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3D-MODELING: THE THIRD EYE OF FORENSIC ODONTOLOGISTS

Dental Science

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ABSTRACT

Digitisation of the dental records in comparison to conventional methods has always been a helping hand to forensic odontologists. 3D-modeling of the data obtained from 3D-scanners and 3 dimensional imaging; CAD/CAM and 3D-printing are the advanced techniques which have influenced the medical and dental fields in diagnosis and treatment planning, have now stepped into forensic dentistry. 3D-surface scanners, CBCT, CT, micro-CT and MRI scans provide three dimensional data of the teeth and surrounding structures. This data is then converted into a 3D-model using 3D-modeling software. 3D-models are used in bitemark analysis; age estimation; post-mortem personal identification and crime scene investigation. The printed 3D-models are used in facial reconstruction and as replica of bones presented as evidence in the court room, thereby preventing mishandling of bony remains. The present paper gives an overview of role of 3D-modeling in forensic odontology.

KEYWORDS

Forensic Odontology; 3D-modeling; 3D-printing; 3D-scanners; Forensic 3D/CAD Supported Photogrammetry

INTRODUCTION

Photography has always served a major source of forensic evidence. The photographs give the visual information of size and shape of the objects depicted in them; however they fail to provide the spatial information between the objects depicted.[1] This is overcome by assessing third dimension of the evidence by 3D modeling and is achieved by 3D scanning. The 3D modeling has its applications in forensic medicine like in crime scene investigations, accident scene reconstructions, assault weapon identification and facial reconstruction for person identification. Apart from its immense application in forensic medicine, it plays an important role in forensic odontology like in bitemark analysis, age estimation and assessment of palatal rugae patterns.

OVERVIEW OF ROLE OF 3D MODELING IN FORENSIC MEDICINE

3D scanning is a method of taking multiple measurements from the surface of an object or environment. [2] There are various methods how 3D scanning can be performed:

I.Based on optical methods

- Photogrammetry and stereo-matching
- CT and MRI scanners
- 3D-Lidar(Light Detection and Ranging) scanners

ii. Based on size of object or scanning range

- Microscanning
- Close-Range Scanning/ virtual digital autopsy
- Mid-Range Scanning
- Long Range Scanning
- Extra Long Range and Kinetic Scanners

Photogrammetry is a method of making measurements from photographs of an object, taken from different angles. There are two types: Aerial and close-range photogrammetry. Aerial photogrammetry is perfomed when a large area has to be scanned, which is achieved by drones or unnamed aerial vehicles. In close-range photogrammerty photographs are taken in all directions and measurements are done using scales and reference points adjacent to the object. The data from the photo-documentation software is imported in 3D-modeling software and a corresponding 3D-model is generated. [3]

Laser surface scanners use the structured light to detect the measurements from the object. The object is illuminated by a LASER source and the reflected light is captured by a camera. The captured data is in the form of thousands of points or dots called as data cloud. The captured data is imported into computer-aided designing software to construct a 3D-model. [4] Close-range scanners are used when object is present within few meters. As the distance increases, mid-range, long and extra-long-range 3D-surface scanners are used.

Virtual digital autopsy is one of the close-range scanning methods which uses post-mortem computed tomography or magnetic resonance imaging for analysis of forensic evidence. These imaging modalities provide documentation of both surface and internal findings with utmost precision and high resolution.[5] The DICOM images of CT and MRI scans are imported in a specialised 3D-modeling software and 3D-model is generated. [6] Various paid and free wares are available for 3D-modeling of DICOM images like Materialise Mimics, Simpleware and ITK-SNAP. The post-mortem CT is used in age estimation, personal identification, sharp and blunt trauma, gunshot injuries, child abuse and skeletal trauma, moreover, MRI because of its higher soft tissue resolution it can also be used in cases of strangulation and detection of medical errors. The 3D-model from CT scan can be combined with photogrammetric 3D-model to analyse trauma to head and extremities. This procedure helps in assessment of external and internal injuries with better precision and is easily demonstrable. [7,8]

Micro-CT scanning works similar to cone beam CT, wherein a cone shaped x-ray beam is projected on the object and multiple basis projection images are generated and 3D volume rendering is done. Baier et al in their case report have elaborated upon the use of micro CT scan and the role 3D-model as demonstrative evidence in the court of law. The victim's skull was scanned using Nikon micro-CT scanner and a surface mesh of the skull section was obtained from the CT images using Simpleware. An original scale 3D-print was prepared from the 3D-model, showed two wounds with different shapes indicating the possibility of assault by two distinctive weapons or a single weapon with two different impact surfaces.[9] It was 3D-modeling with Materialise's Mimics software which made it possible to resolve one of the oldest murder mysteries of mankind. [10]

APPLICATIONS OF 3D MODELING IN FORENSIC ODONTOLOGY

The use of 3D-modeling in forensic odontology is in flourishing phase. The role of 3D-modeling in bite mark analysis is unique. Bite mark analysis is otherwise usually two dimensional which causes lack of information in the 3rd dimension. Forensic 3D/CAD-supported photogrammetry (FPHG) is the method where a series of photographs of the injury and injury causing objects are taken; evaluated in a multi-image evaluation system for spatial location of reference points; and 3D data models are built-up. [11, 12]Thali et al have worked upon 3D documentation of bitemark in a murder victim using 3D/CAD-supported photogrammetry and that of suspects' dental cast using 3D-surface scanner. The data model of dental cast was superimposed and matched with 3D-model of bitemark for the pattern, shapes, angles and dimensions in 3D-modeling software. Furthermore, the software enables the assessment of impact of the teeth over the skin and tissues with progressive increase in pressure of the bite using the 3D-models. [13] Reports have described the pros and cons of use of photogrammetry and surface scanners in documentation of bitemark and dental casts.

Despite both methods provide accurate measurements, 3D-model of bitemark is achieved best with photogrammetry, and surface scanners produce meticulous 3D-models of dental casts.[14,15] A software has been developed at University of Granada named as "Dental-print software". It is a computer based program which produces 3D-models of bitemark and suspect's dental cast for comparison. In a study of bite mark analysis, use of this software showed high specificity. However the validity of the software is yet to be evaluated. [16]

The 3D-modeling of teeth has become possible by the entry of high resolution imaging techniques like cone beam CT and micro-CT. The use of pulp to tooth volume ratios has produced better correlation with age in comparison to area ratios. The DICOM images are imported in 3D-modeling softwares like MIMICS and ITK-SNAP2.4 software and the volume of the pulp and tooth is estimated. [17-19]

3D-modeling of palatal rugae patterns has shown to have role in personal identification. The conventional method of analysing the dimensions of rugae in photographs, consider only two dimensions i.e. anterio-posterior and transverse planes, but the 3D-model of the palate allows the assessment in all three co-ordinates providing more precise results. [20]

The role of 3D-print model in personal identification is well known. The 3D-model of the skull is produced from the digital images obtained from 3D-CT/MRI using various 3D-modeling softwares. Three dimensional computed tomography measurement techniques are way superior to measurements performed on CT slices. [21] Rocha Sdos S et al assessed that the craniometrical measurements using 3D-CT of cadaver skulls are highly precise and hence can be utilized for facial reconstruction for personal identification.[22] The 3D-model obtained from 3D-modeling software is then printed using a 3D-printing machine. The machine uses a coil of thermoplastic material which is heated up and pushed through the nozzle in molten form. The extrusion head moves in transverse and vertical planes which is controlled by computer aided manufacturing software. The molten material flows through the nozzle in layers and solidifies upon cooling, generating the 3D-print.[23] Forensic artists perform facial reconstruction on the 3D-print of skull. 3D-printing can replicate even the most complex structure. 3D-print bone models serve as best alternate to bones because handling of bones in different environments causes deterioration and loss of evidence; moreover presentation of bone remains in the court room could be disturbing to individuals. Hence 3D-printing is immensely employed in facial reconstruction, skeletal fracture pattern identification and impact weapon identification and reconstruction. [24,25]

CONCLUSION

3D-modeling is advantageous over photography. It can be achieved by collection of data using stereo-photogrammetry, 3D-LASER scanners, CT and MRI scans followed by construction of 3D-model using different 3D-modeling softwares. It has applications in crime scene investigations, accident scene reconstruction and disaster victim identification. 3D-modeling plays important role in bite mark analysis. Use of 3D-modeling in other aspects of forensic odontology is still in evolving phase. Future research has to take place in simplification of the present 3D-modeling softwares and in their application in the field of forensic odontology.

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