

Exploring the 3rd Dimension: Application of 3D Printing In Forensic Odontology



Sunali Khanna* and Prita Dhaimade

Asian Academy of Oral & Maxillofacial Radiology, National Academy of Medical Sciences, Nair Hospital Dental College, India

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***Corresponding author:** Sunali Khanna President, Asian Academy of Oral & Maxillofacial Radiology, National Academy of Medical Sciences, Nair Hospital Dental College, India Tel: +91-98-214-59013; Fax: 022-23-080655; Email: www.sunali.me

Abstract

Forensic odontology is a significant part of the forensic sciences and has been an integral part of criminal investigation. Presenting physical models of evidence in court is a recognized practice, however often a number of legal and ethical concerns prevent the investigators from presenting any physical evidence that is of human origins in the court. This causes the judicial systems to rely merely on photographs of these evidences which cannot always provide the accurate amount of information that a three dimensional structure does. The use of 3D digitizing systems such as laser scanners, structured light scanners, photogrammetry, etc. has revolutionized the field of forensic sciences. It allows presentation of three dimensional models of any evidence of human origin without creating bias in the court. The application of these technologies also allows prompt collection of data with minimal degradation and reduction in human errors. Another important application of 3D printing is to impart education in the field of forensics. Thus these 3D digitizing technologies can be wisely adapted to advance forensic sciences.

Introduction

The technology that was originally known as Rapid prototyping (RA), is now referred to as additive manufacturing, which is popularly known as 3D Printing has brought about a complete revolution in the process of prototyping and manufacturing in every field extending from aerospace research to defense, art and even medicine and dentistry [1,2]. The origins of the technology of 3D printing can be traced to the early 1980s although its widespread commercial application is fairly new. Charles Hull, an American Engineer, developed the world's first working 3-D printer in 1984. [3] He defined it as a "system for generating three dimensional objects by creating cross-sectional patterns of the object to be formed" [3]. 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 [3].

Additive manufacturing consist of a complex process beginning with the computerized scanning of the article to be manufactured after which it is digitally sliced into many thin layers and finally this geometric data is utilized by the manufacturing equipment which builds each layer sequentially until the desired 3 dimensional product is completed. [1,4] The integration of 3D printing into the field of dentistry has drastically reduced the processing time and human errors

leading better results and higher patient satisfaction [5,6]. One of the fields of medicine and dentistry where the application of 3D Printing is fairly new is in the field of forensic sciences. [7] Both forensic medicine and forensic odontology has a number of applications for additive manufacturing and this article aims to highlight a few of them.

Discussion

Current Trends in Forensic Odontology

Forensic sciences are multidisciplinary in nature and typically require cooperation and coordination between the law enforcement officials, forensic pathologists, forensic odontologists, forensic anthropologists' etc. [8] Forensic dentistry or forensic odontology is the application of dental knowledge to those criminal and civil laws that are enforced by police agencies in a criminal justice system. As it is wisely said, there is nothing called as a perfect crime and every contact leaves its trace. Although small, forensic odontology plays a significant role in the apprehension of perpetrators owing to the fact that even though the status of a person's teeth changes throughout life, the combination of decayed, missing and filled teeth is measurable and comparable at any fixed point in time [9].

The main streams under the forensic dentist include

- a) identification of human remains,
- b) identification in mass fatalities,
- c) bite mark assessment and lip prints,
- d) age estimation,
- e) in cases of child, spousal, elder abuse etc [10].

Besides this all the 4 types of violence recognized by the World Health Organization, namely physical, sexual, psychological and neglect can manifest in the oro-facial region and hence is of serious concern to dentists and forensic odontologists [11]. Use of forensic odontology to solve crimes dates all the way back to 66AD, where the body of Lollia Paulina was identified using her teeth and Paul Revere was the first forensic dentist in the united states who identified the remains of a revolutionary soldier using his denture [12] Today, a number of sophisticated photography and scanning techniques are employed in forensic odontology, but the invention of 3D printing has opened up countless new avenues in this field which may revolutionize the justice system[7].

3D Printing Forensic Odontology

In the field of forensics, human remains provide definitive evidence; however the judicial system often relies merely on photographic prints and scanned copies of the same in the court. This is because of a number of ethical and legal issues involved with the transfer, transportation and presentation of human remains to the court and the jury [13]. Presenting human remains can be disturbing to some people especially to medical laymen like the jury members. This can lead to prejudicing the jury. Besides this, handling of human bones and remains by multiple people and in different environments can lead to degradation of evidence [14]. The transportation of human remains is also strictly governed by laws because of which authorities from different areas may not have access to such evidence. Finally such presentation of remains may not be acceptable to the family of the victim, and so only photographic representation of the same is used [14].

Even with all this, it cannot be denied that there is definitely loss of data and information when 3 dimensional evidence is represented in a 2 dimensional photograph. In such cases 3d printing can be applied to create life like three dimensional replicas of the human remains from the evidence which can accurately depict all relevant information to the court and the jury, without disturbing anyone or creating bias [15].

Another important aspect of forensic odontology is "bite mark" analysis. Although biting is a dynamic process and relies on multiple variables like the jaws position, teeth, the substrate, the force of biting etc., bite marks can provide valuable evidence to identify the criminal. [16,17] The forensic dentist must first identify the bite mark from any other cutaneous lesion, infection or injury. This must be followed by the verification that the pattern

is related to teeth and was not made by a tool or instrument. Further after establishing that the bite mark is human, it can be compared to the suspect's dentition for inclusionary or exclusionary purposes [18]. In cases where bite marks are to be evaluated, time is an extremely important variable. In cases where food material is the substrate, evaluation must be done before the deterioration of the substrate while in cases of victims, healing can cause distortion and loss of valuable information while if only imprints of teeth were identified initially, they may diminish in intensity [19]. The conventional methods utilize photographs to document the marks and stone pour technique is usually used to record the impression of the bite mark that may cause distortion due to external pressure. [20,21] Using digital scanners to document the bite marks eliminates the external pressure and tendency to undergo distortion. This becomes especially helpful in cases where the bite mark is on soft tissues like breast and buttocks where conventional impression is difficult to record [21].

After scanning the entire bite mark can be recreated in an appropriate material using 3d printing. This can then be utilized to match with the casts of the suspect's teeth, create overlays and can also be presented in court as evidence. The scans themselves can be used for digitally matching the suspect's teeth using new software [22]. Thus 3d printing can curtail the rapid loss of information that occurs in the bite marks and helps preserve maximum information in all the three dimensions [13].

As in the case of bite marks, digital scanning can be utilized for recording, documenting and analyzing footprints, lip prints and fingerprints [23]. 3D printing is a great tool for forensic anthropologists. A number of cold cases have been reopened and 3d printing is employed to solve them. The post mortem CT scans of the victims can be used to recreate the skull and other bones. [24,25] The data from CT scans carried out in cases where forensic examination may have been delayed due to higher priority of clinical needs in any attempt to rescue the victim can themselves be used to create a digital database which can be uploaded to appropriate additive manufacturing equipment and the evidence can be 3D printed [26].

The forensic anthropologists and forensic artists are then able to reconstruct the tentative appearance of the victim, helping in the identification of unidentified victims [27]. Such 3D printed evidence can be easily transported and can be examined by multiple experts without any ethical issues or deterioration. This not only aids educational aspects but also there is more likelihood of key elements being identified on the 3D printed parts that enable post mortem profiling [7,28,29]. Few other applications of 3D printing in Forensic sciences include facial reconstruction, identification of pattern of fracture, identification and reconstruction of weapons used etc [30].

Conclusion

The technology of additive printing has been a boon to many industries and its applications in medical sciences have opened

numerous new avenues. The non-invasive reconstruction of detailed anatomic structures is one of the biggest advantages of 3D printing which can be utilized wisely in forensic sciences, not only to solve cases but also to provide quality education and training.

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