need to use 3D printing technologies effectively?

The questionnaire application was carried out online and the participants were asked to confirm their voluntary participation in the research in the questionnaire forms. The survey was distributed via professional dental associations, university networks, and social media platforms to reach a diverse group of dentists across different regions of Türkiye. Inclusion criteria required participants to be licensed dentists actively practicing in Turkiye, while exclusion criteria included dental students and retired practitioners. The study was approved by Ordu University Clinical Research Ethics Committee (No: 2023/148). The sample set size was calculated in G*Power Software (version 3.1.9.2, Universität Düsseldorf, Germany) using effect size (0.50) with α=0.05 and 95% power. As a result of the power analysis, it was found that a total of at least 40 individuals were required for this study. Ultimately, 358 dentists participated in the survey, representing a diverse range of specializations and practice settings.

All data will be analyzed by entering them into the SPSS (SPSS for Windows 20.0; SPSS Inc, Chicago, Illinois) analysis program. After the normal distribution test was applied to the data, parametric tests were applied to the normally distributed data, while non-parametric tests were applied to the non-normally distributed data. The Pearson Chi-Square and Fisher Exact tests were used to analyze categorical variables, such as gender, professional title, institution, and professional experience, in relation to knowledge, experience, and the availability of 3D printing technologies in clinical practice. Additionally, descriptive statistics, including mean, standard deviation, and percentages, were used to summarize the demographic characteristics of the participants. The significance level was set at $p<0.05$ for all statistical evaluations.

RESULTS

A total of 358 dentists completed this survey. Survey questions regarding dentists' awareness and knowledge about 3D printing technologies are given in Table 1.

The demographic characteristics of the participants are presented in Table 2. The female participants (56.7%) were higher than the male participants (43.3%). While 61.5% of the participants were general dentists, 22.9% were research assistant dentists and 15.6% were specialist dentists. While 44.7% of the participants work in private clinics, 34.1% work in university hospitals and 21.2% work in public hospitals. The number of those with 5 years or less of professional experience was 57.8%, while the number of those with more than 5 years was 42.2%.

Table 3 displays the comparison of participants' responses regarding their knowledge of 3D printing technologies in dentistry. The rate of knowledge about the use of 3D printing technologies was found to be significantly higher for both those working in a public hospital and those with 5 years or less experience in the profession ($p<0.05$).

Table 2: Demographic characteristics of subjects participating in this study (n=358).

		N	%
% Gender	Female	203	56.7
	Male	155	43.3
Title	General Practitioner Dentist	220	61.5
	Research Assistant Dentist	82	22.9
	Specialist Dentist	56	15.6
Workplace	State Hospital	76	21.2
	Private Clinic	160	44.7
	University Hospital	122	34.1
Experience	5 or less than 5 years	207	57.8
	More than 5 years	151	42.2

Table 3: Comparison of dentists about use of 3D printing in dentistry and non-dentistry.

		Awareness about 3D Printing in Dentistry		**P**	**Awareness about 3D Printing in Non-Dentistry**		**P**
		Yes	No		Yes	No	
Gender	Female	184	19	0.616	161	42	0.208
	Male	138	17		131	24	
Title	General Practitioner Dentist	193	27	0.198	179	41	0.178
	Research Assistant Dentist	76	6		63	19	
	Specialist Dentist	53	3		50	6	
Workplace	State Hospital	63	13	0.035*	62	14	0.898
	Private Clinic	144	16		129	31	
	University Hospital	115	7		101	21	
Experience	5 or less than 5 years	192	15	0.038*	178	29	0.011*
	More than 5 years	130	21		114	37	

Significance levels, *P<0.05, **P<0.01, ***P<0.001

The comparison of the participants' answers to the questions 'Have you had the opportunity to experience 3D printer technologies?', 'Do you have a 3D printer in your clinic?' and 'Do you use CAD/CAM systems in your clinic?' are shown in Table 4. The rate of female participants experiencing 3D printer technologies was significantly higher than male participants ($p<0.05$). A statistically significant difference was found between the rates of experiencing 3D printer technologies according to the professional title of the participants ($p<0.05$). A significant difference was found between the experience rates of 3D printer technologies according to the institution where the participants worked ($p<0.05$). The participants' knowledge of whether there is a 3D printer in your clinic was found to be significantly different according to both the professional title and the institution where they work. A statistically significant difference was found according to the participants' gender, professional title, institution and professional experience ($p<0.05$). The comparison of the participants according to their answers to the questions 'Do you think 3D printer technologies will be used more in the future?' and 'Would you like to attend a course/seminar to increase your knowledge about 3D printer technologies?' is given in Table 4. There was no statistically significant difference ($p>0.05$) between the rate of the answers given by the participants according to their gender, professional title, institution and professional experience.

Table 4: Comparison of Dentists' 3D Printing Experience, Availability, and Future Perspectives

		3D Printing Experience		**P**	**3D Printer Availability in Clinic**		**P**	**Milling Restorations Experience**		**P**	**Use of 3D Printing in Future Dentistry**			**P**	**Request to attend seminars about 3D Print**		**P**
		Yes	No		Yes	No		Yes	No		Yes	No	No idea		Yes	No	
Gender	Female	62	141	0.003**	34	169	0.995	53	150	<0.001***	198	2	3	0.390	171	32	0.925
	Male	71	84		26	129		73	82		148	1	6		130	25	
Title	General Practitioner Dentist	72	148	0.029*	19	201	<0.001***	90	130	0.015*	210	1	9	0.067	187	33	0.144
	Research Assistant Dentist	32	50		29	53		20	62		80	2	0		72	10	
	Specialist Dentist	29	27		12	44		16	40		56	0	0		42	14	
Workplace	State Hospital	9	67	<0.001***	2	74	<0.001***	9	67	<0.001***	73	0	3	0.076	61	15	0.494
	Private Clinic	71	89		19	141		84	76		153	1	6		138	22	
	University Hospital	53	69		39	83		33	89		120	2	0		102	20	
Experience	5 or less than 5 years	73	134	0.387	40	167	0.128	63	144	0.027*	202	3	2	0.023*	173	34	0.761
	More than 5 years	60	91		20	131		63	88		144	0	7		128	23	

Significance levels, *P<0.05, **P<0.01, ***P<0.001

The comparison of the participants' answers to the question of which is the best material for 3D printers is given in Table 5. The participants' knowledge of the best material for 3D printers showed a significant difference between male and female participants ($p<0.05$).

The evaluation of the participants' answers to the question of in which applications do you use 3D printers in your clinic is given in Table 6. A statistically significant difference was found between the proportion of the answers given by the participants according to both the institution where they work and their professional experience ($p<0.05$).

Participants were asked the question 'What is the reason for inexperience in 3D printer technologies?'. The responses of the participants are given in Figure 1. 'expensive systems' (77%) was the most common answer, followed by 10% 'lack of sufficient practice', 10% 'complex technical information', and 3% 'being unaware of 3D printers'.

Participants were asked how often they use 3D printers and the responses are given in Figure 2. 75% of the participants reported that they do not use a 3D printer. 12% responded a few times a month, 8% a few times a week, 4% a few times a day.

Table 5: Comparison of dentists about 3D printing experience and 3D printer availability in clinics.

		Thermoplastic material	Light cure resin	Sintered Powder	No idea	P
Gender	Female	19	50	13	121	0.001**
	Male	35	35	17	68	
Title	General Practitioner Dentist	39	49	19	113	0.755
	Research Assistant Dentist	9	22	7	44	
	Specialist Dentist	6	14	4	32	
Workplace	State Hospital	11	13	8	44	0.387
	Private Clinic	29	36	13	82	
	University Hospital	14	36	9	63	
Experience	5 or less than 5 years	26	52	18	111	0.460
	More than 5 years	28	33	12	78	

Significance levels, *P<0.05, **P<0.01, ***P<0.001

Table 6: Comparison of dentists about 3D printing experience and 3D printer availability in clinics.

		Diagnostic Model Production	Prosthetic Restorations	Surgical Guide	Orthodontic Applications	No Idea	P
Gender	Female	19	131	11	25	17	0.800
	Male	16	97	9	15	18	
Title	General Practitioner Dentist	23	140	11	19	27	0.263
	Research Assistant Dentist	6	56	4	12	4	
	Specialist Dentist	6	32	5	9	4	
Workplace	State Hospital	7	46	4	4	15	0.012*
	Private Clinic	17	109	8	14	12	
	University Hospital	11	73	8	22	8	
Experience	5 or less than 5 years	20	143	8	23	13	0.027*
	More than 5 years	15	85	12	17	22	

Significance levels, *P<0.05, **P<0.01, ***P<0.001

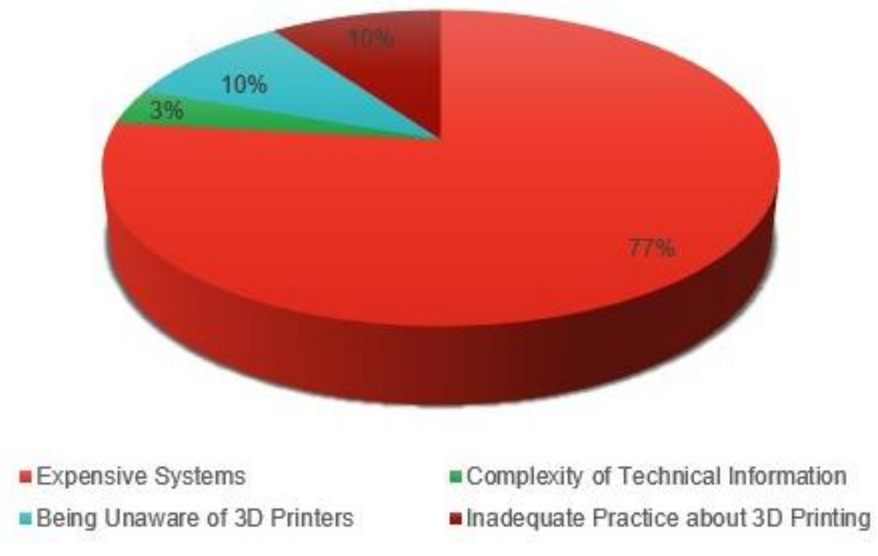

Figure 1: Showing the reason for inexperience

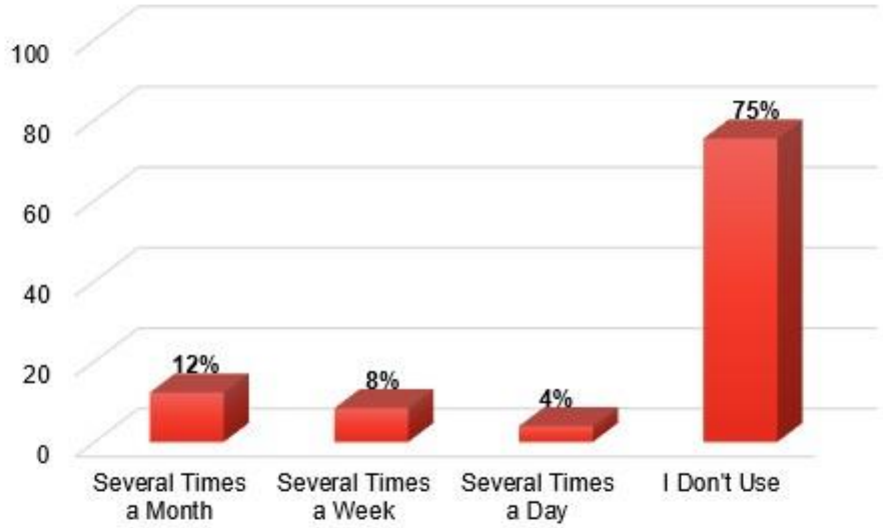

Figure 2: How often is it used

DISCUSSION

3D printer technology is defined as a manufacturing process that creates an object layer by layer, allowing the object to be formed by adding multiple layers to each other. 3D printer technology can also be defined as additive manufacturing or rapid prototyping. 3D printer technology is a promising technology in various fields such as medicine and dentistry, defense, art, architecture and engineering by enabling people to customize and produce their designs.[7]

The development of computer technology and software applications in recent years has contributed greatly to 3D printer technology. The 3D printing process starts with the design of a virtual image of the object to be produced, after which the information is converted into a digital file. The virtual design is realized thanks to a 3D modeling program. For this, CAD software is needed, which enables objects to be created from scratch. Examples of 3D printing technologies include SLA, inject printing, selective laser sintering (SLS), fused deposition modeling (FDM).[2]

Of the 358 dentists, 322 (89.9%) answered 'yes' to this question 'Do you have any information about the use of 3D printing technologies in dentistry? Of those who answered 'yes', 51.3% were female, 53.9% were general practitioner dentists, 32.1% worked at a university hospital and 53.6% had less than 5 years of professional experience. In a study conducted by Dhokar et al.[1] with 700 dentists in Maharashtra, 85.2% answered 'yes' to this question. Similar results have been observed about the use of 3D printing technologies in dentistry. In the study conducted by Chandran et al.[11] with 100 dental students, the rate of those who answered 'yes' was 58%. It is thought that the reason why this rate is lower is that it is a study for students. While the results of our study align with those of Dhokar et al.[1], a key difference is that our participant pool consists exclusively of dentists, whereas Chandran et al.[11] focused on dental students. This difference may account for the lower knowledge levels observed in their study, as students generally have limited clinical exposure. Furthermore, regional variations in access to technology and training opportunities may influence the level of awareness and utilization of 3D printing in different populations.

When we asked 'Have you had the opportunity to experience 3D printing technologies?', 133 out of 358 dentists (37.1%) answered 'yes'. In the study conducted by Chandran et al.[11] with 100 dental students, the rate of those who answered 'yes' was 12%(22). In the study conducted by Dhokar et al.[1]

In the study by Parikh et al.[12] 800 orthodontists in India were asked whether they used 3D Print manufacturing technologies. 47.5% of the respondents answered 'yes'. It was found that orthodontists had more opportunities to experience this technology, while the opposite was the case among students.[12] This variation in experience across different groups highlights the impact of professional specialization on exposure to emerging technologies. Orthodontists, who frequently rely on digital workflows, may have greater familiarity with 3D printing compared to general dentists or students. Therefore, future research should explore how training programs can bridge this gap for less-experienced practitioners.

52.7% of the participants answered, 'no idea' to the question 'What is the best material for 3D printer technologies?', while 23.7% answered 'light curing resin'. In the study conducted by Dhokar et al.[1] 58.7% of the participants gave the answer 'no idea' while 14% gave the answer 'light curing resin'. The results of the study are compatible with current study.[1]

In this study, 63.6% of the participants answered aesthetic and prosthetic restorations to the question 'Do you use 3D printer technology in your clinic in which applications?'. In the study conducted by Dhokar et al.[1] 43.4% of the participants answered in surgical guide preparation. While dentists in Türkiye primarily use this technology for aesthetic procedures, it is thought to be predominantly used for surgical applications in India.[1] The differences observed in application preferences may be attributed to regional differences in dental practice priorities, availability of materials, and regulatory frameworks. Further investigation is needed to determine whether economic and infrastructural factors influence these patterns of usage. This study highlights a significant awareness gap in the clinical application of 3D printing technologies among dentists. Addressing this issue requires integrating structured training modules on 3D printing into dental education curricula and postgraduate courses. Hands-on workshops, simulation-based training, and access to digital laboratories can enhance dentists' confidence and ability to utilize these technologies effectively in daily practice.

77% of the participants answered the question, "What is the reason for inexperience in 3D printer technologies?" with "high-cost systems." In contrast, in the study by Dhokar et al.[1], 30% of the participants stated that 3D printers were not available in clinics, while 29% attributed their inexperience to high costs. Considering that the reason for not being in clinics is high-cost systems, it can be said that the results of this study show similar results with the study of Dhokar et al.[1] Although cost remains a significant barrier, the availability of institutional funding or financial incentives may play a crucial role in increasing access to 3D printing technologies in clinical practice. Exploring cost-effective alternatives and promoting government or private sector investment could help overcome these limitations. This study has certain limitations that should be acknowledged. Firstly, the study was conducted exclusively in Türkiye, limiting the generalizability of findings to other geographic regions. The participant pool consisted only of licensed dentists, excluding dental students, technicians, and other stakeholders who may influence the adoption of 3D printing technologies. Additionally, the self-reported nature of the survey may introduce bias, as responses may not always reflect actual clinical behavior. Future studies with broader sample groups, including international comparisons and longitudinal data, are recommended to gain a more comprehensive understanding of the factors influencing the adoption of 3D printing in dentistry. The findings of this study shed light on the awareness, knowledge, and experiences of dentists regarding the use of 3D printing technologies in dentistry. Interestingly, our results indicate that dentists with less professional experience exhibited higher levels of knowledge and interest in 3D printing technologies. This trend could be attributed to various factors, including the integration of recent technological advancements into dental education curricula, as well as the innate adaptability of younger professionals to emerging technologies.[13,14]

Moreover, this study found that despite the majority of dentists being aware of the applications of 3D printing in dentistry, their level of practical experience with these technologies remains limited. This is consistent with previous research highlighting the gap between awareness and actual utilization of 3D printing technologies among dental professionals.[15,16] The discrepancy between knowledge and experience underscores the need for targeted interventions aimed at bridging this gap and facilitating the integration of 3D printing technologies into routine dental practice.

One notable barrier identified by participants in this study was the perceived costliness of 3D printing systems, with 77% of respondents citing this as the primary reason for their inexperience with technology. This finding aligns with previous studies highlighting cost as a significant hindrance to the adoption of 3D printing technologies in dentistry.[15,16] Addressing this barrier will require collaborative efforts from stakeholders, including universities, governments, and investors, to make 3D printing systems more affordable and accessible to dental practitioners.[17,18]

In light of these findings, several practical implications can be drawn. Firstly, there is a pressing need for targeted educational initiatives, such as courses, seminars, and training programs, aimed at enhancing dentists' knowledge and proficiency in 3D printing technologies.[19] By equipping dental professionals with the necessary skills and knowledge, these initiatives can facilitate the widespread adoption of 3D printing technologies and maximize their potential benefits in dental practice.[20]

Furthermore, efforts to make 3D printing systems more affordable and accessible should be prioritized to overcome financial barriers and promote wider adoption among dental practitioners.[21,22] This could involve exploring financing options, subsidies, or collaborative purchasing arrangements to mitigate the upfront costs associated with acquiring 3D printing equipment.[23,24]

In conclusion, while our study highlights the potential of 3D printing technologies to revolutionize dental practice, it also underscores the need for concerted efforts to overcome barriers to adoption and maximize the benefits of these technologies. By enhancing dentists' knowledge and accessibility to 3D printing systems, we can empower dental professionals to deliver more efficient, precise, and patient-centered care in the digital age. While this study provides valuable insights into the current awareness and application of 3D printing technologies in dentistry, further research is needed to explore long-term clinical outcomes and patient-related benefits. Future investigations should focus on evaluating the cost-effectiveness of 3D printing in dental procedures and its impact on treatment efficiency, precision, and patient satisfaction. Expanding research to include interdisciplinary collaborations with material scientists and biomedical engineers could also lead to innovative advancements in dental applications of 3D printing.

It was observed that although dentists have knowledge about the applications in which 3D printer technologies are used and think that they will be used more in the future, their opportunities to experience and clinical access are low. Making 3D printer technologies more affordable and providing the necessary support by universities, governments and investors will improve the application of 3D printers in dentistry.[24]

CONCLUSION

Our cross-sectional survey indicates that while most dentists accurately identify the principal clinical applications of 3D printing in dentistry. Notably, practitioners with under five years of experience reported significantly higher familiarity and interest, revealing an experience-related gap in hands-on training. Primary obstacles include equipment cost, lack of structured practical education, and uncertainty about workflow integration. We recommend a unified continuing-education initiative that combines concise theoretical briefings with dedicated hands-on workshops, equipping all dentists with the skills required for efficient and precise 3D-printed treatment planning and delivery.

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