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CAD/CAM: a new revolution in forensics

Abstract

All humans have an identity in life. The cornerstone of forensic science is the positive identification of a human using his unique traits and characteristics. One of the most challenging aspects in forensic dentistry is the recognition, recovery and analysis of evidences and its matching with the suspects. A calculated and objective comparison utilizing technology would strengthen the validity of evidences in forensic dentistry. The use of advanced computer aided technology like CAD/CAM, has shown, in recent years, that it is possible to match DNA, Blood group antigens and tooth impression from a chewing gum retrieved to undermine the credibility ofproof in a crime. The computer system of CAD/CAM can be used to construct a 3D-image of an object that has been retrieved from the crime scene by scanning the object and store all the information and can be used to assess the finding. This avoids any errors made by manual techniques which may not be always accurate. This review on CAD/CAM is described in this article with emphasis on its application in Forensics.

Keywords: cad/cam, forensic odontology, crime, computer aided

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Introduction

Dentistry has embraced technological advances in computer-aided dentistry and computer-aided manufacturing (CAD/CAM) for the past three decades since clinical dentistry demands that patients receive the highest quality of care in a timely and compassionate manner to do so.[1] Computer-aided dentistry has been employed to digitize dental structures and the oral cavity for the virtual design of simple and complex prosthetic units.[2] Forensic dentistry which in a new branch of dentistry, deals with the confirmation of an individual's unique identity involved in a crime or death. This process too demands the highest possible degree of accuracy to satisfy the logistical and emotional needs of all parties involved.[3] The experience and expertise of the individual performing the comparison for forensic need; the availability, quality and age of the records; and the postmortem damage are limiting factors.[4]

Often the postmortem identification process compares dental records (radiographs and models) of an individual before death (ante-mortem) to that after death (postmortem), while injury analysis may involve comparisons of bone fragments or contusions to types of weapons or known injuries. A calculated and objective comparison utilizing technology would strengthen the validity of forensic dentistry. The role of CAD/CAM within forensic sciences can help to deal with age estimation, injury analysis, and postmortem identification.Additionally forensic sciences can even employ CAD/CAM technology to assist in the 3-dimensional (3D) reconstruction of crime scene investigations.[5,6] Evaluation of recorded wound pattern and objects is time independent. At the time of examination, objects may have been altered or they may no longer exist at all. Results are presented in comprehensible visual form, enabling the observer to directly and immediately evaluate them.[7]

Some applications of cad/cam in forensic odontology

A study by Thali et al.,[7] presented a new 3D documentation, analysis and visualisation approach based on forensic 3D/CAD supported photogrammetry (FPHG) and the use of a 3D surface scanner. This photogrammetric approach and the use of visualization method are claimed to be the first 3D approach for bite mark analysis in an actual case. In conclusion it was emphasized that, at present, most of the bite mark analysis (overlay and metric analysis) are carried out in 2D space (e.g. photograph and subsequent overlay technique). The documentation had no distortion artifacts as can be found with standard photography. All the data were documented with a metric 3D measurement, orientation and subsequent analysis in 3D space.The authors also highlighted that, beside the metrical analysis between bite marks and cast, it is possible to utilize the topographical 3D feature of each individual tooth through their method.

Kalman[8] has explored the potential of utilizing in-office technology to offer another tool for the forensic dentist. Two models of segmental impression were prepared, one model was set aside and kept pristine and served as the antemortem record and the second model purposely damaged by hammering served as the postmortem record. An in-office E4D CAD/CAM unit (E4D technologies) was employed to digitize the entire postmortem cast. The morphogenesis produced a 3-D computer generated model of the teeth in which missing portions were recreated by the software. The result of the study showed large discrepancy in the dimension of teeth and was attributed to the establishment of the occlusal plane with limited amount of information provided by the segmental impression. This study concluded that, CAD/CAM technology has the potential to lend a helping hand to the discipline of forensic dentistry in the identification and confirmation of an individual's identity. Authors emphasized that refinements to the hardware, software, and operator parameters are required to offer simple yet accurate results. Further studies would be required to alter software algorithms and modify morphogenesis to accommodate segmental records, age, and parafunction to establish a proper occlusal plane.[8]

Application of 3d cad/cam in forensic investigation[9]

The traditional documentary work at the crime scene includes photography of the general situation as well as all sorts of physical evidence. An often neglected factor of high documentary value is

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the mapping/respectively sketching of a crime scene or a disaster. The rough hand-drawing from a crime scene might not be accurate enough to allow the calculation of exact locations of physical evidence, positions of persons, due to missing spatial relationship and 3D viewing. Virtual reality or true 3D visualization could be used to 'enter' the crime scene or to manipulate the scanned body in real time. This will make the overview and awareness of the evidence even better than standard 3D projections on 2D screens. Other solutions that are more available at this moment and perhaps more practical would be using 3D displays or 3D printed models. However, as many courtrooms currently lack even the ability to display evidence by video projection, it remains to be seen how much time it will take before this kind of technology will actually reach the courtroom.[9]

Latest advancements in forensic cad[10]

MapScenes Forensic CAD is the most precise desktop forensic mapping software available in the world. The advantages of this software are:

i. Provides law enforcement professionals and accident reconstruction specialists, with confidence that the evidence they present is precise, compelling, and irrefutable.

ii. Produce scaled diagrams for use in court, creating a strong visual case for the prosecution or defense.

iii. Seamless integration with evidence recorder software ensures accurate diagrams, enabling investigators to testify on specific "conditions and effects" of an incident with confidence.

iv. For times where you need to demonstrate what really happened by creating an animation, you can always continue directly with MapScenes Animation Module.

Advantages of cad/cam in forensics[6,11,12]

The outline of pieces can be created or entire objects can be reconstructed and rendered showing whatever surface detail is required. The products can sometimes be used to analyze visually, reach or to reconstruct events to analyze injury patterns.

i. More advanced simulation techniques could be used to recreate events involving human bodies. For instance, the modeling of skin displacement or the fracturing of bones could be simulated, especially their interaction with the injury causing object.

ii. Calculations could be performed on for instance what pressure would make a bone break, comparable to current car-crash simulations that incorporate the deformation of metal.

iii. An end-to-end crash simulation with realistic physics might be performed using starting parameters from the crash or crime scene.

iv. These simulations increase validity of current visual comparisons and manual animation of injury and injury-causing objects.

v. The matching of patterned injuries with their injury-causing objects is greatly facilitated using these advanced visualization techniques in combination with CAD.

vi. The digitized data can be made accessible around the globe and is available indefinitely afterwards when one accounts for eventual obsoleteness of data type and data storage mediums.

vii. The 3D/CAD program allows one to displace turn and rotate the objects arbitrarily in order to fit and match them for possible congruence.

Disadvantages of cad/cam in forensics[12,13]

i. There is currently no evidence for the validity of virtual autopsies or other merging techniques, nor is it likely that such evidence can be established soon.

ii. This technique has the same context effects as other forensic observer-based techniques, such as pro-prosecution bias, confirmation bias, domain irrelevant information, base rate effect and post-hoc target shifting which must all be considered.

iii. These methods have limitations and scanning equipment is not yet readily available and affordable for most odontologists specifically.

iv. The cost to have individual scans performed is high and currently such equipment is available primarily in hospital or educational settings.

Conclusion

Forensic specialists in many fields are eagerly anticipating the day when this technology becomes more available, affordable, and common place in their respective fields. One must not, however, under estimate the saliency of visual data and its effects on case awareness and its limits. Although these reconstructions use real data, one must not lose sight of the fact that they are simulations, not reality, and must be backed up by hard evidence. Finally, how soon these techniques can make their way into courtrooms remains to be seen.

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None.

Conflicts of interest

None.

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