

Knowledge and Practices on Applications of 3D Printing in Dental Practitioners - A KAP Survey

¹Dr. Aparna Chandel, PG Student, Department of Periodontology and Implantology, National Dental College and Hospital, Derabassi Mohali (Punjab) India

²Dr. Navneet Kaur, Reader, Department of Periodontology and Implantology, National Dental College and Hospital, Derabassi Mohali (Punjab) India

³Dr. Gurpreet Kaur, Professor and HOD, Department of Periodontology and Implantology, National Dental College and Hospital, Derabassi Mohali (Punjab) India

Corresponding Author: Dr. Aparna Chandel, PG Student, Department of Periodontology and Implantology, National Dental College and Hospital, Derabassi Mohali (Punjab) India

Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

Background: The evolution of 3-dimensional imaging and modelling in dentistry is progressing towards a more efficient and cost-effective workflow using state-of-the-art technology. With introduction of this recent advanced technology, it is used in various surgical procedures such as ridge augmentation, sinus lift and guided implant surgery, implant fixtures, preparation of customized scaffold with or without stem cell therapy, education models as well as in drug delivery technology. The 3-dimensional printing technology is becoming more economical technique and able to produce replica of dental models with a high resolution and accuracy.

Aim and Objective: To assess the Knowledge, Attitude and Practice of dental practitioner regarding the use of 3D Dimensional printing in dentistry.

Material and Methods: A Cross Sectional Study was Conducted among 150 Dental Practitioner in Chandigarh in the form of a Self-administered online Questionnaire consisting of 26 Question related to demographic analysis in the first part and Structured descriptive Questionnaire regarding the assessment of Knowledge, Attitude and Practice to create an awareness of 3D Dimensional printing in various fields of dentistry. The questionnaire was in English format and the link prepared form was sent to dental practitioner's-mail ids. The percentage response for each Question from all participants was obtained and the Data was calculated and analysed using Statistical Package for Social Sciences (SPSS) software 21.0.

Results

This study shows that out of many dentists 73% think that 3D printing in dentistry is used in India and 25% think it is not used in India. The source of information through which the dentist got to know about 3D printing was 39% through seminars and presentations, 26% through colleges, 15% through guest lectures, 13% through colleagues, 7% through clinical practice. Through colleges, 15% through guest lectures, 13% through colleagues, 7% through clinical practice.

Conclusion

The 3D printing in dental area is converting the oral health care and need. The predominant standards for its rising usefulness within side the area is due to its spreading awareness, much less time required for direct case remedy and its capability location for research and studies towards treatment planning which will revolutionize dentistry. 3D imaging and modelling may have a large impact on regenerative elements of dentistry. Regenerative dentistry and their biomaterials used for diverse superior surgical procedures inclusive of maxillary and mandibular defects, carcinoma or fibrosis cases or in case of trauma, this more recent three-dimensional imaging permit greater predictability in dealing with complicated interdisciplinary scientific scenarios.

Keywords: 3D printing, Rapid prototyping, Additive manufacturing, Computer aided Designing, Bioprinting, CAD-CAM technology

Introduction

Technology has slowly and steadily paved its way into dentistry. With the introduction of Digital OPG (Orthopantomogram), RVG (Radiovisiography), CBCT (cone beam computed tomography), digital impression machines, and in office CAD-CAM milling machines, proper treatment planning and completing other stuff have become much simpler than it was before the use of technology. The latest invention of this technology is 3D printing which was introduced by Charles Hull in 1984 in dentistry. He was a pioneer of the solid imaging process referred to as stereolithography and stereolithographic (SLA) file format and is generally used format in 3D printing.¹

CAD / CAM technology brings 3D printing in medicine and dentistry to revolutionary growth and provides an excellent view for various anomalies. 3D printing is used mostly to create natural image of the calcified and non- calcified structures that it can be seen as such it is in its normal vicinity position. In dentistry, using CT and CBCT data, and also using intra-oral or laboratory optical surface scan data. Advancement in the computer technology and the software applications has contributed a lot to 3D printing. The 3D printing process begins with the design of a virtual image of the object to be created, and then converts the information into a digital file. A 3D modelling program provides the virtual design that the printer should follow. This requires CAD software that can be used to create objects from scratch.²

The manufacturing approach in 3D Printing usually refers to the creation of an objects layer by layer from a raw material that added one layer at a time to form multiple layers. It uses the information from CAD software that measures thousands of cross sections to build the exact replica of each product.³ The three-dimensional (3-D) printing is also known additive manufacturing or desktop fabrication. The various materials used for depositing or fusing are plastic, metal, ceramic, powders, liquids or the living cells. Super alloys are also used as a raw material such as nickel-based chromium and cobalt chromium; stainless steel; titanium; polymers; and ceramics composite materials and polycaprolactone.

Different techniques of 3D printing have been reported in literature with advantages and disadvantage of each technique that include stereolithography, Photopolymer jetting, selective laser sintering, fused deposition modelling, and powder binder printers. Selective laser sintering uses heated chamber used to soften powder material and use of laser that fuses heated fine powdered material to build up structures layer by layer. Fused deposition modelling uses thermoplastic material extruded through nozzle onto the build platform. Powder binder printers use colored water drops from inkjet printer that causes the cement or plaster to set in layer-by-layer manner on an incrementally descending platform.⁴

Three-dimensional (3D) printing has promising application in various fields of dentistry such as periodontics, implantology, orthodontic, endodontic, prosthodontics, maxillofacial surgery, and restorative dentistry. In the field of periodontology and implant dentistry, 3D scaffolds in the form of bone graft substitutes overcomes the disadvantages of commonly used grafting materials. Scaffold properties are influenced by the used biomaterials and must be specific for the application while in harmony with the native environment to ensure that the defect area is replaced with a healthy, functional tissue matching the original one, without reparative scar formation.¹ The current application in oral maxillofacial surgery includes trauma surgery, pathology induced defects, tissue engineering, complex temporomandibular joint reconstruction and correction of complicated facial asymmetry. 3D printing combined with CAD/CAM method can automate fabrication of dentures. Studies have shown 3D printing technology for dentures makes not only denture bas but denture teeth. 3D printed resin teeth had fractured resistance and biomechanical pattern comparable to conventional prefabricated denture teeth.⁵ Intra oral scans of the patients are utilized to print 3d models that are custom real patient-based models. These customized models are used for training dentist in prosthodontics for veneer and crown preparation.⁶ Digital dentistry has shown significant application in clinical and laboratory techniques in many areas of dentistry. As 3-D printing can replicate the human form more accurately than traditional manufacturing technique. 3D printing has provided comfort and better-quality treatment and enhanced treatment procedure to dentist. Patients' treatment becomes fast, smooth and with greater precision.^{7,8}

The evolvement of newer technology advancement is time consuming phenomenon because of inadequate knowledge and awareness. This may hamper the innovative technique to assess its credibility. Before start-up of this survey, we considered the multiple reviews and systematic analysis to address the application of 3D printing in dentistry along with different techniques and their advantages and disadvantages and use of different materials for the fabrication of printed models through bioprinting. Based on the available literature this survey was conducted with an aim to assess the knowledge and practice of dental practitioners regarding the use of 3D printing in dentistry.

Material and Methods

A descriptive cross-sectional questionnaire-based study was conducted through an online website survey among 150 dental practitioners in Chandigarh, India were questioned about their knowledge on applications of 3D printing in dentistry.

The participants of this study were dental practitioners in Chandigarh including graduates (BDS), postgraduate (MDS), and certified implantologists (certified implantologists including all those dental practitioners who have undergone some training to carry out implant procedures). The study excluded dental practitioners who couldn't be reached through any social media for the online survey, those not willing to participate in the study and those who responded beyond the completion of the set duration of the study.

The self-administered questionnaire comprised of 26 questions out of which 5 questions were of demographic analysis related to age, gender clinical practice and educational qualification. 5 questions were related to their knowledge as well as the source of information about 3D printing, and the remaining 16 were pertaining to their attitude and current practices regarding the experience of working with 3D printer or models, possible application of 3D printing in clinical practice of dentistry.

A survey google forms online tool was utilized in this study. A participant information sheet and questionnaire were sent to the all participant. A reminder mail was given to all those dental practitioners who did not respond after the sending of a questionnaire through google link. This online survey link was promoted through email, social media, or online discussion platforms and potential survey participants were invited to participate in the survey. All data were analysed by using the Statistical Package for Social Sciences (SPSS) software, for windows, version 22. Descriptive statistics have been generated in terms of percentages.

Results

Sociodemographic Characteristics of dental practitioners

Distribution of sociodemographic characteristics of surveyed 150 dental practitioners are shown in Table 1. Out of 150 respondents, 110 who responded positively by participating in this study and completed the questionnaire. In this way the response rate was 73.3% and they were aware about the use of 3D printing technology in dentistry.

Among the respondents, there were 50 (45.5%) male dentists and 60 (54.5%) female dental practitioners with an age below 35 years were 60% and 40% were above the age of 35 years. High percentage of the respondents were graduates (42.7%) and 37.3% were specialized dentists (MDS). 130 dentists have an experience of 5-10 years, which contributes to almost half of the participants (43.3%). 40 dentists have an experience of 11-15 years which contributes to one third of participants (36.4%). Only 22 dentists (20%) were certified Implantologists.

Table 1: Distribution of study participants based on the knowledge and Practice (n=110)

Variable		Dentist (n)	n (%)
Age	<35 year	66	60%
	>35 year	44	40%
Gender	Male	50	45.5%
	Female	60	54.5%
Education	Graduates	47	42.7%
	Certified- Implantologist	22	20%
	Post- Graduates	41	37.3%
No. of years in Practice	0-5 Yrs.	28	25.5%
	6-10Yrs.	21	19.1%
	11-15Yrs.	40	36.4%
	> 15 Yrs.	21	19.1%

Knowledge and Awareness among dental practitioners regarding 3-Dimensional Printing

Table 2 shows knowledge among dental practitioners regarding the awareness, source of information, best material as well as the working principle of 3D printing. Out of the 110 respondents, 88 who correspond to 80% were aware about the use of 3D printing technology in dentistry. The source of information through which the dentist got to know about 3D printing was 39.1% through guest lectures, 23.6% through seminars and presentations, 13.6% through clinical practice, 12.7% through colleagues, 10.9% through collages. Majority 78 (70.9%) of practitioners with knowledge about the

principle behind the working of 3D printers. This might be due to the access to internet, seminars, guest lectures etc. was the best approach to enhance their knowledge about 3D printing in dentistry. 50.9% of the respondents gave a correct response regarding the prerequisites of 3D printers stating the use of CBCT, intra-oral scanners, casts and models for 3D printing. 40% practitioners were aware of the best material for dental 3D printing while nearly 14.5% and 16.4% of the respondents considered light cure resin, Sintered powder and thermoplastic materials to be best suited for 3D printing.

Table 2: Knowledge and Awareness among dental practitioners regarding 3-Dimensional Printing

Questionnaire		Dentists (n)	n (%)
Are you aware about the use of 3D printing in dentistry?	Yes	88	80%
	No	22	20%
What is the source of information through which you got to know about 3D printing in dentistry?	Colleges	12	10.9%
	Clinical Practices	15	13.6%
	Colleagues	14	12.7%
	Guest Lecture	43	39.1%
	Seminar and presentation	26	23.6%
Which do you think is the best material for 3D printing?	Light cure resin	16	14.5%
	Powder blender	5	4.5%
	Sintered powder	16	14.5%
	Thermoplastic	18	16.4%
	I don't know	11	10%
	All the above	44	40%
Are you aware about the working principle of 3D printing?	Yes	78	70.9%
	No	32	29.1%
What do you think is required for the use of 3D printers?	CBCT	8	7.3%
	Intra oral scanner	15	13.6%
	Casts and models	20	18.2%
	All the above	56	50.9%
	I don't know	11	10%

Attitude among dental practitioners regarding 3-Dimensional Printing

Table 3 shows an attitude among dental practitioners towards the application of 3D printing, user friendly software and their experience of working with 3D models. The response of attitude-based questionnaire was observed positive in majority of dental practitioners. When asked about the experience regarding the use of 3D printing, majority of respondents (67.3%) positively agreed that they had an experience of using a model or 3D printers. 58.2% found that the current 3D printing software's is user friendly however, 32.7% respondents don't agree upon user friendly software's which is used in 3-Dimensional printing. Only 37.3% practitioners agreed that the application of 3-Dimensional printing

has an advanced role in the field of dentistry while Majority 54.5% agreed that 3-Dimensional printing application may or may not be used as advancement in the field of dentistry.

Table 3: Attitude among dental practitioners regarding 3-Dimensional Printing

Questionnaire		Dentists (n)	n (%)
Would you like to venture more on the applications of 3D printing in dentistry?	Yes	41	37.3%
	No	9	8.2%
	May be	60	54.5%
Do you find the current 3D printing software's user friendly?	Yes	64	58.2%
	No	10	9.1%
	I don't Know	36	32.7%
Have you had any experience of working with a 3D printer or models?	Yes	74	67.3%
	No	36	32.7%

Practice among Dental Practitioners regarding 3-Dimensional Printing (Table 4)

46.4% of them noted additional morphological defects or unexpected variations when these models were used, 12.7% did not notice any additional feature while 40.9% did not know. Majority of practitioners 46.4% used it to prepare models for surgical planning used it for all these procedures. However, only 1/4th of practitioners (25.5%) of them had used it in preparation of surgical guides and 28.2% in designing of customized prosthesis. Only 45.5% respondents agreed that mock surgery in case of complex craniofacial fractures and surgeries using 3 D printed models becomes more accurate and predictable. 53.6% of the dentist agreed that 3D printed drill guides and templates may be useful in doing root canal treatment in cases of calcified pulp canals and 11.8% disagreed with that. 34.5% felt it might be used.

When asked about using 3D printed implant guides, 48.2% of the dentist felt that it makes the placement of implants in most accurate and less complicated procedures and 51.8% of dentists felt it as least accurate more complicated procedure. 75.5% practitioners agreed that 3D printing is used in India. When asked about the reason for not using the advanced technique in India, 30% considered lack of awareness, 33.6% considered cost factor and 36.4% agreed that it is a complex technique. When asked about the application of 3D printing in orthodontics, 33.6% practitioners agreed that 3D printing is used in various functional (arch wires, brackets and installation models) and removable appliances (Hawley's retainers) as well as clear aligners. Regarding the application of 3D printing in Periodontics, 31.8% practitioners agreed that 3D printing is used for smile designing, aesthetic gingival reconstruction, gingivectomy procedures, periodontal defects, ridge augmentation and in regenerative procedures. When asked about the application of 3D printing in endodontics, 52.7% practitioners positively agreed that 3D printing is used as endodontic guide for obliteration of pulp and in auto transplantation cases. Regarding the prosthodontics, 32.7% practitioners agreed that 3D printing is used for framework of RPD/FPD, CAD/CAM manufactured dentures and for zirconia prosthesis.

Table 4: Practice among dental practitioners regarding 3-Dimensional Printing

Questionnaire		Dentists (n)	n (%)
Did you note any additional morphological defects when 3D printed models were used?	Yes	51	46.4%
	No	14	12.7%
	I don't know	45	40.9%
How was 3D printing used in surgical intervention or preparation?	Preparation of surgical guides for dental implant	28	25.5%
	Preparation of patient specific pathological models for surgical planning	51	46.4%
	Designing of customized prosthesis	31	28.2%
What do you think might be the benefits of performing mock surgery using 3D printed models in case of complex craniofacial fractures and surgeries?	Surgical becomes more accurate and predictable	50	45.5%
	Less time spent on the operating table	19	17.3%
	Patient safety is ensured	17	5.5%
	All the above	24	21.8%
Do you think 3D printed drill guides and templates may be useful in doing root canal treatment in cases of calcified pulp canals?	Yes	59	53.6%
	No	13	11.8%
	May be	38	34.5%
Implant placement using 3D printed implant guides	Most accurate position and least complication procedure	53	48.2%
	Least accurate and more complicated procedure	57	51.8%
Do you think 3D printing in dentistry is used in India?	Yes	83	75.5%
	No	27	24.5%
What do you think might be the reason for 3D printing not widely used in India when compared to other in the field of dentistry?	Lack of awareness	33	30%
	Cost of the equipment	37	33.6%
	Complex technique	40	36.4%
Application of 3D printing in orthodontic?	Clean aligners	24	21.8%
	Various removable appliances such as Hawley retainer	24	21.8%
	Functional appliances such as arch expansion appliances arch wires, bracket and installation models	25	22.7%
	All the above	37	33.6%

Application of 3D printing in periodontic?	Aesthetic gingival reconstruction	13	11.8%
	Gingivectomy procedure	11	10%
	Smile design	12	10.9%
	Regenerative procedure such as 3D dimensional scaffolding	13	11.8%
	Perosseous defect	10	9.1%
	Alveolar ridge augmentation	16	14.5%
	All the above	35	31.8%
Application of 3D printing in endodontic?	Endodontic guide for obliteration of pulp	10	9.1%
	Auto transplantation	15	3.6%
	Educational models	27	24.5%
	All of above	58	52.7%
Application of 3D printing in prosthodontic?	Frame work for RPD/ FPD	8	7.3%
	Wax pattern for dental prosthesis	10	9.1%
	Zirconia prosthesis	16	14.5%
	Complete denture	18	16.4%
	CAD/CAM manufactured denture for treatment of edentulous patient	22	20%
	All of above	36	32.7%
What do you think are the possible applications of 3D printers in your practice?	Surgical guides for al implant	3	2.7%
	Diagnostics models, casts etc	6	5.5%
	Crowns and bridge fabrication	8	7.3%
	Partial denture framework	14	12.7%
	Pre-surgical assessment/planning for maxillofacial reconstruction surgeries	9	8.2%
	Graft volume assessment for cleft repair	11	10%
	Digital orthodontics	19	17.3%
	All of the above	40	36.4%
Are you aware of any commercially available 3D printing facility in your area of practice?	Yes	88	80%
	No	22	20%

Discussion

3D printers create geometrically complex objects through digital modelling. Care and research in dentistry are gradually adopting this technique; digital dentistry manufacturing covers a wide range of technologies, but in its broadest sense, 3D production may be categorized as either subtractive or additive. In the former process, a numerically controlled machine

connected to a CAD/CAM system mills a workpiece (such as a ceramic block). In the latter, products are built in layers using 3D digital data, doing away with molds and machining.

Additive techniques manufacture objects rapidly and at a low cost, reusing residual materials, allowing the construction of complex structures and the customization of parts in a sustainable manner.⁹ 3D printing assists in the planning of prosthetic, orthodontic and surgical procedures; the making of dental, craniomaxillofacial and orthopedic implants, copings, implant structures, drill guides and among others.¹⁰ Dentistry has been drastically changed by technological progress in intraoral scanner, accessibility of 3D printers and the development of biomaterial impressions. Their application as scaffolds for craniofacial tissue engineering offers great potential as an alternative to autologous bone grafts in alveolar cleft osteoplasty.¹¹ Scaffolds can also be customized internally to target and fix target cells.

Recent studies in the forefront of regenerative dentistry show AM have permitted “bioprinting”: the production of supporting components for living cells in complex 3D functional tissues. Selecting materials for 3D bioprinting depends mainly on biocompatibility with cell growth and function and the material’s processing characteristics (e.g., viscosity, extrusion capacity and post-printing stability).¹² A variety of low-cost desktop additive manufacturing 3D printers offer high precision and the ability to process a wide range of printing materials, including an increasing number of biocompatible materials. Binder/powder combinations like polymers, thermoplastic resins, ceramics and metals comprise most of the materials used in dentistry. However, materials such as the cobalt-chromium alloy still lack sufficient research to draw conclusions about the adequacy of their use in dental clinical practices.¹³

Hence this cross-sectional questionnaire-based study was conducted through an online website was conducted to assess the knowledge and practice of dental practitioners regarding the use of 3D printing in dentistry. The result of this study emphasizes the need to increase the knowledge and awareness of 3D printing in dentistry. In the current study, 45.5% were male and 54.5% were female dental professionals and majority of the dental professionals were graduates (42.7%) and 37.3% were post graduate qualification in the present study. Only 20% were certified implantologists. A study by Parikh Maitry et al.¹⁴ assessed the knowledge, attitude, and practices of 3D printing among orthodontists in India. This study stated 47.5% of the orthodontists had utilized this technology, whereas the current study shows just 38.7% of the dental practitioners having some experience of it which might be due to the inclusion of all graduates and postgraduates. While their study concentrates on just the orthodontists, the current study makes an effort to incorporate all practising dentists and doesn’t limit its usage to orthodontic appliances.

Some significant findings of the current study one needs to ponder upon were that in spite of 80% of the respondents being aware about this technology and only 67.3% of the dental practitioners had some experience of 3D printing. 70.9% of them knew it working principle, 50.9% knew of the prerequisites, and 40% being aware of the best material significantly indicates that there should be a need of complete knowledge regarding 3D printing. In the current study, nearly 14.5% and 16.4% of the respondents considered light cure resin, Sintered powder and thermoplastic materials to be best suited for 3D printing. Thus, the primary end result of the study is that instead of the literature available about applications of 3D printing in dentistry, the actual knowledge of the dental practitioners is inadequate to utilize it in routine practice.

According to other studies advances in 3D imaging, CBCT, intraoral scanning and CAD/CAM technology 3D printing is becoming more popular and important technology. Studies done on 3D printed appliances and prosthesis showed that they are comparable in terms of their biocompatibility, quality and function to the existing conventionally used methods in the dental technology laboratory.^{15,16} A study by Msallem et al.¹⁷ suggests choosing a 3D printer after considering the technology it uses, its intended application and material budgetary constraints. The effort seems worth it, given the tremendous flexibility in construction material, object geometry and mass production customization.¹³

Current utility in oral maxilla-facial surgical treatment consists of trauma surgical treatment, pathology caused defects, tissue engineering, complicated temporomandibular joint reconstruction and correction of complex facial asymmetry. Congenital or acquired maxillofacial defects may be restored greater efficaciously the use of 3D printing. In the present study, some difference in opinion exists among those who have utilized this regarding its use to detect additional morphological defects. Only 46.4% of them noted additional morphological defects or unexpected variations when these models were used. When asked about using 3D printed implant guides, only 48.2% of the dentist felt that it makes the placement of implants in most accurate and less complicated procedures.

Regarding the application of 3D printing in various fields of dentistry like prosthodontics, periodontics, orthodontics and endodontics has been growing in the last years, for fabrication of RPD/FPD, wax patterns, crown and bridge CAD/CAM manufactured dentures, smile designing, aesthetic gingival reconstruction, gingivectomy procedures, periodontal defects, ridge augmentation, for fabrication of implant surgical guides, various functional and removable appliances as well as clear aligners, endodontic guide for obliteration of pulp. In the current study, only 1/3rd of dental practitioners positively agreed for 3D printing is used in various specialities of dentistry. This may be due to lack of knowledge and awareness along with complex technique to be used among dental practitioners.

To the best of our knowledge, the lack of studies assessing the knowledge and awareness among dental practitioners about 3D printing make it pertinent to explore. As this cross-sectional study is questionnaire based, data were collected via self-reported information by the dental professionals and questions regarding the clinical efficiency and knowledge of 3D printing were not included. Also, the data collected via online survey forms reduced response errors and entry errors. Further studies can be directed toward the clinical efficiency in terms of cost efficiency, ease of diagnosis, and treatment and prognosis; technical aspects and patient's response after being treated using 3D printed models or appliances. A study on larger sample size carried across the country would help provide a clear picture about the inclusion of this technology in routine dentistry.

Conclusion

The study concludes that 3D printing has several applications in dentistry. 3D printed models can be used in treatment planning and simulation. 3D printed implants and implant guides are proved to be more accurate and successful. 3D printing enables rapid prototyping in dentistry through flexible processing and material development (polymers, metals and ceramics). Additive manufacturing will constitute a major advance in dental workflow, reducing surgery times, improving biomaterial and, above all, assuring the satisfactory treatment of patients in this new technological era. The results from this study emphasize the need to increase the awareness of 3D printing in dentistry.

References

1. Kaur N, Grover D, Kaur G. Future dental devices- 3-dimensional printing approach in dentistry. *IP Int J Maxillofac Imaging* 2012;7(2):37-47.
2. Evans J, Desai P. Applications for Three-Dimensional Printing in dentistry. *Decisions Dent* 2016;1(09):28-30,32.
3. Barazanchi A, Li KC, Al-Amleh B, Lyons K, Waddell JN. Additive technology: Update on current materials and applications in dentistry. *J Prosthodont* 2017; 26:156-63.
4. Dawood A, Marti B, Sauret-Jackson V, Darwood A. 3D printing in dentistry. *Br Dent J* 2015; 219:521-9.
5. Yoo-jin chung, Ji-Man Park, Tae-Hyung Kim, Jin-Soo Ahn, Hyun-Suk Cha et al. 3D Printing of Resin Material for Denture Artificial Teeth: Chipping and Indirect Tensile Fracture Resistance. *Materials*, 2018; 11: 1798.
6. Gunpreet Oberol, Sophie Nitsch, Michael Edelmayer, klara Janjic et al. 3D Printing –Encompassing the Facets of Dentistry. *Frontiers in bioengineering and biotechnology*, Nov 2018; 6: 172.
7. Cristian Zaharia, Alin-Gabriel Gabor, Andrei Gavrilovici, Adrian Tudor Stan, Iaura Idorasi et al. Digital Dentistry – 3D Printing Applications. *JIDM*, 2017; 2(1): 50-53.
8. Shahnaz Mahamood, Maimoona Abdul Khader, Hashim Ali. Application of 3-D Printing in Orthodontics: A Review. *International journal of scientific study*, Feb 2016; 3(11): 267-270.
9. 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.
10. Dawood A, Marti Marti B, Sauret-Jackson V, Darwood A. 3D printing in dentistry. *Br Dent J.* 2015;219(11):521-9.
11. Tao O, Kort-Mascort J, Lin Y, Pham HM, Charbonneau AM, El Kashty OA, et al. The Applications of 3D Printing for Craniofacial Tissue Engineering. *Micromachines (Basel).* 2019;10(7):480.
12. Unagolla JM, Jayasuriya AC. Hydrogel-based 3D bioprinting: A comprehensive review on cell-laden hydrogels, bio ink formulations, and future perspectives. *Appl Mater Today.* 2020; 18:100479.
13. Barazanchi A, Li KC, Al-Amleh B, Lyons K, Waddell JN. Additive Technology: Update on Current Materials and Applications in Dentistry. *J Prosthodont.* 2017;26(2):156-63.
14. Parikh M, Kulkarni N, Parikh M. Knowledge, attitude, and practice on 3D printing among orthodontist in India – An online questionnaire study. *Int J Adv Res Dev* 2019; 4:26-30.
15. Patil SR, Maragathavalli G, Ramesh DNSV, et al. Assessment of maximum bite force in oral submucous fibrosis patients: A preliminary study. *Pesqui Bras Odontopediatria Clin Integr* 2020; 20:482.
16. Yun PY. The application of three-dimensional printing techniques in the field of oral and maxillofacial surgery. *J Korean Assoc Oral Maxillofac Surg* 2015; 41:169–170.
17. Msallem B, Sharma N, Cao S, Halbeisen FS, Zeilhofer HF, Thieringer FM. Evaluation of the Dimensional Accuracy of 3D-Printed Anatomical Mandibular Models Using FFF, SLA, SLS, MJ, and BJ Printing Technology. *J Clin Med.* 2020;9(3):817.