ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 14, Issue, 06, pp.21563-21566, June, 2022
DOI: https://doi.org/10.24941/ijcr.43353.06.2022

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

3D PRINTING IN FORENSIC ODONTOLOGY

***Dr. Anjali Singh, Dr. Deepak Bhargava, Dr. Puja Bansal and Dr. Khushboo alam**

School of Dental Sciences, Sharda University

ARTICLE INFO

Article History:
Received 15th March, 2022
Received in revised form
29th April, 2022
Accepted 05th May, 2022
Published online 30th June, 2022

Key words:
Forensic,odontology, 3D printing

****Corresponding Author:***
Anjali Singh

ABSTRACT

Today, 3D printing is most commonly used in dentistry for the manufacture of drill guides for dental implants, study models for prosthodontics, orthodontics and surgery, and the fabrication of copings and frameworks for implant and dental restorations. However, we are yet to see forensic odontologists, lawyers, and expert witnesses appreciate the advantages of 3D printing for its use in court of law. The major application of 3D printing in forensic odontology includes bite mark analysis, 3D-computed tomography facial reconstruction, dental age estimation, sex determination, and physical models. The use of 3D digitizing systems such as laser scanners, structured light scanners, photogrammetry, etc. has revolutionized the field of forensic sciences. The application of these technologies also allows prompt collection of data with minimal degradation and reduction in human errors. Thus, these 3D digitizing technologies can be wisely adapted to advance forensic sciences. Though, the applications in this domain are in the stage of infancy, it definitely has a promising future

Citation: ***Dr. Anjali Singh, Dr. Deepak Bhargava, Dr. Puja Bansal and Dr. Khushboo Alam.*** **2022.** "3D printing in forensic odontology". *International Journal of Current Research*, 14, (06), xxxx-xxxx.

INTRODUCTION

In forensics, branch that deals with the identification of the suspect using the evidences that may be derived from the teeth and associated parts of the oral cavity , is known as Forensic Odontology. It may allow forensic experts to create more robust forensic evidence for their use in courts and medico-legal cases (Kanaparthi, 2020). Today, 3D printing is most commonly used in dentistry for the manufacture of drill guides for dental implants, study models for prosthodontics, orthodontics and surgery, the manufacture of dental, craniomaxillofacial and orthopaedic implants, and the fabrication of copings and frameworks for implant and dental restorations (Chaudhary, 2018). The term 3D printing is generally used to describe a manufacturing approach that builds objects one layer at a time, adding multiple layers to form an object. This process is more correctly described as additive manufacturing, and is also referred as rapid prototyping. Charles Hull, an American Engineer, developed the world's first working 3-D printer in 1984 He defined it as a "system for generating three dimensional objects by creating cross-sectional patterns of the object to be formed". Later in 1986, he founded 3-D Systems, developed the first commercial 3-D Printing machine called the Stereo lithography Apparatus while also obtaining patency for this Stereo lithographic technique (Ramya, 2016).

3D PRINTING METHODS

The different methods of 3D printing were standardized into seven groups by The American Society for Testing and Materialsin the US (ISO/ASTM 52900) (Hodgdon *et al*., 2018). These technologies are described in Table 1.

APPLICATION OF 3D PRINTING IN FORENSIC DENTISTRY

The application of 3D printing in dentistry are as follows:

DENTAL AGE ESTIMATION-. An important aspect of forensic odontology is the age determination of an individual based on dentition status.[7]By the age of 20 years, growth and dental development are complete while the physiological changes predominate. The different methods applied for dental age assessment include the evaluation of tooth morphology, morphology of the primary and permanent dentition, the degree of skeletal ossification, and the analysis of biochemical modifications within the dental hard tissues. Chaudhary R K et al. in their review suggested that, an accurate3D dentition model may aid in assessing the individuals age byremoving the need of direct examination in the oral cavity. They opined that 3D models would eliminate the problems faced dueto improper visualization, saliva, and improper access.

The samegroup also suggested that these 3D models of the mandible canbe used for age estimation using the mandibular gonial angle (Balla, 2016).

BITE MARK ANALYSIS- The most important application of 3D printing in forensic odontology could be in bite mark analysis where it could help to collect and display valuable evidence. Biting is a dynamic process which relies on multiple factors such as the position of jaws and teeth, number of teeth present, the pressure of biting, and size and shape of the tooth. Digital scanning can be carried out to recreate entire bite marks using 3D printing. This information can then be compared with a suspect's dentition casts and can also be presented in a court of law as evidence. The scans themselves can be used for digital comparison of the suspect's teeth using new software. Thus, 3D scanning can help avoid the rapid loss of information that occurs in some bite marks and helps preserve maximum information in all 3D (Chaudhary *et al*., 2018).

3D FACE RECONSTRUCTION- Forensic facial reconstruction also known as facial approximation can be used to identify unknown human remains. With the advancement in 3D technology, quick, efficient, and cost-effective computerized 3D forensic facial reconstruction method enables visual identification of the victim by the associated family members more definitely (Kanaparthi, 2020).

GENDER DETERMINATION- The 3D printed model said in direct assessment and measurements of tooth sizes, shape, orientation, intercaninedistances, intermolar distances, the overjet, the overbite, and archlengths. An accurate printed model could improve the accuracy of sex determination procedures and for population identification from the nonmetric dental traits such as Carabelli formation (Dawood, 2015)

APPLICATION OF 3D PRINTING IN OTHER FIELDS OF DENTISTRY

- **ORAL SURGERY**: 3D printing techniques can be used in areas such as oral surgery — by making surgical guides and conducting various blocks to augment bone defects, and for learning modules to create mandibles and jaws that can be easily showed to the students (Cuperus, 2012).
- **IMPLANTOLOGY:** The use of 3D printing technology has gained popularity
- in dental implantology due to the introduction of guidelines of the surgical procedure to insert a dental implant. Rapid prototyping techniques allow industrial or customized manufacturing of 3D objects by using data taken from a computer (Zaharia, 2017).
- **MAXILLOFACIAL PROSTHESIS:** The absence of parts of the external ear can be caused by congenital disorders or can be acquired. When trying to restore these missing parts with prosthetic materials, the prosthesis should be customized for a better understanding of its part in the complex. When defects are unilateral, it is best to scan the opposite side and restore the affected side by duplication. Besides ears, scientists have managed to print cartilage and blood cells (Sykes, 2004).
- **PROSTHODONTICS:** Custom trays can be manufactured from computerized scans of impressions/models and printed, or can be created with readily available materials (Jacob, 2013).

EXAMPLES OF 3D PRINTING IN FORENSIC DENTISTRY (Hornick, 2017)

- **HONG KONG-** The Hong Kong Police Briefing Support Unit is using its own 3D printers to make crime scene models, which help them understand the crime and present cases in court. The unit also uses 3D printed models of buildings and streetscapes for counter-terrorism planning. Like many law enforcement agencies, the Hong Kong police have made such models for many years, but 3D printers do it faster, with greater accuracy**.**
- **JAPAN -** 3D printed crime scene models can also be used to help gather additional evidence. In 2013, a 3D printed model of a crime scene helped Japanese police gather thousands of possible case-related clues from local citizens.
- **ENGLAND** -In the case of the 2013 death of six-year-old Ellie Butler in Sutton, England, forensic pathologists supported the homicide prosecution of her parents by presenting detailed replicas of Ellie's severely damaged skull, which were 3D printed from CT scans of her remains**.**

In 2015, England police used a combination of 3D scanning and printing to obtain a conviction of Lorenzo Simon who was accused of murdering his tenant, Michael Spalding. The murderer separated the whole body with a saw, partially burnt, and disposed them within a suitcase. Using this 3D technology, the West Midlands Police with the help of Warwick's

University identified the bone found in the suspect's backyard was a matching piece of fractured bone found in the suitcases.

1.U.S.A.-In late 2016, the Greene County Ohio Sheriff's Office partnered with Ohio State University to try to identify the remains of a woman found in the woods near Dayton. After all attempts to identify the victim from the badly decomposed remains had failed, the police turned to 3D printing. After CT scanning and 3D printing a model of the victim's skull, the model was fleshed out with clay. Images of the model were then released to the public, which quickly led to the victim being positively identified. The police investigation then shifted into high gear, resulting in suspects being identified, arrested and charged a short time later.
New York State Police recently teamed with the State University of New York New Palz's Hudson Valley Advanced Manufacturing Centre to solve a 47-year-old Jane Doe murder case. After the SUNY team 3D printed a replica of the victim's skull, it was handed off to a forensic artist to recreate the victim's face. Before this step was completed, the victim was identified by other means.

INDIA

Nirbhaya Case: Delhi gang rape – 2012

On December 16, 2012 in Delhi, India, Nirbhaya, a twenty-three years old female was the victim of multiple rape when she was a passenger on a private bus. She was accompanied by a male friend.71 Due to the severe injuries which she received in the brutal assault, she later died on Dec 29, 2012. The suspects were traced within twenty-four hours. 72 Six men were found guilty including a juvenile. The numerous bite marks on the victim's corpse were compared with the dental models of the accused. Dr Ashit B Acharya, (Head of forensic odontology department, Dharwad) analysed the bite

Table 1. Descriptions of the types of 3D printing technologies

METHOD	DESCRIPTION	MATERIAL USED
Fused Deposition Modelling (FDM) or Material extrusion (Zaharia, 2017; https://www.sculpteo.com/en/3d-printing/3d-printing-technologies/)	It is probably the most popular and affordable printing method. In this process the material is melted and extruded through anozzle to 3D print a cross section of an object each layer at a time, building them from bottom to top	Plastic or Alumide
Power bed fusion (e.g., Selective Laser Sintering (SLS) (https://www.sculpteo. com/en/3d-printing/3d-printing-technologies)	It fabricates an object by melting successive layers of powder together; thereby facilitating creation of complex and interlocking forms	Plastic or Alumide
Stereolithography (SLA) (Zaharia, 2017; https://www.sculpteo.com/en/3d-printing/3d-printing-technologies/)	It was the first commercially available printer for rapid prototyping, developed by Charles Hull in 1983. It is one of the most popular rapid prototyping methods used. Uses a vat of UV light curable photopolymer resin or photosensitive monomer resin	Resin or Wax
Digital Light Processing (DLP) (Zaharia, 2017; https://www.sculpteo.com/en/3d-printing/3d-printing-technologies/)	uses a safelight (light bulb) projector to cure photopolymer resin. The layer is created upside down. After construction of the desired object, the residual liquid polymer is drained. DLP along with lost-wax casting technique is used to melt the wax and create the object in desired material of choice.	Resin or Wax or Metal
Continuous Liquid Interface Production (CLIP) (https://www.sculpteo.com/en/3d-printing/3d-printing-technologies)	Projectsa continuous sequence of UV images, generated by a digital light projector, through an oxygen-permeable, UV-transparent window below a liquid resin bath	Resin or Wax
Multi Jet printers (https://www.sculpteo.com/en/3d-printing/3d-printing-technologies)	Polyjet and Multi Jet 3D Printing use a UV light to crosslink a photopolymer	Resin or Wax
Direct Metal Laser Sintering (DMLS) (https://www.sculpteo.com/en/3d-printing/3d-printing-technologies)	It is similar to SLS and uses a laser as a power source to sinter metal powder by aiming a laser and tracing a cross section of the object layer by layer. The major difference is the sintering temperature	Metals like stainless steel, Titanium, Chrome-Cobalt
Electron Beam Melting (EBM) (https://www.sculpteo.com/en/3d-printing/3d-printing-technologies)	It uses an electron beam as the power source instead of a laser to melt metal powder layer by layer within a high vacuum; thus, producing high density metal parts and retaining the material's properties	Metal

marks with the aid of computer software and postulated that two of the bite marks were identical with two suspects. The submitted evidence was approved by the court on May 6th, 2013.73 One of the accused committed suicide during his trial and the juvenile was sentenced to three years imprisonment. The remaining four adults faced the death penalty (http://ashithacharya.com/cases#:~:text=The%20'Nirbhaya'%20Case&text=Such%20bite%20marks%20can%20look,of%20the%20five%20accused%20persons).

CONCLUSION

The technology of 3D printing can be boon to forensic odontology, and their implementations have opened numerous directions. The biggest advantage of 3D printing is non-invasive reconstruction of detailed anatomic structures which can be used to solve cases and also to provide quality education and training. 3D printing has made possible to construct complex part with minimal discrepancies that could be accepted in court of law. 3D-printed models of bone and teeth can be useful to forensic odontologists in both analysis and as an exhibit in evidence which can provide the clarity of communications in the courtroom. As increasing resolution and better software become available, and as costs decreases, this technology is taken up by more users in all fields. It is clear that 3D printing will have an increasingly important role to play in forensic odontology (Chaudhary, 2018).

REFERENCES

Kanaparthi A, Katne T, Gantala R, Gotoor S. Delve into the third dimension: Pertinence of 3D printing in forensic odontology. J Indian Acad Oral Med Radiol 2020; 32:172-7

Chaudhary RK, Doggalli N, Chandrakant HV, Patil K. Current and evolving applications of three-dimensional printing in forensic odontology: A review. Int J Forensic Odontology 2018; 3:59-65.

Ramya A. and Vanapalli S (2016) 3d Printing Technologies in Various Applications 1-14.

Hodgdon T, Danrad R, Patel MJ, Smith SE, Richardson ML, Ballard DH, et al. Logistics of three-dimensional printing: primer for radiologists. Acad Radiol 2018;25(1):40–51.

- Zaharia C, Gabor AG, Gavrilovici A, Stan AT, Idorasi L, Sinescu C, Negruțiu ML. Digital dentistry—3D printing applications. Journal of Interdisciplinary Medicine. 2017 Mar 1;2(1):50-3

https://www.sculpteo.com/en/3d-printing/3d-printing-technologies/

Kohli Tarika MA. 3D printing in dentistry–An overview. Acta Scientific Dental Sciences. 2019;3:35-41.

Balla S, Baghirath PV, Vinay BH, Kumar JV, Babu DG. Accuracy of methods of age estimation in predicting dental age of preadolescents in South Indian children Forensic Leg Med 2016; 43:21-5

Dawood A, Marti BM, Sauret-Jackson V, Darwood A. 3D printing in dentistry. Br Dent J 2015;219:521-9

Cuperus AM, Harms MC, Rangel FA, Bronkhorst EM, Schols JG, Breuning KH. Dental models made with an intraoral scanner: Avalidation study. Am JOrthoDentofacial Ortho 2012;142:308-13.

Zaharia C, Gabor AG, Gavrilovici A, Stan AT, Idorasi L, Sinescu C, Negruțiu ML. Digital dentistry—3D printing applications. Journal of Interdisciplinary Medicine. 2017 Mar 1;2(1):50-3.

Brunello G, Sivolella S, Meneghello R, et al. Powder-based 3D printing for bone tissue engineering. Biotechnol Adv. 2016;34:740-753.

Sykes LM, Parrott AM, Owen CP, Snaddon DR. Applications of rapid prototyping technology in maxillofacial prosthetics. Int J Prosthodont. 2004;17:454-459

Jacob GS. Three-Dimensional Printing of Dentures Using Fused Deposition Modeling. Inside Dental Technology. 2013;4.

Hornick J: How Police Departments are Using 3D Printing to Solve Crime. c2017https://www.police1.com/police-products/3d-laser-scanners/articles/how-police-departments-are-using-3d-printing-to-solve-crime-n3uNyyd8mWTVXxCZ/

http://ashithacharya.com/cases#:~:text=The%20'Nirbhaya'%20Case&text=Such%20bite%20marks%20can%20look,of%20the%20five%20accused%20persons.

****