



COGNIZANCE AND PRACTICES OF 3D PRINTING AMONG DENTISTS OF UTTARAKHAND: A CROSS-SECTIONAL STUDY

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Running Title – Knowledge, Awareness and Practices of 3D Printing among Dentists of Uttarakhand

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Abstract

Background: 3D Printing technology allows the production of an individualized 3D object based on a material of choice, a specific computer- aided design and precise

manufacturing. 3D Printing technology has a wide range of applications in dentistry. Therefore, the present study aimed to evaluate the knowledge and practices of dentists in Uttarakhand regarding the use of 3D printing in their usual practice.

Material and Methods: The study was conducted in the form of a self-administered online questionnaire consisting of 19 questions which were circulated among the dentists by generating a google link for the survey and sending it to the willing participants via various social media platforms and e-mails. Statistical analysis was carried out using SPSS version 17 software and Chi square test was applied.

Results: 83.1% of the participants were aware about the use of 3D printing in dentistry, 68.5% had an idea about its non-dentistry related uses and 43.8% knew its working principle. 54.2% respondents were unaware about the best material for 3D printing. Only 33.5% were aware of all of its procedural expenses. Just 20.8% had an experience of either observing or working with 3D printers of which 33.8% thought that it had enhanced their ability to execute the surgical procedure. 79.2% had no experience of using 3D printers, the reason mostly being unavailability in their area of practice. A statistical difference was found in the knowledge and practices based on age, sex, education, and experience with P value ≤ 0.05 .

Conclusion: Precise knowledge of 3D printing is necessary for enhanced predilection and treatment outcomes. Based on the outcome of the study dentists should be encouraged with optimal hands-on training to ensure its unhesitating and efficient practice.

Key Words: 3D Printing, Computer-aided design, Dental Practitioners, Questionnaire, Survey

Introduction

In 1984, Charles Hull, an American Engineer, developed the world's first working printer. In 1986, he patented Stereolithography Apparatus and built and developed a 3D printing system.^[1] Since then, 3D printing has been making huge strides of progress. What began as a largely industrial tool to facilitate conception-to-prototype development 3D printing has evolved into an extensively used technology, affecting numerous aspects of recent society. The term "3D printing" grew out of the research and development labs of the automotive and aerospace diligence.^[2] It's employed for rapid prototyping, which has been universally used in industrial designing, engineering, and manufacturing fields for about 30 years. With the fleet development of new materials, printing technologies, and armentarium, 3D printing is presumably to totally change the conventional teaching and experimental modes.^[3]

Forensic sciences is one of the fields of medicine and dentistry where the application of 3D printing is fairly new. Both Forensic medicine and forensic dentistry has numerous applications of 3D printing. 3D printing may be a useful gizmo for forensic anthropologists. A number of cold cases have been reopened and 3D printing is utilized to unravel them. The post mortem CT scans of the victims are often accustomed to recreate the skull and other bones.^[1]

In the field of medicine, like as traumatology, cardiology, neurosurgery, plastic surgery, and craniomaxillofacial surgery. 3D printing is frequently used for digital imaging in surgical planning, custom surgical devices, and patient- physician communication. In the field of dentistry, its employments range from prosthodontics, oral and maxillofacial surgery, and oral implantology to orthodontics, endodontics, and periodontology.^[3] The incorporation of any new technological advancement may be a time-consuming phenomenon majorly because of inadequate knowledge and awareness.^[10] Therefore, hindering innovative research that is required to assess its reliability. Our recent research has considered multiple reviews inscribing the applications of 3D printing in dentistry.^[3-9]

Aim:

To evaluate the knowledge on applications of 3D printing among dentists of Uttarakhand in their usual practice.^[11]

Materials and Methods

This study was conducted after obtaining ethical clearance from Ethical Committee and Institutional Review Board of college.

A cross- sectional questionnaire based study was conducted through an online survey among the dentists of Uttarakhand, India following the standard statements of STROBE guidelines.^[12]

The study participants mainly included Graduates (BDS), Post Graduates (MDS), Faculty (working in an institution) and Practitioners from Uttarakhand who were willing to take the survey. The dentists who couldn't be reached through social media platforms and the ones who were not willing to take the survey were excluded from the study.

An online questionnaire was customized based on a previously validated and published study consisting of 19 questions which consisted of 4 demographic, 9 knowledge based and 6 practice based questions. Permission from the original author was taken before adopting the questionnaire.

The sample size was calculated using following formula:

$$\text{Sample size } N = \frac{z^2 \cdot p \cdot (1-p)}{d^2}$$

z= 1.96 = a value for confidence level of 95%

p= 0.85 = prevalence

d= 0.05 = margin of error

Hence, the sample size was calculated to N= 195.9216 (196)

However, the sample kept in the study protocol was N not less than 250 which met the power of the study. The study duration was 1 month. The questionnaire was made using google forms and the link was circulated among the dentists through social media platforms like whatsapp and e mail. The responses were not accepted after the last date of form submission. The responses were recorded on the google form and the excel sheet was entered into Statistical Package for Social Sciences (SPSS version 23, IBM Corp, Chicago). Categorical data was analyzed using chi- square test. Graphs and tables were used for describing data. The level of significance was set at $P < 0.05$.

Results

Out of the 260 respondents 184 (70.8%) participants were females and 76 (29.2%) were males among which majority belonged to the age group of 24- 30 years (51.2%) [Figure 1 and 2]. 216 (83.1%) respondents out of all were aware about the use of 3D printing technology in dentistry. It was found that every respondent above the age of 35 years was aware about 3 D printing followed by respondents in the age group of 31 to 35 years ($P < 0.01$) and 92.1% were males ($P < 0.01$) and 97.1% ($P < 0.01$) were private practitioners with more than 11 years of practice. [Table 1]

About 68.5% of respondents knew about non-dental applications of 3D printing. About 92% of respondents were in the age group of 31 to 35 years ($P < 0.01$) and 73.7% were males ($P < 0.01$). Faculties had the highest awareness ($P < 0.01$) and about 83% of respondents had 6 to 10 years of practice ($P < 0.01$). [Table 1]

Only 43.8% of respondents were aware of the working principle of 3D printing. It was found that 33.7% of respondents less than 24 years of age ($P < 0.01$), 39.7% of females ($P < 0.01$) and graduates 35.8% of had the least awareness. Those respondents with newer practice were significantly less aware than others ($P < 0.05$).

It was found that 54.2% of respondents did not know the best material for 3D printing. Majority of those unaware were the younger respondents ($P < 0.05$) and graduates ($P < 0.05$) [Table 2]

Only 33.5% of respondents were aware about the procedural expenses that was observed more in 25 to 30 years, more among males and graduates with less than 5 years of private practice ($P < 0.01$). Only 30% of respondents reported about the availability of 3D printing facility in their area of practice observed more among younger respondents ($P < 0.01$), females ($P < 0.01$) and graduates with relatively newer private practice ($P < 0.01$). Only 20.8% of respondents had experienced either working/observing with 3D printers, 33.8% who had used 3D printing models thought the use of it had enhanced their ability to execute a surgical procedure; 14.6% noted additional morphological defects and only 25.4% finding the 3D printers user friendly. Surprisingly, respondents up to the age of 35 years, females more than males; graduates with less than 5 years of practice found it user friendly ($P < 0.01$) [Table 3].

Among those who did not have any experience of working /observing with 3D printers, it was found that majority of did not have the facility of 3D printing in their area of practice and

about 14% were aware of 3D printing but did not know its applications in dentistry [Figure 3].

It was found that majority of did not have the facility of 3D printing in their area of practice and about 14% were aware of 3D printing but did not know its applications in dentistry. Observation depicted that respondents aged above 30 years knew the requirements for 3D printing ($P < 0.01$) that was highest among those with a post-graduate degree ($P < 0.05$) [Figure 4]

Response to application of 3D printing in dentistry varied with 12.47% exclusively reporting as surgical guides for dental implants followed by 9.3% reporting for pre-surgical assessment and diagnostic models [Figure 5]

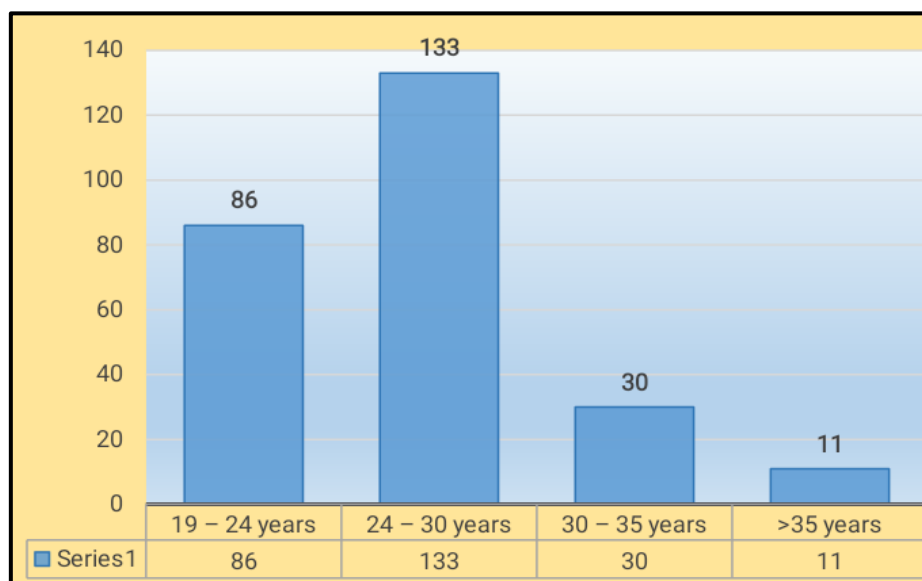


Figure 1: Distribution on the basis of Age

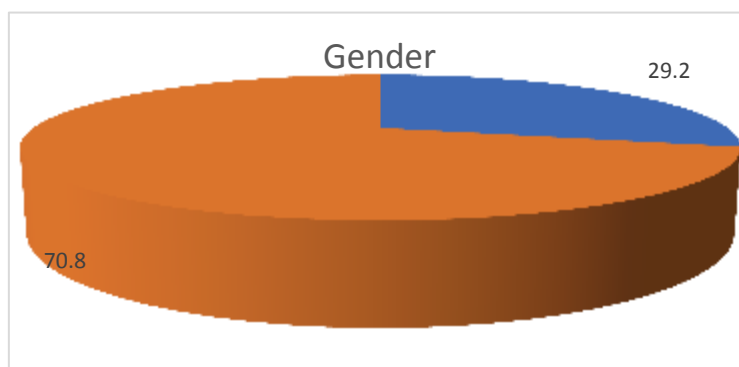


Figure 2: Distribution of study participants according to Gender

Table 1: Awareness among dental practitioners about uses of 3D printing in dentistry, non-dentistry related uses and working principle of 3D printers

		Dental 3-D Printing	Non-Dental 3-D Printing	Working Principle of 3D Printing
Age	19 to 24 years	76.2**	60.4*	33.7**
	25 to 30 years	86.5**	70.6**	46.8
	31 to 35 years	88**	92**	64
	> 35 years	100	62.5	62.5
Gender	Males	92.1**	73.7**	53.5
	Females	79.3**	66.3**	39.7**
Education	Faculty	88**	84**	68
	Graduates	78**	64.2**	35.8**
	Post-Graduate	87**	75.6**	43.9
	Practitioners	97.1**	68.6*	62.9
Years of Practice	0 to 5 years	82.6**	67.2**	42.1*
	6 to 10	83.3**	83.3**	66.7
	11 to 15	100	66.7	33.3
	15 >	100	75	50

Level of significance at $P < 0.05$; Statistically significant at $*P < 0.05$ and $**P < 0.01$ using Chi Square test

Table 2: Awareness about best material for 3D printing

		Light Cure Resin	Thermoplastic Resin	Powder	Powder Blender	Others	I don't Know	P value
Age	19 to 24 years	4	4	19.8	3	8.9	60.4	$P = 0.04^*$
	25 to 30 years	11.9	4	27	1.6	3.2	52.4	
	31 to 35 years	20	16	16	4	0	44	
	> 35 years	0	12.5	37.5	0	12.5	37.5	
Gender	Males	10.5	7.9	34.2	2.6	3.9	40.8	$P = 0.517$ NS
	Females	8.7	4.3	19	2.2	6	59.8	
Education	Faculty	16	20	20	0	4	40	$P = 0.021^*$
	Graduates	9.4	2.6	19.5	3.1	7.5	57.9	
	Post-Graduate	4.9	9.8	34.1	0	2.4	48.8	

	Practitioners	8.6	2.9	31.4	2.9	0	54.3	
Years of Practice	0 to 5 years	8.9	4.7	23	2.6	5.5	55.3	P = 0.55
	6 to 10	16.7	16.7	22.2	0	0	44.4	NS
	11 to 15	0	0	33.3	0	0	66.7	
	15 >	0	0	50	0	25	25	

Table 3: Knowledge and experience of 3D printers in dentistry

		Awareness about Procedural Expenses	3D Printing Facility in Area of Practice	Experience of Observing/ Working with 3D Printers	Did 3D printing enhance execution of a surgical procedure?	Were additional morphological defects/unexpected variations noted?	Are 3D printing software user friendly?
Age	19 to 24 years	29.7**	29.7**	18.8**	37.6**	15.8**	23.8**
	25 to 30 years	32.5**	26.2**	19.8**	28.6**	12.7**	23.8**
	31 to 35 years	56	48	32	40**	20	32*
	> 35 years	25	37.5	25	50	12.5	25.4
Gender	Males	35.5*	26.3**	18.4**	32.9**	9.2**	17.1**
	Females	32.6**	31.5**	21.7**	34.2**	16.8**	28.8**
Education	Faculty	40	40	28*	56**	8	44
	Graduates	35.2**	28.9**	22**	34**	15.7**	23.9**
	Post-Graduate	26.8**	24.4**	17.1**	22**	14.6**	22*
	Practitioners	28.6*	34.3	14.3**	31**	14.3**	22.9**
Years of Practice	0 to 5 years	33.2**	28.1**	19.1**	33.6**	13.2**	24.3**
	6 to 10	38.9	50	38.9	33.3	33.3	33.3
	11 to 15	0	33.3	0	33.3	0	33.3
	15 >	50	50	50	50	25	50

Level of significance at *P < 0.05 and **P < 0.01 using Chi-Square test

Figure 3: Reason for inexperience with 3D printing

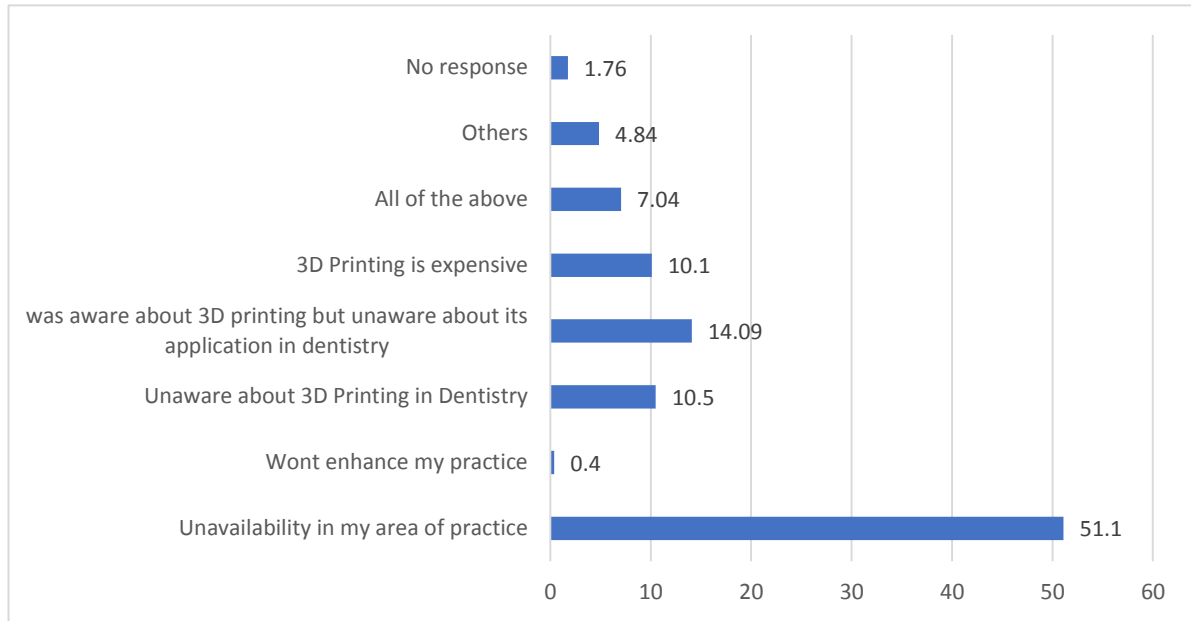


Figure 4: Reason for inexperience with 3D printing

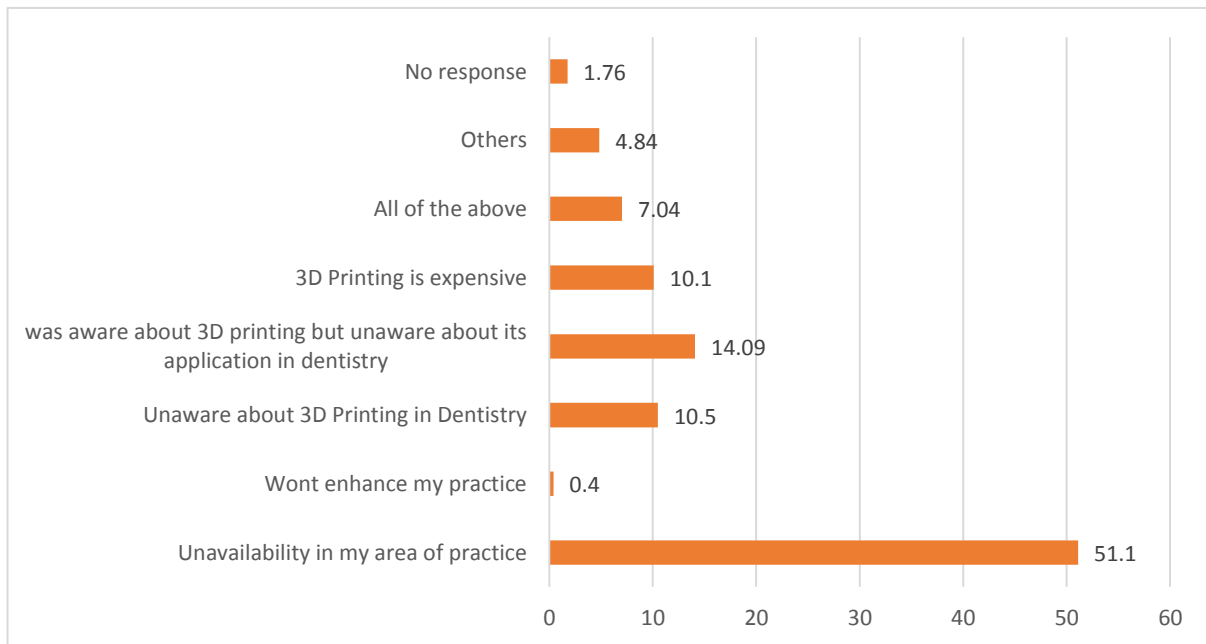
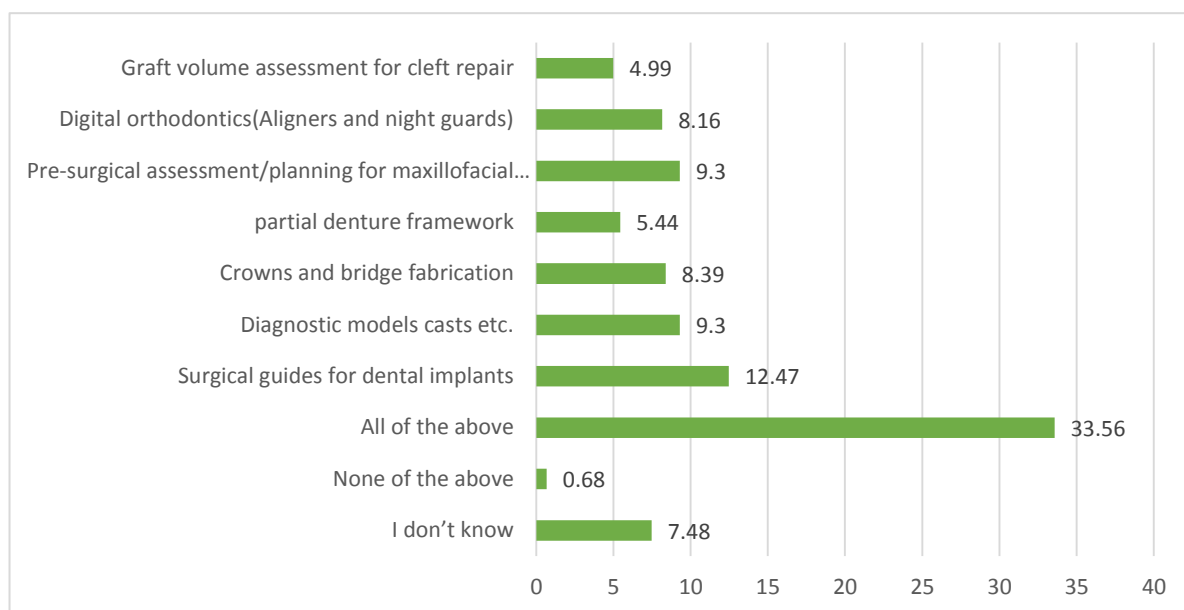


Figure 5: Possible application of 3D printing in practices



Discussion

3D printing is an emerging technology that is gaining immense popularity in the field of dentistry because of its wide applicability. The 3D printing process begins with a design of a 3D model, created by a computer-aided design (CAD) software. The model is then converted into cross-sectional slices and sent to the 3D printer, which deposits layer after layer of the chosen material to produce an object.^[13] This wonderful modality allows for the fabrication of working models,

prosthodontic restorations, orthodontic appliances, surgical guides for implant placement, and maxillofacial prostheses.^[14]

For using 3D printing in day-to-day practice, a dentist should have ample amount of knowledge regarding this technology and should be aware about its principle, working, materials and cost. Many areas in India are still devoid of 3D printers and labs due to lack in technological development hence, making it less accessible for many practicing dentists.

This study was carried out with the aim of assessing the knowledge and practices of dentists in Uttarakhand regarding the use of 3D printing in their usual practice.

A study done by Dhokar et al also assessed the knowledge and practices of 3D printing among the dental practitioners of Maharashtra.^[10] They found that in their population, 85.2% of the respondents were aware about dental 3D printing, 47.6% knew its working principle, 52.5% knew the pre-requisites, while 58.7% were unaware of the best material for dental 3D printing which was quite similar to the results of the current study. In the present study 83.1% of the participants were aware about the use of 3D printing in dentistry, 68.5% knew about its non-dentistry related uses and 43.8% knew its working principle. 54.2% respondents did not know the best material for 3D printing. Their study included dental practitioners all over Maharashtra which is a larger state, the number of dentists with experience of more than 15

years (61.5%) was more than the current study where majority practitioners had an experience of 6- 10 years (61.1%).

Abarna Jawahar et al. conducted a similar study among 100 dental practitioners of Chennai with less questions included in the survey.^[11] The number of years of practice/ experience and experience of working with 3D printer were not considered unlike the present study. The study stated that 73% of dental practitioners were aware regarding the use of 3D printing and 40% of dentists had lack of awareness regarding this technology which was the main reason of their inexperience with 3D printing whereas only 10.4% of dentists from Uttarakhand population were unaware regarding 3D printing as per the current study.

Parikh Maitry et al., in their study assessed the knowledge, attitude, and practices of 3D printing among orthodontists in India.^[15] This study stated 89% of respondents indicated that they heard of 3D printing used specifically for Dento maxillofacial region, whereas the current study shows just 83.1% of the dentists were aware about the general use of 3D printing. While their study, on a greater extent related with just the knowledge of orthodontists, the current study tried to inculcate general dental practitioners as well as all the branches of dentistry and didn't restrict it only to orthodontists.

There are quite a few limitations of this study as well like, less accessibility for those who can't be reached through social platforms, less sample size, constrained area of study as it was only limited to Uttarakhand and minimal number of practitioners among the study participants as majority of respondents were freshly passed graduates.

Further more studies can be carried out on a larger scale all over India to know more regarding the knowledge of 3D printing and it's popularity among the dentists and more clinical questions can be added to the survey to get a clear picture regarding it's use in routine practice by the dental practitioners.

Conclusion

The study concludes that although, 3D printing has wide number of applications in dentistry, it still has to pave it's way in the field of dentistry to gain more popularity among dentists in their routine practice. The knowledge and practice of 3D printing among dentists of Uttarakhand is somehow confined and it needs to be upgraded for which more surveys can be carried out in the future and more workshops, hands- on training, CDE programmes and seminars can be conducted at institutional level to build an impregnable foundation for the Undergraduates and Postgraduates who are the looming dentists and the future of dentistry, regarding the use of this advanced technology which can further make their routine practice more convenient and hassle free.

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References

1. Sunali K, Prita D. Exploring the 3rd Dimension: Application of 3D Printing In Forensic Odontology. *J Forensic Sci & Criminal Inves.* 2017; 3(4): 555-616.
2. Sniderman D 3D Printing Takes Off. American Society Of Mechanical Engineers website. 2012 Available at: <http://bit.ly/2vAauKy>.
3. Tian, Y., et al. (2021). "A Review of 3D Printing in Dentistry: Technologies, Affecting Factors, and Applications." *Scanning* 2021: 9950131.
4. Dawood, A., Marti, B., Sauret-Jackson, V. et al. 3D printing in dentistry. *Br Dent J* 219, 521–529 (2015).
5. Kohli T. 3D printing in dentistry – an overview. *Acta Sci Dent Sci* 2019;3:35-41
6. van Noort, R. (2012). "The future of dental devices is digital." *Dental Materials* 28(1): 3-12.
7. Ballard, David H et al. "Clinical Applications of 3D Printing: Primer for Radiologists." *Academic radiology* vol. 25,1 (2018): 52-65.
8. Yun PY. The application of three-dimensional printing techniques in the field of oral and maxillofacial surgery. *J Korean Assoc Oral Maxillofac Surg.* 2015 Aug;41(4):169-70.
9. Ramya, A.. "3D PRINTING TECHNOLOGIES IN VARIOUS APPLICATIONS." (2016).
10. Dhokar, Amol & Atre, SwaraliY & Bhatnagar, Sunanda & Bhanushali, NikhilV. (2020). Knowledge and practices of 3d printing in dental practitioners of Maharashtra: A cross-sectional study. *Journal of Indian Academy of Oral Medicine and Radiology.* 32. 127.
11. Abarna Jawahar, G Maragathavalli, Knowledge on Applications of 3D Printing in Dentistry among Dental Practitioners-A KAP Survey, *J Res Med Dent Sci*, 2021, 9 (2): 205-210
12. Cuschieri S. The STROBE guidelines. *Saudi J Anaesth* 2019;13:S31-4
13. Nestic D, Schaefer BM, Sun Y, Saulacic N, Sailer I. 3D Printing Approach in Dentistry: The Future for Personalized Oral Soft Tissue Regeneration. *J Clin Med.* 2020 Jul 15;9(7):2238.
14. Turkyilmaz I, Wilkins GN. 3D printing in dentistry - Exploring the new horizons. *J Dent Sci.* 2021 Jul;16(3):1037-1038.
15. Parikh M, Kulkarni N, Parikh M. Knowledge, attitude, and practice on 3D printing among orthodontist in India—An online questionnaire study. *International Journal for Advance Research and Development.* 2019;4(3):26-30.