Journal of Oral Biology and Craniofacial Research 13 (2023) 253–258

Contents lists available at ScienceDirect

Journal of Oral Biology and Craniofacial Research

journal homepage: www.elsevier.com/locate/jobcr

Assessment of knowledge, awareness, and practices toward the use of 3D printing in dentistry among dental practitioners and dental technicians: A cross-sectional study

Aditya Acharya, Raisa N. Chodankar *, Raghunath Patil, Anandkumar G. Patil

Department of Prosthodontics and Crown and Bridge, KAHER' S KLE VK Institute of Dental Sciences, Belagavi, Karnataka, 590010, India

ARTICLE INFO

Keywords:
Additive manufacturing
Dentists
Dental technicians
3-dimensional printing
Rapid prototyping
Surveys and questionnaires

ABSTRACT

Background: The applications and scope of digitization and technology in dentistry are becoming increasingly valuable right from clinical dentistry to research, student training, teaching, and laboratory techniques. Mastering 3D printing and its usage are essential for dental practitioners and dental technicians as it allows them to choose and necessarily know what is offered, as well as how to implement it in everyday practices thereby contributing to the betterment of the dental profession. The study aims to assess dental practitioners' and dental technicians' knowledge, understanding, and practices related to the use of 3D printing in dentistry.

Methods: A cross-sectional questionnaire-based study was done among dental practitioners and technicians in Karnataka, India who were given access to a self-explanatory questionnaire via Google link consisting of questions that evaluated their knowledge, awareness, and practices regarding 3D printing. The Chi-square test was used for statistical analysis.

Results: A total of 380 replies were obtained after the questionnaire was circulated. Awareness regarding the use of digital technology in dentistry was known by 98.9% of practitioners and 92.7% of technicians, of which we discovered that 9.28% of practitioners and 17.7% of technicians were unfamiliar with 3D printing, which was statistically significant ($p = 0.0400^*$). 81.6% of practitioners consider 3D printing can be used to fabricate complex design prostheses.

Conclusion: The participants' understanding of digital dentistry and 3D printing is acceptable. The majority of dental professionals expressed an interest in adopting 3D printing and believe that there should be a forum for collecting and exchanging skills and knowledge about 3D printing.

1. Introduction

Over the last decade, the rise of digitalization and three-dimensional (3D) printing has modified the way dentistry is practiced.[1] The applications and scope of digitization and technology in dentistry are becoming increasingly valuable right from clinical dentistry to research, student training, teaching, and laboratory techniques.3D printing, also known as rapid prototyping or additive manufacturing (AM), entails the layer-by-layer addition of a material to construct an object or structure utilizing CAD/CAM technology or advanced imaging and scanning.[1–3] After obtaining the model data with the use of scanners or data from Computed tomography or Cone-beam computed tomography scans, a Standard tessellation file (STL) of the 3D model design is prepared using computer-aided design (CAD) software, after which processing and slicing of the 3D model are done. The STL file is then transferred to the 3D printer, where the product is manufactured layer by layer and the final step is post-processing the product.[2,4]

AM techniques are applied in a variety of dentistry disciplines, from dental model prototypes to surgical guides and splints, orthodontic aligners, and prostheses such as crowns, bridges, and veneers, laminates. In addition to craniomaxillofacial implants, tissue scaffolds for both hard and soft tissue printing can also be 3D printed which has a major role in craniofacial reconstruction and implantology.[3–7] 3D printing's advantages include quick production, high precision, and customization, and it may be used for everything ranging from removable to fixed prostheses.[7] Greater surface precision, as worn cutting tools do not

* Corresponding author. Department of Prosthodontics and Crown and Bridge, KAHER' S KLE VK Institute of Dental Sciences, JNMC Campus, Nehrunagar, Belagavi, Karnataka, 590010, India.
E-mail address: raisachodankar@gmail.com (R.N. Chodankar).

https://doi.org/10.1016/j.jobcr.2023.02.001
Received 16 June 2022; Received in revised form 3 November 2022; Accepted 4 February 2023

1 Are you aware of the use of digital technology in dentistry?

- Yes No

2 Are you aware of the use of 3D printing in dentistry?

- Yes No

3 For which product do you think 3D printing is used in dentistry?

- Crown and bridge fabrication
- Implant drill guides
- Partial denture framework
- Maxillofacial prosthetics
- Occlusal splints
- Digital orthodontics
- Regenerative dentistry
- Educational tool. -Others (please specify)

4 What are the 3D printing technologies you are aware of?

- Stereolithography (SLA, SL)
- Photopolymer jetting (PPJ)
- Selective laser sintering (SLS)
- Fused Deposition Modeling (FDM).
- Electron Beam Melting (EBM)
- Power binder printers
- Direct light processing
- Bioprinter

5 Which materials do you think are compatible with 3D printing?

- Photopolymerizing resin
- Thermoplastic polymers
- Waxes
- Metals (Titanium, Nickel chrome and cobalt chrome)
- Ceramics -Others (please specify)

6. Do you think there is an ease of communication with the laboratory technician when it comes to 3Dprinting?

- Yes No

7. What mode of communication would you prefer to give/ receive to the laboratory?

- Intra oral scan Model scan
- Others

8. Have you attended any training programs on 3D printing?

- Yes No

9. If yes , what form of training program have you attended ?

- Hands on training

Webinars/ lectures -Others

10. Would you prefer 3D printing over conventional methods?

- Yes No

11. Do you think there is a need to increase the knowledge/teaching about 3D printing during undergraduate/postgraduate and dental mechanic courses?

- Yes No

12. Do you think digital technology is the future of dentistry and will have a positive impact on our profession?

- Yes No

13. What do you think are the advantages of 3D printing in dentistry?

- Can be used for Complex design
- Time-saving
- Lesser material wastage
- High precision and accuracy
- Use of complex machinery

14. What do you think are the limitation of the use of 3D printing?

- Costly
- Need for skilled operators
- Use of limited materials and additional treatment to materials required
- Increased speed of fabrication and decreased accuracy
- Others

15. What according to you are the advantages of 3D printing over CAM?

- Minimal wastage of raw material
- Cannot give the precision fit of the inside contour
- The ability of mass production
- No microscopic crack developed into ceramic.

16.Do you think 3D printing will help to reduce the time for actual patient care?

- Yes No

17. In the current COVID-19 scenario, do you think digital dentistry has a role to play?

- Yes No

18. Are you interested in incorporating 3D printing into your regular workflow?

- Yes No

Fig. 1. Shows the custom questionnaire form including questions 1- 18.

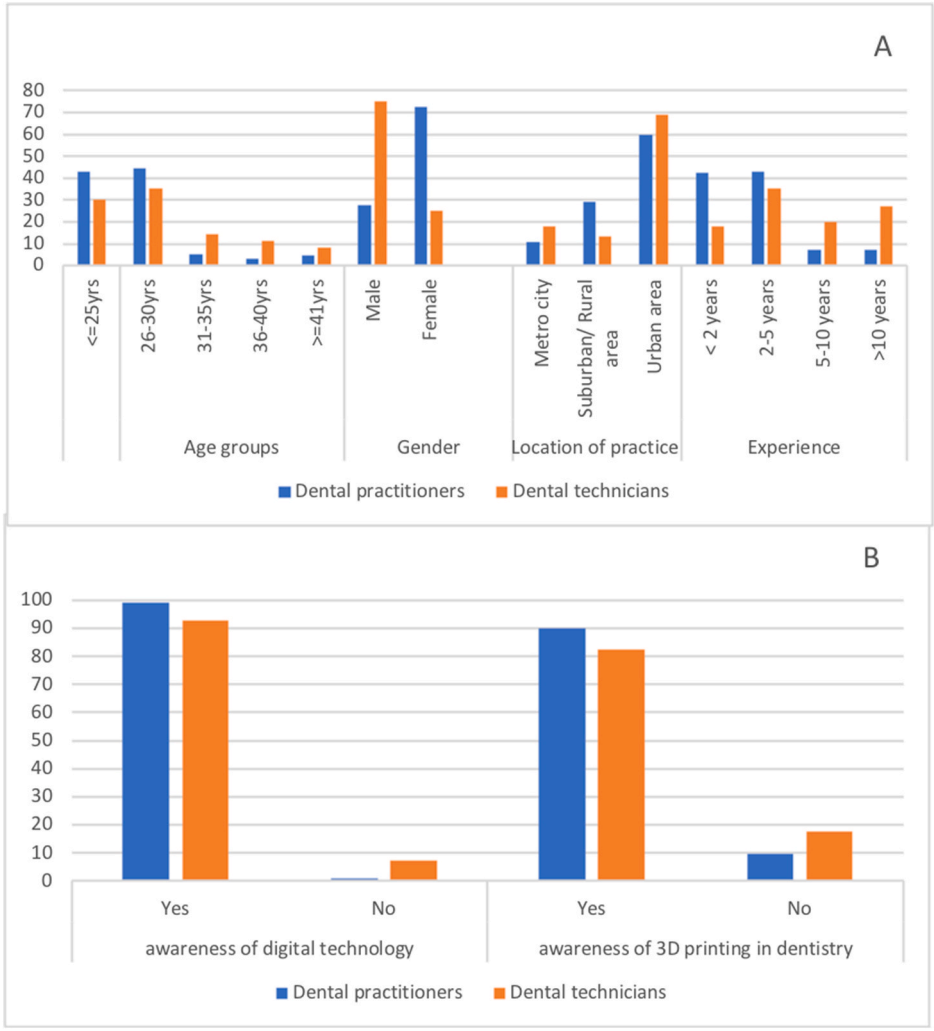

Fig. 2. A) Demographic details of participants. 2B) Shows participants' awareness of digital technology and 3D printing in dentistry.

affect precision and mass manufacturing, is one of the advantages of 3D printing over subtractive techniques.[8,9] Three categories can be used to group the 3D printing technology. Powder bed fusion (PBF), which primarily uses metal materials, includes selective laser melting (SLM), selective laser sintering (SLS), electron beam melting (EBM); Vat photopolymerization (VPP), which includes digital light processing (DLP), stereolithography (SLA), and photo jet uses photosensitive resin materials and fused deposition modeling (FDM). —all have their advantages and limitations[5,8,9]

There have been surveys to evaluate dental practitioners' knowledge and practices of 3D printing in Maharashtra[10] The impact of social media on additive manufacturing technology among dental specialists and their routine use of 3D printing was also explored in a survey[11] The goal of the present study was to assess and comprehend dental practitioners' and dental technicians' knowledge, awareness, and practices regarding 3D printing in Karnataka, India.

2. Materials and methodology

2.1. Ethics statement

The Institutional Ethical Committee approval was obtained from KAHER KLE VK Institute of Dental sciences Belagavi, Karnataka, India (certificate number: 1506 dated November 02, 2021). The study objectives were given to the participants, and they gave their informed consent.

2.2. Study design and setting

A cross-sectional questionnaire-based study was conducted among dental practitioners and dental technicians in Karnataka, India in November–December 2021.

2.3. Eligibility criteria

Dental technicians from private dental laboratories and dental institutions, Dental practitioners (BDS and MDS, teaching faculty), and Postgraduate students in India were included in the study. The study excluded individuals other than dentists and dental technicians as well as undergraduate dental students. Participants who declined to participate in the study were withdrawn from the study. The sample size was estimated using the formula $n = ((Z\_(1-\alpha/2))\hat{2}\ (pq))/d\hat{2}$ where n is the sample size, p is the prevalence of knowledge towards the use of digital technology in dentistry among dental professionals obtained from the pilot study (84%), and d is the permissible error. Thus, the estimated sample size was 291. Convenience sampling was used, and participants were given access to this self-explanatory questionnaire via a Google link through e-mail and social media platforms. Compulsory fields were included in the online survey form, guaranteeing that no incomplete responses were accepted.

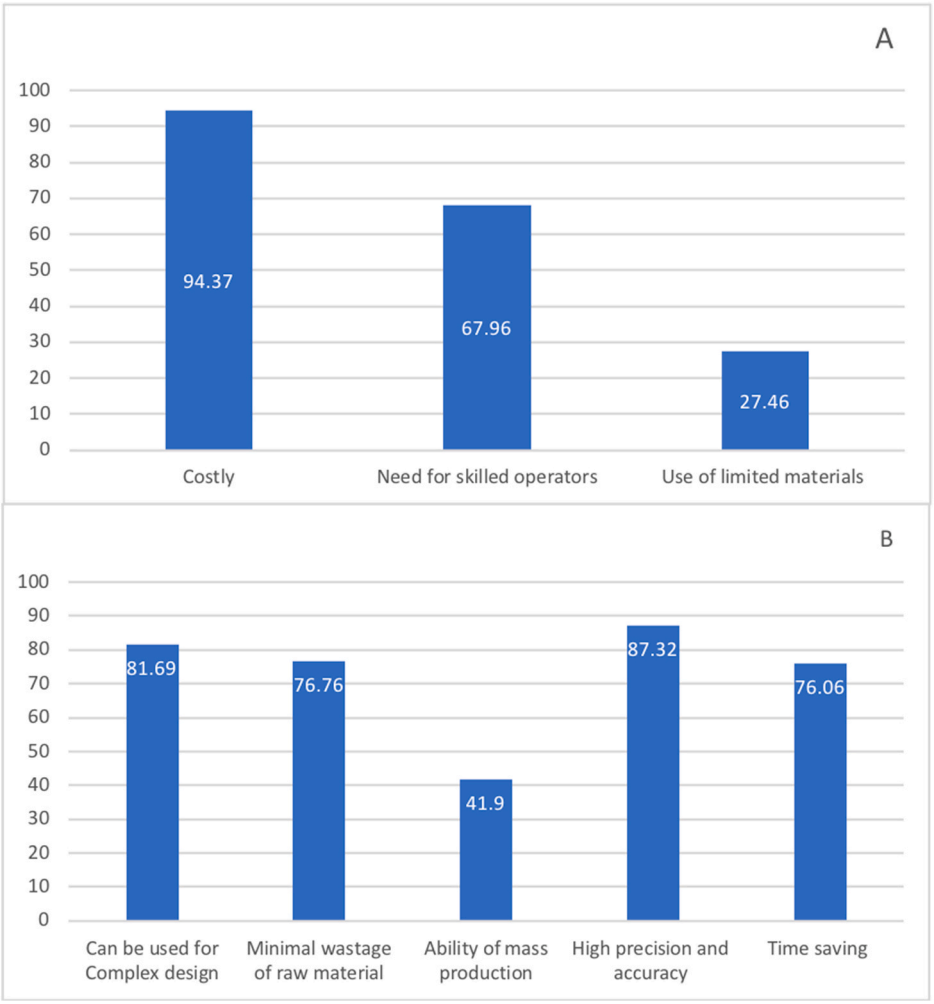

Fig. 3. A. Responses of the dental practitioners to limitation of the use of 3D printing. 3B. Responses of the dental practitioners to advantages of 3D printing.

2.4. Study proforma and data collection

The custom questionnaire was divided into two sections, with the first including demographic information and the second comprising the questions.

With five open-ended questions and thirteen closed-ended questions, questions (Q1-Q5) were beneficial in determining knowledge and awareness, while questions (Q6-Q12) were useful in determining the current clinical practice of 3D printing among dental practitioners and technicians. The practitioners were asked specific questions (Q13-Q18) about their awareness of the limitations and benefits of 3D printing, as well as patient-related questions(Fig. 1). The questionnaire form was validated by pilot testing 40 dental practitioners and 20 technicians. Faculty from the department of Prosthodontics, KAHER VK Institute of Dental Sciences, Belagavi, Karnataka, along with subject experts, validated the questionnaire for the relevance of questions specific to the survey's topic (Content validity). Based on the pilot study, the questionnaire's reliability and internal consistency were established, with a Cronbach's alpha internal consistency score of 0.78. During the study, if any problems occurred during filling up the questionnaire form, the researcher quickly rectified them.

2.5. Statistical analysis

Individual replies from each participant were compiled on a Microsoft Excel sheet. For statistical analysis, the Statistical Package for the Social Sciences (SPSS) Software version 20.0 (IBM Corp., USA) was used. The Chi-square test was used to see if there was any notable correlation between the questionnaire items dental practitioners and dental technicians and with a level of significance p-value <0.05.

3. Results

Upon the distribution of the pretested questionnaire in the form of a Google form link, a total of 380 replies were received of which 284 came from dental practitioners, among which 115 were pursuing postgraduate studies, 92 were general practitioners, 59 were specialists, and 18 were prosthodontics teaching faculty. Among the 96 responses by the dental technicians, 61 were employed at private laboratories and 35 at dental colleges. We found that 72.5% of dental practitioners were females and 75% of technicians were males, with the majority belonging to the age group of 26–30 years, with an average experience of 2–5 years, and 59.86% practising in urban areas (Fig. 2A).

Awareness of the use of digital technology in dentistry was known by 281(98.9%) dental practitioners and 89 (92.7%) dental technicians, of which we discovered that 9.28% of practitioners and 17.7% of technicians were unfamiliar with 3D printing in dentistry, which was statistically significant ($p = 0.0400$). (Fig. 2B).

Additional questions were presented to the dental professionals, such as the limitations of 3D printing in dentistry which 94% believe it is expensive, 67.9% said skilled operators are required, and 27% think that just a limited number of materials may be utilized in 3D printing (Fig. 3A). When asked if digital dentistry plays a role in the current COVID-19 scenario, 277 dentists responded yes.

Table 1
Shows the participants' responses to knowledge regarding applications, technologies, and materials in 3D printing. *p-value <0.05 to be considered significant.

		Dental practitioners (n,%)	Dental technicians (n,%)	Total (n,%)	χ^2	P- value
For which product do you think 3D printing is used in dentistry?						
Crown and bridge fabrication	Yes	252,(88.73%)	79, (82.29%)	331,(87.11%)	2.650	0.104
	No	32, (11.27%)	17,(17.71%)	49, (12.89%)		
Implant drill guides	Yes	187,(65.85%)	29,(30.2%)	216,(56.84%)	37.143	0.0001*
	No	97,(34.15%)	67,(69.8%)	164,(43.16%)		
Partial denture framework	Yes	170,(59.86%)	47,(48.96%)	217,(57.11%)	3.481	0.0620
	No	114,(40.14%)	49, (51.04%)	163,(42.89%)		
Maxillofacial prosthetics	Yes	220,(77.46%)	35,(36.46%)	255,(67.11%)	54.655	0.0001*
	No	64,(22.54%)	61, (63.54%)	125, 32.89%)		
Occlusal splints	Yes	165(58.10%)	17(17.71%)	182,(47.89%)	46.902	0.0001*
	No	119,(41.9%)	79(83.29%)	198,(52.11%)		
Digital orthodontics	Yes	173(60.92%)	18(18.75%)	191,(50.26%)	51.026	0.0001*
	No	111,(39.08%)	78(81.25%)	189,(49.74%)		
Regenerative dentistry	Yes	92,(32.39%)	6,(6.25%)	98,(25.79%)	25.624	0.0001*
	No	192,(67.61%)	90,(93.75%)	282,(74.21%)		
Educational tool	Yes	138,(48.59%)	0,(0.00%)	138,(36.32%)	73.249	0.0001*
	No	146,(51.41%)	96, (100%)	242,(63.68%)		
Others (please specify)	Yes	3,(1.06%)	1,(1.04%)	4,(1.05%)	0.000	1.0000
	No	281,(98.94%)	95, (98.96%)	376,(98.95%)		
What are the 3D printing technologies you are aware of?						
Stereolithography	Yes	197, (69.37%)	44, (45.83%)	241, (68.95%)	17.127	0.0001*
	No	87,(30.63%)	52,(54.17%)	139,(31.05%)		
Photopolymer jetting	Yes	76,(26.76%)	55, (57.29%)	182,(47.89%)	29.607	0.0001*
	No	208,(73.24%)	41, (42.71%)	198,(52.11%)		
Selective laser sintering	Yes	168,(59.15%)	23, (23.96%)	118,(31.05%)	35.553	0.0001*
	No	116,(40.85%)	73,(76.04%)	262,(68.95%)		
Fused Deposition Modeling	Yes	79, (27.82%)	18, (18.75%)	131,(34.47%)	3.103	0.078
	No	205,(72.18%)	78,(81.25%)	249,(65.53%)		
Electron Beam Melting	Yes	63,(22.18%)	26, (27.08%)	143,(37.63%)	0.961	0.327
	No	221,(77.82%)	70,(72.92%)	237,(62.37%)		
Power binder printers	Yes	27, (9.51%)	11, (11.46%)	108,(28.42%)	0.304	0.582
	No	257,(90.49%)	85,(88.54%)	272,(71.58%)		
Direct light processing	Yes	45,(15.85%)	5, (5.21%)	46, (12.11%)	7.157	0.007*
	No	239,(84.15%)	91,(94.79%)	334,(87.89%)		
Bioprinter	Yes	115,(40.49%)	6, (6.25%)	67, (17.63%)	38.764	0.0001*
	No	169,(59.51%)	90,(93.75%)	313,(82.37%)		
Which materials do you think are compatible with 3D printing?						
Photopolymerizing resin	Yes	193,(67.96%)	47,(48.96%)	240,(63.16%)	11.130	0.0001*
	No	91, (32.04%)	49,(51.04%)	140,(36,84%)		
Thermoplastic polymers	Yes	173,(60.92%)	52, (54.17%)	225,(59.21%)	1.353	0.245
	No	111,(39.08%)	44,(45.83%)	155,(40.79%)		
Waxes	Yes	78,(27.46%)	32,(33.33%)	110,(28.95%)	1.201	0.273
	No	206,(72.54%)	64,(66.67%)	270,(71.05%)		
Metals	Yes	166,(58.45%)	41, (42.71%)	207,(54.47%)	7.170	0.007*
	No	118,(45.55%)	55,(57.29%)	173,(45.53%)		

4. Discussion

From medical simulation, prosthodontics, orthodontics, restorative dentistry, and oral implantology to instrument manufacturing, these are just a few of the domains where 3D printing is used. Its use indicates that this area of digital dentistry has the potential for everyday use in several domains.[1] Despite its advancement, data on evaluating dental practitioners' and dental technicians' 3D printing knowledge and practices are limited. The key strength of this research is the paucity of research on 3D printing in dentistry among dental practitioners and dental technicians, both of whom actively engage in the clinical and laboratory fabrication of the desired products.

An online survey conducted by Hegedus, T. et al.[11] found that the majority of dentists, dental technicians, and CAD/CAM experts used their 3D printers to fabricate prostheses (87), surgical guides (69), orthodontics (52), castable waxes (45), and splints(79). In our survey, some dentists suggested that 3D printing could be helpful in the construction of complete dentures and rehabilitation utilizing patient-specific implants in the maxillofacial region (1.06%). 48.59% of dental practitioners and none of the technicians think that 3D printing can be used as an educational tool in dentistry (p = 0.0001) (Table 1). 3D printed models can aid in the production of models that are based on simulated everyday clinical scenarios which can be used to strengthen dental education and provide students to practice their manual skills and hands-on preclinical and clinical dental training.[12,13]

According to Hegedus T et al., intraoral scanners (73) and lab scanners (67) were utilized approximately equally, and frequently in combination.[11] The intraoral scanner was favoured by 70% of dental practitioners, and 57% of technicians, while CBCT was preferred by 1% of both (p = 0.0001). By using patient data from imaging procedures like computed tomography (CT) or magnetic resonance imaging (MRI), 3D printing technologies customize facial implants for each patient.[14] With the intra-oral scanner, clinic operations are simpler, plaster models are eliminated, and the dentist and dental technician can communicate more effectively, which lowers errors. The confocal trend in intraoral scanning technology has progressed, making scanning more precise and quicker.[15]

Metal alloys have been extensively used in 3D printing to manufacture all kinds of metal products including AM titanium (Ti) dental implants, custom subperiosteal Ti implants, custom Ti mesh for bone grafting techniques, cobalt-chromium frames for implants superstructure, crowns and bridges, prostheses that can provide us with dense end-products[1,8,16] and according to our survey, 58.45% of dental practitioners and 42.7% of technicians think metals are compatible with 3D printing (p = 0.007*) (Table 1).

When asked about the advantages of 3D printing, 81.6% of dental

Table 2
Shows the practice-based question. *p-value <0.05 to be considered significant.

	Dental practitioners (n,%)	Dental technicians (n,%)	Total (n, %)	χ^2	P- value
What mode of communication would you prefer to give to the laboratory technician?					
CBCT	3, (1.06%)	1,(1.04%)	4, (1.05%)	25.988	0.0001*
Intraoral scan	200,(70.42%)	40,(41.67%)	240, (63.16%)		
Model scan	81,(28.52%)	55,(57.29%)	136, (35.79%)		
Have you attended any training programs on 3D printing?					
No	195(68.66%)	42 (43.75%)	237 (62.37%)	18.972	0.0001*
Yes	89 (31.34%)	54 (56.25%)	143 (37.63%)		
If yes, what form of training programs on 3D printing have you attended?					
Hands on training	8, (2.82%)	5,(5.21%)	13, (3.42%)	1.242	0.265
Hands on training, Webinar/ lectures	11,(3.87%)	11,(11.46%)	22 (5.79%)	7.568	0.006*
Webinar/ lectures	70,(24.65%)	38,(39.58%)	108 (28.42%)	7.867	0.005*

practitioners consider 3D printing can be used to fabricate complex design prostheses, including designs with hollow components such as hollow obturators or hollow complete dentures.[17] 76.7% of dentists believe that there is minimal waste of raw material when the product is 3D printed (Fig. 3B) Material waste can be decreased by 40%, resulting in a positive benefit on manufacturing sustainability.[5] During the printing process, SLM and SLS powder material that was not utilized can be recycled up to 95–98%.[9] 76% of practitioners think that 3D printing is time-saving and when it comes to the time devoted to patient care, 96.48% of dental practitioners believe 3D printing will assist to minimize the time taken to treat patients.3D printing can benefit one-day dentistry, but careful planning is essential before making this decision to guarantee a successful and precise workflow.[18]

According to our research, 68.66% of dentists and just 43.75% of technicians have received training ($p = 0.0001$*) (Table 2). Due to a lack of knowledge, support, and services, dentists and dental technicians may have a tough time determining which brand to purchase or difficulties in the fabrication of products.[11] Therefore, effective training, experience, and information exchange should be conducted via webinars, workshops, and social media. 3D printing should be incorporated in dentistry undergraduate courses, according to 55.99% of practitioners.

Limitations: The study has some limitations, such as the fact that it is not available to those who cannot be reached via social media or e-mail and a small sample size.

Suggestions: A larger sample size would aid in providing a more thorough picture of the technology's implementation into routine dentistry from various parts of the country. The study population of dental practitioners and technicians assures that a higher percentage of those included have already implemented this technology in their usual practice or are likely to do so in the future. Further studies can yield a comparison of the demands and methods of 3D printing used by different specialities, including prosthodontics, orthodontics and dentofacial orthopaedics, oral and maxilla facial surgery, endodontics etc. More research may be done to compare traditional methods with 3D printing in terms of precision, fit, and accuracy, as well as longevity of the prosthesis or product. Future research should concentrate on the long-term viability of 3D printing to ensure a smooth transition from analogue to digital dentistry.

5. Conclusion

3D printing is gaining space in dentistry right from prosthodontics, restorative dentistry, orthodontics, implantology, and instrument production. By expanding diagnostic, therapeutic, and educational potential, 3D printing is redefining digital dentistry. As a result of the industry's increased research and hope, more opportunities would open up. The majority of dental professionals expressed an interest in adopting 3D printing into their daily work routines and believe that digital technology would have a favourable impact on our profession. We should provide a forum for collecting and exchanging skills and knowledge about 3D printing through our digital community and active participation in workshops.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

No potential conflict of interest relevant to this article was reported.

References

1 Pillai S, Upadhyay A, Khayambashi P, et al. Dental 3D-printing: transferring art from the laboratories to the clinics. *Polymers*. 2021;13(1):157. https://doi.org/10.3390/polym13010157.
2 Bhambhani R, Bhattacharya J, Sen SK. Digitization and its futuristic approach in prosthodontics. *J Indian Prosthodont Soc*. 2013;13(3):165–174. https://doi.org/10.1007/s13191-012-0181-2.
3 Gupta C, Mittal A. Role of digital technology in prosthodontics: a step toward improving dental care. *Indian J Oral Health Res*. 2018;4(2):35–41. https://doi.org/10.4103/ijohr.ijohr_19_18.
4 Oberoi G, Nitsch S, Edelmayer M, Janjić K, Müller AS, Agis H. 3D printing-encompassing the facets of dentistry. *Front Bioeng Biotechnol*. 2018;6:172. https://doi.org/10.3389/fbioe.2018.00172.
5 Alharbi N, Wismeijer D, Osman RB. Additive manufacturing techniques in prosthodontics: where do we currently stand? A critical review. *Int J Prosthodont (IJP)*. 2017;30(5):474–484. https://doi.org/10.11607/ijp.5079.
6 Athirasala A, Tahayeri A, Thrivikraman G, et al. A dentin-derived hydrogel bioink for 3D bioprinting of cell-laden scaffolds for regenerative dentistry. *Biofabrication*. 2018;10(2), 024101. https://doi.org/10.1088/1758-5090/aa9b4e.
7 Jacobs CA, Lin AY. A new classification of three-dimensional printing technologies: systematic review of three-dimensional printing for patient-specific craniomaxillofacial surgery. *Plast Reconstr Surg*. 2017;139(5):pp1211–1220. https://doi.org/10.1097/PRS.0000000000003232.
8 Tian Y, Chen C, Xu X, et al. A review of 3D printing in dentistry: technologies. *Affecting Factors Appl*. 2021;17, 9950131. https://doi.org/10.1155/2021/9950131.
9 Loges K, Tiberius V. Implementation challenges of 3D printing in prosthodontics: a ranking-type delphi. *Materials*. 2022;15(2):431. https://doi.org/10.3390/ma15020431.
10 Dhokar A, Atre S, Bhatnagar S, Bhanushali N. Knowledge and practices of 3d printing in dental practitioners of Maharashtra: a cross-sectional study. *J Indian Acad Oral Med Radiol*. 2020;31:127–133. https://doi.org/10.4103/jiaomr.jiaomr_49_20.
11 Hegedus T, Kreuter P, Kismarczi-Antalffy AA, et al. User experience and sustainability of 3D printing in dentistry. *Int J Environ Res Publ Health*. 2022;19(4):1921. https://doi.org/10.3390/ijerph19041921.
12 Azari A, Nikza S. The evolution of rapid prototyping in dentistry: a review. *Rapid Prototyp J*. 2009;15(3):216–225. https://doi.org/10.1108/13552540910961946.
13 Höhne C, Schwarzbauer R, Schmitter M. 3D printed teeth with enamel and dentin layer for educating dental students in crown preparation. *J Dent Educ*. 2019;83(12):1457–1463. https://doi.org/10.21815/JDE.019.146.
14 Memon AR, Wang E, Hu J, Egger J, Chen X. A review on computer-aided design and manufacturing of patient-specific maxillofacial implants. *Expet Rev Med Dev*. 2020;17(4):345–356. https://doi.org/10.1080/17434440.2020.1736040.
15 Pokpong A, Rokaya D, Peampring C, Sanohkan S. Confocal 3D optical intraoral scanners and comparison of image capturing accuracy. *Comput Mater Continua (CMC)*. 2021;66(1):303–314. https://doi.org/10.32604/cmc.2020.011943.
16 Suzuki Y, Shimizu S, Waki T, Shimpo H, Ohkubo C. Laboratory efficiency of additive manufacturing for removable denture frameworks: a literature-based review. *Dent Mater J*. 2021;40(2):265–271. https://doi.org/10.4012/dmj.2020-206.
17 Alfaraj A, Su FY, Lin WS. CAD-CAM hollow obturator prosthesis: a technical report. *J Prosthodont*. 2022;31(7):635–638. https://doi.org/10.1111/jopr.13513.
18 Strub JR, Rekow ED, Witkowski S. Computer-aided design and fabrication of dental restorations: current systems and future possibilities. *J Am Dent Assoc*. 2006;137(9):1289–1299. https://doi.org/10.14219/jada.archive.2006.0389.